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वार्षिक प्रतिवेदन
Annual Report
2012–13

सीएसआईआर – राष्ट्रीय भौतिक प्रयोगशाला
CSIR - National Physical Laboratory
New Delhi - 110 012

Dr. Poonam Arora received CSIR Young Scientist Award 2012 in "Physical Sciences including Instrumentation" on CSIR Foundation Day at Vigyan Bhawan, September 26, 2012.

Dr. Priyanka Heda Maheshwari received CSIR Young Scientist Award 2012 in "Engineering Sciences" on CSIR Foundation Day at Vigyan Bhawan, September 26, 2012.

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Annual Report
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With Best Compliments from :

Prof. R. C. Budhani
Director

CSIR-National Physical Laboratory

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CSIR-National Physical Laboratory

निदेशक

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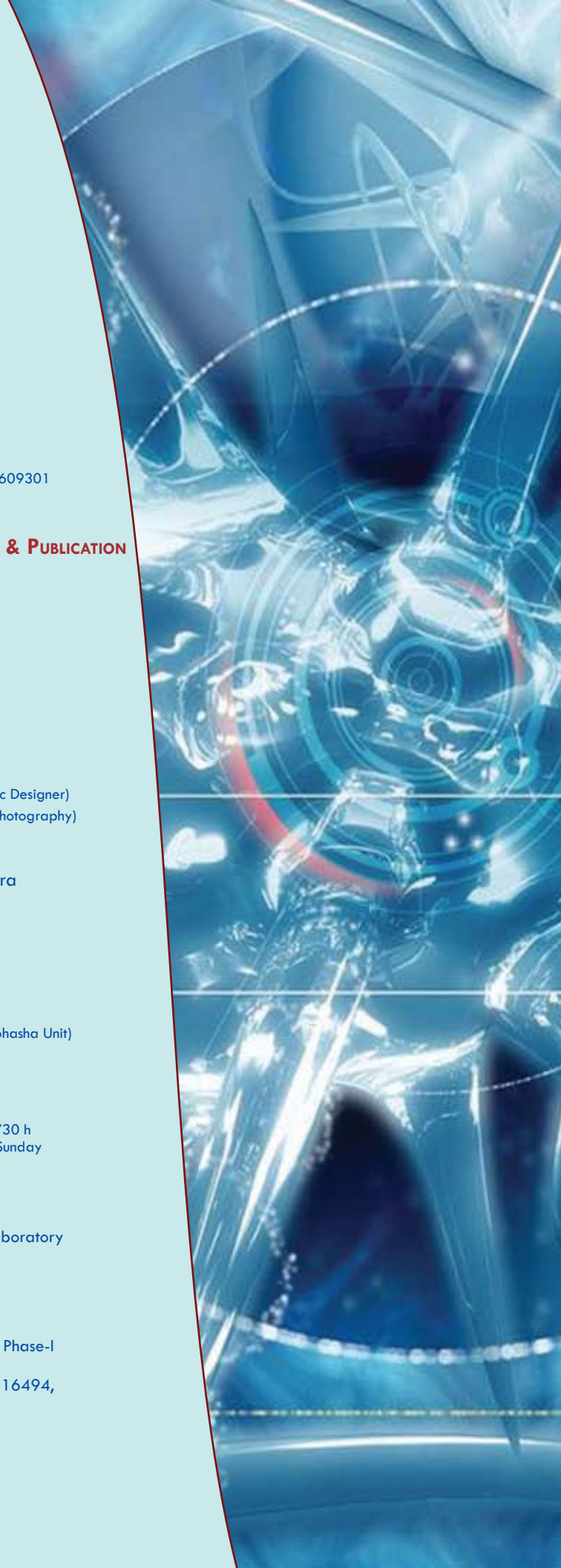


विषय सूची
Contents

निदेशक की लेखनी से...

वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद् (सीएसआईआर) – राष्ट्रीय भौतिक प्रयोगशाला (एनपीएल) की वर्ष 2012–13 की वार्षिक रिपोर्ट आपके समक्ष प्रस्तुत करते हुए मुझे अत्यधिक हर्ष का अनुभव हो रहा है। सीएसआईआर – एनपीएल वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद् की एक अग्रणी प्रयोगशाला है तथा साथ ही भारत का राष्ट्रीय मापिकी संस्थान भी है। यह प्रयोगशाला भौतिक विज्ञान एवं माप विज्ञान में अनुसंधान के अग्रणी क्षेत्रों में सक्रिय रूप से कार्य कर रही है। यह ऊर्जा, नैनो प्रौद्योगिकी, उन्नत पदार्थ, क्वांटम संहत पदार्थ, रेडियो तथा वायुमंडलीय विज्ञान, क्वांटम माप–विज्ञान से संबंधित विभिन्न नवोन्मेषी अनुसंधान क्षेत्रों में अनुसंधान एवं विकास तथा मापन के उन्नत मानकों के विकास को संवर्धन प्रदान करती है। अपनी संस्थापना के बाद से ही, राष्ट्रीय भौतिक प्रयोगशाला भारतीय उद्योगों को समर्थन प्रदान करती रही है तथा समाज को ज्ञान आधारित प्रौद्योगिकियां उपलब्ध कराकर तथा ज्ञान को निरंतर उन्नत बनाकर समाज को अपनी सेवा देती रही है।

अब विश्वभर में इस बात को महत्त्व दिया जाने लगा है कि एक संधारणीय समाज का निर्माण करने तथा व्यापक औद्योगिक विकास के कारण उत्पन्न होने वाली पर्यावरण संबंधी अनेक समस्याओं का समाधान करने के लिए विज्ञान, प्रौद्योगिकी तथा नवप्रवर्तन से संबंधित अवधारणाओं को समेकित रूप में उपयोग में लाना अत्यधिक आवश्यक है। इस संदर्भ में सीएसआईआर–एनपीएल जैसे सरकारी क्षेत्र के अनुसंधान संस्थानों को एक अत्यधिक उल्लेखनीय भूमिका का निर्वहन करना है। राष्ट्रीय भौतिक प्रयोगशाला इस उत्तरदायित्व के प्रति पूर्णतः जागरूक है और इस दिशा में एक सुनिश्चित भूमिका का निर्वहन कर रही है एवं देश के सर्वांगीण विकास हेतु इसे विश्व स्तरीय प्रतिस्पर्धा का सामना करने में सक्षम बनाने के लिए अपना महती योगदान कर रही है। इन उद्देश्यों को पूर्ण करने के लिए राष्ट्रीय भौतिक प्रयोगशाला भौतिक विज्ञान के क्षेत्र में एक अग्रणी एवं वैश्विक स्तर पर मान्यताप्राप्त प्रयोगशाला बनने के लिए क्रमिक रूप से तथा निरंतर आमूल बदलाव की प्रक्रिया से गुजर रही है। वर्ष 2012–13 के दौरान यह प्रक्रिया जारी रही तथा प्रयोगशाला की पहले से मौजूद विश्वसनीय अनुसंधान अवसंरचना में कुछ अतिरिक्त वृद्धि की गई। मानव संसाधन के मामले में, जो किसी भी संगठन का आधार होता है, प्रयोगशाला निरंतर युवा और साथ ही अनुभवी वैज्ञानिकों को अपने संगठन में बनाए रखने के प्रति प्रयासरत रही है। इन सभी प्रयासों के फलस्वरूप वर्ष के दौरान अनुसंधान एवं विकास के क्षेत्र में अत्यधिक उल्लेखनीय प्रगति हासिल की जा सकी है। हमारे दो वैज्ञानिकों डॉ. पूनम अरोड़ा तथा डॉ. प्रियंका एच. माहेश्वरी ने अपने असाधारण योगदान से क्रमशः भौतिक विज्ञान एवं अभियांत्रिकी विज्ञान के क्षेत्रों में प्रतिष्ठित सीएसआईआर युवा वैज्ञानिक पुरस्कार, 2012 प्राप्त किया।

प्रयोगशाला के सभी सातों विशिष्ट तथा विषय समर्पित प्रभागों अर्थात ऊर्जा संचयन भौतिकी प्रभाग; पदार्थ भौतिकी और इंजीनियरिंग प्रभाग; रेडियो एवं वायुमंडलीय विज्ञान प्रभाग; काल एवं आवृति प्रभाग; शीर्ष स्तरीय मानक एवं औद्योगिक मापिकी प्रभाग; क्वांटम परिघटना एवं अनुप्रयोग प्रभाग; और परिष्कृत तथा विश्लेषणात्मक उपकरण प्रभाग में उत्कृष्ट अनुसंधान कार्य किए गए। इन क्षेत्रों में उत्कृष्ट मौलिक तथा अनुप्रयुक्त अनुसंधान कार्यों के आधार पर, कुछ उच्च प्रतिष्ठित पत्र–पत्रिकाओं में अनेक लेख प्रकाशित किए गए और साथ ही महत्त्वपूर्ण आविष्कारों के संबंध में राष्ट्रीय तथा अंतर्राष्ट्रीय पेटेंट भी दर्ज कराए गए।

ऊर्जा संचयन भौतिकी प्रभाग द्वारा एक आशोधित एवं नवोन्मेषी PTB7 : PC60BM प्रकाश अवशोषी सक्रिय परत से युक्त बहुलक सौर सेलों (पीएससी) के संबंध में अनुसंधान कार्य किए गए। इसमें 6% (पीसीई) से अधिक पावर परिवर्तन दक्षता के किफायती, दक्ष, सुनम्य तथा टिकाऊ बहुलक सौर सेल उपलब्ध कराने की क्षमता है। इस आविष्कार को अंतर्राष्ट्रीय स्तर पर प्रमाणित किया गया है और इसे पेटेंट कराया जा रहा है। सिलिकन सौर सेलों के क्षेत्र में काले सिलिकन सौर सेल सम्बंधित "संकल्पना प्रमाण" तैयार किया गया है जिससे इन युक्तियों की लागत कम की जा सकती है। प्रभाग द्वारा किए गए अन्य महत्त्वपूर्ण योगदानों में a-C फिल्मों से ग्रेफीन का संश्लेषण, $Bi_2Te_3 + BiTe$ (8 mole %) नमूने के लिए 470 K तापमान पर 1.1 का ZT मान प्राप्त करना, अनुकूलित SiO_2 परावैद्युत पदार्थों पर एकध्रुवी कार्बनिक फील्ड प्रभाव ट्रांजिस्टर (ओएफईटी) का संविरचन, अत्युच्च आवृत्ति की पीईसीवीडी तथा उन्नत किस्म की सीआईजीएस अवशोषक परत का प्रयोग करके सौर सेलों के लिए नीली, रवाहीन और सूक्ष्म क्रिस्टलीय सिलिकन की पतली परत के निक्षेपण पर ऐपीटैक्सीय GaN को विकसित करना शामिल है। इस प्रभाग में कुछ नई सुविधाओं को भी स्थापित कर उन्हें चालू किया गया जैसे कि वाष्पित्र तथा संपुटीकरण प्रणाली, परमाण्विक परत निक्षेपण प्रणाली, अत्यंत तीव्र फेमटो–सेकंड लेज़र स्पेक्ट्रमदर्शी तथा अत्युच्च निर्वात स्पंदित लेज़र निक्षेपण (यूएचवी–पीएलडी) प्रणाली से समेकित ग्लव बॉक्स का प्रयोग करके बहुलक सौर सेल युक्ति संविरचन सुविधा।

पदार्थ भौतिकी और इंजीनियरिंग प्रभाग ने भी बुनियादी तथा अनुप्रयुक्त दोनों प्रकार के अनुसंधान कार्यों पर बल दिया। लौह वैद्युत द्रव क्रिस्टल (एफएलसी) में विद्युत द्वारा माडुलित प्रकाश संदीपन की कार्य प्रक्रिया का अध्ययन किया गया तथा प्राप्त निष्कर्षों को एक उच्च प्रतिष्ठित पत्रिका में प्रकाशित कराया गया। ईंधन सेल के लिए दो महत्त्वपूर्ण एवं वाणिज्यिक दृष्टि से व्यवहार्य कार्बन संघटकों, जैसे कि, सरंध्र चालक कार्बन पेपर और सम्मिश्र द्वि–ध्रुवी प्लेट को विकसित किया गया। जैव–चिकित्सीय सेंसरों के क्षेत्र में माइक्रो फ्लुइडिक तकनीकों का प्रयोग करके कॉलेस्टेरोल स्तर के मापन के लिए तथा हृद् जैव मार्करों के संसूचन के लिए व्यापक अनुसंधान कार्य जारी रखे गए। जिन कुछ महत्त्वपूर्ण इंजीनियरी पदार्थों के संबंध में अन्वेषण तथा अभिलक्षण–निर्धारण से संबंधित कार्य किया गया, उनमें p प्रकार के ताप वैद्युत पदार्थ, अत्युच्च दक्षतांक से युक्त Cu_2Se तथा दुर्लभ मृदा मुक्त स्थायी चुंबकीय पदार्थ शामिल हैं। सौर सेलों के लिए नैनो फॉस्फर्स को विकसित करना तथा डिस्प्ले युक्तियों के लिए संवर्धित संदीप्ति से युक्त मादित नैनो क्रिस्टलों और क्वांटम डॉटों का संश्लेषण करना इस प्रभाग की अन्य उपलब्धियां हैं। प्रभाग द्वारा प्रकाश उत्सर्जी डायोड (एलईडी) के लिए नूतन नैनो फॉस्फर्स और जैव–संबद्ध अनुप्रयोगों के लिए संदीप्त–चुंबकीय नैनो फॉस्फर्स को विकसित करने की दिशा में कार्य किया गया।

रेडियो तथा वायुमंडलीय विज्ञान प्रभाग ने अंटार्कटिका में 31वें भारतीय वैज्ञानिक अभियान दल में भाग लिया तथा अंतरिक्ष मौसम एवं जलवायु परिवर्तन के क्षेत्र में वैज्ञानिक प्रयोगों को सफलतापूर्वक पूरा किया। मोबाइल वायरलेस संचार में तरंगदैर्घ्यों के संचरण–पथ–हानि घातांक के संबंध में पूर्वानुमान लगाने के उद्देश्य से सिराक्यूज विश्वविद्यालय के सहयोग से विद्युत चुंबकीय बृहत् प्रतिरूपण का कार्य किया गया। इस कार्य का उद्देश्य भावी नेटवर्क आयोजना के लिए एक उपयुक्त संचरण मॉडल (प्रतिरूप) विकसित करना था। हाल ही में आकस्मिक समतापमंडलीय उष्मन से संबद्ध आयनमंडलीय एफ2–क्षेत्र में परिवर्तनीयता के संबंध में जानकारी प्राप्त करने के लिए उपकरणों को संस्थापित किया गया है। विभिन्न प्रौद्योगिकीय विकल्पों के अंतर्गत दिल्ली में नगरपालिका ठोस कचरा से ऊर्जा उत्पादन की संभावना का आंकलन किया गया। भारत में ऊर्जा क्षेत्र से ग्रीन हाउस गैसों के उत्सर्जन के बारे में 2001–02 से लेकर 2009–10 तक की अवधि से संबंधित एक अद्यतन सूची तैयार की गई जिसमें ताप विद्युत संयंत्रों, सड़क परिवहन, रेलवे, विमानन और समुद्री परिवहन के साधनों द्वारा ग्रीनहाउस गैसों का उत्सर्जन शामिल है। परिवर्तित हो रहे पर्यावरण और उसके प्रभाव का अभिलक्षण निर्धारित करने से संबंधित 12वीं योजना–नेटवर्क परियोजना पर कार्य आरंभ कर दिया गया है। राष्ट्रीय भौतिक प्रयोगशाला में उपलब्ध विभिन्न अत्याधुनिक विश्लेषणात्मक सुविधाओं का प्रयोग करके भारत के वायुमंडल में उपस्थित वायुमंडलीय ऐरोसोल का विस्तृत रासायनिक, भौतिक तथा समस्थानिक अभिलक्षण निर्धारण किया गया। लिडार का प्रयोग करके नई दिल्ली के वायुमंडल में निम्न क्षोभमंडलीय ऐरोसोलों और बादल की ऊंचाई के संवितरण से संबंधित अध्ययन भी किया गया।

काल एवं आवृति प्रभाग सूक्ष्मतरंग आवृति मानकों, प्रकाशीय आवृति मानकों तथा परिशुद्ध समय प्रणालियों से संबंधित अनुसंधान कार्यों में सक्रिय रूप से संलग्न है। इस प्रभाग द्वारा की गई प्रमुख वैज्ञानिक उपलब्धियों में निम्नलिखित शामिल हैं: प्रथम सीज़ियम (Cs) फाउंटेन आवृति मानक तथा इसकी आवृति के प्रारंभिक मूल्यांकन के कार्य को निरंतर जारी रखना; द्वितीय सीज़ियम (Cs) फाउंटेन को अभिकल्पित तथा विकसित करना; इसरो के आईआरएनएसएस (भारतीय क्षेत्रीय नौसंचालन उपग्रह प्रणाली) के लिए अंतरिक्ष घड़ियों हेतु रूबिडियम सेलों तथा बल्बों को स्वदेश में विकसित करना; एकल ट्रेप इटर्बियम आयन के प्रकाशीय आवृति मानक परियोजना का प्रारम्भिक कार्य; एनटीपी (नेटवर्क समय प्रोटोकोल) इंटरनेट समय सेवा का सृजन तथा अंतर्राष्ट्रीय परमाण्विक समय निर्धारित करने में प्रभाग की सभी परमाणु घड़ियों का योगदान। सीएसआईआर–एनपीएल ने हाल ही में 0.3 नैनो सेकंड की अनिश्चितता को शामिल करके अपनी घड़ियों की परिशुद्धता की विश्व भर की अन्य शुद्ध घड़ियों के साथ तुलना करने का कार्य आरंभ किया है। उपग्रह लिंकों का प्रयोग करके घड़ियों के इस परिशुद्ध, नियंत्रित तथा स्वचालित इंटर–कम्पैरिज़न के फलस्वरूप राष्ट्रीय भौतिक प्रयोगशाला की सीज़ियम घड़ियां एवं हाइड्रोजन मेसर अंतर्राष्ट्रीय परमाणु टाइम स्केल, टीएआई को अपना योगदान दे रहे हैं। इन भारतीय घड़ियों को ब्यूरो इंटरनेशनल डेस पोइड्स एट मेजर (बीआईपीएम, पेरिस) द्वारा पहली बार मान्यता प्रदान की गई है।

शीर्ष स्तरीय मानक एवं औद्योगिक मापिकी प्रभाग जिसमें 12 समूह शामिल हैं, ने विभिन्न प्रदत्त क्रियाकलापों में अत्यधिक रुचि लेते हुए उन्हें निष्पादित करने का कार्य जारी रखा। परिशुद्धता के संबंध में निरंतर बढ़ती हुई मांग को पूरा करने के महत्त्व तथा अनिश्चितता में वृद्धि को ध्यान में रखते हुए इस प्रभाग की दो प्रमुख उपलब्धियां निम्नलिखित हैं: (1) ग्यारहवीं पंचवर्षीय योजना में निर्धारित की गई परियोजना 'मापिकी के क्षेत्र में प्रगति – सीएसआईआर/एनडब्ल्यूपी–45' के निष्पादन के लिए 31 मार्च, 2014 तक का समय विस्तार तथा अतिरिक्त निधि प्राप्त करना; और (2) बारहवीं पंचवर्षीय योजना के अंतर्गत एसएफसी/सीएसआईआर वित्तपोषण द्वारा 'विज्ञान एवं प्रौद्योगिकी के क्षेत्र में मापन से संबंधित नवप्रवर्तन (एमआईएसटी)' नामक एक नई परियोजना को अनुमोदित किया जाना। विभाग के क्रियाकलापों को प्रदर्शित करने वाले एक पोस्टर का सीएसआईआर के 70 पोस्टरों में शामिल किए जाने के लिए चयन किया गया तथा उसे 26 सितंबर, 2012 को आयोजित सीएसआईआर स्थापना दिवस पर प्रस्तुत किया गया। प्रभाग के कुछ महत्त्वपूर्ण अनुसंधान एवं विकास से संबंधित योगदानों में निम्नलिखित शामिल हैं: (1) लंबाई मापन मशीन का प्रयोग करके बेलनाकार वस्तुओं के बाह्य व्यास का माप करना; (2) प्रकाश विद्युत रेखिक पाइरोमीटर का प्रयोग करके ग्रेफाइट–में–धातु, 'कृष्णिका कोटरों द्वारा सिलवर व कॉपर स्थिर बिंदुओं को प्राप्त करके उच्च तापमान से संबंधित प्राथमिक मानकों को ज्ञात करना; (3) स्पेक्ट्रमी स्विचन आधारित सूचना प्रक्रमण (एसएसबीआईपी) के संबंध में विस्तृत अध्ययन; और (4) चावल की भूसी से प्राप्त एक नई अवशोषक सामग्री को विकसित करना। इस प्रभाग द्वारा (1) निम्न ताप संलग्नक से युक्त एक नया ट्रिपल रमन स्पेक्ट्रममापी; (2) उच्च ताप प्राथमिक मानक; (3) मल्टीफेरोइक संपरीक्षक; (4) सड़क यातायात शोर और हवाई अड्डा शोर के मापन हेतु 24–घंटे शोर मॉनीटरन प्रणाली; (5) डीएन 100 आकार के एक स्वचालित जल प्रवाह अंशांकन मानक; तथा (6) निम्न मान के क्षीणकारी (0.1 डेसिबल से 10 डेसिबल) के अंशांकन हेतु स्वचालित शक्ति अनुपात तकनीक को स्थापित किया गया है।

क्वांटम परिघटना एवं अनुप्रयोग प्रभाग में व्यापक प्रकार के तनु फिल्म और उपकरण संविरचन तकनीक, जैसे कि, स्पंदित लेज़र निक्षेपण, डीसी और आरएफ मैग्नेट्रॉन कण क्षेपण, ऊष्मीय वाष्पन, फोटो–लिथोग्राफी, आर्गन आयन मिलिंग तथा केंद्रित आयन किरणपुंज को संक्रमण धातु ऑक्साइड की विषम संरचनाओं, स्पिनट्रॉनिक पदार्थों, अतिचालक/लौह चुंबक विषम संरचनाओं, चुंबकीय नैनो रिंगों और ग्रेफीन/टंग्स्टन आधारित जंक्शनों को निर्मित करने के लिए प्रयोग में लाया गया। विभिन्न तनु फिल्म आधारित नमूनों के चुंबकीकरण, ac–सुग्राहिता तथा प्रतिरोधकता के अभिलक्षण निर्धारण हेतु एक 'स्किवड आधारित 7 टेस्ला चुंबकत्वमापी' संस्थापित किया गया तथा उसका प्रचालन आरंभ किया गया। उच्च चुंबकीय क्षेत्र की उपस्थिति में अत्यधिक निम्न तापमान पर ऑक्साइड अंतरापृष्ठों, नैनो–वायर और जंक्शनों के उन्नत नमूनों में नई क्वांटम परिघटना को जानने के लिए 14 टेस्ला चुंबक से युग्मित 10 mK डाइल्यूशन रेफ्रिजरेटर की सुविधा स्थापित करने की योजना बनाई गई है। इसके अतिरिक्त, निम्न तापमान पर 50 टेस्ला की चुंबकीय क्षेत्र प्रणाली के माइक्रो सेकंड के सन्निकट स्पंद स्थापित करने के लक्ष्य को प्राप्त करने की दृष्टि से स्पंदित चुबक से संबंधित एक नया क्रियाकलाप आरंभ किया गया। अति चालक पदार्थ समूह ने BiS_2 निक्टॉइडों और MgB_2 अति चालकों के संबंध में योगदान जारी रखा। प्रणाली को निरंतर बेहतर स्थायित्व तथा पुनरुत्पादकता के साथ प्रचालित करने के लिए प्रोग्रामनीय जोसेफसन वोल्टेज मानक का आगे और अभिलक्षण निर्धारण किया गया। फोटो संसूचकों की निरपेक्ष क्वांटम दक्षता के मापन के लिए तथा क्वांटम सूचना प्रक्रमण में उनके अनुप्रयोग हेतु आधारभूत क्वांटम ऑप्टिकल अध्ययन के लिए एसपीडीसी परिघटना पर आधारित सुविधा स्थापित की गई। कैंसर–रोधी

औषधियों के डीएनए और विभिन्न ऑलिगो न्यूक्लियोटाइडों के साथ अन्योन्यक्रिया तंत्र को स्पष्ट करने के लिए फूरिये रूपांतरण अवरक्त स्पेक्ट्रममापी तकनीक को प्रयोग में लाया जा रहा है।

परिष्कृत और विश्लेषणात्मक उपकरण प्रभाग (एसएआईडी) जिसमें चार समूह अर्थात एक्स किरण विश्लेषण, इलेक्ट्रॉन तथा आयन सूक्ष्मदर्शिकी, ईपीआर और आईआर स्पेक्ट्रमविज्ञान तथा विश्लेषणात्मक रसायन विज्ञान से संबंधित समूह शामिल हैं, पदार्थ के विभिन्न पहलुओं से संबद्ध मूलभूत अभिलक्षणों अर्थात रासायनिक संघटन, शुद्धता, संरचना (त्रुटियों सहित) और क्रिस्टलीय पूर्णता से संबंधित अध्ययन करने के कार्य के प्रति समर्पित रहा। इस प्रभाग में उच्च गुणवत्तायुक्त तथा अत्याधुनिक अभिलक्षणन सुविधाएं उपलब्ध हैं।

एक्स–किरण विश्लेषण समूह जो शुद्ध और/या मादित LN, KDP, BMZ, ZTS, LA, LAP, LAM, GPI, निनहाइड्रिन आदि जैसे प्रौद्योगिकीय दृष्टि से महत्त्वपूर्ण क्रिस्टलों को विकसित करने तथा उनके अभिलक्षण निर्धारण से संबंधित कार्यों के प्रति समर्पित है, द्वारा की गई प्रगति सराहनीय रही है। सॉलिड स्टेट लाइटिंग हेतु महत्त्वपूर्ण अर्ध–चालक GaN आधारित प्रकाश उत्सर्जी डायोड (एलईडी) युक्तियों का अभिलक्षण निर्धारण तथा पाउडर XRD प्रमाणित संदर्भ पदार्थों (सीआरएम) को विकसित करना इस प्रभाग का अतिरिक्त उल्लेखनीय योगदान था। इलेक्ट्रॉन तथा आयन सूक्ष्मदर्शिकी समूह में वास्तविक तथा अन्योन्यक्रियाशील स्थिति में परमाण्विक पैमाने पर भी पदार्थों की सूक्ष्म संरचना की व्याख्या से संबंधित कार्य किया गया। सूक्ष्मदर्शिकी समूह विभिन्न नैनो संरचना वाले पदार्थों (ZnO, TiO_2 SnO_2, CuO, Al_2O_3, ग्रेफीन, स्वर्ण आदि) तथा ग्रेफीन से पुनर्बलित Bi_2Te_3 नैनो सम्मिश्र पदार्थों जैसे ऊर्जा दक्ष ताप विद्युत पदार्थों एवं MWCNT और उनकी तनु फिल्मों को विकसित करने के प्रति भी समर्पित रहा। हाल में यह समूह नैनो पदार्थों के जीव वैज्ञानिक अनुप्रयोगों (सुरक्षा, स्वास्थ्य तथा पर्यावरण) तथा उनके संगत मानकीकरण पर केंद्रित एक नए क्रियाकलाप में संलग्न रहा है। प्रभाग द्वारा किए जा रहे क्रियाकलापों के विषय क्षेत्र में लक्षित औषधि सुपुर्दगी, प्रतिबिंबन, कैंसर उपचार, नैनो विष–विज्ञान तथा थेरानॉस्टिक्स जैसे विषय शामिल रहे हैं। ईपीआर तथा चुंबकीय तरल क्रियाकलाप में विभिन्न प्रचक्रण अनुनाद संवेदी पदार्थों तथा लौह–तरल पदार्थों सहित अन्य संबंधित पदार्थों का अभिलक्षण निर्धारण शामिल रहा है। Gd, Pr आदि दुर्लभ मृदा सामग्रियों से मादित मिश्रित फेराइटों के नैनो चुंबकीय कणों की जांच की गई तथा उनके भौतिक गुणों जैसे कि संरचना, आकारिकी, प्रवाहिकीय और चुंबकीय गुणों का अध्ययन किया गया। रसायन विज्ञान में मापिकी एवं प्रमाणित संदर्भ पदार्थ विश्लेषणात्मक रसायन विज्ञान समूह द्वारा किए गए दो सर्वाधिक महत्त्वपूर्ण कार्य थे। आयन वर्णलेखन (आईसी) प्रणाली द्वारा As^{5+}, Cr^{3+} और Cr^{6+} का अनुरेखण स्तर निर्धारित करने के लिए तथा आईयूपीएसी एवं यूराकेम दृष्टिकोणों के अनुसार उनके वैधीकरण के लिए नई विधियों को विकसित करना उल्लेखनीय है।

वर्ष के दौरान प्रयोगशाला द्वारा अनेक सम्मेलनों तथा समारोहों का आयोजन किया गया। इसके अन्तर्गत प्रमुख सम्मेलनों तथा सेमिनारों में आयोजित पहला सम्मेलन टीएपीएसयूएन (नेटवर्क के माध्यम से सौर ऊर्जा को प्रयोग में लाने के लिए प्रौद्योगिकी एवं उत्पाद) के अंतर्गत "भावी सौर ऊर्जा प्रौद्योगिकियों के क्षेत्र में प्रगति" विषय पर 4–5 दिसंबर, 2012 के दौरान आयोजित किया गया। सम्मेलन के दौरान अत्यधिक विचारोत्पादक सत्र आयोजित किए गए जिनसे सामग्रियों, युक्तियों, सौर ऊर्जा के भंडारण तथा वितरण के संबंध में नए प्रतिमानों से संबंधित नूतन संकल्पनाएं विकसित करने में सहायता प्राप्त हुई। इस सम्मेलन का उद्घाटन माननीय नवीन एवं नवीकरणीय ऊर्जा मंत्री डॉ. फारुख अब्दुल्ला द्वारा किया गया। स्विट्जरलैंड के फेडरल इंस्टिट्यूट ऑफ फेडरोलॉजी के प्रोफेसर माइकेल ग्रेटजल, जो रंग संवेदीकृत सौर सेलों के क्षेत्र में अग्रणी स्थान रखते हैं, ने "सौर प्रकाश से ईंधन तथा बिजली उत्पादन के लिए नैनो–संरचनायुक्त प्रकाश प्रणाली" विषय पर अपने मुख्य भाषण के दौरान प्रतिभागियों को अभिप्रेरित किया। माननीय विज्ञान एवं प्रौद्योगिकी, पृथ्वी विज्ञान मंत्री तथा सीएसआईआर के उपाध्यक्ष श्री जयपाल रेड्डी की उपस्थिति ने इस सम्मेलन की शोभा बढ़ाई।

चुंबकीय तरल पदार्थ विषय पर पांच दिवसीय अंतर्राष्ट्रीय सम्मेलन (आईसीएमएफ–13) 7–11 जनवरी, 2013 के दौरान आयोजित किया गया जिसमें चुंबकीय तरल पदार्थों के विशिष्ट अभिलक्षणों पर ध्यान केंद्रित करते हुए मुख्य अभिभाषण तथा पूर्ण व्याख्यान, आमंत्रित वार्ता एवं मौखिक प्रस्तुतीकरण दिए गए तथा इसके साथ ही पोस्टर सत्र का भी आयोजन किया गया। इस अंतर्राष्ट्रीय सम्मेलन द्वारा शिक्षाविदों, प्रौद्योगिकी विशेषज्ञों तथा उद्योगपतियों के बीच पारस्परिक संपर्क हेतु एक मंच प्राप्त हुआ जिसमें चुंबकीय तरल पदार्थों के भौतिक, रासायनिक, यांत्रिकी, प्रवाहिकीय और जीव–वैज्ञानिक गुणों के क्षेत्र में विस्तृत आधारभूत एवं व्यवहारिक जानकारी को शामिल किया गया।

सीएसआईआर–एनपीएल एवं मेट्रोलॉजी सोसाइटी ऑफ इंडिया (एमएसआई) द्वारा संयुक्त रूप से अंतर्राष्ट्रीय सम्मेलन "मापिकी के क्षेत्र में प्रगति", AdMet-2013 (इस श्रृंखला का 8वां सम्मेलन) 21–23 फरवरी, 2013 के दौरान आयोजित किया

गया और साथ ही 20 फरवरी, 2013 को रासायनिक माप विज्ञान में एक दिवसीय कार्यशाला का भी आयोजन किया गया। यह मापिकी के क्षेत्र में प्रत्येक तीन वर्ष के बाद आयोजित किए जाने वाला एक प्रमुख वैज्ञानिक सम्मेलन है। इसमें 6 राष्ट्रीय मापिकी संस्थानों सहित 15 देशों तथा विश्वभर के विभिन्न संस्थानों से आए चार सौ पंजीकृत प्रतिभागियों ने भाग लिया। एनआईएएस, बंगलुरु के निदेशक प्रोफेसर वी.एस. राममूर्ति ने मुख्य अतिथि के रूप में समारोह का उद्घाटन किया तथा पीटीबी, जर्मनी के अध्यक्ष प्रो. जे.एच. उलरीच ने प्रमुख भाषण दिया।

नैनो विज्ञान से संबंधित सभी प्रमुख मुद्दों जैसे कि अंतर्राष्ट्रीय तथा राष्ट्रीय मानकों की आवश्यकता, नैनो माप–विज्ञान, नैनो पदार्थ का संश्लेषण तथा अभिलक्षण निर्धारण, विषाक्तता तथा नैनो ऑप्टिक्स इत्यादि नैनो विज्ञान से संबंधित सभी प्रमुख मुद्दों पर चर्चा करने के लिए 25–26 फरवरी, 2013 के दौरान "नैनो विज्ञान तथा नैनो प्रौद्योगिकी हेतु मानकीकरण" विषय पर पहला राष्ट्रीय सेमिनार आयोजित किया गया। इस दो दिवसीय सेमिनार में अनेक राष्ट्रीय स्तर के विशेषज्ञों ने भाग लिया। इसे विज्ञान एवं प्रौद्योगिकी विभाग द्वारा चलाए जा रहे नैनो विज्ञान एवं प्रौद्योगिकी मिशन द्वारा समर्थन प्रदान किया गया। इसके अतिरिक्त, 27 सितंबर, 2012 को नैनो मापिकी विषय पर एक कार्यशाला का आयोजन किया गया तथा राजभाषा यूनिट द्वारा 7–8 नवंबर, 2012 के दौरान "रेडियो तथा वायुमंडलीय विज्ञान के विभिन्न पहलू" विषय पर एक राष्ट्रीय सेमिनार का हिन्दी में आयोजन किया गया।

सीएसआईआर–एनपीएल ने देशभर में फैली विभिन्न शैक्षणिक संस्थाओं से एम एससी/एम टेक/ एम सीए पाठ्यक्रमों में अध्ययन कर रहे छात्रों को प्रशिक्षण प्रदान किया। इस वर्ष के दौरान लगभग 96 छात्रों ने अल्पावधिक एवं दीर्घावधिक प्रशिक्षण कार्यक्रमों में भाग लिया। वैज्ञानिक तथा नवोन्मेषी अनुसंधान अकादमी (एसी एसआईआर) के "उन्नत पदार्थ भौतिकी एवं इंजीनियरिंग" में इंजीनियरी के स्नातकोत्तर अनुसंधान कार्यक्रम (पीजीआरपीई) में 10 छात्रों को प्रवेश दिया गया। इस वर्ष के दौरान 26 नए अनुसंधान अध्येता शामिल हुए और प्रयोगशाला में इनकी कुल संख्या बढ़कर 97 हो गई। वैज्ञानिक तथा नवोन्मेषी अनुसंधान अकादमी में चौंतीस छात्रों का भौतिकी तथा रसायन विज्ञान विषयों में पीएच डी के लिए पंजीकरण किया गया। अन्य विश्वविद्यालयों जैसे कि भारतीय प्रौद्योगिकी संस्थानों (आईआईटी), दिल्ली विश्वविद्यालय, दिल्ली प्रौद्योगिकीय विश्वविद्यालय तथा जवाहरलाल नेहरू विश्वविद्यालय आदि में पीएच डी के लिए पहले से ही तिरसठ छात्रों का पंजीकरण किया गया है।

स्कूलों, कॉलेजों, विश्वविद्यालयों, तकनीकी संस्थानों, विज्ञान तथा प्रौद्योगिकी संगठनों के छात्रों, अध्यापकों, संकाय सदस्यों के लिए दौरों का आयोजन करना सीएसआईआर–एनपीएल का एक महत्त्वपूर्ण कार्य है। इस वर्ष के दौरान इस प्रकार के छह संस्थागत दौरे आयोजित किए गए। मापिकी, गुणवत्ता प्रबंधन प्रणाली, पदार्थ अभिलक्षण तकनीक और साथ ही बौद्धिक संपदा अधिकारों सहित अन्य विशिष्ट विषयों के क्षेत्र में औद्योगिक प्रशिक्षण कार्यक्रम भी आयोजित किए गए। ऐसे 9 पाठ्यक्रमों का आयोजन किया गया जिनमें विभिन्न उद्योगों, परीक्षण तथा अंशांकन प्रयोगशालाओं तथा अन्य विभिन्न राष्ट्रीय तथा अंतर्राष्ट्रीय विज्ञान एवं प्रौद्योगिकी संगठनों के कार्मिकों ने भाग लिया।

वर्ष के दौरान एससीआई जर्नलों में कुल 350 वैज्ञानिक तथा तकनीकी लेख प्रकाशित किए गए। भारत में 6 पेटेंट दर्ज कराए गए तथा 3 पेटेंट विदेशों में दर्ज कराए गए। 2012–13 के दौरान 17 अंतर्राष्ट्रीय पेटेंटों और 3 भारतीय पेटेंटों, जिन्हें पिछले वर्ष दर्ज कराया गया था, को स्वीकृति प्रदान की गई। 17 नई परियोजनाओं (प्रायोजित तथा परामर्शदात्री) को शुरू किया गया तथा 2355 अंशांकन रिपोर्टें जारी की गईं जिसके फलस्वरूप लगभग 470 लाख रुपए का ईसीएफ अर्जित किया गया।

प्रोफेसर अनिल के. गुप्ता, भारतीय प्रबंध संस्थान (आईआईएम), अहमदाबाद ने 21 मई, 2012 को "राष्ट्रीय प्रौद्योगिकी दिवस" के साथ–साथ आयोजित किए गए "विश्व मापिकी दिवस" के अवसर पर "जलवायु संबंधी जोखिमों का रचनात्मक रूप में सामना करना" विषय पर प्रमुख भाषण दिया। ब्यूरो इंटरनेशनल डेस पोइड्स एट मेजर (बीआईपीएम, पेरिस) द्वारा निर्णीत वर्ष 2012 के "विश्व मापिकी दिवस" की थीम "मापिकी–हम आपकी सुरक्षा हेतु मापन करते हैं" थी। प्रोफेसर गुप्ता ने जलवायु संबंधी जोखिमों का सामना करने में नवप्रवर्तन तथा रचनात्मकता की भूमिका का वर्णन किया। इस अवसर पर राष्ट्रीय भौतिक प्रयोगशाला ने Pb (2), Ca, Cr और सल्फेट के एकल–तत्त्वीय जलीय विलयनों के 5 प्रमाणित संदर्भ पदार्थ (सीआरएम) जारी किए। राष्ट्रीय प्रौद्योगिकी दिवस के उपलक्ष्य में राष्ट्रीय भौतिक प्रयोगशाला की नवप्रवर्तक टीमों को उनके पेटेंटों, सॉफ्टवेयर कॉपीराइटों और प्रौद्योगिकी अंतरणों के लिए पुरस्कृत किया गया।

वैज्ञानिक एवं औद्योगिक अनुसंधान परिषद् (सीएसआईआर) का 70वां स्थापना दिवस समारोह 26 सितंबर, 2012 को मनाया गया। इस अवसर पर प्रोफेसर सुशांत दत्त गुप्ता, उप कुलपति, विश्व भारती, शांतिनिकेतन ने "समावेशी शिक्षा, टैगोर

मॉडल तथा हिग्स कण" विषय पर स्थापना दिवस व्याख्यान प्रस्तुत किया। सीएसआईआर–एनपीएल द्वारा वैज्ञानिक एवं औद्योगिक अनुसंधान परिषद् (सीएसआईआर) के स्थापना दिवस समारोहों के एक हिस्से के रूप में 28 सितंबर, 2012 को ओपन–डे सत्र आयोजित किया गया। ओपन–डे सत्र वैज्ञानिकों तथा राष्ट्रीय भौतिक प्रयोगशाला में किए जा रहे अनुसंधान कार्यों के बारे में जानने में रुचि रखने वाले व्यक्तियों के बीच पारस्परिक संपर्क स्थापित करने का एक अवसर है जो वर्ष में एक बार आता है। इस समारोह में लगभग 2000 व्यक्तियों ने भाग लिया।

सर सी वी रमन के प्रति श्रद्धांजलि के रूप में 28 फरवरी, 2012 को राष्ट्रीय विज्ञान दिवस–2012 मनाया गया। इस अवसर पर मिशिगन विश्वविद्यालय, संयुक्त राज्य अमेरिका के प्रोफेसर एस.डी. महंती ने विज्ञान दिवस व्याख्यान प्रस्तुत किया। एक पोस्टर प्रस्तुतीकरण कार्यक्रम का भी आयोजन किया गया जिसमें सीएसआईआर–एनपीएल के सभी अनुसंधान अध्येताओं के कार्यों को प्रदर्शित किया गया। इनमें से सर्वोत्तम 5 पोस्टरों का पुरस्कार हेतु चयन किया गया।

राष्ट्रीय भौतिक प्रयोगशाला द्वारा 11 मार्च, 2013 को XXXIVवां कृष्णन स्मृति व्याख्यान को आयोजित करना एक सम्मान की बात थी, जिसमें आईबीएम के अध्येता तथा विश्वविख्यात अनुसंधानकर्ता डॉ. स्टुअर्ट एस.पी. पार्किन* द्वारा यह स्मृति व्याख्यान प्रस्तुत किया गया। "इलेक्ट्रॉनिक्स से संबंधित प्रचक्रण! नैनो विज्ञान तथा नैनो प्रौद्योगिकी में प्रचक्रण धाराओं का विज्ञान तथा प्रौद्योगिकी" विषय पर दिया गया यह व्याख्यान अत्यधिक सूचनाप्रद तथा सम्मोहक था। प्रोफेसर एस.के. जोशी, विक्रम साराभाई प्रोफेसर, जेएनसीएएसआर, बंगलुरु ने समारोह की अध्यक्षता की।

शैक्षणिक कार्यों को आयोजित करने के साथ ही राष्ट्रीय भौतिक प्रयोगशाला ने 4–5 मार्च, 2013 के दौरान आईएआरआई, दिल्ली में आयोजित पूसा बागबानी प्रदर्शनी में भी भाग लिया तथा इस प्रदर्शनी में सबसे अधिक संख्या में पुरस्कार जीते। 14 श्रेणियों में आयोजित की गई प्रतियोगिताओं में प्रयोगशाला ने 37 प्रथम, 24 द्वितीय, 14 तृतीय पुरस्कार तथा 15 चैलेंज कप/शील्ड प्राप्त किए। हमारे बागबानी अनुभाग द्वारा किए गए प्रयास अत्यधिक सराहनीय थे।

मैं, प्रयोगशाला की प्रगति के लिए सीएसआईआर–एनपीएल के सभी कर्मचारियों तथा साथ ही युवा अनुसंधानकर्ताओं की अथक सहायता तथा वास्तविक योगदान के लिए उनकी हृदय से सराहना करता हूं। यहां यह कहना महत्त्वपूर्ण है कि उनके हार्दिक तथा समर्पित सहयोग के बिना प्रयोगशाला द्वारा प्राप्त की गई अधिकांश उपलब्धियों को पूरा कर पाना संभव नहीं होता। मैं इस अवसर पर सीएसआईआर मुख्यालय, अनुसंधान परिषद् और प्रबंध परिषद् से समय–समय पर प्राप्त मूल्यवान मार्गदर्शन एवं सहायता जो हमें हमारे लक्ष्यों को पूरा करने में अत्यधिक सहायक सिद्ध हुई, की भी सराहना करता हूं। विभिन्न अवसरों पर राष्ट्रीय भौतिक प्रयोगशाला के दौरे पर आए राष्ट्रीय तथा अंतर्राष्ट्रीय स्तर के विशेषज्ञों का हमारे अनुसंधानकर्ताओं के साथ संपर्क और विचार–विमर्श हमारे लिए काफी लाभकारी तथा प्रेरणाप्रद सिद्ध हुआ है।

अंत में, मैं इस रिपोर्ट को समय से प्रकाशित करने के लिए प्रकाशन समिति के अध्यक्ष डॉ. वीरेंद्र शंकर के नेतृत्व में समिति के योगदान के लिए उनका आभार व्यक्त करता हूं। श्री टी. राघवेंद्र, डॉ. टी.डी. सेनगुट्टुवन, श्री वी.डी. अरोड़ा, श्री प्रेम चंद, सुश्री अनीता शर्मा, सुश्री सरोज उपाध्याय, श्री विजय सिंह और श्री सुभाष चंद्र का सहयोग और उनके द्वारा किए गए विशेष प्रयास भी अत्यधिक सराहनीय हैं।

(आर सी बुधानी)
निदेशक

* डॉ. पार्किन द्वारा लगभग एक दशक पहले चुंबक–प्रतिरोधी तनु फिल्म संरचनाओं के क्षेत्र में की गई खोज के परिणामस्वरूप चुंबकीय डिस्क ड्राइवों की भंडारण क्षमता में 1000 गुना वृद्धि हुई। वर्तमान में डॉ. पार्किन भंडारण श्रेणी के एक नए मेमोरी डिवाइस 'रेसट्रैक मेमोरी' को विकसित करने की दिशा में काम कर रहे हैं जिसे हार्ड डिस्क ड्राइवों और अनेक प्रकार के परंपरागत सॉलिड स्टेट मेमोरी युक्तियों के स्थान पर प्रयोग में लाया जा सकता है।

From the Director's Desk...

I am delighted to present the Annual Report of CSIR-National Physical Laboratory (NPL) for the year 2012-13. CSIR-NPL is one of the leading laboratories of the Council of Scientific & Industrial Research (CSIR) in addition to being the National Metrology Institute (NMI) of India. It promotes R&D in various innovative research fields related to energy, nanotechnology, advanced materials, quantum condensed matter, radio & atmospheric sciences, quantum metrology and development of advanced standards of measurements. All along since its inception, NPL has been supporting Indian industries and contributing to society by providing them knowledge-based technologies and continuous advancement in knowledge.

It is now globally recognized that to realize a sustainable society and to address many environmental issues emanating from massive industrial growth, integrated implementation of science, technology, and innovation is highly essential. In this context public research institutes like CSIR-NPL have to play a very significant role. The National Physical Laboratory is fully conscious of this responsibility and is playing a defining role in this direction, and contributing significantly towards India's global competitiveness in all sectors development. To meet its objectives, NPL has been steadily and continuously undergoing transformation to be a frontline and globally recognized laboratory in physical sciences. During the Year 2012-13, this process continued and further additions were made to the already existing world class research infrastructure of the laboratory. In terms of human resource, which is the backbone of any organization, the laboratory continued to move towards a favourable mix of young as well as experienced scientific work force. All these efforts culminated into enhanced and important R&D accomplishments during the year. Two of our scientists, Dr. Poonam Arora and Dr. Priyanka H. Maheshwari with their exceptional contributions bagged the coveted CSIR Young Scientist Award, 2012 in the areas of Physical Sciences and Engineering Sciences respectively.

Outstanding research was carried out in all the seven distinguished and theme-dedicated divisions, namely, Physics of Energy Harvesting; Materials Physics and Engineering; Radio & Atmospheric Sciences; Time & Frequency; Apex Level Standards & Industrial Metrology; Quantum Phenomenon & Applications

and Sophisticated & Analytical Instruments. Based on the excellent fundamental and applied research in these areas, several papers were published in journals with high impact factor as well as some national and international patents were filed on important inventions.

Physics of Energy Harvesting Division reported Polymer Solar Cells (PSCs) with a modified and innovative PTB7:PC60BM light absorbing active layer. This has the potential of giving cost effective, efficient, flexible and stable polymer solar cells with power conversion efficiency (PCE) of > 6 %. The invention, internationally certified, is being patented. In the area of silicon solar cells, a 'Proof of Concept' of black silicon solar cells was developed which has the potential to reduce the cost of these devices. Other important contributions included : synthesis of graphene from a-C films, ZT value of 1.1 at 470K for Bi_2Te_3+BiTe (8 mol %) sample, fabrication of unipolar OFET on optimized SiO_2 dielectric materials, growth of epitaxial GaN on sapphire, amorphous & microcrystalline silicon thin film deposition for solar cells using VHF PECVD and improved quality of CIGS absorber layer. Some new facilities were also created and made operational in the division such as polymer solar cell device fabrication facility using glove box integrated with evaporator and encapsulation system, atomic layer deposition system, ultra-fast femto-second laser spectroscopy and ultra high vacuum pulsed laser deposition (UHV-PLD) system.

The Division of Materials Physics and Engineering also emphasized on both basic and applied research. The mechanism of electrically modulated photoluminescence in ferroelectric liquid crystal (FLC) was studied and reported in a high impact journal. Two important and commercially viable carbon components for fuel cell, namely, porous conducting carbon paper and composite bipolar plate were developed. In the area of biomedical sensors, extensive research continued for the measurement of cholesterol level and detection of cardiac biomarkers using micro fluidic techniques. The important engineering materials, which were investigated and characterized, included p-type of thermoelectric material, Cu_2Se, with a very high figure-of-merit and rare earth free permanent magnetic materials. Another achievement was development of nanophosphors for solar cell and synthesis of doped nanocrystals and quantum dots with enhanced luminescence for display devices. Novel nanophosphors for LEDs and luminomagnetic nanophosphors for bio-related applications were other thrusts areas of development.

Radio and Atmospheric Sciences Division participated in the 31st Indian Scientific Expedition to Antarctica and successfully carried out scientific experiments in the field of space weather and climate changes. Electromagnetic macro modeling, with an objective of predicting the path loss exponent of propagation, in mobile wireless communication was carried out in collaboration with Syracuse University. Idea was to find out a suitable propagation model required for future network planning. The ionospheric F2-region variability recently linked to sudden stratospheric warming (SSWs) was established. Assessment of Energy Generation Potentials of Municipal Solid Waste (MSW) in Delhi under Different Technological Options was carried out. An updated inventory of greenhouse gas emissions from the energy sector in India comprising of emissions from thermal power plants, road transport, railways, aviation and marine transport were prepared for the period of 2001-02 to 2009-10. Work on the 12th plan network project to characterize the changing atmosphere and its impacts were initiated. Detailed chemical, physical and isotopic characterization of atmospheric aerosols over India was done using different state-of-the art analytical facilities available at NPL. Studies on the altitude distribution of lower tropospheric Aerosols and Clouds over New Delhi using Lidar was also carried out.

Time and Frequency Division is actively involved in research on microwave frequency standards, optical frequency standards and precise timing systems. Major scientific achievements included: continual

operation of the first Cs fountain frequency standard and preliminary evaluation of its frequency; design and development of second Cs fountain; indigenous development of rubidium cells and bulbs for space clocks for ISRO's IRNSS (Indian Regional Navigation Satellite System); initial work on the project on development of single trapped ytterbium ion optical frequency standard; creation of NTP (Network Time Protocol) internet time service and contribution of all atomic clocks in the division to the international atomic time. CSIR-NPL has recently started comparing the accuracy of its clocks with other precision clocks around the world with an uncertainty of 0.3 ns. This precise, regulated and automated inter comparison of clocks using satellite links has resulted in the NPL's cesium clocks and a hydrogen maser contributing to the International Atomic Time Scale, TAI. Weightage to these Indian clocks have been assigned by Bureau International des Poids et Measures (BIPM, Paris) for the first time.

Apex Level Standards and Industrial Metrology Division consisting of twelve groups continued to participate very keenly in the various assigned activities. In view of the importance to meet the continually increasing demand of accuracy and improved uncertainties, two major milestones achieved were: (1) Extension of the 11th Five year Plan project "Advances in Metrology – CSIR/NWP-45" up to 31st March, 2014 with additional fund and (2) Approval of a new project under 12th Five year Plan entitled "Measurement Innovation in Science & Technology (MIST) under SFC/CSIR funding. A poster containing the divisional activities was selected as one of the 70 posters of CSIR and presented at the CSIR foundation day on 26th September, 2012. Some of the important R&D contributions of the division included: (1) Measurement of external diameter of cylindrical shaped artifacts using a Length Measuring Machine, (2) High temperature primary standards by realizing silver and copper fixed points by metal-in-graphite blackbody cavities using Photo-electric linear pyrometer, (3) Elaborate studies on spectral switching based information processing (SSBIP), and (4) development of New Rice Husk Material as an Absorber. The division could establish: (1) A new Triple Raman Spectrometer with low temperature attachment, (2) High Temperature Primary Standards, (3) Installation of Multiferroic Tester, (4) Set-up for 24 h Noise Monitoring System for Road Traffic Noise and Airport Noise Measurements (5) An automatic Water Flow Calibration Standard of size DN100, and (6) Establishment of automated Power Ratio Technique for the calibration of lower value attenuators (0.1dB to 10 dB).

In the Quantum Phenomenon & Applications Division, wide range of thin film and device fabrication techniques such as Pulsed Laser Deposition, DC and RF Magnetron Sputtering, Thermal Evaporation, Photo-lithography, Argon Ion Milling and Focused Ion Beam were employed to produce transition metal oxide heterostructures, spintronic materials, superconductor/ferromagnet heterostructures, magnetic nanorings and graphene/tungsten based junctions. A "SQUID based 7 Tesla Magnetometer" was installed and made functional to characterize magnetization, ac susceptibility and resistivity of various thin film based samples. To understand novel quantum phenomena in advanced samples of oxide interfaces, nano-wires and junctions at very low temperatures in presence of high magnetic fields, a facility of 10 mK dilution refrigerator coupled with a 14 Tesla magnet has been planned. Besides, a new activity of pulsed magnet was initiated with an aim to establish ~ ms pulse of 50 Tesla magnetic field systems at low temperatures. Superconducting materials group continued to contribute in BiS_2, pnictides and MgB_2 superconductors. The Programmable Josephson Voltage Standard was further characterized to operate the system consistently with better stability and reproducibility. A facility based on the phenomena of SPDC for measurement of absolute quantum efficiency of photo-detectors and basic quantum optical studies for their application in quantum information processing was established. Fourier transform infrared spectroscopic technique is being tried to delineate the interaction mechanism of anticancer drugs with DNA and different oligonucleotides.

Sophisticated Analytical Instruments Division comprising of four groups namely: X-ray Analysis, Electron & Ion Microscopy, EPR & IR Spectroscopy and Analytical Chemistry remained dedicated to the basic characterization of materials regarding different aspects, namely, chemical composition, purity, structure (including defects) and crystallographic perfection. The division houses high quality and state-of-the-art characterization facilities.

The progress made by X-ray Analysis group, devoted to the growth of technologically important crystals like pure and/or doped LN, KDP, BMZ, ZTS, LA, LAP, LAM, GPI, ninhydrin etc. and their characterization, was admirable. The characterization of important semiconducting GaN based LED devices for solid state lighting and development of powder XRD Certified Reference Materials (CRMs) were its additional significant contributions. In the electron and ion microscopy, the microstructural interpretation of materials even at atomic scale in real and reciprocal space was accomplished. The Microscopy group was also dedicated to the growth of various nanostructured materials (ZnO, TiO_2, SnO_2, CuO, Al_2O_3, Graphene, Gold, etc.) and energy efficient thermoelectric materials like Bi_2Te_3 nano composites reinforced with graphene and MWCNTs and their thin films. It was recently involved in a new activity focused on biological applications (safety, health and environment) of nanomaterials and their respective standardization. The thematic areas of the activity included targeted drug delivery, imaging, cancer therapy, nanotoxicology, and theranostics. EPR and magnetic fluid activities encompassed the characterization of materials of interest including various spin resonance sensitive materials and ferrofluids. Nanomagnetic particles of mixed ferrites doped with rare earth e.g. Gd, Pr etc., were investigated for their physical properties like structural, morphological, rheological and magnetic properties. The metrology in chemistry and certified reference materials were the two most important assignments carried out by Analytical Chemistry group. The development of new methods to determine trace level of As^{5+}, Cr^{3+} and Cr^{6+} by Ion Chromatography (IC) system and their validation according to the IUPAC and EURACHEM approaches was noteworthy.

During the year, several conferences and seminars were organized by the laboratory. Among the prominent ones, under TAPSUN, the first conference on "Advances in Futuristic Solar Energy Technologies" was organized during December 4-5, 2012. The brain storming sessions throughout the conference helped in forming innovative ideas towards a new paradigm of materials, devices, storage and distribution of solar energy. The conference was inaugurated by Dr. Farooq Abdullah, Hon'ble Minister, MNRE. Prof. Michael Gratzel of Swiss Federal Institute of Technology and pioneer of Dye Sensitized Solar Cells motivated the participants with his key note address entitled "Nano-structured Photo-systems for the generation of Fuels and Electricity from sunlight". Hon'ble Minister of Science & Technology, Earth Sciences and Vice President, CSIR, Shri Jaipal Reddy, also graced the occasion.

A five-day international conference on magnetic fluids (ICMF-13) with keynote and plenary addresses, invited talks and oral presentations focusing on specific tenets of magnetic fluids along with poster sessions was held during January 7-11, 2013. It provided a platform for interaction between academicians, technology experts and industrialists and covered detailed fundamental and practical knowledge in the field of physical, chemical, mechanical, rheological and biological properties of magnetic fluids.

The International Conference "Advances in Metrology", AdMet – 2013, (8^{th} conference in AdMet series) was jointly organized by CSIR-NPL and Metrology Society of India (MSI) during February 21-23, 2013 along with one day workshop in Chemical Metrology on February 20, 2013. It is one of the major scientific events held every three years in the area of Metrology. Four hundred registered participants attended the conference from 15 countries including 6 NMI's and various institutes across the globe. Prof. V.

S. Ramamurthy Director, NIAS, Bengaluru, inaugurated the conference as Chief Guest and Prof. J. H. Ullrich President, PTB Germany, delivered the Keynote Address.

To discuss all the key issues concerning nanoscience such as need for international and national standards, nanometrology, nanomaterial synthesis and characterization, toxicity, and nano-optics, 1st National Seminar on Standardization for Nanoscience and Nanotechnology was held during February 25-26, 2013. Several national experts on the subject participated in the two day deliberations. It was supported by Mission on Nano science and Technology, DST. In addition, a workshop on Nano-Metrology was held on 27th September, 2012 and a national conference on "Various aspects of Radio and Atmospheric Sciences" was organized in Hindi by Raj Bhasha Unit during November 7-8, 2012.

CSIR-NPL provided training to students, pursuing M.Sc./M.Tech./MCA, from different educational institutions spread all across the country. During the year, about 96 students underwent short and long term training. Under the Academy of Scientific and Innovative Research (AcSIR), for Post Graduate Research Programme in Engineering (PGRPE) in "Advanced Materials Physics & Engineering", ten students were admitted. Twenty six fresh research fellows joined during the year, making a total strength of 97. Under AcSIR, thirty four students are registered for Ph.D. in Physical and Chemical Sciences. Sixty three students are already registered for Ph.D. at other universities such as IITs, Delhi University, Delhi Technological University and JNU etc.

Organization of institutional visits involving students, teachers, faculty members from schools, colleges, universities, technical institutes, S&T organizations is an important activity of the CSIR-NPL. Six of such institutional visits took place during the year. Industrial training was also organized in the area of Metrology, Quality Management System, Materials Characterization Techniques as well as other specialized topics including Intellectual Property Rights (IPR). Nine of such courses were organized and were attended by the personnel belonging to various industries, testing & calibration laboratories and other various national and international S&T organizations.

During the year, a total of 350 scientific and technical papers were published in SCI Journals. Six patents were filed in India and three patents were filed abroad. Seventeen international patents and three Indian patents filed in previous years were granted during 2012-13. Seventeen new projects (sponsored and consultancy) were undertaken and 2355 calibration reports were issued, which contributed to generation of an ECF of about 470 lakhs.

Prof Anil K. Gupta, IIM, Ahmedabad, delivered key note address entitled "Coping with Climatic Risks Creatively" on "World Metrology Day" which was celebrated on May 21, 2012 together with "National Technology Day". The theme of "World Metrology Day", as decided by BIPM, was *Metrology-We measure for your safety*. Prof. Gupta described the role of innovation and creativity in coping with climatic risks. On the occasion, NPL released five certified Reference Materials (CRM) of mono-elemental aqueous solutions of Pb (two), Ca, Cr and sulfate. To mark the National Technology Day, the teams of innovators from NPL were awarded for their patents, software copyrights and technology transfers.

The 70th CSIR's Foundation Day was celebrated on 26th September, 2012. Prof. Sushant Duttgupta, Vice Chancellor, Vishva Bharati, Shanti Niketan, delivered Foundation Day lecture entitled "Inclusive Education, The Tagore model and the Higgs Particle". As a part of celebrations, the CSIR-NPL Open-Day was held on 28th September, 2012 The Open-Day is once a year opportunity for direct interaction between scientists

and the public to know about research activities of the laboratory. Around 2000 visitors turned up on the occasion.

As a tribute to Sir C.V. Raman, the National Science Day 2012 was celebrated on 28th Feb, 2012. Prof. S.D. Mahanti, University of Michigan, USA, delivered the Science Day Lecture. A Poster Presentation Event was also organized where the work of all research fellows of CSIR-NPL was exhibited. Out of these, five best posters were selected for awards.

It was an honour for NPL to hold the XXXIV Krishnan Memorial Lecture which was delivered by a world renownd researcher, Dr. Stuart S.P. Parkin*, an IBM Fellow, on March 11, 2013. The lecture entitled "Spin on Electronics! Science and Technology of Spin Currents in Nano-science and Nano-Technology" was very informative and fascinating. Prof. S. K. Joshi, Vikram Sarabhai Professor, JNCASR, Bangalore, presided over the function.

Along with the academics, NPL also participated in Pusa Horticulture Show held at IARI, Delhi, during March 4-5, 2013, and bagged largest number of prizes in the show. In 14 categories, it won 37 first prizes, 24 second prizes, 14 third prizes and 15 Challenge Cups/Shields. The effort was quite commendable on the part of our Horticulture Section.

I earnestly appreciate the unconditional support and sincere contributions of each and every member of CSIR-NPL staff including young researchers towards the progress of the laboratory. It is important to emphasize that without their wholehearted and dedicated cooperation, much of our accomplishment would not have been possible. I also wish to acknowledge the valuable guidance and support provided by the CSIR Head Quarters, our Research Council and Management Council in achieving our aims. The visits of national and international experts to the laboratory and interaction with our researchers had been most rewarding and motivational.

Finally, I wish to acknowledge the contribution of the Publication Committee under the leadership of Dr. Virendra Shanker in bringing out this report. The cooperation and special efforts of Sh. T. Raghavendra, Dr. T.D. Senguttuvan, Sh. V. D. Arora, Sh Prem Chand, Ms Anita Sharma, Ms Saroj Upadhyay and Sh Subhash Chandra are also appreciated.

(R. C. Budhani)
Director

* Parkin's discoveries in magneto-resistive thin film structures enabled a 1000 fold increase in the storage capacity of magnetic disk drives in little more than a decade. Most recently, Parkin is working on a novel storage class memory device, "Racetrack Memory", which could replace both hard disk drives and many forms of conventional solid state memory.

प्रस्तावना

Preamble

CSIR-National Physical Laboratory is one of the first National laboratories set-up under CSIR. Its foundation stone was laid by the first Prime Minister of India, late Pandit Jawaharlal Nehru on 4th January 1947. Late Dr. K.S. Krishnan, FRS, was the first Director of the laboratory. The main building was opened by the then Deputy Prime Minister, late Sardar Vallabhbhai Patel on 21st January 1950.

CHARTER

The main objectives of NPL have been a) to establish, maintain and improve National Standards of Measurements and to realize the Units based on International system, b) to identify and conduct research in areas of Physics, which are most appropriate to the needs of the Nation and for the advancement of the field, c) to assist industries, national and other agencies in their developmental tasks by precision measurements, calibration, development of devices, processes and other allied problems related to physics and d) to keep itself informed of and study critically the status of physics.

CUSTODIAN OF NATIONAL STANDARDS OF MEASUREMENT

National Physical Laboratory has the responsibility of realizing the units of physical measurements based on the International System (SI units) under the subordinate legislations of Weights & Measures Act 1956 (reissued in 1988 under the 1976 Act). NPL also has the statutory obligation to establish, maintain and update the national standards of measurement & calibration facilities for different parameters. The seven SI base units are metre, kilogram, second, Kelvin, Ampere, candela, mole and the SI supplementary units are radian (rad) & steradian (sr). The other derived units for physical measurement, that the laboratory currently maintains, are: force, pressure, vacuum, luminous flux, sound pressure, ultrasonic power; ac voltage; current and power; low frequency voltage; impedance and power; high frequency voltage; attenuation and noise; microwave power and frequency.

NATIONAL APEX BODY FOR CALIBRATION

The laboratory provides apex level calibration services in the country, offering National Accreditation Board for Testing and Calibration (NABL), the national accreditation body in the country, (i) its qualified assessors as needed for establishing best measurement capability of the applicant laboratory; (ii) its technical input to enable NABL to decide the suitability of the applicant laboratory for accreditation, and (iii) its faculty to train testing laboratories for estimation of uncertainty in their measurements.

Besides, the laboratory is engaged in development of Certified Reference Materials to

ensure high quality measurement and traceability of analytical measurements to national/international measurement system (SI unit) in order to fulfill the mandatory requirement of quality systems (IS/ ISO/IEC-17025:2005) and of the NABL.

MAJOR ACHIEVEMENTS

National Physical Laboratory has to its credit innumerable number of achievements, a few major achievements are: a) Introduction of Metric system of measurements in India, b) Development of Indelible ink- the indelible contribution to Indian democracy, c) Estimation of methane gas emission from India- a nationwide measurement campaign giving countrywide advantage in environment protection, d) Setting up a pilot plant for development of Electronic Components (ferrites), which led to setting up a public sector Unit called Central Electronics Ltd. (CEL) in 1973, e) Development of know-how of the Electrostatic Photocopying machine using indigenous materials and f) Indian Standard Time.

THE MAJOR THRUST AREAS OF R & D

(A) Metrology

- ✓ Calibration & Testing Services to Industries
- ✓ Electrical & Electronic Standards
- ✓ Physico - Mechanical Standards
- ✓ Metrology in Chemistry
- ✓ Nano Metrology
- ✓ Primary Standards
- ✓ Realization of SI units

(B) Materials

- ➢ Light weight, high strength metallic materials
- ➢ Bulk Nanometallic and Nanocomposite materials
- ➢ Carbon & Carbon composites
- ➢ Plasma Processed Materials
- ➢ Organic and Inorganic Photovoltaics
- ➢ Luminescent Materials
- ➢ Organic Light Emitting Diodes
- ➢ Conducting Polymers & Composites
- ➢ Superconducting materials and Superconductivity
- ➢ Fuel cells
- ➢ Sensors (based on Bio, Gas, Chemicals, MEMS)
- ➢ Advanced Characterization Techniques

(C) Radio and Atmospheric Sciences

- Ionosphere & Troposphere
- Atomospheric Environment
- Global Climate Change
- Antarctica and Arctic studies
- Radio-Propagation
- Communications (fixed, mobile and marine)

ORGANIZATION AND MANAGEMENT

The laboratory has structured its total activities under seven scientific decision units. These are: (i) Physics of Energy Harvesting, (ii) Materials Physics and Engineering, (iii) Radio and Atmospheric Sciences, (iv) Time and Frequency Standards, (v) Apex Level Standards and Industrial Metrology, (vi) Quantum Phenomena and Applications (vii) Sophisticated and Analytical Instruments.

In addition, it has set-up eight support units for its organization and management. These are (i) Administration (ii) Finance & Accounts, (iii) Stores & Purchase, (iv) Works and Services, (v) Workshop and Cryogenics, (vi) Computation & Network Facility, (vii) Directorate, (viii) Intellectual Property and Human Resource.

CSIR–NPL

Organizational Structure

Research & Development Divisions

- **Physics of Energy Harvesting** Division - 01
- **Materials Physics & Engineering** Division - 02
- **Radio & Atmospheric Sciences** Division - 03
- **Time & Frequency Standards** Division - 04
- **Apex Level Standards & Industrial Metrology** Division - 05
- **Quantum Phenomena & Applications** Division - 06

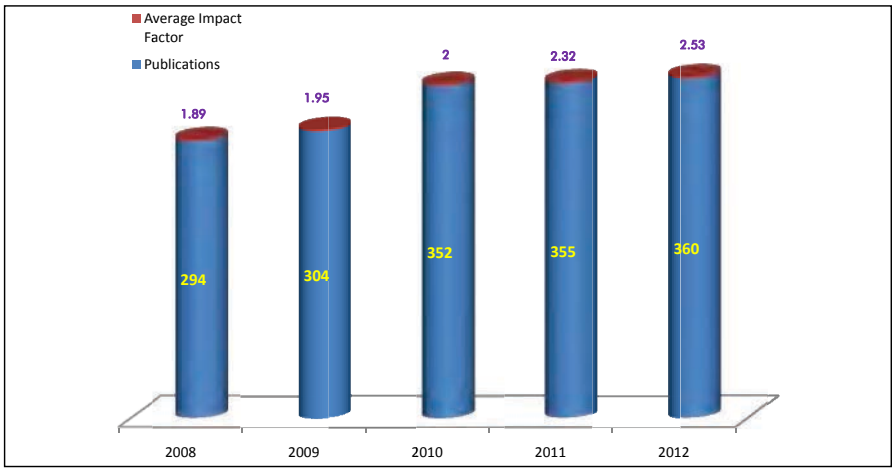
Scientific & Administrative Support Divisions

- **Administration** SASD - 01
- **Finance & Accounts** SASD - 02
- **Stores & Purchase** SASD - 03
- **Works & Services** SASD - 04
- **Workshop & Cryogenics** SASD - 05
- **Computation & Network Facility** SASD - 06
- **Directorate** (Sophisticated & Analytical Instruments, PME, QS) SASD - 07
- **Intellectual Property & Human Resource** (HRD, ISTAG, ILG, IPR, CFCT, Library) SASD - 08

निष्पादन संकेतक

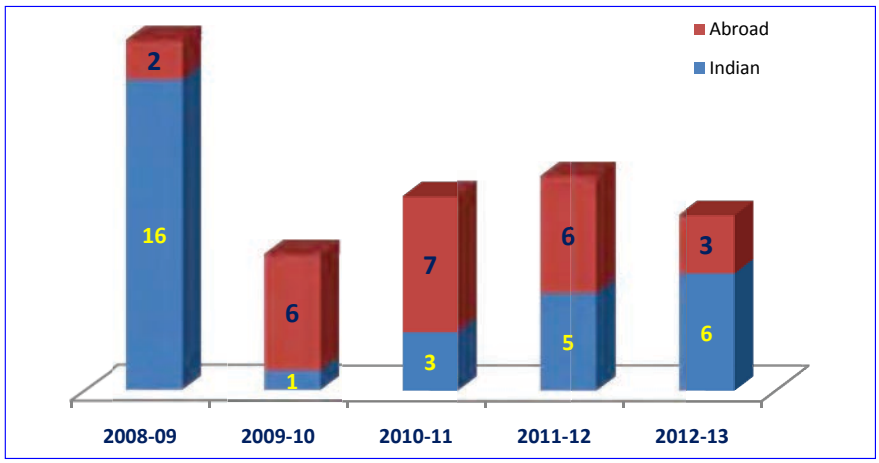
Performance Indicators

PUBLICATIONS

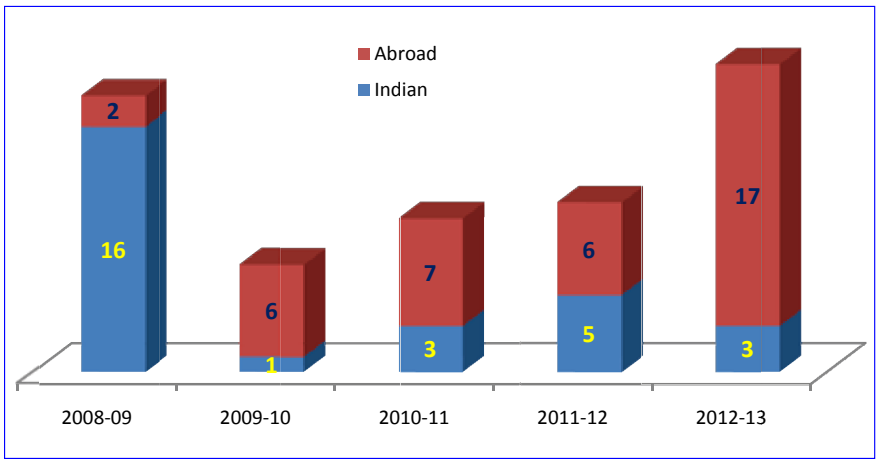


PATENTS

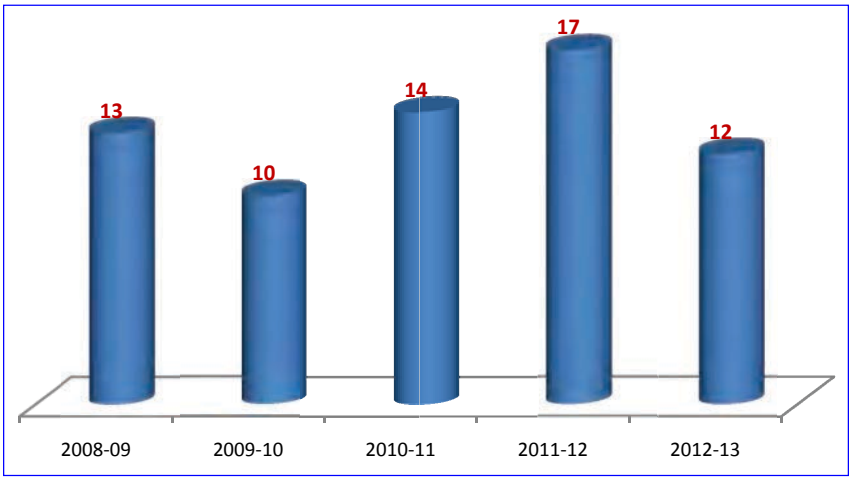
PATENTS FILED



PATENTS GRANTED

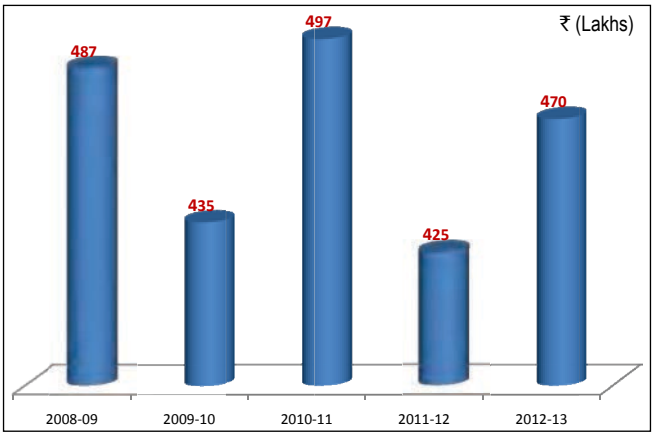


NEW EXTERNALLY FUNDED PROJECTS UNDERTAKEN DURING LAST FIVE YEARS

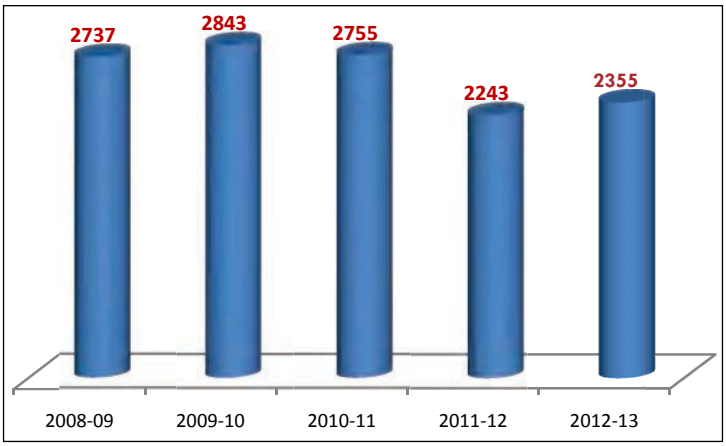


CALIBRATION AND TESTING AT NPL

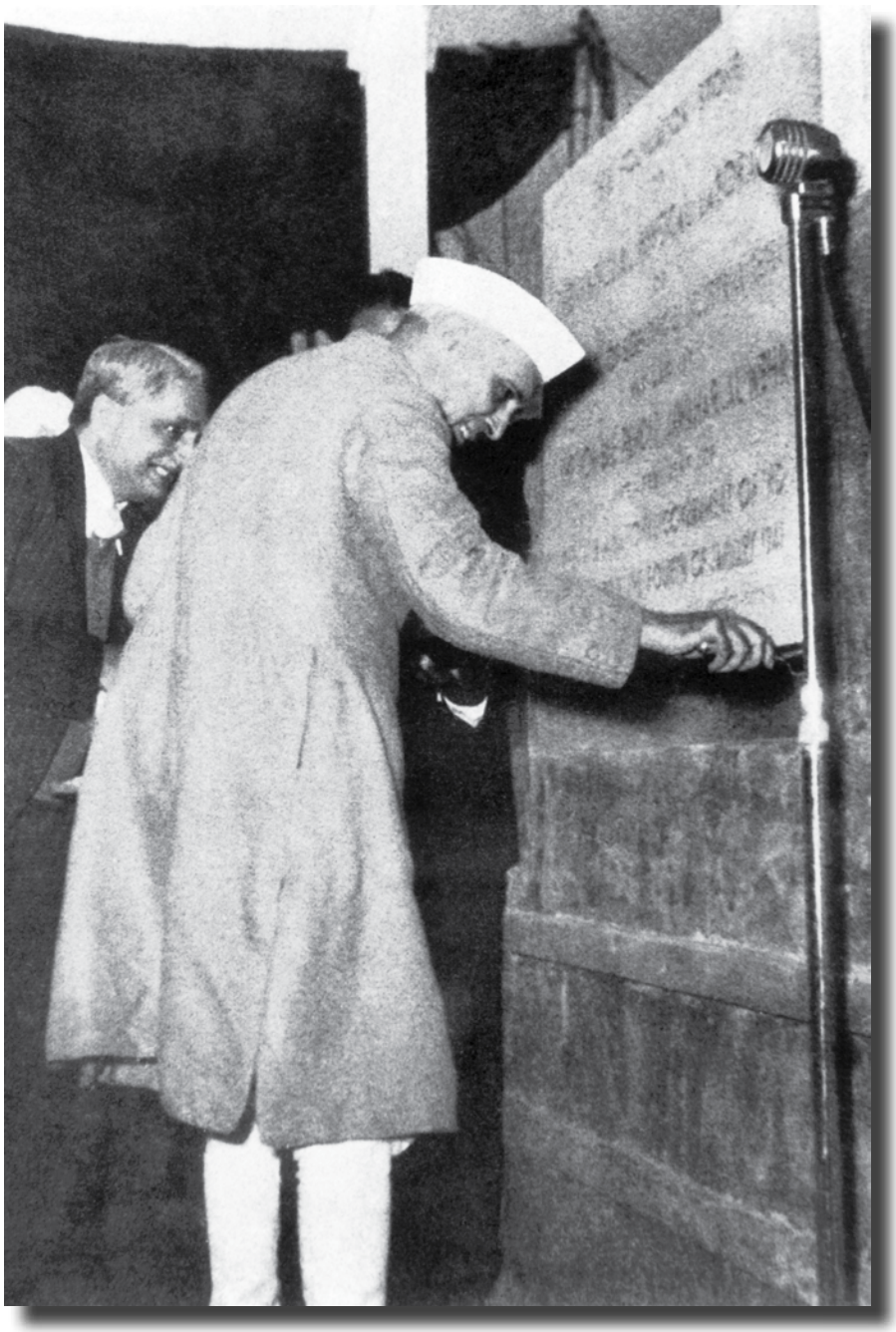
Earnings



Number of Reports



अतीत के सुनहरे पल ...



Pandit Jawaharlal Nehru, Laying the Foundation Stone of NPL (1947)

AcSIR | वैज्ञानिक तथा नवोन्मेषी अनुसंधान अकादमी

AcSIR | Academy of Scientific & Innovative Research

AcSIR Academy of Scientific & Innovative Research

The Academy of Scientific and Innovative Research (AcSIR) was established through a Gazette notification dated 2nd April 2012 with a view to emerge as a world class institution of national importance.

Under AcSIR, CSIR-NPL is running a Ph.D. programme and an Integrated M.Tech.-Ph.D. (IMP) programme in Advanced Materials Physics and Engineering.

The important aspect of the programme is that the course work has been designed in such a manner to provide emphasis on both, the theoretical aspects of fundamentals of material physics and engineering of materials for development of components and devices. The state of the art research facilities and research expertise of scientific manpower of the laboratory acting as the faculty makes the programme very unique and different.

Various courses offered during different semesters under the Ph.D. & IMP programme are as follows:

- Fundamentals of Electronic Materials & Semiconductor Devices
- Physics & Technology of Thin Films
- Advanced Materials Characterization Techniques
- Nanostructured Materials
- Quantum Optics & Advanced Solid State Optical Devices
- Engineering Materials
- Research Methodology, Scientific Writing & Communication Skills
- Superconductivity & Magnetic Materials
- Advanced Measurement Techniques & Metrology
- Advanced Computational Physics

Ph.D. Programme

- 14 students were enrolled in August 2012 batch.
- 9 students were enrolled in Jan. 2013 batch.
- As on March 2013 total number of students registered were 54.

Integrated M.Tech.-Ph.D. (IMP) programme

- In August 2012 session, 9 students were enrolled at CSIR-NPL under this programme
- As on March 2013, total number of students (2011 & 2012 batch) under this progrmme were 15.
- 4 students of 2011 batch published several research papers in SCI journals during the last semester.

A classroom view of AcSIR

XII पंचवर्षीय योजना – प्रोजेक्ट्स

XII Five Year Plan – Projects

XII Five Year Plan Projects

NETWORK PROJECTS

- Measurements for Innovation in Science & Technology, and for improvement of Quality & Economy of Life **(MISTQUE)**
- Advanced Quantum Research and Innovation with Ultra Small Systems **(AQuaRIUS)**
- Development of Advanced Materials for Next-Generation Energy-Efficient Devices **(D-NEED)**
- Probing the Changing Atmosphere and its Impacts in the Indo-Gangetic Plains (IGP) and Himalayan Regions **(AIM-IGPHim)**

SUPRA INSTITUTIONAL PROJECT

- Research and Development of Single Trapped Ion based Optical Frequency Standard **(STIOS)**

TECHNOLOGIES AND PRODUCTS FOR SOLAR ENERGY UTILIZATION THROUGH NETWORK (TAPSUN PROJECTS)

Novel approaches for solar energy conversion
(Dr Suresh Chand)
(₹ 3446.25 Lakhs)
(NWP-54)

Efficient silicon photovoltaics with smart electronics and lighting systems
(Dr P K Singh)
(₹ 4130.45 Lakhs)
(NWP-55)

Innovative solutions for solar energy storage
(Dr R B Mathur / Dr S K Dhawan)
(₹ 647.50 Lakhs)
(NWP-56)

Funding Agency: CSIR

R&D on thin film solar cells
(Dr Shushil Kumar)
(₹ 4906.60 Lakhs)
(GAP 113532)

Funding Agency: MNRE

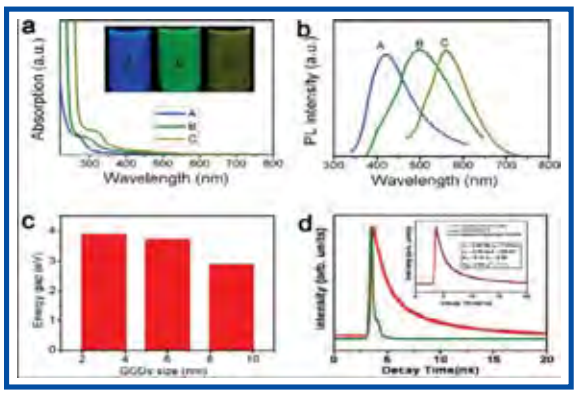
अनुसंधान – मुख्य विशेषताएं

Research Highlights

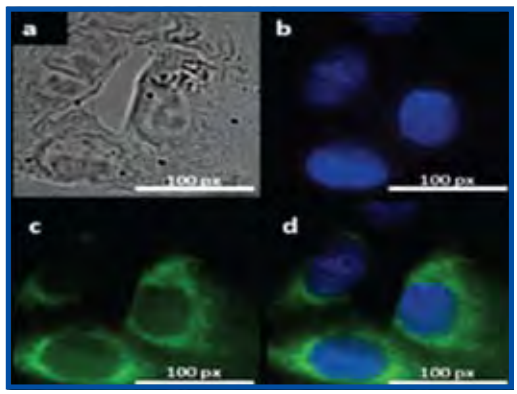
Luminescent Graphene Quantum Dots (GQD) Derived from Carbon Fibers

NanoLetters, 12 (2012) 844-849, Impact Factor : 13.19 *(Citation-21)*

- A facile synthesis of GQDs in large scale.
- Emission color and the bandgap of GQDs size dependent
- Due to low cytotoxicity and excellent biocompatibility they can be used as an eco-friendly material in biolabeling and bioimaging.



Optical properties of the GQDs.
(a) UV-vis spectra of GQDs (b) PL spectra of GQDs with different emission color excited at 318, 331, and 429 nm, respectively. (c) Relationship between the energy gap and the size of GQDs. (d) TRPL decay profile of blue GQDs recorded at room temperature.

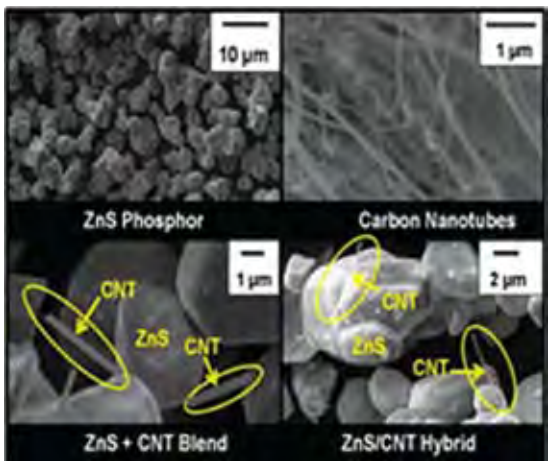


Fluorescent images of human breast cancer cell T47D after incubation with green GQDs for 4 h

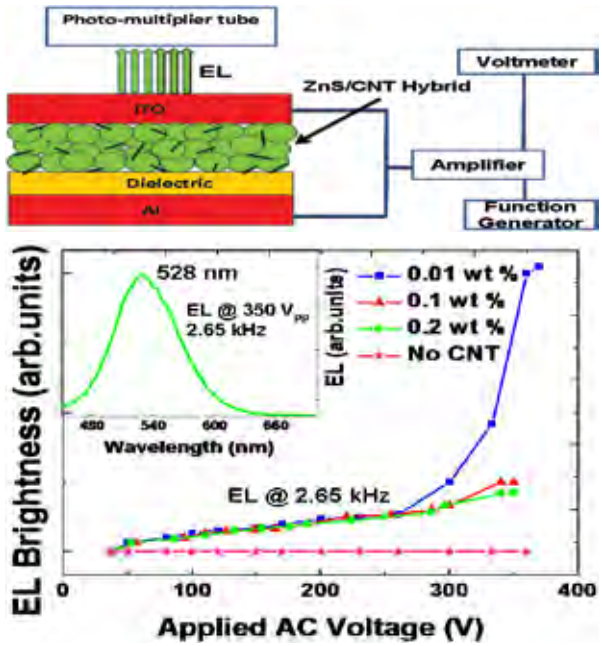
Development of Low Power Driven Electroluminescent (EL) Device

(Novel EL Lamp has been devised incorporating MWCNTs in ZnS phosphor)

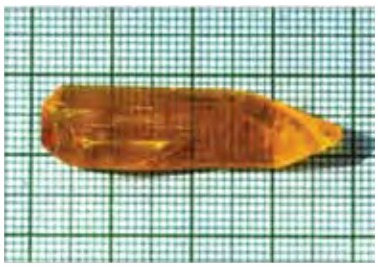
D. Haranath et al. Nanotechnology 23 (2012) 435704. (IF: 3.98)



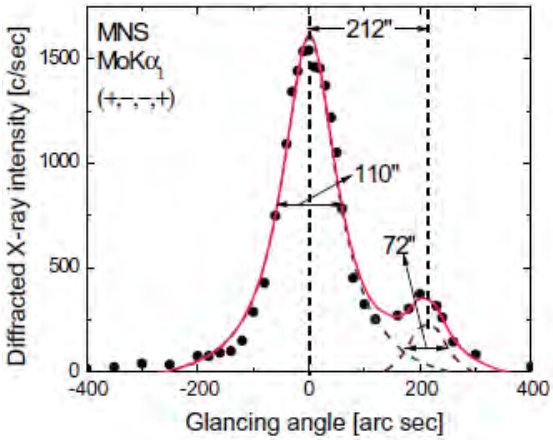
ZnS phosphor, MWCNTs, ZnS+CNT blend and ZnS/ CNT hybrid material after annealing. The operation of the lamp at 50 Vpp and 2.65 kHz and the scheme depicting the role of CNTs in triggering the EL.



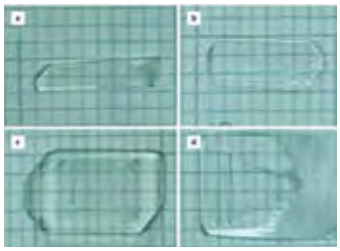
Growth of new Organic NLO single crystal 4-methoxy 4-nitrostilbene (MONS)

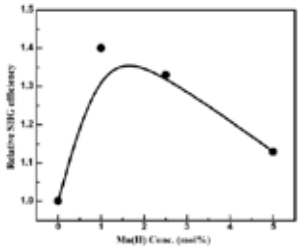


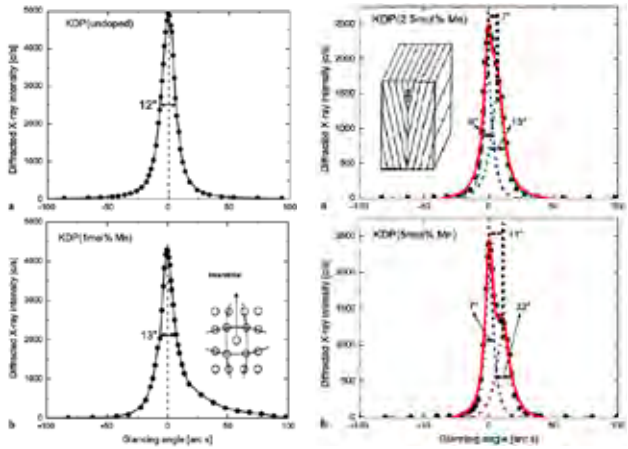
Crystal system = triclinic
Space group = P1
a= 11.716, b= 12.002, c= 14.949
SHG efficiency = 1.55 times to KDP



Enhancement of Second Harmonic Generation (SHG) efficiency by Mn (II) doping in KDP single crystals



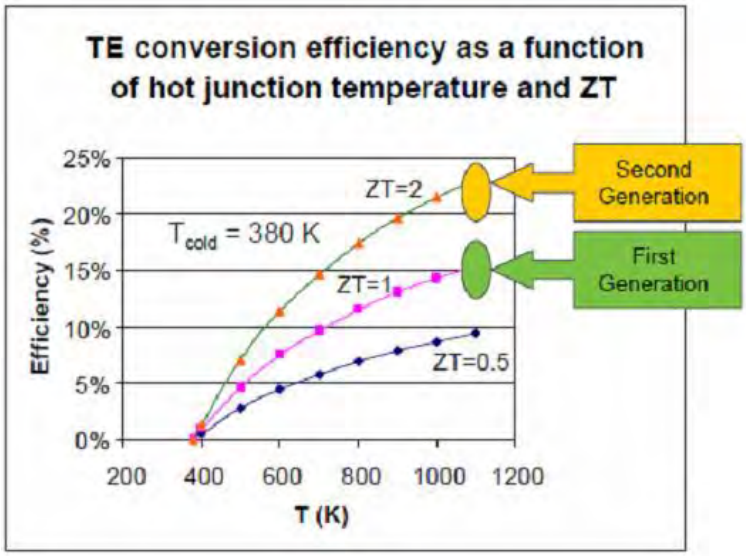




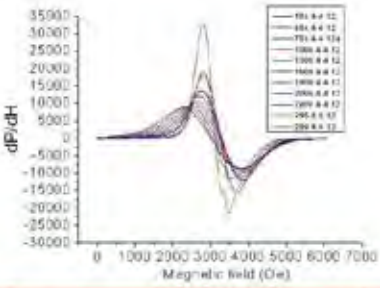
Device efficiency of a thermoelectric module: A robust technology

Milestone: Figure of merit ZT of 2 to reach 20% conversion efficiency at 550 C
Direct conversion of solar heat to electricity (No solar cells will be needed)

(Courtesy : US Department of Energy)



FMR investigations of water based Fe_3O_4 ferrofluid



ZFC spectra of ferrofluid (4K – 298K)

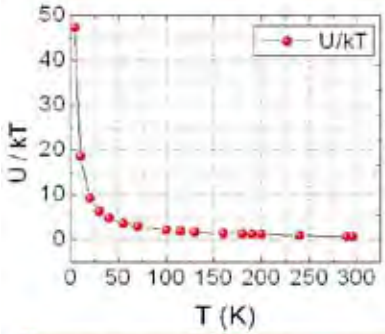
$$\tau = \tau_0 \exp U/kT$$

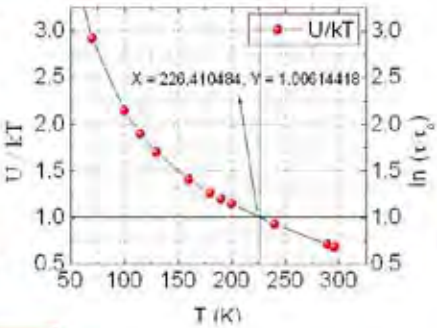
$$U = KT\left(1 - \frac{H}{H_a}\right)$$

$$H_a = \frac{2K}{M_s}$$

U>kT ➡ Ferromagnetic

U<kT ➡ Superparamagnetic





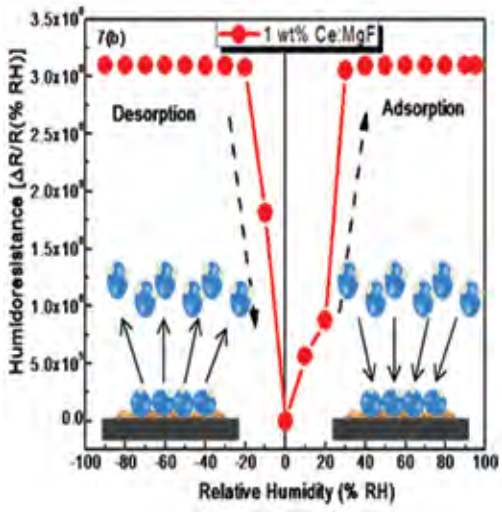
At $T=T_b$, $U=kT$

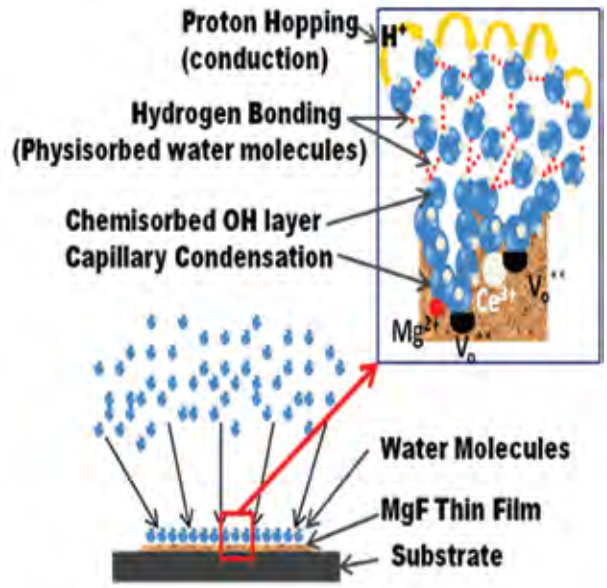
Here T_B=226.4K

Deduced from ZFC spectra

Investigated ferromagnetic to superparamagetic behavior. The blocking temperature (T_B) is 226.4 K. This is directly related to freezing of carrier liquid and leading to spin-glass kind of transition.

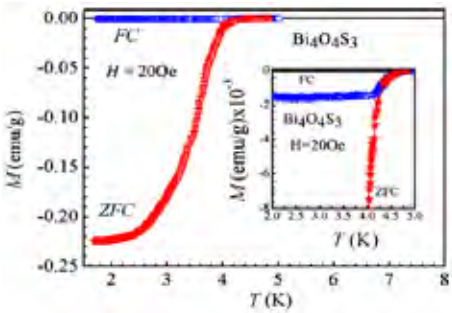
Colossal Humido-resistance (CHR)

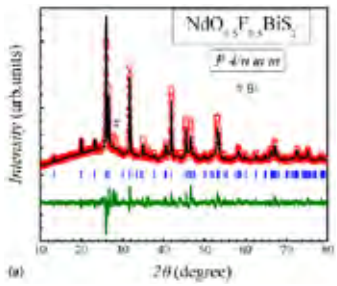


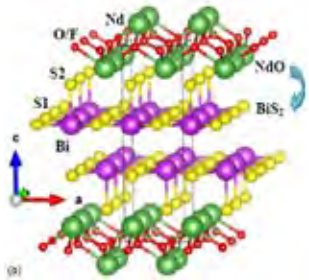


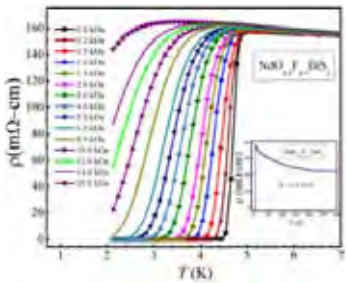
Kotnala et al,Magnetics group
Patent Disclosure Filed

Superconducting Materials: BiS_2 based superconductivity

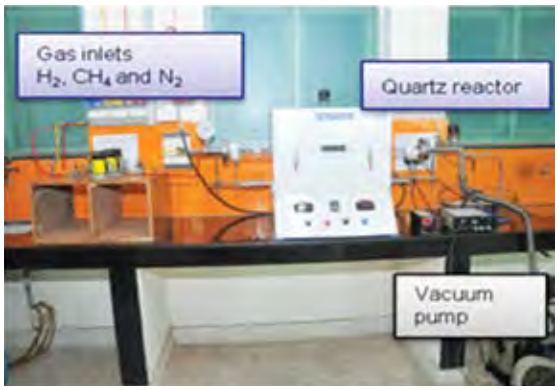


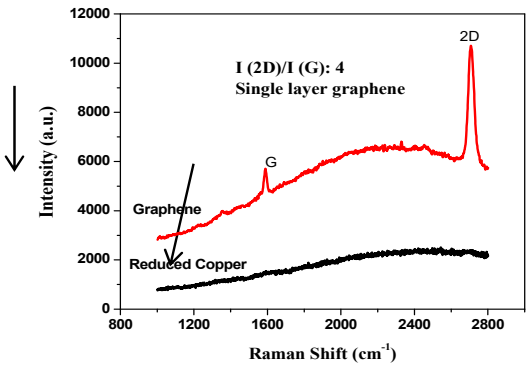




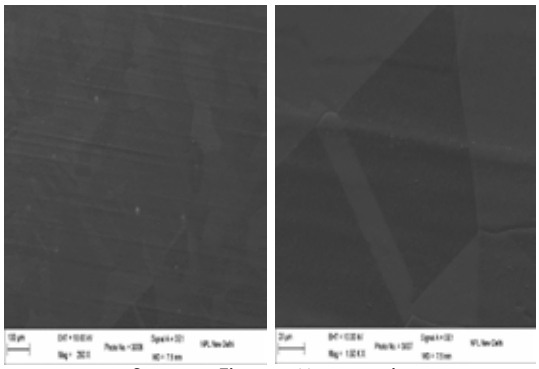


Single layer Graphene by Chemical Vapour deposition technique



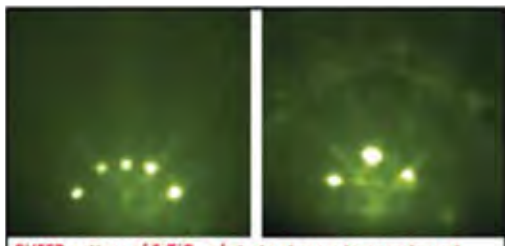


Optical micrograph



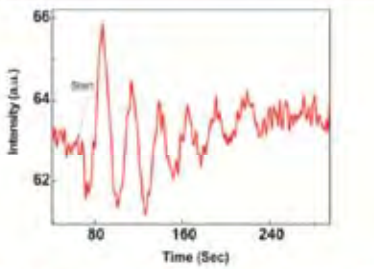
Scanning Electron Micrographs

Results of thin film deposition with in-situ RHEED

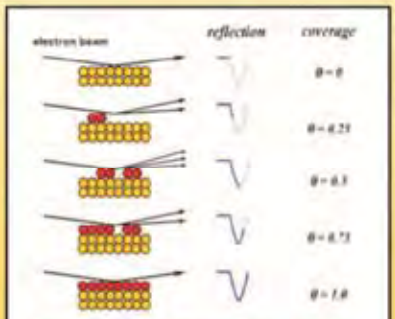


RHEED pattern of $SrTiO_3$ substrate at room temperature at different positions

(a) RHEED pattern of $SrTiO_3$ at room temperature in 5E-7 mbar vacuum. (b) showing streaks which are the characteristics of 2D lattice prior to deposition (c) & (d) deposition at 770 °C in 5E-5 mbar O_2, showing epitaxial, smooth 2D crystalline growth.



The Intensity Vs Time plot shows, Intensity oscillations, which are the characteristics of layer by layer growth in 2D.



Example of RHEED intensity oscillations

Streak remain preserves prior to the deposition, during and after deposition up to room temperature, shows good crystalline quality.

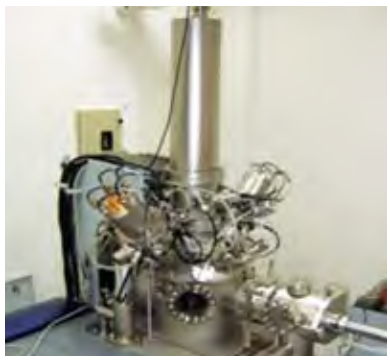
Organic Photovoltaics Activity


Laser patterning

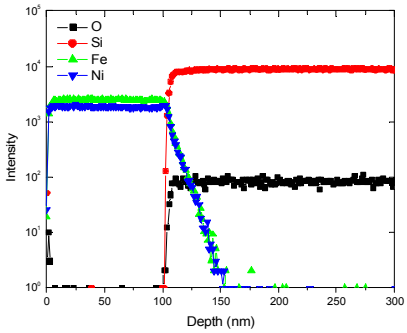

OPV Device fabrication

1. Al/MoO3/PTB7/PC70BM/PSN/ITO Inverted solar cell 7.7%
2. Al/PC60BM/ModifiedPTB7/ITO direct illumination ~ 6.2 %
3. Patent Filed: Ref. No. **DEL 2650, 27th August 2012**
   Patent II Gloal Disclosure in Process

Time of Flight Secondary Ion Mass spectrometry (TOF – SIMS)

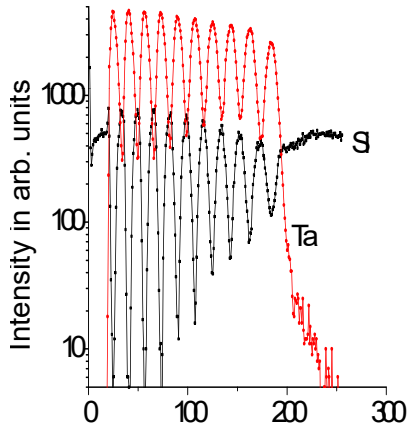


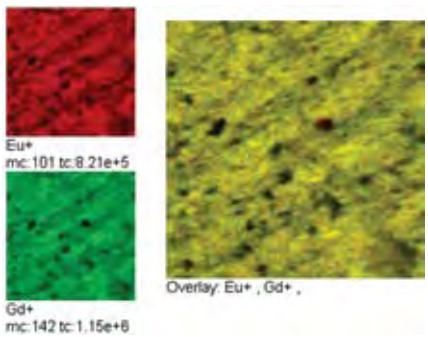
Depth profile of $NiFe/SiO_2$ sample grown using newly installed PLD system



Thin Solid Films, *in press* (2012)

Depth profile of Ta/Si multilayer structures (10 layers each)





Best poster award in "International Conference on Luminescence and its Applications (2012)"

अतीत के सुनहरे पल ...

Dr K S Krishnan, Dr K N Mathur, Pandit Jawaharlal Nehru, Dr S S Bhatnagar and Smt Indira Gandhi, during the construction of NPL

महत्वपूर्ण उपलब्धियां

Significant Achievements

New Standards Established

Quantum Metrology & Measurements

Programmable Josephson Voltage Standard

(operating at minus 269 degree Celsius)

Dimension

High Precision Roundness Measuring Machine:

Nominal Range	:	**0-4000 mm**
Working Range	:	**0-3700 mm**
Resolution	:	**0.01 µm**
Maximum Error	:	**1.5 µm**
Repeatability	:	**0.1 µm**

Fluid Flow

Newly Developed DN 100 Flow System

New DN100 Rig along with DN50 and DN200

Weighing Tanks, Fishtail, Nozzle and Diverter (designed and developed in NPL)

Temperature

Establishment of High Temperature Blackbody Source

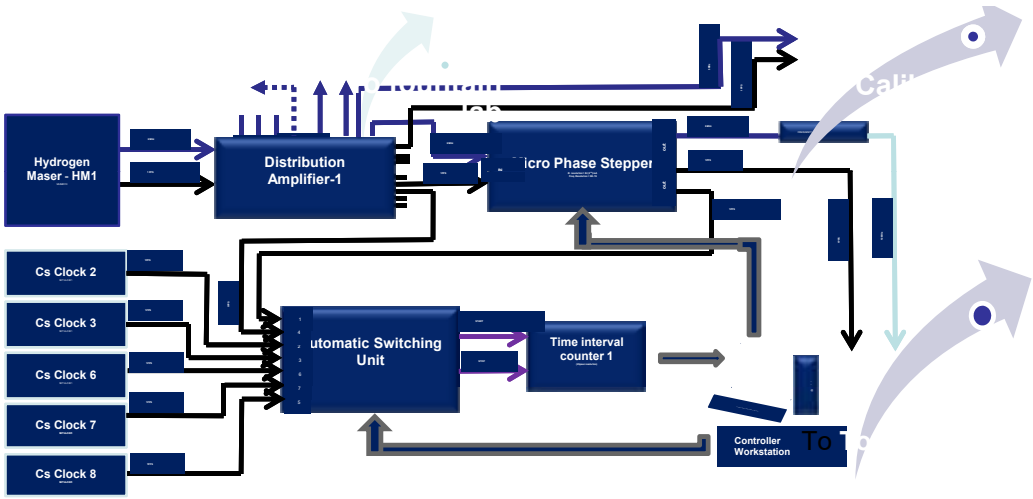
(for the calibration of infrared total radiation pyrometers in the range 600 to 3000°C.)

Fixed point realization facility for the new Co-C and Fe-C metal carbon eutectics using three zone heating furnace have been developed.

Time and Frequency

1. Generation of a stable UTC time scale linked to BIPM with a jitter of 0.3ns. The variation in the time scale UTC (NPLI) is within 10 ns over the last one year. Its frequency is stable to better than 1 x 10^{-14}.
2. A new Time Service has been started over the Internet using the NTP protocol. This would enable time synchronization of Personal Computers connected to the Internet. The domain name is : time.nplindia.org

Schematic of Time Scale UTC(NPLI)



Materials & Products

CSIR – TAPSUN Project

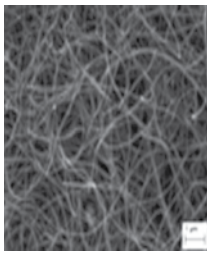
NPL – CECRI Partnership

High Performing Carbon Materials

Free standing Carbon based Anode -for Li – ion battery

INNOVATIVE SOLUTION FOR SOLAR ENERGY STORAGE

Carbon Nanotube based anode | ***Carbon Fiber based anode***



Discharge capacity- 196 mAh/g

Discharge Capacity– 206 mAh/g

Development of Fuel Cell

CSIR – New Millennium Indian Technology Leadership Initiative

for Clean Energy Generation

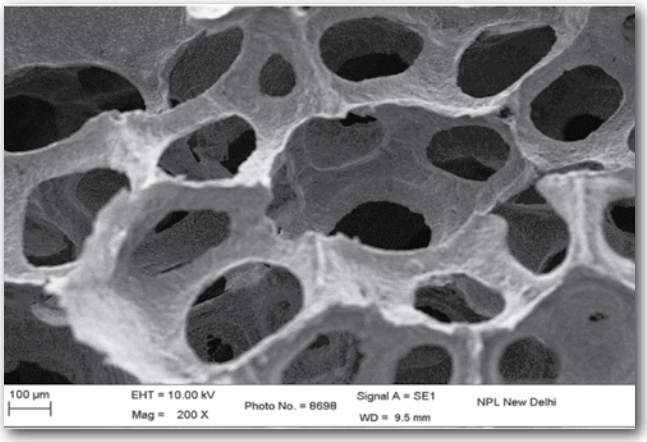
- Porous conducting carbon paper of much better than International quality Developed by NPL Scientists
- Carbon composite bipolar plate of superb quality developed by NPL Scientists
- Fuel Cell Assembled by CECRI
- DuPont USA Polymer applied by NCL

-To be used for mobile communication towers (Reliance Industries)

NPL
CECRI
NCL

Reliance Industries (Industrial partner)

CNT incorporated carbon foam



Carbon foam : sponge-like rigid engineering materials low density, large surface area with open cell wall structure

Applications

- EMI SHIELDING Material for Aerospace Applications
- ANODE MATERIAL for Lithium ion Batteries
- Light weight Electrode for Lead Acid Batteries

Advantages

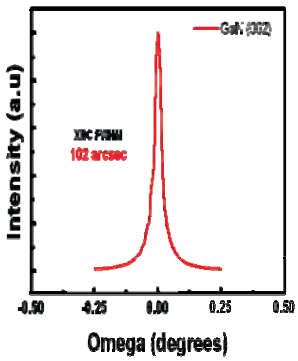
- Significant weight reduction
- Size reduction of battery
- Better current collection efficiency
- Easy recycling
- Higher energy & power densities

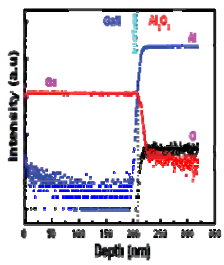
Patent Applied : Light weight carbon foam as electromagnetic interference (EMI)shielding and thermal interface material for aerospace applications

Materials & Products Continued ...

Laser Molecular Beam Epitaxy of GaN based Materials

Source materials: HVPE grown poly-crystalline GaN target & RF Nitrogen plasma
Substrate : Sapphire (0001)
Growth Temp : 720°C

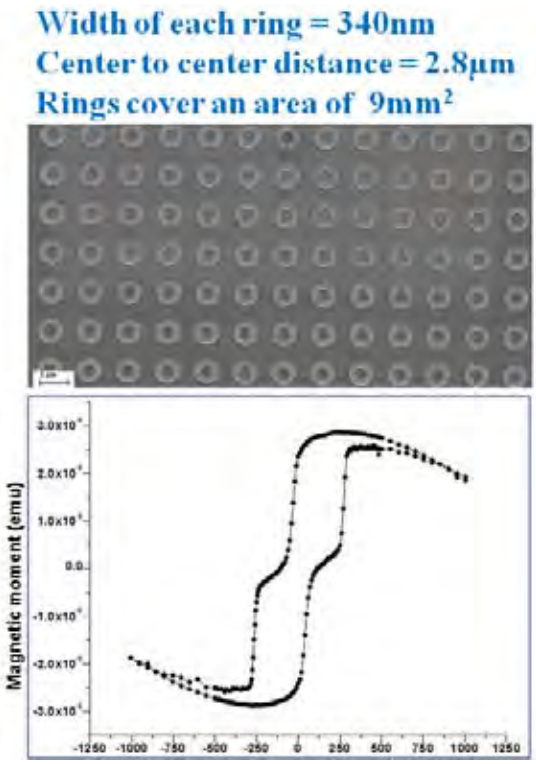




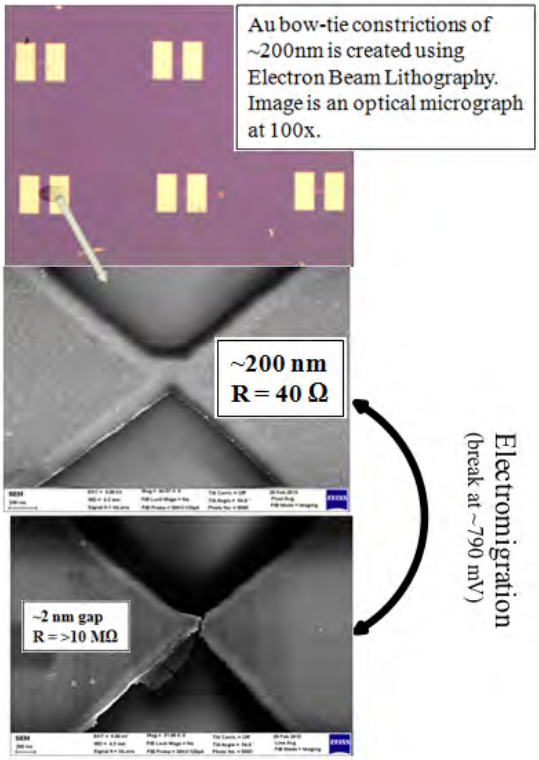
- **High crystalline quality GaN epitaxial layers grown on sapphire (0001) - X-ray rocking curve FWHM of (0002) plane : 102 arcsec** (Reported: ~200 arcsec)
- **Low background impurity level, especially oxygen that alters the electrical property (below detection limit of SIMS : <ppm)** (Reported: High Oxygen impurity level)

Nano Fabrication

- Ferromagnetic (NiFe) nanorings by E-beam lithography



- Gold Break junctions < 5nm on Si/SiO_2



Radio & Atmospheric Sciences

Scientific facilities at Antarctica developed by CSIR-NPL

Maitri Station Since1981
Ionospheric parameters
Radio & microwave communication
Studies of Polar Environment

New Indian Research station 'Bharati' (69° 24'S, 76° 11' E) at Larsemann Hills, Antarctica. The new station is 3000 kilometre away from the present Maitri station (70° 45' S, 11° 44' E) set up under the leadership of CSIR – NPL Scientist set up for space physics Research

Estimation of Ammonia Emission from Agriculture field

Estimated emission factor of ammonia from rice-wheat cropping system at IARI research farm, New Delhi. The average emission factor of ammonia was **96.7 gNH_3-N/kg-N/ha for wheat and 82.9 g NH_3-N/kg-N/ha for rice.**

नवसृजित सुविधाएं

Facilities Created

Facilities Created

Metrological Characterization of Weights

(of ISRO, Sriharikota used for satellite payload weighing)

A unique facility in India

Measurement of 500 kg weight using substitution method (ABBA cycles) carried out at CSIR - NPL

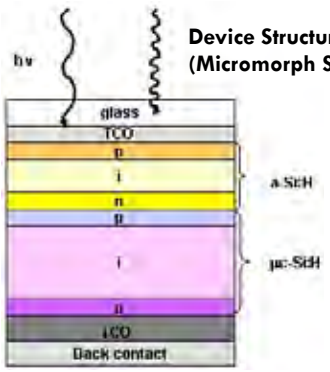
New Helium Liquefier

New Facility at CSIR-NPL to Strengthen Quantum Metrology Program

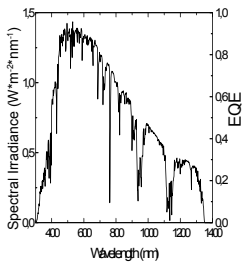
Multi-chamber PECVD system

for micromorph silicon solar cells (Area:10 x 10 cm^2)

Thin Film Silicon Solar Cells
(MNRE, Govt. of India, Sponsored Project)



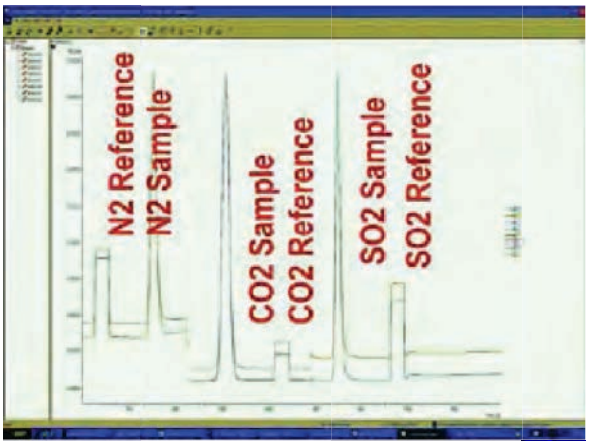
Device Structure (Micromorph Si Cell)



Revived a non functional 25 years old multi-chamber PECVD system (M/s GSI, USA)

Facilities Created Continued ...

Stable Isotope Mass Spectrometer CF-IRMS facility



- To measure stable Carbon, Nitrogen and Sulphur isotopic atmospheric particles for characterizing sources.

Ref. Gas	Stability (Based on 10 equi-injections of ref. gas) ‰	Recommended	Linearity (Based on 10 injection @ different pressure ‰/nA	Recommended
N_2	0.02	0.08	0.02	0.03
CO_2	0.01	0.08	0.02	0.03
SO_2	0.01	0.1	0.02	0.05

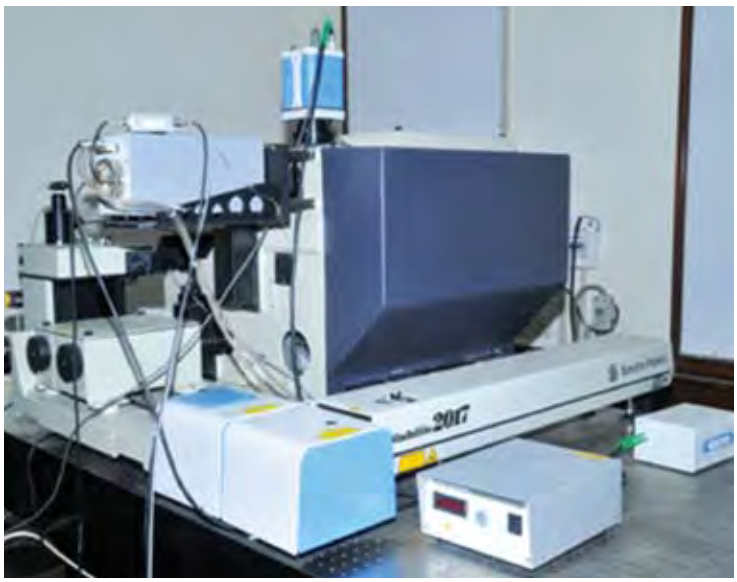
Equal Arm Balance

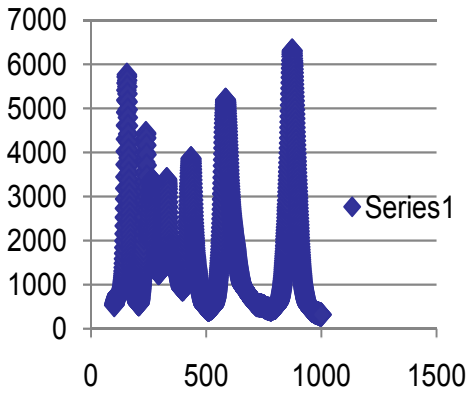
(Raymor HCE-25G, 25 kg capacity with sensitivity 1 mg)

Equal arm balance for gravimetric preparation of gas standard mixture.

Facilities Created Continued ...

High Resolution Raman Spectrometer





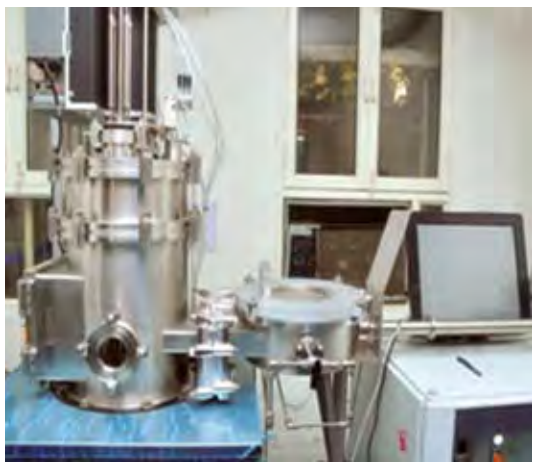
Key Features:

- Triple monochromator, can go down to ~ 20 cm^{-1}
- High Pressure Cell
- Continuous flow He cryostat Raman Imaging

JY Raman Spectrometer (T-64000) with new Sample Stage for low temperature applications installed in January, 2013

Atomic Layer Deposition System

Unit Process : Silicon Surface Passivation



ALD system has been partially installed (HfO_2) and initial experiments are being performed.

महत्वपूर्ण समारोहों की झलकियां

Glimpses of Important Events

FIRST TAPSUN CONFERENCE -
"Advances in Futristic Solar Energy Technologies"
December 4-5, 2012

International Conference "Advances in Metrology" AdMet - 2013
February 21-23, 2013

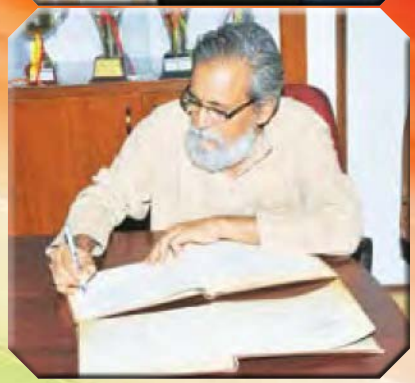
International Conference on Magnetic Fluids (ICMF-13)
January 7-11, 2013

CSIR-NPL Participation
CSIR Foundation Day Celebrations at Vigyan Bhawan, New Delhi
September 26, 2012

Research Council Meetings
December 14, 2012 and March 31, 2013

Independence Day Celebrations at CSIR-NPL
August 15, 2012

XXXIV Krishnan Memorial Lecture
(Lecture by Dr. Stuart S.P. Parkin, IBM Fellow)
March 11, 2013



World Metrology Day & National Technology Day Celebration

(Keynote address by Prof. Anil Gupta, IIM, Ahmedabad)

May 21, 2012

CSIR Foundation Day Celebrations
(Lecture by Prof. Sushanta Dattagupta Vice Chancellor, Visva Bharati, Shanti Niketan)
September 26, 2012

CSIR Foundation Day Celebrations Continued...

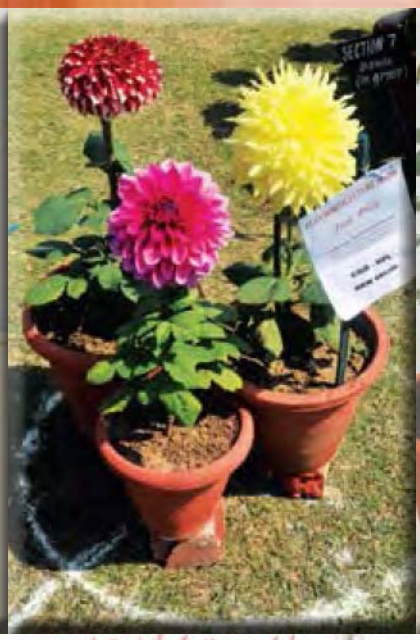
CSIR-NPL Open Day Celebrations
September 28, 2012








National Science Day Celebrations
(Science Day Lecture by Prof. S.D. Mahanti, USA)
February 28, 2013



Participation of CSIR-NPL in Pusa Horticulture Show
March 4-5, 2013

Training Programme on Standards April 24-27, 2012

Workshop on Advanced Materials Characterization Techniques July 10-13, 2012

Training Programme on Quality August 22, 2012

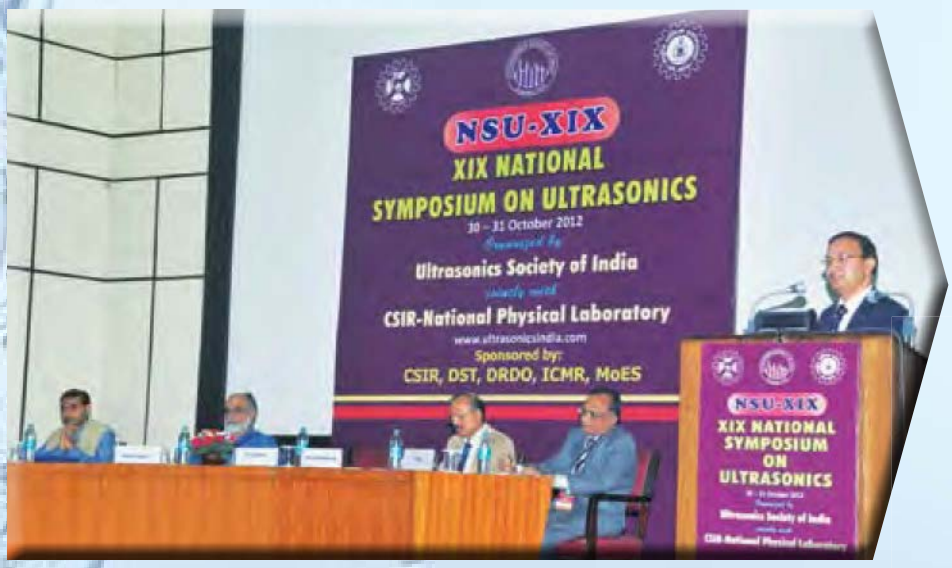
Training Programme for Legal Metrology Officers August 27-29, 2012

International Meeting of "Measurement Innovation in Science & Techniques" (MIST) March 15, 2013

Fourth meeting of sectoral monitoring committee under "Physics Science Cluster of CSIR" March 30, 2013

Training Programme on Temperature and Humidity Standards & Metrology November 06-09, 2012

"IIT Delhi Distinguished Alumni Award 2012" Conferred to Prof. R.C. Budhani October 28, 2012



XIX National Symposium on Ultrasonics October 30-31, 2012

अतीत के सुनहरे पल ...

Shri Lal Bahadur Shastri, Speaking on the Occasion of Celebrations of Dr K S Krishnan's 60th Birthday (1958)

ऊर्जा संचयन भौतिकी

Physics of Energy Harvesting

ऊर्जा संचयन भौतिकी

ऊर्जा संचयन भौतिकी (पीईएच) प्रभाग को सौंपा गया मुख्य अधिदेश वैज्ञानिक एवं औद्योगिक अनुसंधान परिषद् (सीएसआईआर) के 'सौर ऊर्जा मेगा मिशन पहल' अर्थात 'सीएसआईआर–टीएपीएसयूएन' (नेटवर्क के माध्यम से सौर ऊर्जा को प्रयोग में लाने के लिए प्रौद्योगिकी एवं उत्पाद) कार्यक्रम के अंतर्गत अत्याधुनिक वैज्ञानिक एवं प्रौद्योगिकीय अनुसंधान एवं विकास कार्य करना है। सीएसआईआर–टीएपीएसयूएन वित्तपोषित परियोजनाओं के अंतर्गत विभिन्न क्षेत्रों में जैसे कि कार्बनिक प्रकाश वोल्टीय (एनडब्ल्यूपी–54), क्रिस्टलीय तथा बहु–क्रिस्टलीय Si सौर सेल (एनडब्ल्यूपी–55), अक्रिस्टलीय/सूक्ष्म/नैनो क्रिस्टलीय Si और सीआईजीएस सौर सेलों (नवीन एवं नवीकरणीय ऊर्जा मंत्रालय द्वारा वित्तपोषित परियोजना जीएपी 113532), अकार्बनिक तथा कार्बनिक प्रकाश उत्सर्जी युक्तियाँ (एनडब्ल्यूपी–55) अनुसंधान एवं विकास कार्य किए गए।

इसके अतिरिक्त, ओएलपी 120132 के अंतर्गत कई अन्य अतिमहत्त्वपूर्ण क्षेत्रों में अनुसंधान एवं विकास कार्य किए गए जिनमें ताप–विद्युत–बल्क, नैनो एवं तनु फिल्म, बहुरूपी कार्बन तनु फिल्म तथा प्रकाशीय तनु फिल्म शामिल हैं। इसके अतिरिक्त भारत–यूके के बीच संयुक्त ऊर्जा पहल के अंतर्गत "ऐक्साइटोनिक सौर सेलों की दक्षता तथा उत्पादन क्षमता को उन्नत बनाना" (एपीईएक्स) नामक संयुक्त परियोजना के अंतर्गत अनुसंधान एवं विकास कार्य किए जा रहे हैं जिसमें दोनों देशों के लगभग 10 अग्रणी संस्थानों द्वारा सहभागिता की गई है तथा सीएसआईआर–एनपीएल द्वारा अग्रणी भूमिका का निर्वहन किया जा रहा है।

वर्ष के दौरान, इन क्षेत्रों में किए गए उत्कृष्ट मौलिक तथा अनुप्रयुक्त अनुसंधान कार्यों से सम्बन्धित अनेक लेख उच्च इम्पैक्ट फैक्टर वाली पत्र–पत्रिकाओं में प्रकाशित किए गए हैं और साथ ही कुछ महत्त्वपूर्ण आविष्कारों के संबंध में कुछ राष्ट्रीय तथा अंतर्राष्ट्रीय पेटेंट भी दर्ज कराए गए हैं। उदाहरण के लिए, बहुलक सौर सेलों (पीएससी) को विकसित करने के संबंध में उल्लेखनीय प्रगति की गई है। आशोधित PTB 7 : PC 60 BM प्रकाश अवशोषी सक्रिय परत को विकसित पीएससी सम्बन्धित एक अभिनव योगदान है, जिसका उपयोग करके कम खर्च पर, दक्ष, सुनम्य तथा स्थिर बहुलक सौर सेलों का उत्पादन किया जा सकता है। इस आशोधित पदार्थ का प्रयोग करके 6.2% विद्युत परिवर्तन दक्षता (पीसीई) प्राप्त की गई है और इसे संयुक्त राज्य अमेरिका में स्थित प्रोफेसर हीगर की प्रयोगशाला में किए गए स्वतंत्र मापन द्वारा प्रमाणित किया गया है। इस आविष्कार का पेटेंट दर्ज कराया जा रहा है। Si सौर सेल के क्षेत्र में भी उल्लेखनीय प्रगति की गई है जिसमें सिलिकन सतह को अक्रिय बनाने के लिए टाइटैनियम सिलिका फिल्म व हैफनियम ऑक्साइड फिल्म, वैकल्पिक परावर्तन–रोधी आवरण तथा सिलिकन सौर सेल के लिए काली सतह तैयार करने हेतु एक सरल प्रक्रिया विकसित करना शामिल है। इसके अतिरिक्त, अन्य क्षेत्रों में जैसे कि एफसीवीए तकनीक द्वारा निक्षेपित a-C फिल्मों से ग्रेफीन का संश्लेषण, Bi_2Te_3+BiTe (8 ग्राम–अणुक%) प्रतिदर्श के लिए 470 K तापमान पर ZT का मान 1.1 प्राप्त करना, एकध्रुवीय अर्ध–चालक पदार्थ DH4 का प्रयोग करके इष्टतमीकृत SiO_2 परावैद्युत पदार्थों पर एकध्रुवीय कार्बनिक फील्ड प्रभाव ट्रांजिस्टर (ओएफईटी) का संविरचन, अत्युच्च निर्वात स्पंदित लेज़र निक्षेपण (यूएचवी–पीएलडी) प्रणाली द्वारा सौर सेलों के लिए सैफायर पर ऐपीटैक्सीय GaN को विकसित करना, डीएलटीएस तकनीक द्वारा त्रुटि से संबंधित अध्ययन, सौर सेलों के लिए वीएचएफ–पीईसीवीडी तथा उन्नत गुणवत्ता के सीआईजीएस अवशोषक परत द्वारा अक्रिस्टलीय तथा सूक्ष्म क्रिस्टलीय सिलिकन तनु फिल्म निक्षेपण से सम्बन्धित महत्त्वपूर्ण योगदान किए गए हैं।

इस प्रभाग में कुछ नई सुविधाओं का भी सृजन किया गया है जिनमें वाष्पित्र तथा संपुटिकरण प्रणाली से युक्त ग्लव बॉक्स का प्रयोग करके बहुलक सौर सेल युक्ति का संविरचन, परमाण्विक परत निक्षेपण प्रणाली, अल्ट्रा फास्ट फेमटो–सेकंड लेज़र स्पेक्ट्रोस्कोपी, अत्युच्च निर्वात स्पंदित लेज़र निक्षेपण (यूएचवी–पीएलडी) प्रणाली आदि के नाम उल्लेखनीय हैं।

Physics of Energy Harvesting

The primary mandate of Physics of Energy Harvesting (PEH) Division is to carry out cutting edge scientific and technological R&D under the CSIR Mega Solar Energy Mission Initiative viz. – the CSIR TAPSUN (Technologies and Products for Solar energy utilization through Networks) Program. Under CSIR TAPSUN funded projects, R&D was carried out in various areas such as organic photovoltaic (NWP-54), crystalline and poly crystalline Si solar cells (NWP-55), amorphous/ micro/noncrystalline Si and CIGS solar cells (MNRE funded project GAP113532) and inorganic and organic light emitting devices (NWP-55).

Besides this, R&D work was carried out in some more important activities under OLP-120132 which included thermoelectric-bulk nano and thin films, polymorphic carbon thin films and optical thin films. Also under the joint Indo-UK energy initiative a joint project entitled "Advancing the efficiency and production potential of excitonic solar cells (APEX)" R&D remained in progress where about 10 leading institutes from the two countries are participating and CSIR-NPL is the lead laboratory.

During the year, drawing on the excellent fundamental and applied research in these areas several papers have been published in journals with high impact factor as well as some national and international patents have been filed on important inventions. For example, there has been a significant progress on the development of Polymer Solar Cells (PSCs). One of the innovative contribution in PSCs is the development of a modified PTB7:PC60BM light absorbing active layer which has the potential of giving cost effective, efficient, flexible and stable polymer solar cells. Using this modified material, power conversion efficiency (PCE) ~ 6.2% has been achieved which has been certified by independent measurements made in the Prof Heeger's Laboratory in USA. The invention is in the process of patenting. There has also been significant progress in the area of Si solar cells which includes, titanium silica films for silicon surface passivation, hafnium oxide films for silicon surface passivation, alternative anti-reflection coatings and development of a simple process for producing black surface for silicon solar cells. Besides this important contributions have been made in other area such as synthesis of graphene from a-C films deposited by FCVA technique, obtaining ZT value of 1.1 at 470K for Bi_2Te_3 +BiTe (8mol %) sample, fabrication of unipolar OFET on optimized SiO_2 dielectric materials using unipolar semiconducting material DH4, growth of epitaxial GaN on sapphire by Ultra High Vacuum Pulsed Laser Deposition (UHV-PLD) System, defect related studies using DLTS technique, amorphous & micro-crystalline silicon thin film deposition for solar cells using VHF PECVD and improved quality CIGS absorber layer.

Some new facilities were also created in the division which includes, polymer solar cell device fabrication facility using glove box integrated with evaporator and encapsulation system, atomic layer deposition system, ultrafast femto- second laser spectroscopy, ultra high vacuum pulsed laser deposition (UHV-PLD) system, etc.

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Silicon Solar Cells Group

1. Titanium silica films for silicon surface passivation

We have studied the effect of surface passivation using commercially available titanium silica ARC solution which is a mix of titanium oxide and silicon oxide. Other properties like reflectivity, refractive index and thickness of the films are measured to optimize process conditions. Prior to spin coating of titanium silica solution the samples are dipped in 5% HF solution to remove oxide layer followed by sintering for 2 minutes in air ambient using rapid thermal processing. The samples are annealed at different temperatures ranging from 400 to 850°C. Minority carrier lifetime values measured using Sinton lifetime tester show enhanced surface passivation in 650-750°C range (Figure 1.1). Consequently, the effective lifetime values increased from 3µs (un-coated) to 24 µs (650-750°C sintered films). The reflectivity, refractive index and the thickness of the films as a function of sintering temperature are depicted in Figure 1.2 and 1.3. The reflectivity shows that these films could be a good ARC on silicon surface (minimum R_λ ~3%) and the minima shifts with the change in its refractive index in 400-750°C. These films could be used as ARC and passivating layer on silicon solar cells.

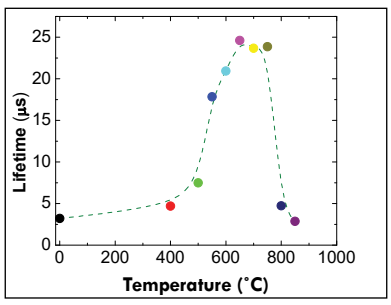

Fig. 1.1 Lifetime dependence on sintering temperature

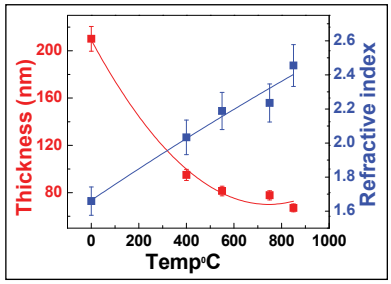

Fig. 1.2 Thickness and refractive index as a function of sintering temperature

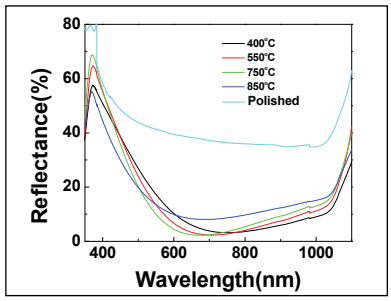

Fig. 1.3 The reflectance as a function of wavelength at various sintering temperatures

2. Hafnium oxide films for silicon surface passivation

HfO_2 films are deposited on silicon substrate using Atomic Layer Deposition system (M/s Picosun Oy, Finland, Model SUNALETM R-200). These films are deposited using TEMAHf and H_2O precursor in thermal process keeping substrate temperature 300°C. Nitrogen gas is used as carrier gas in this process. Lifetime is measured using Sinton lifetime tester and microwave photo-conductance decay technique.

In preliminary experiments, two order of magnitude improvement in surface recombination velocity is obtained. Al_2O_3 film deposition and sintering conditions optimization work is under progress along with HfO_2 sintering process.

3. Alternative anti-reflection coatings for silicon solar cells

Optical reflection from the silicon surface, which is approximately 35-40% of incoming light, is one of the most important issues to be considered in silicon solar cells. Several methods have been proposed over the past years to reduce the reflectance of silicon surface like wet-chemical texturization/etching, reactive ion etching (RIE), etc. However, the surface quality of Si is deteriorated by generating high density of defects after wet or dry etching. The resulting surface recombination centres further hinder Si solar cells from high efficiency.

Growth of complementary structures similar to that of textured structures on polished silicon would leave silicon surface less-defective. Since the silicon surface is polished, the surface area would be less and hence the less surface defect density. In this direction, indium oxide (In_2O_3), which is a wide band gap semiconductor of 3.8 eV, was employed to fabricate well-aligned In_2O_3 nanocones serving as an AR coating layer. A simple thermal evaporation technique was used to grow In_2O_3 nanocones at lower thermal budget. In_2O_3 nanocones were grown in two-step process, involving the deposition of In rich In_xO_y film using carbothermal reduction method, followed by annealing in oxygen environment.

The surface topography of annealed In_2O_3 films is shown in Fig. 1.4a. The morphology shows a uniform distribution of vertically grown cones that have a maximum height of ~ 800 nm. The uniformity and aspect ratio of cones could be tailored by monitoring the thermal budget. This kind of vertically grown nanocones/tapered cones are expected to present gradient profile of refractive index, which is advantageous in reducing the optical reflectivity of silicon surface as shown in Fig.1.4b. It is found on the basis of the optical reflectance that In_2O_3 nanocones offer a minimum reflectance (~ 3%) over a broad wavelength range from 350 nm to 1100 nm. This approach therefore expected to enhance the solar cell efficiency with a low cost process and further studies are under progress.

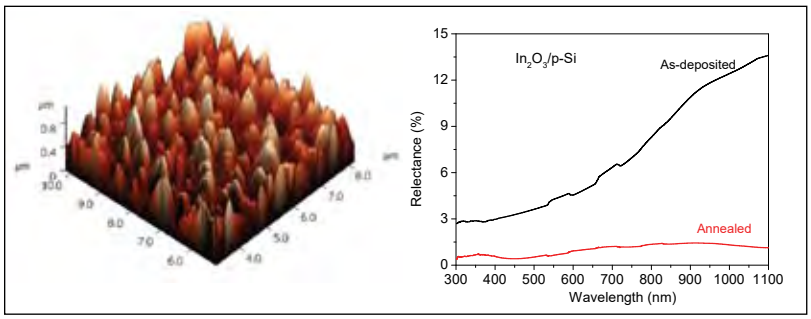

Fig. 1.4 (a) Surface topography of annealed In_2O_3 films, (b) Optical reflectance of as-deposited and annealed films.

4. Development of a simple process for producing black surface for silicon solar cells

A simple, fast (~30-45 seconds) two-step wet chemical etching process has been developed which could produce almost zero reflective (~1-2%) i.e. nano-textured **black silicon** surface on large area (Figure 1.5). The process is based on silver assisted etching of silicon in aq. $HF+H_2O_2$ bath at room temperature. A '*Proof of Concept*' of black silicon solar cells has been developed by using the nano-textured surface as emitter following the standard protocol for n^+-p-p^+ structured solar cells. Significant improvement in short circuit current density (>20%) and efficiency (~1.25% absolute) has been achieved compared with planar reference cell (Figure 1.6). This improvement has been attributed to primarily enhanced light absorption due to nano-scale texturing of the silicon surface.

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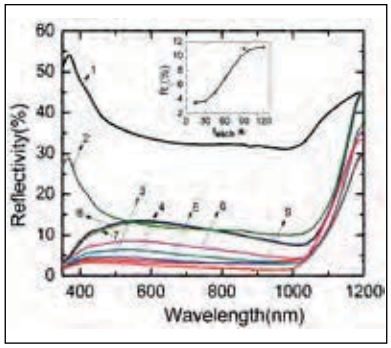


Fig. 1.5 Reflectivity (R_λ) versus wavelength (λ) curves of polished (CMP), aT-Si, nT-Si (prepared for different texturization time durations) and nT mc-Si surface (the best reflectivity). The curves are identified by numbers as **(1)**: CMP; **(2)**: aT-Si; **(3)**:nT-Si (15s); **(4)**:nT-Si (30s); **(5)**:nT-Si (45s); **(6)**:nT-Si(60s); **(7)**:nT-Si (90 s); **(8)**:nT-Si (120s) and **(9)**:nT-mc Si (30s). The inset shows the variation of average R_λ (in 400-1000 nm range) of different nT-Si surface with increasing texturing time (t_{etch}).

Effectiveness of the silver catalyzed nano-texturization process has also been tested on the industrial 125x125 mm^2 pseudo square Si wafers. It is interesting to note that the process is equally effective to produce very low reflective black surface over the entire area and therefore the process steps can easily be adopted in silicon solar cell fabrication. Further, in order to test the adoptability of the developed process in industrial environment, the nano-textured black silicon wafers were processed in industrial solar cell fabrication line. More than **13%** efficiency could be achieved in the nano-textured silicon solar cells without ARCs. This value is better than the efficiency achieved on small cells fabricated at CSIR-NPL.

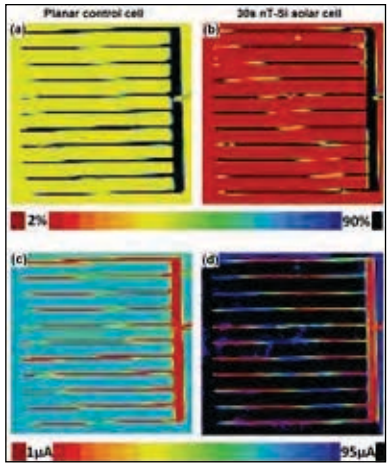


Fig. 1.6 Spatial distribution of reflectance and light induced current of the control and 30 s nT-Si solar cells. (a) and (b) are reflectance maps for control and nT-Si solar cell respectively; and (c) and (d) are LBIC maps for control and 30 s nT-Si black solar cell respectively. These maps were recorded with excitation laser of wavelength 855 nm.

Major Facility Established

Atomic Layer Deposition system procured from M/s Picosun Oy, Finland, Model No. SUNALE™ R-200 is installed. System is capable of handling 8 inch wafers. It has a load lock facility to transfer the sample without disturbing the deposition

Fig. 1.7 Atomic Layer Deposition System installed in Room No. 54.

chamber conditions once it is ready. This feature helps in saving time when a number of samples are prepared in a day. Substrate temperature could be varied from ambient to 500°C. System has thermal, plasma and ozone processes capability. It is being utilized for the deposition of aluminum oxide and hafnium oxide films for silicon surface passivation.

Polymorphic Carbon Thin Films Group

(i) R&D on amorphous carbon thin films having embedded nanocrystallites deposited by filtered anodic jet carbon arc (FAJCA) technique

Amorphous carbon films having embedded nanocrystallites deposited using FAJCA technique have been characterized by XRD, HRTEM, SEM, AFM, XPS, Raman, electrical conductivity, optical band gap, nanoindentation and field emission measurements. XRD dominantly confirms the amorphous nature of the films. HRTEM exhibits initially an amorphous structure but on closer examinations the film was constituted of amorphous phase with the nanoparticle embedded in the amorphous matrix. An ultrafine nanograined microstructures with average grain size between 20 to 30 nm are observed throughout and the majority of grains were single crystallites as observed in HRTEM. The sp^3, sp^2, conductivity (σD), activation energy (ΔE), optical band gap (E_g), residual stress (S), hardness (H), elastic modulus (E), plastic index parameter (H/E), percentage elastic recovery (% ER), emission threshold (E_T) and emission current density (J_{max}) of a-C films evaluated are found to be strongly dependent on the applied negative substrate bias. Maximum values of H = 58.3 GPa, E = 426.2 GPa, H/E = 0.136, %ER = 86.3 accompanied with sp^3= 82.6 % have been obtained in a-C films deposited at - 60 V substrate bias. The lowest value of E_T = 9.4 V/μm accompanied with J_{max} = 0.6 mA/cm^2 at 20 V/μm electric field has been obtained in a-C film deposited at 0 V substrate bias and the values of E_T increase and those of J_{max} decrease continuously with the increase of substrate bias.

(ii) R & D on phosphorous doped amorphous/microcrystalline silicon carbon films deposited by filtered cathodic vacuum arc (FCVA) technique

FCVA technique has been used to deposit phosphorous doped amorphous / microcrystalline silicon carbon films using phosphorous doped silicon ingot as cathode material in the gas environment of C_2H_2. Various process parameters such as arc current, substrate temperature, substrate bias and pressure have been attempted. The advantage of this process is that no hazardous and toxic gases like PH_3 and SiH_4 have been used and this is a high deposition rate process. A growth rate of ~5A°/s has been achieved using 100 A arc current in phosphorous doped amorphous/microcrystalline silicon carbon films. The films have been characterized by the electrical conductivity (σD), activation energy, (ΔE) optical band gap (Eg), XRD, EDAX and SEM. The atomic percentage of carbon evaluated by EDAX study in phosphorous doped a-SiC film at different arc currents (30-100A) are found to be in the range from 11.6 to 28.1 at. %. The values of σD ~10^{-3}-10^{-1} ohm^{-1} cm^{-1}, ΔE ~0.08-0.10eV and E_g~ 2-3 eV have been obtained in the films. These values are consistent with the values obtained in P doped amorphous / microcrystalline SiC: H films deposited by the conventional PECVD technique using SiH_4, PH_3 and CH_4 gas mixtures. A heterostructure junction has also been made by depositing n-type a-Si films on p- type Si wafer to judge the quality of the silicon films and a diode quality factor between 1.1-1.5 has been achieved.

(iii) Improved surface properties of β-SiAlON substrates by diamond like carbon (DLC) coatings

Attempts have been made to improve the hardness and surface roughness of β-SiAlON ceramic substrates by diamond-like carbon (DLC) coating using RF PECVD technique. By

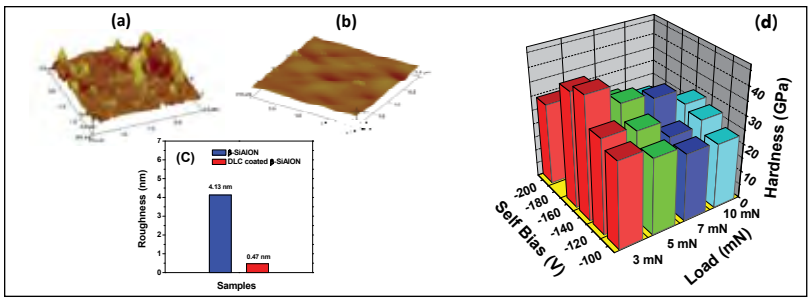


Fig. 1.8 AFM image of (a) β-SiAlON (b) β-SiAlON ceramic coated with DLC at -140 V and (c) bar diagram of roughness of uncoated and DLC coated β-SiAlON ceramic (d) variation of hardness with load for β-SiAlON ceramic coated with DLC at difference self-biases

optimizing the self-bias and bonding environment, we report the deposition of very hard (43.4 GPa) and ultra smooth (surface roughness ~ 0.47 nm) DLC coating on β-SiAlON substrates at a self-bias of -140 V. The hardness of DLC coated β-SiAlON is improved from 4.13 to 43.4 GPa and surface roughness is improved from 4.13 to 0.47 nm. DLC coating has demonstrated 3 times increment in hardness and 10 times reduction in surface roughness. Owing to high hardness, high wear resistance and low surface roughness, DLC coated SiAlON structure can find wide biomedical applications such as prosthetic hip joint replacement.

(iv) Synthesis of graphene from a-C films deposited by FCVA technique

FCVA technique is used to deposit a-C films (10-38 nm thick) on catalytic nickel thin film grown on SiO_2/Si substrates and subsequently converted these films into large area graphene by post annealing the sample in vacuum in the temperature range from 650 to 850 °C. Micro-Raman spectroscopic study, optical image and SEM micrograph on a-C films with thicknesses of 10 nm and 18 nm have revealed the formation of few layer graphene with optical transmittance in the range 85-88 %. It has been observed that the quality of graphene layers can be controlled by thickness of a-C films and annealing temperature. Optimum temperature of annealing has been found to be 750°C. In future, lowering the thickness of a-C films and also on copper catalysis substrates will be explored to prepare single and bilayer graphene for variety of applications.

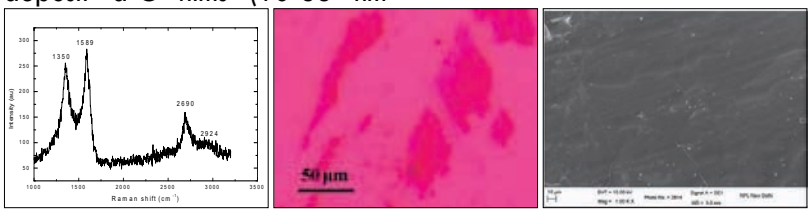


Fig. 1.9 Raman spectra, Optical image, SEM micrograph of a-C films deposited by FCVA technique

(v) R & D on nanostructured carbon thin films deposited by microwave plasma enhanced chemical vapor deposition (MWPECVD) technique

Nanostructured carbon thin films have been deposited on n-type silicon wafer and corning glass substrates by MWPECVD system using Ar and C_2H_2 gas mixture by varying pressure from 55 mTorr to 110 mTorr at a fixed 220 W microwave power. A vacuum of ~ $2x10^{-6}$ Torr was achieved using turbo molecular and rotary pump combination. The values of dark conductivity ~10^{-7} ohm^{-1} cm^{-1}, band gap ~3.20-3.40 eV and transmittance in the range 85 to 95 % have been obtained in these films. The size of nanostructure flake was found to be 5 to 30 μm as observed in SEM. Raman spectroscopy shows D, G, and 2D band at ~1358 cm^{-1},~1597 cm^{-1} and ~2778 cm^{-1}, respectively in these films. The appearance of 2D peak confirms that some graphene based nanostructures is forming. A typical XRD pattern shows a broad peak at 23° and a sharp reflection at 10.4°. The broad hump is due to amorphous nature and peak at ~10.4° may correspond to graphene oxide. It is being further examined in HRTEM. The system is being modified to form multilayer graphene using high temperature and high pressure conditions.

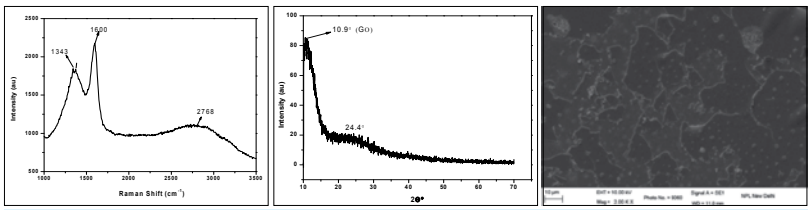


Fig. 1.10 Raman spectra, XRD spectra, SEM micrograph of carbon thin films deposited by MWPECVD technique

Organic and Hybrid solar Cells

R&D work was carried out at CSIR- NPL on the development of OPV devices using the existing donor/acceptor materials and modifying them suitably for improved power conversion efficiency (PCE).

The simple structure organic solar cell has been optimized with different donor materials. The simple structure contains Indium tin oxide (ITO) as anode, PEDOT:PSS as hole transport layer, active layer and aluminum as cathode. The active layer is the blend of donor and active layers. The suitable choice of donor and acceptor materials is based on the energy band diagram of the device. Figure1.11 shows the energy band diagram of P3HT and PCBM based device.

The standard procedure for the device fabrication has been used like chemical cleaning of ITO, UV cleaning of substrate, spin coating of polymer under ambient condition and cathode deposition in high vacuum condition. Although many improvements in the device fabrication process has to be done. The optimization process is going on. The P3HT:PCBM device was optimized with different concentration in the solution and different ratio of donor and acceptor materials. The device was optimized at different post annealing time. The current voltage characteristics of the optimized device in dark and under illumination have been shown in Figure 1.12. The maximum value of power conversion efficiency for the device is around 2% that is almost same as the reported value for the same simple structure device. Since the fill factor of the device is of low value the standard device structure incorporating interface layers needs to be developed for the mentioned active layer.

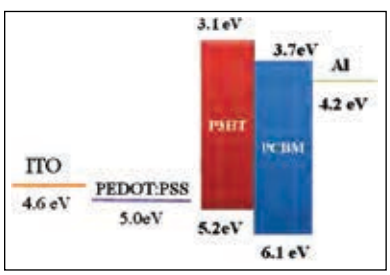


Fig. 1.11: The energy level band diagram of the simple structure P3HT: PCBM device

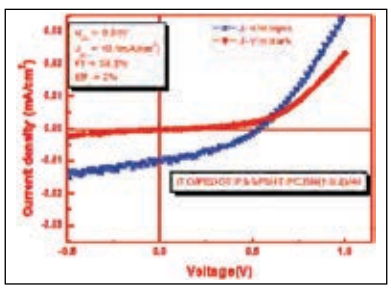


Fig. 1.12: The current-voltage characteristics of the device in dark and under illumination

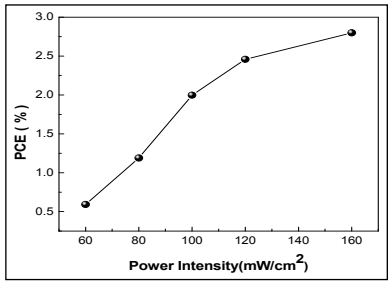


Fig. 1.13: The variation of power conversion efficiency with illumination power intensity

The device was characterized under illumination at different illumination intensity. The power conversion efficiency of the device increases with light intensity and get saturated at high value of intensity. Figure 1.13 shows the variation of power conversion efficiency with light intensity. The power conversion efficiency at half sun is 0.7% and at one sun is around 2%.

The optimization of organic solar cells using low band gap polymer PTB7 as donor and PC71BM as acceptor has also been carried out. The solvent used for the active layer blend being chlorobenzene. The solution concentration and ratio of D-A materials was optimized. The current voltage

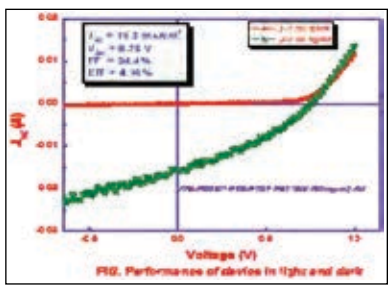


Fig. 1.14: The current-voltage characteristics of the device in dark and under illumination

characteristics for the optimized device in the configuration ITO/PEDOT:PSS/PTB7:PC71BM/Al is shown in Figure 1.14.

The device shows the current density and voltage under illumination at one sun is 15mA/cm^2 and 0.7V, respectively. Final efficiency of the device is about 4.2% which is even little better than the reported value for the same simple structure device.

The R&D using low band gap polymer was further continued with the addition of a solvent viz. using a binary solvent i.e. being a combination of CB and DIO in the ratio 97:3%.

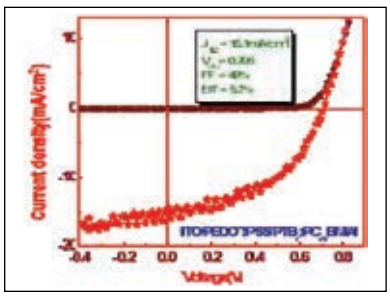


Fig. 1.15: The current-voltage characteristics of the device in dark and under illumination

The addition of DIO solvent results in further enhancement in PCE which now goes from 4.2% to ~5.2% . The dark and light characteristics of such a device in configuration ITO/PEDOT:PSS/PTB7:PC71BM/Al;CB(97%)+DIO(3%) is shown in Figure 1.15.

Besides the above, R&D was also carried out using the alternate acceptor to PCBM viz. ICBA. For this OPV devices were prepared in the device configuration ITO/PEDOT:PSS/PTB7:ICBA/Al. In this also very important and interesting results were obtained wherein PCE ~ 4.4% has been obtained as shown in Figure 1.16.

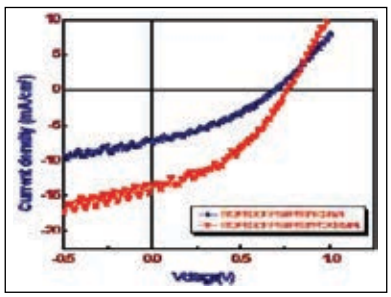


Fig. 1.16: The current-voltage characteristics of the PTB7 device in dark and under illumination

In addition, R & D work was undertaken for the development of OPV devices by suitable modification of the existing low band gap polymer for mobility and power conversion efficiency (PCE) enhancement.

The existing electron donor low band gap conjugated polymer PTB7 has been modified to enhance its spectral response. Based on the current voltage characteristics in pure PTB7 and modified PTB7 it has been found that in modified PTB7 the mobility increase and the trap filling takes place at a lower voltage which indicates its usefulness in improving the PCE. And indeed it has been found that modified PTB7 when used in combination with $PC_{60}BM$ acceptor shows power conversion efficiency (PCE) in the range of 4-6% as compared to highest internationally reported value of PCE ~ 3% obtained with PTB7/$PC_{60}BM$ active layer. This is a very important finding and the results are not shown here as the invention is in process of patenting.

The importance of the invention lies in the drawback that PCE of ~7.4% with PTB7 is obtained only in combination with $PC_{70}BM$ rather than with $PC_{60}BM$. And $PC_{70}BM$ is quite expensive as compared to $PC_{60}BM$. In fact polymer solar cells based on PTB7 and $PC_{60}BM$ show maximum PCE ~3%. Therefore, in our invention, modified PTB7 in combination with $PC_{60}BM$ showing PCE in the range 4-6.0% is an efficient and cost effective alternative for polymer solar cells which is quite pivotal from commercialization point of view. The J-V characteristics of the polymer solar cell in configuration ITO/PEDOT:PSS/modified PTB7:$PC_{60}BM$/Al and PCE ~ 6.2% are shown in Figure 1.17.

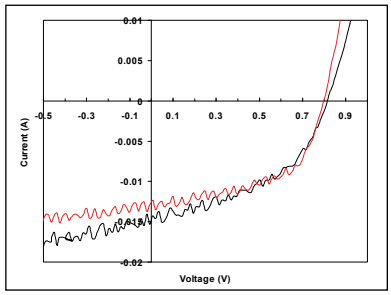


Fig. 1.17: The current –voltage characteristics of the PTB7 device in dark and under illumination

The patent on this work has been filed as “Improvement in power conversion efficiency in conjugated polymer modified PTB7- $PC_{60}BM$ based bulk heterojunction solar cells” with

Ref. No. DEL 2650 dated 27th August 2012.

Further work is in progress in improving the PCE using modified PTB7.

R&D was undertaken towards direct growth of CdS nanoparticles network in poly (3-hexylthiophene-2, 5-diyl) (P3HT) polymer film for hybrid photovoltaic. In this we demonstrated a high yielding green approach for the synthesis of CdS nanoparticles network in P3HT polymer film. Triethyl amine was used as a co-ligand instead of a highly poisonous pyridine to synthesize xanthate functionalized Cd(II) ion in high yields under ambient conditions. There was a significant decrease in the band gap of P3HT from 2.2 eV to 1.85eV in P3HT:CdS composite, which has not been observed previously. The TEM image shows that *in-situ* synthesized CdS nanoparticles are evenly distributed in the P3HT network and a significant photoluminescence quenching of P3HT with CdS suggests its potential application for photovoltaic devices.

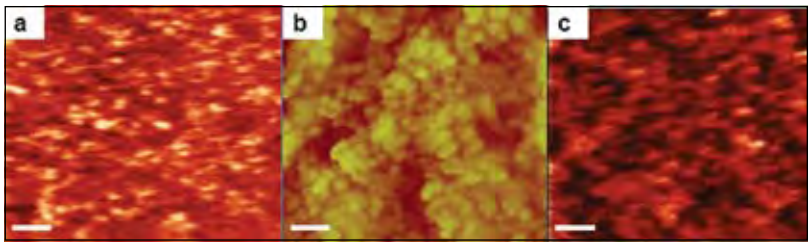


Fig. 1.19. AFM images of P3HT: CdS (a) after annealing, in-situ growth, (b) CdS NPs (synthesized without P3HT) and (c) P3HT Films (scale bar 200 nm).

The TEM image (Figure 1.18a) of P3HT: CdS NPs (1:1) network shows that the CdS NPs are embedded homogeneously into the matrix of P3HT. The amorphous appearance of the diffraction pattern (Figure 1.18b) indicates the CdS particle size is > 10 nm.

Figure 1.19 gives a comparative study of the AFM images of P3HT:CdS (after annealing, in-situ grown), CdS NPs (synthesized without P3HT) and P3HT films. From Figure 1.19a, it can be observed that a homogeneous active layer was obtained with P3HT:CdS after annealing.

The XRD pattern indicates the formation of CdS nanoparticles due to the broadening of [111] peak (Figure 1.20a). The presence of [220] and [311] signals shows that the particles have cubic crystalline structure.

Figure 1.20b shows comparative FTIR spectra of Cd.S:P3HT (after annealing) and Cd.X . The band at 1003 cm^{-1} of Cd.X shows that the S=C—S xanthate group is acting as a bidentate ligand. The band at 1145 cm^{-1} may be attributed to the C—O group (enhanced due to O—C=S resonance in the xanthate group). The bands at 1554 cm^{-1} and 1385 cm^{-1} may be attributed to the C=C (aromatic) and the C—N of the amine group of the diethyl amine co-ligand, respectively. P3HT: CdS (after annealing) shows broad FTIR spectrum which confirms the formation of the polymeric network of the P3HT. On comparing the FTIR spectra of P3HT: CdS with that of Cd.X, a blue shift was observed (from 1003 cm^{-1} to 1030 cm^{-1}) which can be attributed to the ligation of C=S (aromatic) of P3HT with cadmium. Moreover, the

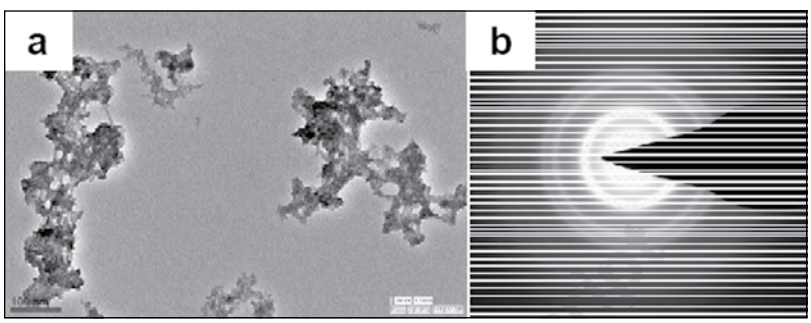


Fig. 1.18. (a) TEM image and (b) Diffraction pattern of P3HT: CdS NPs network.

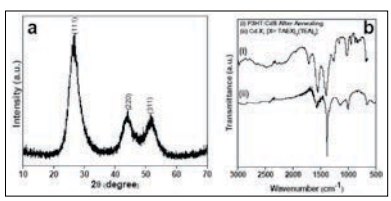


Fig. 1.20. (a) XRD pattern of annealed CdS NPs (b) Comparative FTIR spectra of (i) P3HT:CdS after annealing and (ii) Cd.X [X=(TAEX)2(TEA)2] in chlorobenzene solution.

degradation of xanthate was confirmed by the disappearance of the bands at 1145 cm^{-1} and 1003 cm^{-1}, which indicates the removal of C—O and S—C=S groups.

Figure 1.21(a) shows the UV-Vis. absorption spectra of Cd.X, P3HT: Cd.X, P3HT: CdS, CdS and P3HT. There is a marked shift of the band-edge of the P3HT after the formation of the P3HT:CdS composite from 2.2eV to 1.85eV as compared to that of 1.92 eV obtained by earlier researchers. The reduction in the band gap of the CdS:P3HT would give a highly efficient solar cell as compared to the counterparts. Figure 1.21 (b) shows the Photoluminescence (PL) spectra of P3HT polymer and P3HT:CdS (1:1) composite in the chlorobenzene solvent. The PL spectrum of P3HT shows a significant quenching after the addition of CdS NPs which implies a significant charge transfer from P3HT to CdS NPs. Smaller size CdS NPs have larger surface energies and hence a higher quenching capability.

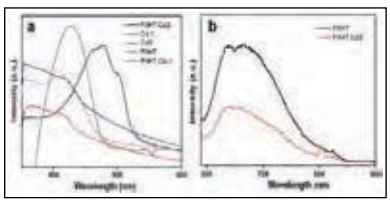
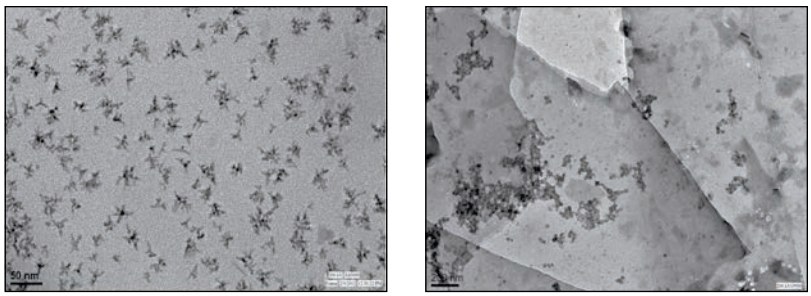


Fig. 1.21. (a) Comparative UV-Vis. spectra of Cd.X, P3HT: Cd.X, P3HT: CdS, CdS and P3HT b) PL study of P3HT in chlorobenzene with CdS NPs, 1:1 (w/w).

In addition to above, synthesis of Graphene-CdSe composites was carried out under different concentrations of graphene additions. CdSe nanoparticles were synthesized in different shapes as spheres or tetrapod structures to prepare graphene composites for polymer solar cell application. The structural, microstructural and optical investigations of the composites were carried out. Figure 1.22 (a) displays the TEM image of as prepared CdSe tetrapod and (b) consisted of a 2D graphene sheet coated with CdSe QD.



(a) (b)

Fig. 1.22: TEM images of CdSe (a) and CdSe/Graphene Composite(b)

Also, we have investigated the effect of surface modification of as-synthesized oleylamine-capped spherical CdSe QDs of size (5-7 nm). The as prepared CdSe QDs are highly luminescent, monodispersive and exhibit energy transfer effects upon their dispersion in MEH-PPV polymer matrix. However, repetitive washing of CdSe QDs upon suitable chemical treatment leads to enhancement in charge transfer process as observed in their corresponding MEH-PPV:CdSe nanocomposites. This enhancement in charge transfer is mainly due to the partial removal of oleylamine capping ligand as shown in Figure 1.23, which acts as a hindrance in the interaction between polymer and CdSe QDs and makes it useful for possible application in organic solar cells.

Study of Effect of Au NP on the efficiency of OPV in terms of enhanced Absorption of light and charge transport of charge carriers

The efficiency of polymer solar cell is still significantly lower than its inorganic counterparts, which prevents practical applications in large scale. The thickness of active layer is limited to a few hundred nanometers by the short exciton diffusion length and low carrier mobility of polymer materials, resulting in the weak

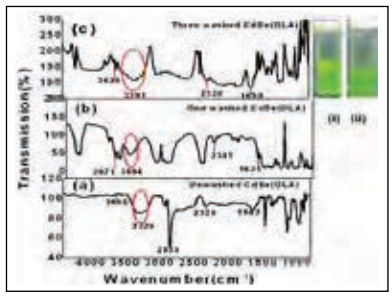


Fig. 1.23. FTIR spectra of CdSe QD's (a) unwashed (as-synthesized) (b) one-time washed (c) three-times washed. (i) & (ii) corresponds to UV photographs of unwashed and three-times washed CdSe QD's.

absorbance of polymer solar cells. Therefore, how to increase the light absorption of active layer at a limited thickness still remains as a challenge, motivating the development of a variety of light trapping techniques. Incorporating metal nanoparticles (NPs) that support localized surface plasmon resonance (LSPR) into the BHJ polymer solar cells has been proved as a promising approach to enhance light absorption without the need for a thick active layer. P3HT and PCBM were used as active layer donor and acceptor material. Gold nanoparticles were added in the active layer. Four devices were made which had different concentration of Gold nanoparticles (Figure.1.24).

Device 1 *Bare device (0%) gold nanoparticles.*

Device 2 *2% gold Nanoparticles (2 weight percent of the weight of active layer material).*

Device 3 *1% gold Nanoparticles (1 weight percent of the weight of active layer material).*

Device 4 *0.5% gold Nanoparticles (0.5 weight percent of the weight of active layer material)*

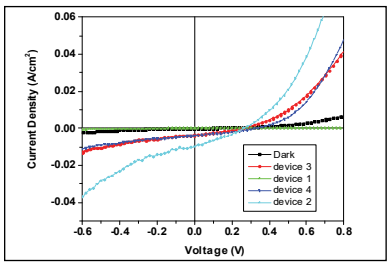


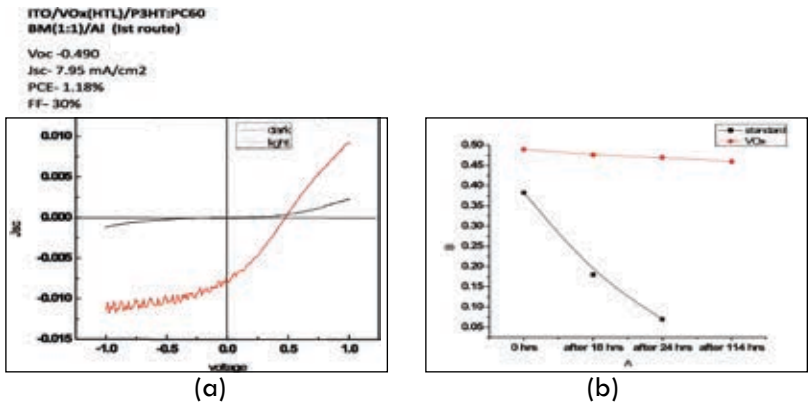
Fig. 1.24. J-V curves of OPV devices at different concentration of Gold nanoparticles.

The PCEs of the polymer solar cells have been improved by introducing metal NPs into active layer,

Development of alternate HTL layers by solution processing routes

The conventional bulk heterojuction (BHJ) PSCs are designed with an active layer sandwiched by a hole conducting poly (ethylenedioxythiophene):polystyrene sulfonate (PEDOT:PSS) on top of an indium tin oxide (ITO). The reason is that PEDOT:PSS has a good hole-transporting ability and a high work function (5.2 eV) compared with bare indium tin oxide (ITO) (4.8 eV), which is suitable for the highest occupied molecular orbital (HOMO) of most donor-type semiconductors. However, the long-term stability of PSCs, which is critically important for their future applications, with PEDOT:PSS as the HSL is not satisfying. The high acidity and hygroscopic nature of PEDOT:PSS have been associated with reduction of the device stability. Therefore, developing a suitable HTL layer that can retain the high charge-transporting performance of HSL similar to that of PEDOT:PSS, but overcomes its defect for device stability is extremely desired. Another problem that is faced due to the air sensitive low work function metal Al as cathode which can be oxidized easily decreasing the stability of PSC's. To overcome these issues and to improve the device lifetime presently inverted device structures are used, where the nature of charge collection is reversed.

Transition metal oxides, such as nickel oxide (NiO), vanadium oxide (V_2O_5), tungsten oxide (WO_3), and molybdenum oxides (MoO_x) have been successfully used to replace PEDOT:PSS. However these transition metal oxides are deposited by vacuum based deposition techniques, which is incompatible with solution processing technique in PSCs. Thesefore, a solution



(a) (b)

Fig. 1.25. (a) I-V characteristics of a device with VOx as hole transport layer and (b) the device stability (Voc) with time

based anode modification layer with low temperature annealing is in great demand. In our group, we investigated different routes for MoOx, NiO and VOx film deposition. These metal oxide layers were processed by solution methods, followed by thermal annealing at relatively low temperatures to observe the suitability of these layers as HTL layers and compatibility for inverted solar cell structures. Further instead of the commonly adopted vacuum deposition techniques, the sol-gel process offers a simple low cost and highly controlled method for metal oxide layer synthesis. Different thickness of the layers were prepared by varying the concentration of the sol, and annealing temperatures were changed from room temperature to 250°C, different PSCs were prepared, tested for stability of the derived devices in room air conditions. Till now in this route, we have not placed any ETL, and the cells were prepared in normal synthesis conditions (proper glove box facility was not used). Some of the initial results based on VOx as HTL are shown in Figure 1.25.

Different sol gel synthesis routes were used to prepare VOx layer. The device structure used was glass/ITO/VOx/active later (P3HT:PCBM)/Al. To change the thickness of the layer solution concentration was varied and annealing temperature was optimized. The VOx HTL layer shows good stability as compared to the PEDOT:PSS layer. The results indicate the stability of the cells were better when transition metal oxides were used as HTL instead of PEDOT:PSS, the best results so far are for VOx.

Further R&D in the direction of the development of inverted solar cells is in progress using the low band gap donor materials.

Thermoelectrics - Bulk, Nano and Thin Films

We are working on Bismuth Telluride (Bi_2Te_3) based thermoelectric materials, which is a good thermoelectric material at near room temperature. We prepared Bi_2Te_3 by a chemical route, namely, solvothermal route. Bismuth and Tellurium precursors were mixed in the ratio of 2:3 along with different solvents (methanol, ethanol, distilled water and ethylene glycol) to synthesize Bi_2Te_3 powders. The homogeneity is confirmed by XRD and Raman's spectra analysis. To measure the thermoelectric properties of the sample the powder was consolidated into the pellet by Spark Plasma Sintering (SPS). These pellets were found to have the relative density greater than 98% of the theoretical density of crystalline Bi_2Te_3. The electrical conductivity (σ), Seebeck coefficient (S) and thermal conductivity (κ) were measured, and overall thermoelectric figure of merit (ZT) was calculated as: $\mathbf{ZT=S^2\sigma T/\kappa}$. $S^2\sigma$ is known as the power factor. ZT=0.42 at 197°C which comparatively less than best reported ZT (0.7) at 180°C by hydrothermal route [Fu et.al, CrystEngComm, 2012, 14, 2159]. The reason was the high thermal conductivity value (κ) due to the increased particle size as a result of heat treatments to remove the phosphine group. In order to decrease the κ value, some nanorange boundaries needed to be introduced to increase the phonon scattering, so, BiTe prepared by microwave assisted flash combustion was added in different mol% (2, 4,6,7,8,10,11,12 mol %) into Bi_2Te_3. We could obtain ZT value of 1.1 at 470K was obtained for Bi_2Te_3 +BiTe (8mol %) sample.

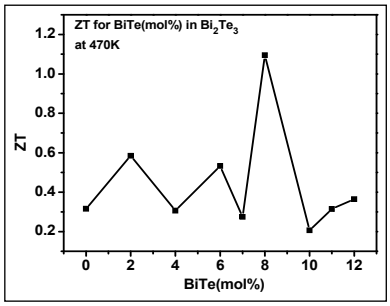


Fig. 1.26 Variation of ZT vs mol% BiTe

Organic & Inorganic LEDs

Fabrication of Unipolar OFET on optimized SiO_2 dielectric materials using unipolar semiconducting material DH4T.

Unipolar OFET has been fabricated on heavily doped *n*-type silicon substrate with 270-nm-thick thermal grown SiO_2 as insulator (Figure 1.27). Shadow mask of different channel length (30, 40, 50, 60, 80 and 100 µm)

has been used to form source/drain. The contact material of Au is deposited by thermal evaporation at a base pressure *1x10^{-6} torr* to create electrode structure. The DH4T layer is grown at a rate of 0.2 Å/s with the substrate at room temperature and layer thickness is 55nm.

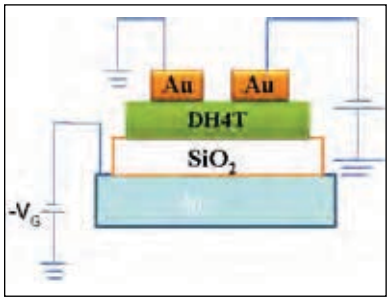


Fig. 1.27. Schematic diagram of p-type OFET

The device configuration is a bottom gate/top contact with gold electrode contacts. The output and transfer characteristics of a unipolar OFET are shown in Figure 1.28. The source electrode is grounded and the range of applied drain and gate voltage for *p*-type characteristics is from 0 to -40 V. Clear *p*-type characteristics are observable and the highest drain current is measured to 37.5μ A, while *n*-type characteristics are not observed in these devices.

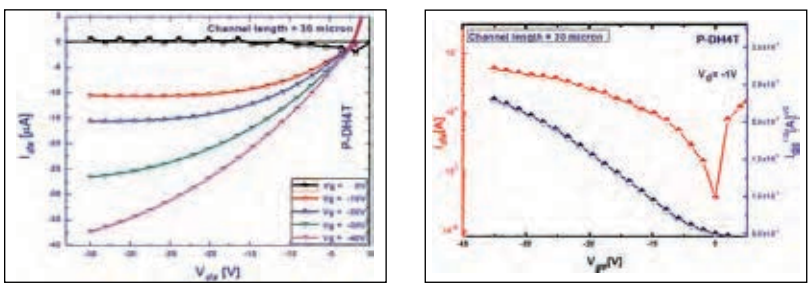


Fig. 1.28. Output and transfer Characteristics of OFET

This can be explained by carrier trapping effects due to the -OH groups at the organic/insulator interface. Slight deviation from the ideal saturation current at high voltage may be attributed to the short channel effect and the injection barrier from Au to the active layer. The mobility of DH4T has been calculated using transfer characteristics and found to be 9.13x10^{-2} cm^2/V.Sec which is comparable to the reported value.

Effect of doping of cesium carbonate on electron transport in Tris (8-hydroxyquinolinato) aluminum

Electron transport studies in Tris (8-hydroxyquinolinato) aluminum (Alq_3) is hindered due to lack of efficient electron injecting electrode. We demonstrate that an electron injection layer of Cs_2CO_3 forms ohmic contact with Alq_3 (figure 1.29) which enables the observation of SCLC. This allows us to directly determine the electron mobility in Alq_3 which was found to be 1x 10^{-3} cm^2/V s at room temperature. Doping of Cs_2CO_3 leads to increase in conductivity as well as mobility. Mobility has increased to 1x

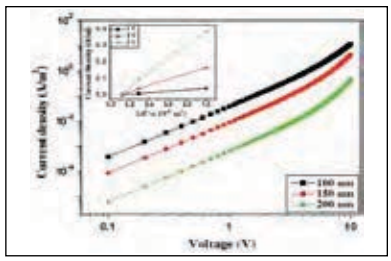


Fig. 1.29. J–V characteristics of electron only devices for Alq_3 thicknesses of 100, 150 and 200 nm. Inset shows the thickness scaling of current density at 1, 2 and 3 V.

10^{-7} cm^2/V s for 33% doping of Cs_2CO_3.

Study of shifting of recombination zone in multi-emissive layer organic light emitting devices and its effect on color stability

Color stability in multi-emissive layer organic light emitting devices (Me-OLEDs) has been investigated. OLEDs were based on multiple emitters with a common host CBP doped with three dopants, BCzVBi, Ir(ppy)3 and Ir(btp)2acac for blue, green and red emission. A major variation in CIE coordinates were found from (0.312, 0.294) to (0.236,0.267) with increase in voltage from 6 to 9V. This coordinate shift in Me-OLEDs has been attributed to the shifting of recombination zone with increase in voltage. In order to support our experimental observation, the EL spectrum of Me-OLEDs has been expressed as a linear combination of EL intensities of OLEDs with its individual constituting layers as emitters (Figure 1.30). In this way, the contribution of each layer in the EL spectrum of Me-OLEDs has

been evaluated at each voltage. It has been observed from these calculations that the contribution of red emitter decreases from 47% to 33.33% and blue emitter increases from 38% to 51.67% with the increase in voltage from 6 to 9V. This supports our hypothesis of shifting of recombination zone with the change in voltage. This shifting has been attributed to the field dependency of electron mobility in CBP. Me-OLED with CBP layers between the emitters was fabricated to improve the color stability. Significant improvement in color stability was achieved without changes in current efficiency in Me-OLED with inter layers.

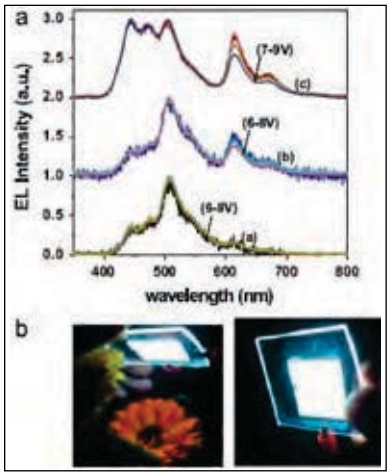


Fig. 1.30. (a) Normalized EL spectrum for Me-OLEDs with 0.5wt% (curve a), 0.65wt% (curve b) and 0.75wt% (curve c) Ir(btp)2acac doped CBP. (b) Photographs of device.

Growth & Characterization of GaN/AlN multilayer structure grown by RF-plasma MBE

The GaN/ AlN multilayer sample was prepared by alternate deposition of GaN and AlN using a RF plasma assisted molecular beam epitaxy (MBE) on a commercially purchased MOCVD grown 3.5μ thick GaN epi-layer on a 2-inch c-plane Sapphire substrate The temperature-dependent change in the photoluminescence intensity of GaN/AlN multilayer structure has been investigated. The coexistence of small intensity in blue luminescence (BL) and significant intensity in yellow (YL) and orange luminescence (OL) is observed in the temperature range 20 to 300 K. The intensity of YL and OL is found to vary linearly with temperature. The linear dependence results an excitonic recombination take place with an increase in temperature. MBE grown samples were characterized by SEM and a cross section view has been obtained on the multilayered structure of GaN/AlN. The cross section view indicates the initial inter-diffusion of first few layers, however as the number of layers were increased the interface was observed to be very sharp. The thickness of the layers was found to be in conjunction with the thickness obtained by ellipsometry. Depth profiles of GaN/AlN multilayers were carried out by time of flight secondary ion mass spectroscopy (TOF-SIMS) using Cs^+ primary ion beam. TOF-SIMS clearly shows the periodicity of the secondary $AlCs^+$ signal, which correlates well with the secondary signal from $GaCs^+$ ions. Depth profile indicates the presence of well defined GaN/AlN interfaces.

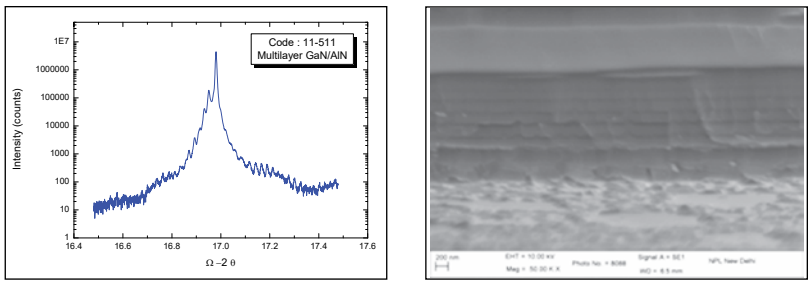


Fig. 1.31: HRXRD and cross sectional SEM data display the formation of GaN/AlN multilayer structure

Growth of epitaxial GaN on sapphire by Ultra High Vacuum Pulsed Laser Deposition (UHV-PLD) System

The experimental process has been optimized for the growth of GaN epitaxial layers on sapphire (0001) substrates with high crystalline quality and smooth surface. The effect of Ga/N flux ratio on the growth mode of GaN has been studied. The Ga plume obtained by the laser ablation of a liquid Ga target with a laser energy density of 8 J/cm^2 is presented in the inset of figure 1.32. The Ga/N flux ratio is found to be critical in determining the growth mode and the Ga-rich condition promotes the two dimensional GaN growth with a smooth surface. The influence of growth temperature has also been investigated on

the crystalline property of grown GaN epitaxial layers using x-ray rocking curve (XRC) measurements. High quality GaN layers, with a rocking curve full width at half maximum value of 250 arcsec, have been achieved on sapphire (0001) substrate at 500-600°C, which is about 150-200°C lower than the conventional molecular beam epitaxy technique. The 2θ and omega x-ray scans of GaN layers are shown in figure 1.32.

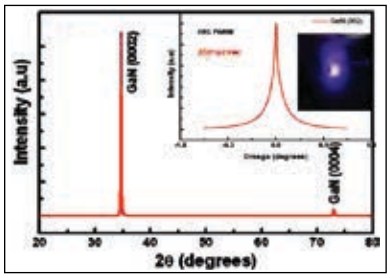


Fig. 1.32. X-ray 2θ and omega (inset) scans of GaN epitaxial layer grown on sapphire (0001) substrate. The Ga laser plume ablated with a laser energy density of 8 J/cm^2 is also shown in the inset.

New Facility Established

Ultra High Vacuum Pulsed Laser Deposition (UHV-PLD) System

A UHV-PLD system (SVT Associates, USA) has been installed for developing the growth process of group-III nitride epitaxial layers and their hetero-structures for high electron mobility transistor (HEMT) applications. The system multiple target stage is capable of holding both solid as well as liquid targets for laser ablation. The atomic nitrogen source is supplied through radio frequency (RF) nitrogen plasma cell. The system is equipped with reflection high energy electron diffraction (RHEED) facility to monitor the growth front in-situ. Recently, the experimental process has been optimized for growth of GaN epitaxial layers on sapphire (0001) substrates with high crystalline quality and smooth surface.

Fig. 1.33: Ultra High Vacuum Pulsed Laser Deposition (UHV-PLD) System for growth of III-Nitrides

Ultrafast Optoelectronics and Terahertz Photonics

Ultrafast pump probe spectroscopy / transient Absorption spectroscopy on wide band gap materials like GaN/ ZnO etc and Terahertz generation and detection

Recently at CSIR-NPL we have installed a new facility of femto second Laser, which has a great potential to provide a new dimension to the materials research. The installed ultrafast laser or femtosecond laser is a pulsed laser with 1kHz rep rate, average power of 4 mJ and the pulse width of <35 fs.The basic configuration of the system comprises of an oscillator, and an amplifier system coupled to an Operational Parametric amplifier (OPA). The Oscillator is a Verdi Pumped Micra system from Coherent inc., the output of this Oscillator is > 350mW @800nm with an adjustable bandwidth of <30nm to m> 100nm. The pulse width is adjustable with <25fs with a Rep. rate of 80MHz, the peak tunablity is 760nm to 850nm

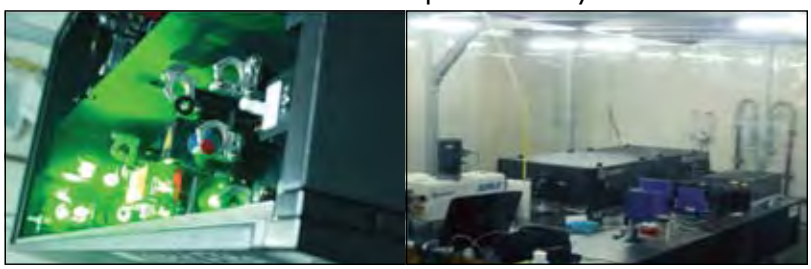


Fig. 1.34: Ultrafast Transient absorption spectroscopy

(30nm bandwidth). This oscillator output is seeded to the Amplifier pumped with 20mJ @1KHz, 250ns pulse centered around 527nm, Evolution 30 model. The output of the Regenerative amplifier is 4mJ@1κ Hz centered around 800nm with a pulse width of <35fs.

Transient absorption spectroscopy: Pump probe spectroscopy

i. With the help of pulsed lasers, it is possible to study processes that occur on time scales as short as 10^{-15} seconds.

ii. Here, the absorbance at a particular wavelength or range of wavelengths of a sample is measured as a function of time after excitation by a flash of light.

iii. In a typical experiment, both the light for excitation ('pump') and the light for measuring the absorbance ('probe') are generated by a pulsed laser.

iv. If the process under study is slow, then the time resolution can be obtained with a CW probe beam and repeated conventional spectrophotometric techniques.

Optical Thin Films & Ceramics Group

(1) Development of Hot wire CVD

We are engaged in the design and development of Hot Wire CVD system for the deposition of polysilicon films for solar cell application. We have designed HWCVD system to meet our requirements and accordingly procured several Hardware components for its fabrication, and assembled it. Finally, its performance also tested in terms of the base vacuum and deposition pressure control (through throttle valve). The achievable base vacuum is 2 x 10^{-7} Torr.

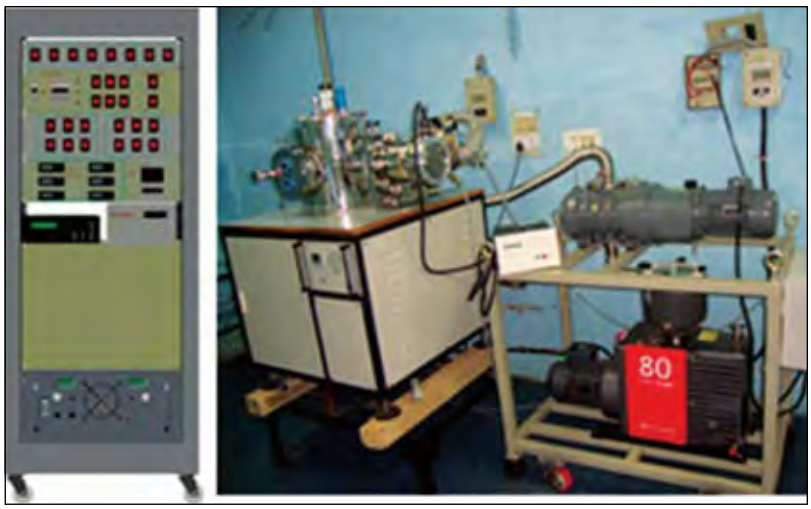


Fig. 1.35: Hot Wire CVD system for the growth of polycrystalline Si thin films

(2) Defect related studies using DLTS technique

Deep Level Transient Spectroscopy (DLTS) is an efficient powerful method used for observing and characterizing deep level defects in semiconductors. It is a capacitance / current thermal scanning technique, usually operating at high frequency (1MHz). It uses a p-n junction or Schottky barrier as a probe to monitor the changes in the charge state of a deep center. In the many variants of the basic DLTS technique the deep levels are filled with free carriers by electrical or optical methods. Subsequent thermal emission processes give rise to a capacitance / current transient. The transient is analyzed by signal processing while the temperature is varied at a constant rate, which results in a full spectroscopic analysis of band gap. It is spectroscopic in the sense that it can also resolve signals due to different traps. DLTS is a technique which is sensitive enough, rapid and easy to analyze. It is able to distinguish between majority and minority carrier traps. DLTS can also give the concentrations, energy and capture rates of both kinds of traps.

The group is also equipped with surface profiler for thickness measurements and ellipsometer for optical constants estimation of thin films.

Fig. 1.36: Deep Level Transient Spectroscopy (DLTS) system

Silicon Thin Film Photovoltaic Group

Amorphous & Microcrystalline silicon thin film deposition for solar cell

Amorphous & Microcrystalline silicon thin films usually deposited by variation of pressure, power, frequency, dilution (Ar, He, H_2 etc.) silane flow rate etc. using PECVD technique. The films deposited under such conditions are characterized by Raman spectroscopy, low angle X-ray diffraction (XRD), Fourier transform infrared (FTIR) spectroscopy, atomic force microscopy (AFM) and UV-visible (UV-Vis) spectroscopy etc. to see the effects of process parameters on deposition rate, crystalline volume fraction, hydrogen bonding and morphology of Si:H thin films. Growth rate of microcrystalline silicon films above 10 A^0/sec was obtained at certain process conditions using VHF PECVD deposition technique. A transition region from amorphous to micro/nanocrystalline structure has been found by the variation of silane flow, power, pressure & dilution. Different crystalline volume fraction (20 % to 60 %) and band gap (1.50 eV to 1.90 eV) were achieved by variation of silane flow rate (5-30 sccm). The structures of these films were found to be mixed-phase consisting of amorphous and micro/nano-crystalline as revealed from Raman spectra (Fig. 1.37).

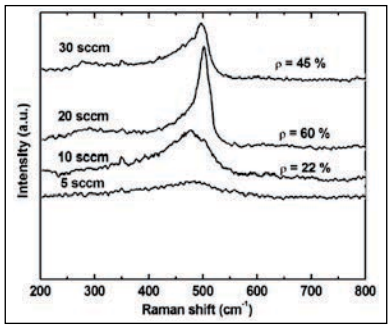


Fig. 1.37: Raman spectra of mixed phase structure (a-Si:H & µc-Si:H) of silicon thin films grown using VHF (60 MHz) PECVD process as a function of silane flow rate (Ar flow rate fixed). Crystalline fraction (ρ) estimated using Raman spectra is also indicated.

Boron doped hydrogenated microcrystalline silicon (µc-Si:H) thin films were also deposited by VHF PECVD (60 MHz) by decomposition of silane (SiH_4) and diborane (B_2H_6) mixtures which were diluted in Argon (Ar). Films were deposited on 7059 corning glass and ITO coated glass at the temperature of 200°C. The pressure level of individual gas mixtures (Ar, SiH_4 and B_2H_6) were calculated based on partial pressures and the flow of Ar, SiH_4 and B_2H_6 to the deposition chamber were controlled by MFC's while keeping the chamber pressure as 0.25 Torr. We systematically studied the influence of boron doping on the film properties by varying the B_2H_6 flow from 0.25–1.5 % of the total chamber pressure. SEM was used to analyze the surface morphology of the deposited films. From the SEM analysis it can be observed that the films deposited with 0.25 % diborane showed well defined crystallites with uniform size distribution throughout the sample (Fig 1.38). n-doping of these materials was also performed and single junction microcrystalline silicon p-i-n solar cells were made.

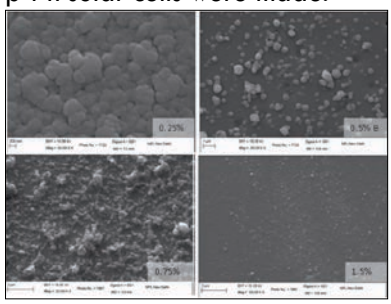


Fig. 1.38: SEM micrographs of p-doped µc-Si:H films.

Simulation work for efficient solar cells

The group also involved in simulation work for the improvement of the efficiency of p-i-n silicon solar cells. The efficiency of hydrogenated amorphous silicon (a-Si:H) p-i-n solar cell strongly depend on p-layer band gap and its thickness. i and n- layer band gap also play a key role in the conversion efficiency. Hence we optimized the p, i and n layer band gaps by computer aided one-dimensional AFORS-HET software. Such an optimized value of these band gaps would further helps to prepare efficient solar cells experimentally. In addition, we have used various types of diamond like carbon films as window layer to see its effect on the efficiency of the cells and compared the results with conventional silicon carbon alloy. We are also trying to simulate the layers for Micromorph silicon tandem junction solar cells using ZnO as interlayer between amorphous & microcrystalline silicon solar cells. In addition, simulation approach was also used for HIT solar cells to achieve ~ 27 % efficiency using the same AFORS-HET software.

Chemical route for compound semiconductor PV

(1) Multicomponent Chalcogenide Nanocrystals: $Cu_2ZnSn(Se_{1-x}, S_x)_4$

We have shown that polyhedral-shaped Multicomponent chalcogenide nanocrystals (MCNs) of $Cu_2ZnSn(S_xSe_{1-x})$ having high monodispersity & uniform morphology can be successfully synthesized by the hot-injection method through careful tuning of the S and Se precursor reactivities using TOP/TOPO method.

- We have synthesized sulpho-selenides (CZT(S, Se)) using different ratios of S and Se. Identical approach is being utilized for the development of CIG (S,Se) to achieve enhancement in the band-gap as well as improved electrical properties. The main objective being to control the stoichiometry of multicomponent chalcogenide nc's. (MCNs) without formation of unwanted side products for PV applications. The salient features of these systems are:
- Agglomeration tendency decreases with decrease in Se content (100% Se to 100% S) as evident from TEM micrographs (Fig. 1.39 (a-c)).
- For CZTSeS stoichiometric system (50% Se, 50%S), monodispersed, hexagonal-shaped, uniformly distributed nanocrystals were found (Fig. 1.39 (b)).
- Size of nanocrystals decreases with increase in S or decrease in Se content and hence increase in band gap (E_g ~ 1.2 eV to 1.5 eV).
- Distinct change in morphology observed with variation in Se/S content (Fig. 1.39 (a-c)).
- As the Se-content decreases, the smaller S atoms (1.84 Å) replace the larger Se atoms (1.98 Å) resulting in an decrease in the lattice parameters.

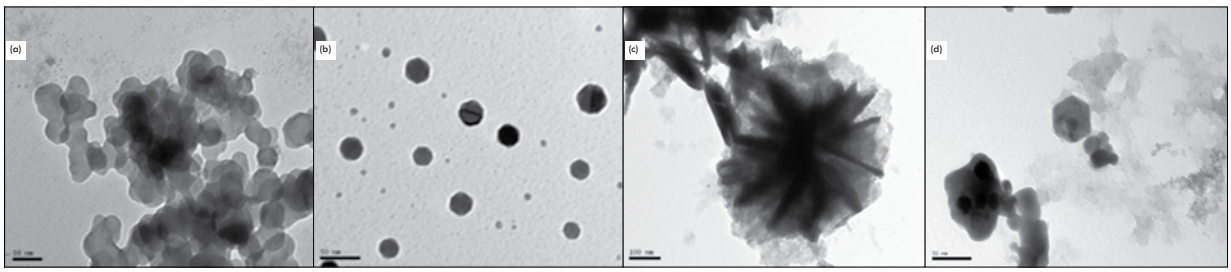


Fig. 1.39 TEM micrograph of (a) CZTSe; (b) CZTSeS; (c) CZTS and (d) CIGSeS

- In the case of CIG (S,Se) nanocrystals, TEM micro-graph shows hexagonal shaped nanoparticles with agglomeration tendency (Fig. 1.39 (d)). Presence of few binary phases are also indicated.

(2) Properties of CdS Films Grown by Chemical Bath Deposition

Synthesis of highly crystalline CdS buffer layers (Eg ~ 2.55 eV, d ~ 60 nm) by Chemical bath Deposition (CBD) method. The salient features are:

- CdS films exhibit the coexistence of hexagonal and cubic phases. This is related to the polymorphic tendency of the CdS structure and indicates a strong influence of local parameters in the deposition conditions. The preferred orientation of CdS film is due to the controlled nucleation process associated with the low-formation rate of CdS.
- Increase in thickness (60-150 nm) leads to decrease in band gap (2.55-2.42 eV).
- AFM studies indicated that average surface roughness decreases from ~63 nm to 8 nm with decrease in deposition time from t=15 mins. to t= 5 mins. corresponding to thicknesses of 170 & 60 nm respectively (Fig. 1.40 a & b).

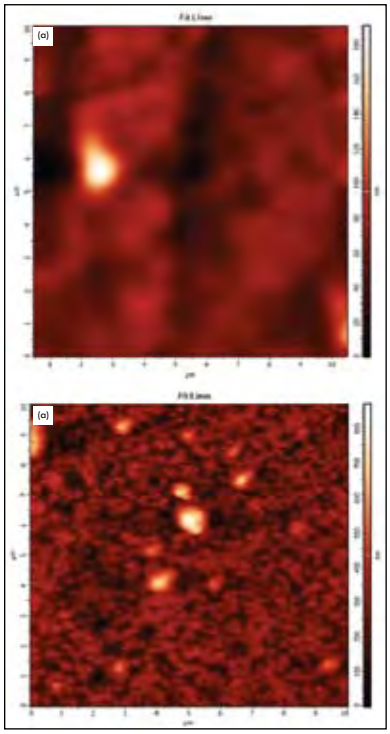


Fig. 1.40 AFM micrographs of CdS thin films deposited at (a) t=15 mins & (b) t=5 mins

(3) Improved Quality CIGS Absorber Layer

In this work, TOPO/TOP-capped CIGS absorber layer quality has been improved by removal of organic capping ligand by successive purification in suitable chemical mixture without resorting to high temperature, ligand-exchange process by using toxic, hazardous chemical like pyridine. The salient features of these absorber layers are:

- Here at an optimum purification time (2T), low series resistance and resistivity (Table 1.1), low lattice strain as calculated from Hall-Williamson method and higher crystallite size is obtained. For unpurified CIGSe sample, series resistance and resistivity values are quite high (Table 1.1) owing to the presence of capping ligands. At higher purification times (6T), leads to decrease in constituent elements with considerable oxidation effect resulting in a porous network with high strain values and thus poor absorber properties.
- Reduced interparticle distance upon washing for two-times leads to better charge transport between CIGSe nanocrystals due to removal of steric hindrance of capping ligands.

Table – 1.1

Times of Purification for CIGSe	Series Resistance(Ω)	Shunt Resistance(Ω)	Resistivity (Ωm)
0T	529.100	1000	2.760×10^3
2T	214.132	763.35	1.117×10^3
4T	497.512	2437.45	2.595×10^3
6T	Diode is shorted (enhanced porosity)		

अतीत के सुनहरे पल ...

Dr S S Bhatnagar, Sardar Vallabhbhai Patel,
Dr Shyama Prasad Mukherjee at the inauguration of NPL

पदार्थ भौतिकी एवं इंजीनियरिंग

Materials Physics and Engineering

पदार्थ भौतिकी एवं इंजीनियरिंग

इस प्रभाग का उद्देश्य चुनिंदा क्षेत्रों में निरंतर अनुसंधान एवं विकास कार्यों के माध्यम से औद्योगिक तथा कार्यनीतिक क्षेत्रों के लिए अत्याधुनिक सामग्री, प्रक्रम तथा प्रौद्योगिकियों को विकसित करना है। सरकारी तथा निजी दोनों क्षेत्रों से संबद्ध विभिन्न अनुसंधान तथा विकास संगठनों के लिए अनेक विकास परियोजनाओं जैसे कि सीएसआईआर नेटवर्क परियोजना, प्रायोजित परियोजना, अनुदान सहायता से चलाई जाने वाली परियोजना, सहयोगात्मक तथा परामर्शदात्री परियोजनाओं को सफलतापूर्वक क्रियान्वित किया जा रहा है/पूरा किया जा रहा है।

विविध नैनो कणों द्वारा मादित द्रव क्रिस्टल पदार्थों के भौतिक गुणों में संवर्धन करके उनके अनुप्रयुक्त तथा बुनियादी पहलुओं से संबंधित कार्य किए जा रहे हैं। इस प्रभाग द्वारा किया जा रहा एक अन्य कार्य ग्रेफीन के संश्लेषण/ Fe_3O_4 युक्त पॉलिऐनिलीन (पीजीएफ) सम्मिश्र पदार्थों के संश्लेषण का वैद्युत चुंबकीय परिरक्षण हेतु अध्ययन तथा संक्षारण संरक्षण अध्ययन किया जा रहा है।

राष्ट्रीय भौतिक प्रयोगशाला (एनपीएल) ने ईंधन सेल के दो महत्त्वपूर्ण कार्बन संघटकों अर्थात सरंध्र चालक कार्बन पेपर और सम्मिश्र द्वि–ध्रुवीय प्लेट को सफलतापूर्वक विकसित किया है जिसका कार्य–निष्पादन वाणिज्यिक आधार पर उपलब्ध संघटकों के अनुरूप है। सरंध्र चालक कार्बन पेपर से संबंधित प्रौद्योगिकी का वाणिज्यीकरण किया जा चुका है और इसे ईंधन सेलों के लिए प्रयोग में लाया जा रहा है। लिथियम–आयन बैटरियों के लिए कार्बन आधारित ऐनोड (ऋण ध्रुवों) को विकसित करने का कार्य भी किया जा रहा है।

इस समूह द्वारा वर्तमान में सौर सेलों के लिए संवर्धित डाउन तथा अप–परिवर्तन संदीप्ति दक्षता से युक्त नैनो फॉस्फोरस को विकसित करने, डिस्प्ले युक्तियों के लिए संवर्धित संदीप्ति हेतु मादित नैनो क्रिस्टलों तथा क्वांटम डॉट का संश्लेषण, सौर स्पेक्ट्रम आशोधन हेतु कोर– शेल नैनो फॉस्फोरस, प्रकाश उत्सर्जी डायोड (एलईडी) हेतु नए नैनो फॉस्फोरस तथा जैव संबद्ध अनुप्रयोगों हेतु संदीप्त–चुंबकीय नैनो फॉस्फोरस के संश्लेषण पर मुख्य रूप से ध्यान दिया जा रहा है।

प्रभाग द्वारा सीरिआ से युक्त मैग्नीशियम फेराइट की तनु फिल्मों के स्पंद लेज़र निक्षेपण (पीएलडी) का कार्य किया जा रहा है। एक बाह्य चुंबकीय क्षेत्र का प्रयोग करके बहु–संस्तरयुक्त तनु फिल्मों में विशाल चुंबकीय प्रतिरोध (जीएमआर) के कारण चुंबकीय पठन शीर्षों के क्षेत्र में एक आमूल बदलाव लाया जा सका है। वायुमंडल में स्थित आर्द्रता के संपर्क में लाने पर तनु फिल्मों के प्रतिरोध में अत्यधिक परिवर्तन देखा गया है। अभी तक स्थापित आर्द्रता संवेदक अनुप्रयोगों के अतिरिक्त, इस प्रभाव का नए प्रकार के ऊर्जा संरक्षी अत्यधिक आर्द्रता प्रतिरोध (सीएचआर) आधारित युक्तियों के लिए सर्वाधिक उत्तम रूप में प्रयोग किया जा सकता है।

जैव–चिकित्सीय यंत्रीकरण अनुभाग बुनियादी तथा अनुप्रयुक्त विज्ञान में अनुसंधान कार्य को समर्पित है और भौतिकी, रसायन विज्ञान, जैव प्रौद्योगिकी तथा यंत्रीकरण के सिद्धांतों का प्रयोग करके समेकित अनुसंधान क्षेत्र में अनुसंधान कार्य करता है जिसका मुख्य उद्देश्य (i) कॉलेस्टेरोल जैव–संवेदक की प्रक्रम प्रौद्योगिकी को विकसित करना, (ii) कैंसर के निदान हेतु जैव संवेदकों को विकसित करना, (iii) सूक्ष्म तरल तकनीक का प्रयोग करके हृद्–जैव मार्करों को विकसित करना, और (iv) निरंतर अनुसंधान तथा विकास कार्यों के माध्यम से संक्रामक रोगों के लिए जैव संवेदकों को विकसित करने के लिए नवीन पदार्थों का संश्लेशण विश्लेषण करना, अनुसंधान से प्राप्त परिणामों को प्रकाशित करना, पेटेंटों को दर्ज कराना, प्रौद्योगिकीय अंतरण तथा उद्योगों व राष्ट्रीय प्रयोगशालाओं को परामर्श आदि प्रदान करना है।

सीएसआईआर नेटवर्क परियोजना के अंतर्गत *"सौर ऊर्जा तथा अपशिष्ट ऊष्मा का प्रयोग करने के लिए नए प्रकार के ताप विद्युत पदार्थों तथा युक्तियों का विकास"* नेटवर्क के माध्यम से सौर ऊर्जा को प्रयोग में लाने के लिए प्रौद्योगिकी तथा उत्पाद (नेटवर्क परियोजना – एनडब्ल्यूपी 54) के अंतर्गत अनुसंधान में संवर्धित दक्षतांक से युक्त नई ताप विद्युत पदार्थों का विकास तथा अनेक नई नैनो संरचनायुक्त ताप वैद्युत पदार्थों की अभिकल्पना, संश्लेषण, अभिलक्षणन तथा ताप वैद्युत गुणों के मूल्यांकन पर ध्यान केंद्रित किया गया। इस अनुसंधान कार्य का मुख्य उद्देश्य एक ताप वैद्युत युक्ति के रूप में समेकन के लिए अनुरूपी ऋणात्मक तथा धनात्मक प्रकार (n और p प्रकार) के ताप वैद्युत अवयवों को विकसित करना था। इस परियोजना के अंतर्गत एक उल्लेखनीय उपलब्धि नैनो संरचनायुक्त कॉपर सैलिनाइड यौगिक का विकास है। इसे बॉल मिलिंग तथा स्पार्क प्लाज्मा सिंटरिंग का प्रयोग करके संश्लेषित किया गया जिससे 913 K पर उच्च ताप वैद्युत गुणांक का मान ~2 प्राप्त किया जा सका।

Materials Physics and Engineering

The objective of the division is to develop state-of-the-art materials, processes and technologies for industrial and strategic sectors through constant R&D in selected areas. Several developmental projects, such as CSIR network, sponsored, grant-in-aid, collaborative and consultancy are successfully being implemented/ completed for different R & D organizations, both in the public and private sectors.

The applied and basic aspects of liquid crystal materials are being carried out by doping different nanoparticles and improving their physical properties. Another activity is the synthesis of graphene / Fe_3O_4 incorporated polyaniline (PGF) composites which is being studied for electromagnetic shielding and corrosion protection studies.

CSIR-NPL has successfully developed two important carbon components of the fuel cell viz. porous conducting carbon paper and composite bipolar plate matching the performance of commercially available components. Technology for porous conducting carbon paper has been commercialized and is being used in the fuel cells. The development of carbon based anodes for Li-ion batteries is also being carried out.

Development of nanophosphors with enhanced down and up-conversion luminescence efficiency for solar cells, synthesis of doped nanocrystals and quantum dots for enhanced luminescence for display devices, core-shell nanophosphors for solar spectrum modification, novel nanophosphors for LEDs and luminomagnetic nanophosphors for bio-related applications are the current thrust of the group.

Pulsed laser deposition (PLD) of thin films of ceria added magnesium ferrite is being carried out. Giant magnetoresistance (GMR) in multilayer thin films by applying an external magnetic field brought a breakthrough in the area of magnetic read heads. A colossal charge in the resistance has been observed in thin films by exposing it in the humidity present in atmosphere. The effect can be best exploited for new type of energy conservation colossal humidoresistance (CHR) based devices besides its established humidity sensor applications.

The biomedical instrumentation section is dedicated to research in both pure and applied science and integrated research field involving the principles of Physics, Chemistry, Biotechnology and Instrumentation with principal motives i) to develop the process technology of cholesterol biosensor, ii) to develop biosensors for cancer diagnosis, iii) to develop cardiac biomarkers by using microfludic technique iv) to synthesize new materials for the development of biosensors for infectious diseases through sustained R&D, research publications, patents, technology transfer, consultancy to industry, national labs etc.

Under CSIR Network Project - Technologies and Products for Solar energy utilization through Networks (TAP-SUN) on "*Development of novel thermoelectric materials and devices for harnessing solar energy and waste heat*" (Network Project – NWP 54), the research was focused on the development of novel thermoelectric materials with enhanced figure-of-merit and on the design, synthesis, characterization and thermoelectric property evaluation of several novel nanostructured thermoelectric materials. The focus of research was to develop compatible n & p-type thermoelectric elements for integration as a thermoelectric device. One of the significant achievement in this project was the development of nanostructured copper selenide compound, synthesized using ball milling and spark plasma sintering, which yielded a high thermoelectric figure-of-merit of ~ 2 at 973 K.

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Sh Vinod Kumar Tanwar

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Dr Sunil Kumar Singhal
Dr Sanjay Rangnate Dhakate
Sh. Bhanu Pratap Singh
Dr (Ms) Priyanka Heda Maheshwari
Dr (Ms) Saroj Kumari
Sh Pinaki Ranjan Sen Gupta
Sh Rajesh Kumar Seth

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Dr (Ms) Santa Chawla
Dr Divi Haranath
Dr Bipin Kumar Gupta

D 02.04 Multiferroics and Magnetics

Dr R K Kotnala
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Sh Bathula Sivaiah
Sh M Saravanan
Sh Rajiv Sikand
Sh Rakesh Khanna

D 02.07 Piezo electric Sensors and Actuators

Sh Subodh Kumar Singhal

Polymer and Soft Materials

The Polymeric and soft materials section is dedicated to research in fundamental and applied science of polymers, soft materials and liquid crystals. Research in liquid crystal has substantially grown in recent years. Ordering in these mesophases results in light transmission under crossed polarizers.

In NPL, we are focusing on the tuning of electro-optical properties of ferroelectric liquid crystals by doping with various types of nanomaterials like metal and metal oxide nanoparticles, quantum dots, carbon nanotubes and graphene etc. The group has also undertaken the integrated M.Tech–Ph.D./ Ph.D. programme on advanced carbon materials under Academy of Scientific and Innovative Research (AcSIR)

Electrically modulated photoluminescence in ferroelectric liquid crystal

We have studied and reported the effect of electric field on photoluminescence (PL) of a deformed helix ferroelectric liquid crystal (DHFLC) material, namely, FLC 6304 (Rolic, Switzerland). For the first time we are successful in modulating the PL characteristics (both the intensity and wavelength) by applying an electric field over the DHFLC material without any doping. In addition to this, switching of the PL intensity has also been achieved. The probable mechanism has been discussed on the basis of field-induced helix unwinding model in the DHFLC material.

The LC sample cell for the present study was prepared using highly conducting (~30 Ω/Sq.cm) indium tin oxide (ITO) coated glass plates. The desired electrode patterns on the ITO substrates were achieved using a photolithographic technique. The active electrode area was 45 mm × 45 mm. The thickness of the cell was maintained uniformly ~ 5 μm using Mylar spacers. The homogeneous alignment was obtained using rubbed polyimide technique. The FLC 6304 material was filled in isotropic phase by means of capillary action and then cooled gradually to room temperature. The phase sequence of this DHFLC material is as follows:

$$Cryst. \xleftarrow{-14^{0}C} SmC^{*} \xleftarrow{60.5^{0}C} SmA \xleftarrow{64^{0}C} Iso.$$

The room temperature PL excitation and emission spectra of the filled LC sample cell was recorded in the fluorescence mode using luminescence spectrometer (Edinburgh, F900, UK) equipped with a xenon lamp. A dc regulated power supply was used for applying external electric field across the LC cell. Dielectric permittivity of the sample was measured using an impedance analyzer (Wayne Kerr, 6540 A, UK).

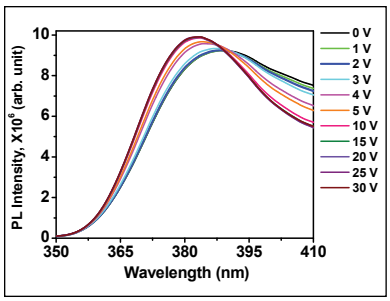


Fig. 2.1 PL emission spectra of pure FLC 6304 material excited with 333 nm at various voltages

The PL excitation spectrum of the filled LC sample cell was recorded over the range 200-360 nm using the luminescence spectrometer. Initial parameters like slit width, excitation step, and dwell time were kept constant at 5 nm, 1 nm, and 0.1 s respectively, for the sample. It was found that the FLC 6304 material has a clear absorption peak at 333 nm while that of ITO coated glass plates is at 258 nm. The PL emission of this DHFLC material was then recorded by registering the excitation wavelength at 333 nm.

Figure 2.1 shows the PL emission spectra ranging from 350-410 nm at various applied voltages (0-30 V). The emission spectrum of the DHFLC material is found to be voltage dependent. Both PL peak position and intensity get modified by changing the applied voltage. It is observed that there is almost no change in peak position when the applied voltage is less than 3 V. At around 3 V, it gets slightly shifted to lower wavelength and this shift gets pronounced as the voltage is further increased to 4 V. This shifting continues up to 10 V and remains constant thereafter. It is a well-known fact that in DHFLC material the helix is easily distorted by electric field which leads to a change in the refractive index of the material. This further results in shifting of the PL peak position. Hence, the observed shifting in the peak position with voltage is attributed to the change in refractive index due to helix distortion in the DHFLC material. For better understanding, this voltage induced helix distortion is shown schematically in Fig. 2.2.

At low voltages (< 3 V), only deformation of helix occurs [Fig. 2.2 (a)] where the pitch is almost same which results in no change in the PL peak position. The pitch of the present DHFLC material is 0.35 µm which is almost linearly dependent on the electric field above a threshold voltage which is defined as value of the voltage required to switch the DHFLC molecules. Above this threshold voltage (3 V), the twist walls become unstable and the helix starts unwinding which leads to the shift in the peak position towards lower wavelength. Due to the surface inhomogeneity there is a voltage range (4 < V < 10) where unwound and helical parts coexist [Fig. 2.2 (b)], which is manifested as the observed shifting in the PL emission peaks in this range. In this intermediate voltage range, in some areas the helical structure remains stable while in other areas switching occurs between two unwound states which lead to non-uniform switching. At and above saturation voltage (≥10 V), which is defined as the voltage where complete switching of DHFLC molecules takes place, the helix is unwound everywhere [Fig. 2.2 (c)] and the switching becomes uniform. This complete unwinding of the helix

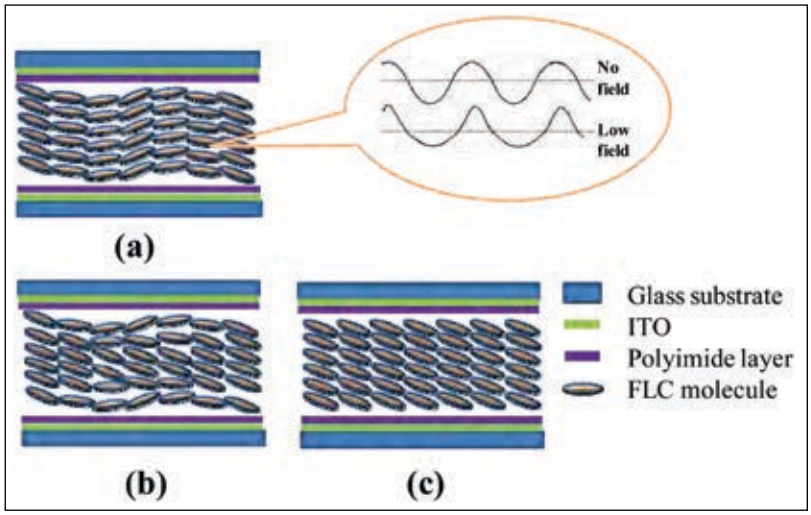


Fig. 2.2 Schematic showing helix unwinding process in DHFLC material: (a) helix deformation at low voltages (0 – 3 V), (b) co-existence of unwound and helical parts (4 – 10 V) and (c) complete helix unwinding above 10 V.

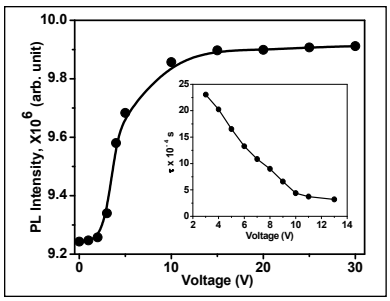


Fig. 2.3 Variation of PL intensity excited at 333 nm and response time (inset) with the applied voltage of FLC 6304 material

causes no peak shifting above 10 V.

Figure 2.3 shows the variation of PL intensity with the applied voltage. It is clear from the figure that the PL intensity increases above a threshold voltage (3 V) and continues up to a saturation voltage (10 V). Figure 2.3 (inset) shows the response time of the material as a function of applied voltage which further confirms these values of voltages. The mechanism behind these observations can similarly be explained on the basis of voltage-stimulated unwinding of the helical structure in the DHFLC material. It is known that upon application of voltage, the helix gets destabilized resulting in a highly light scattering state. Hence, the excitation photons undergo multiple scattering by this highly scattering state before emission out of the LC cell to give the enhanced PL brightness. As discussed before, the helix unwinding process in FLC 6304 material starts from around 3 V and retains up to 10 V, which explains the observed increase in the PL intensity in this voltage range. Another possible reason for this variation of the PL intensity could be due to supra-helical structure. However, such structures have not been observed in the present FLC material which is in concurrence to earlier reported work.

Apart from this, the PL intensity of the DHFLC material can be switched between low intensity (field-off) and high intensity (field-on), which is shown in Fig. 2.4. The change in PL intensity between these switching states has been visualized and captured as a digital image [Fig. 2.4 (a)]. The increase in the light intensity provides evidence of electrically switchable PL in the DHFLC material.

Time-dependent switching of PL intensity in response to several cycles of field-off (0 Vμm-1) and field-on (6 Vμm-1) is shown in Fig. 2.4 (b) whereas the corresponding PL emission spectra (λ_{ex} = 333 nm) are compared in the inset of Fig. 2.4 (b). The time interval (2 min) between two cycles is accounted to the total time required for each PL scan and stabilization of the applied field. It can be seen that the PL intensity quickly reaches to maximum during the field-on state while it goes to minimum in field-off state. This fast switching can be understood as FLC 6304 material is reported to have fast response time (~ 1-5 ms) to the external applied field. This electrically switchable and repeatable PL intensity reveal the possibility of using DHFLC material in optical switches.

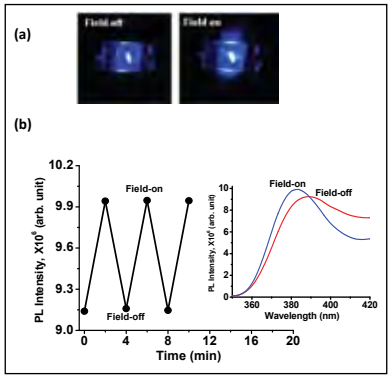


Fig. 2.4 Electrical switching of PL intensity of FLC 6304 material: (a) photos showing light emission from LC sample cells under excitation (b) Time-dependent switching of PL intensity in response to several cycles of field-off (0 Vμm-1) and field-on (6 Vμm-1), inset shows the corresponding emission spectra.

Reduced graphene oxide/γ-Fe_2O_3/carbon fiber sandwich for excellent electromagnetic interference shielding in the X-band

Composite sheet consisting of a reduced graphene oxide (RGO)/γ-Fe_2O_3/ carbon fiber sandwich has been produced by compression molding. Its electrical conductivity lies in the range 0.48–171.21 S/cm. Transmission and scanning electron microscopy observations confirm the presence of nano particles of γ- Fe_2O_3 (~9.8 nm) and carbon fiber (~1 mm) which gives flexural strength to the RGO sandwich. Thermogravimetric analysis show that the thermal stability of the RGO sandwich depends upon the amount of RGO and phenol resin in the sandwich. Complex parameters, i.e., permittivity

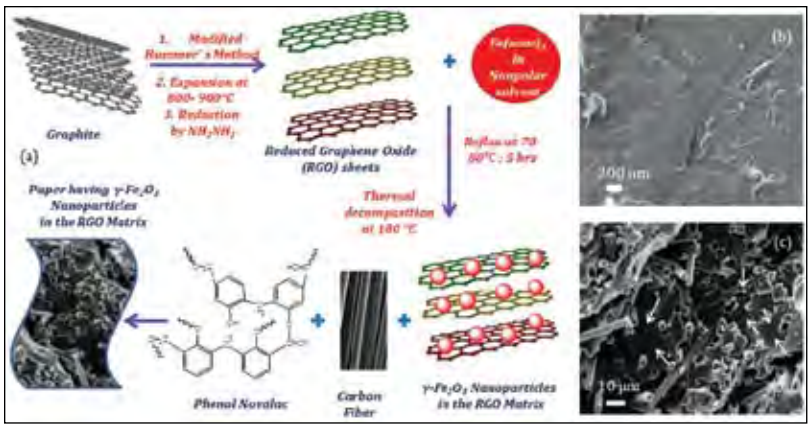


Fig 2.5 (a) Schematic representation of preparation of RGO sandwich containing different wt% of γ-Fe_2O_3 nanoparticles using phenol resin in the organic medium (b) SEM images of RGO and (c) RGO/γ-Fe_2O_3 sheet having 1% carbon fiber and 50wt% of phenol resin showing the pullouts of carbon fibers and the fracture surface of sheet (Avanish Pratap Singh, Parveen Garg, Firoz Alam, Kuldeep Singh, R.B. Mathur, R.P. Tandon, Amita Chandra & S.K. Dhawan, Carbon 50 (2012) 3868-3875 (I.F. 5.38)

($\varepsilon^*=\varepsilon'-i\varepsilon''$) and permeability ($\mu^*=\mu'-i\mu''$) of RGO/γ-$Fe_2O_3$/ carbon fiber have been calculated from experimental scattering parameters (S_{11} & S_{21}) using theoretical calculations given in Nicholson–Ross and Weir algorithms. The microwave absorption properties of the paper have been studied in the 8.2-12.4GHz (X–Band) frequency range. The maximum shielding effectiveness observed is 45.26 dB, which strongly depends on dielectric loss and volume fraction of γ- Fe_2O_3 in RGO matrix.

RGO has been incorporated with varying amount of γ-Fe_2O_3 to make a sandwich along with carbon fiber and its effect on mechanical, electrical and the EMI shielding properties have been investigated. Carbon fibers have been used to strengthen the sandwich. Also, the effect of varying phenol resin on the electrical and mechanical properties has been studied. The vibrating sample magnetometer (VSM) study of paper with different amounts of γ-Fe_2O_3 has been carried out to find their magnetic induction and hence its effect on EMI shielding absorption. The sandwich paper having thickness 0.2~0.4 mm has shown high value of shielding effectiveness ranging from 16.98 to 42.83dB (~99.99%) in the microwave range (X-band).

Figure 2.6 shows the variation of the SE with frequency in the 8.2-12.4 GHz range. From the experimental measurement, the shielding effectiveness due to absorption (SEA) has been found to vary from 9.14–33 dB with decrease in the γ-Fe_2O_3 content while the SER varies from 11 to 7.66 dB for the same. Thus, the total SE achieved for the GF sandwich is 42.83dB (GFR31) which is much higher than the pristine RGO sheet (GFR10). It has been observed that for conducting RGO/γ-Fe_2O_3 sheet, SE is mainly dominated by absorption while the shielding effectiveness due to reflection (SE_R) is constant and contributes comparatively little. To further investigate the reasons behind the observed increase in SE, the electromagnetic attributes (complex permittivity and permeability) have also been evaluated.

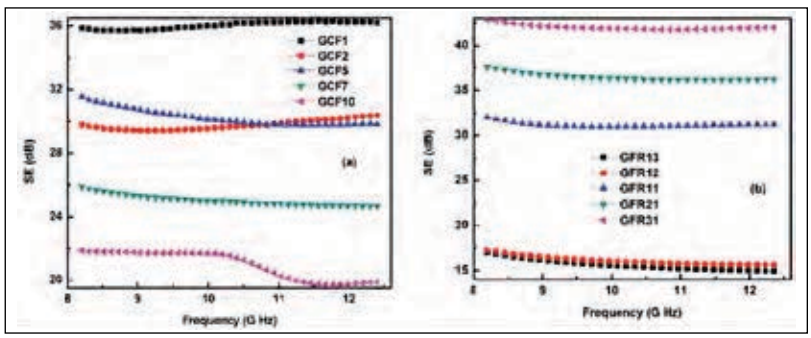


Fig. 2.6 Variation in EMI SE of sandwich consisting RGO/γ-Fe_2O_3/carbon fiber (a) having fixed 50% wt ratio of phenol resin and different weight ratio of carbon fiber GCF1 having 99:1 % wt ratio of RGO and carbon fiber, respectively, GCF2 98:2, GCF 95:5, GCF 93:7, GCF 90:10 accordingly, (b) having fixed 1% wt ratio of carbon fiber and different weight ratio of γ-Fe_2O_3: GFR13, GFR12, GFR11, GFR21 and GFR31.

Synthesis of graphene/Fe_3O_4 incorporated polyaniline (PGF) composite:

Reduced graphene oxide embedded with ferric oxide nano particles were incorporated into polyaniline matrix by emulsion polymerization which shows nice distribution of nano ferric oxide particles in RGO matrix.

TEM images of Fe_3O_4, GF and PGF2 composite have been shown in Fig. 2.8. Fig. 2.8a shows, large-scale Fe_3O_4 nanoparticles with a relatively uniform size of 10–20 nm. It is evident that two-dimensional graphene's surface was decorated by a large quantity of Fe_3O_4 nanoparticles (shown in Fig. 2.8b), and both the outline of graphene and Fe_3O_4 nanoparticles can be clearly observed. It is further demonstrated that Fe_3O_4 nanoparticles have grown on the graphene sheets and were distributed over the graphene's surface as compared to the agglomerated morphology of pristine Fe_3O_4 nanoparticles. Fig. 2.8c and 2.8d show the TEM images of the PGF2 composite, the Fe_3O_4 nanoparticles distributed on the graphene and polyaniline.

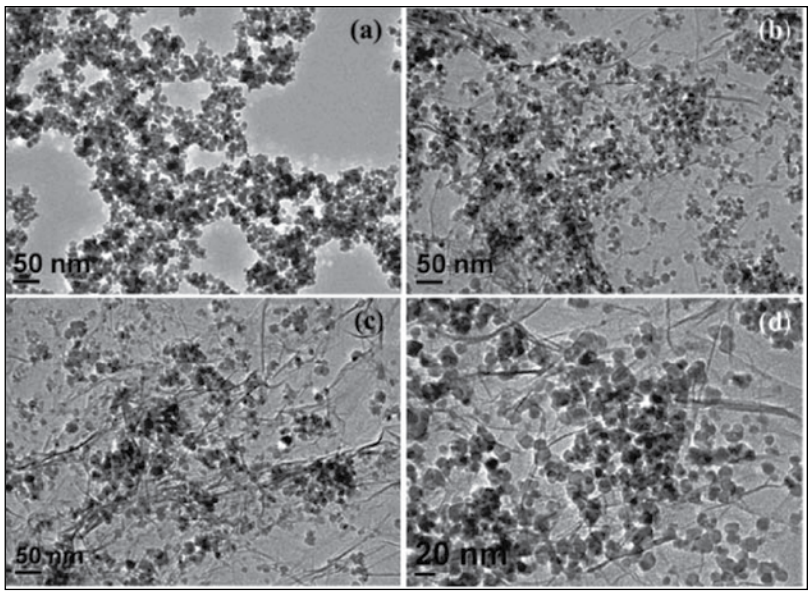


Fig. 2.8 TEM images of (a) Fe_3O_4, (b) GF, (c) PGF2 at 30 K and (d) PGF2 composite at 60 K resolution respectively

It is interesting to note that, in PGF composites, the contribution to SE values mainly comes from the absorption rather than refection, as observed in metals. PGF composites have shown excellent frequency stability in the measured frequency range, which was found to increase with increasing GF content (Fig. 2.9). PGF2 has a higher SEA of 22–26 dB (left black scale) with a SER of 4.7–6.3 dB (right blue scale) as compared to PGF1 (SEA ~ 21 dB and SER ~4.5 dB) in the 12.4–18 GHz range, while polyaniline–Fe_3O_4 (PF12) has a lower value shielding effectiveness (SEA ~ 7–9 dB and SER ~ 1.5–2.5 dB) in comparison to PGF composites in the same frequency range having a thickness of 2.5 mm.

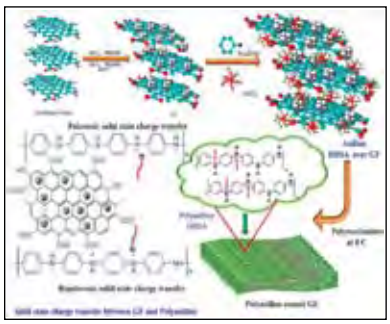


Fig. 2.7 Schematic representation of the formation of conducting polymer polyaniline - Graphene oxide - Ferrite nano composites

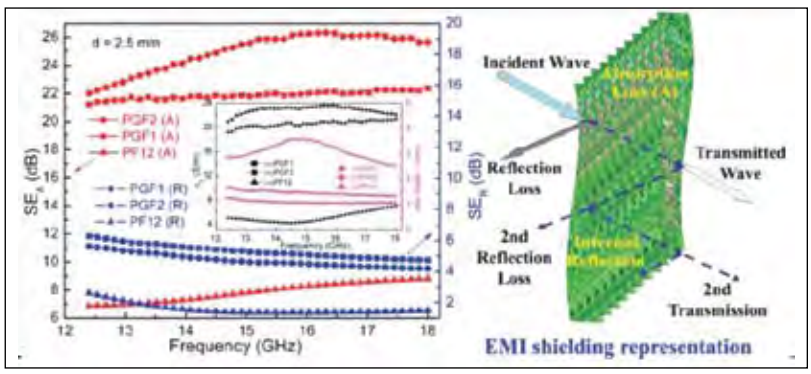


Fig. 2.9 Dependence of shielding effectiveness (SEA and SER) of PF12, PGF1 and PGF2 composites as a function of frequency for sample thickness d ~ 2.5 mm and EMI shielding representation. The inset illustrates the variation of microwave conductivity and skin depth with frequency

Robust Multifunctional Free Standing Polypyrrole Sheet for Electromagnetic Shielding

A multifunctional free standing sheet of polypyrrole has been fabricated using a versatile in-situ chemical polymerization of pyrrole along with carbon fibers followed by thermal curing in the presence of phenolic-novolac resin for the electromagnetic shielding application. Different formulations have been designed in order to optimize the electrical, thermal and mechanical properties. The addition of carbon fibers endows to enhance the electromagnetic interference shielding effectiveness (23 dB) with absorption as the dominant shielding mechanism in the 12.4–18 GHz (Ku-Band) frequency range. This material has strength of 78.96 MPa with an electrical conductivity of 0.034 S/cm and outperforms many other sheet-like materials in stiffness and strength. Its combination of macroscopic flexibility and stiffness is a result of a unique interlocking arrangement of the polypyrrole-carbon fibers with phenolic resin.

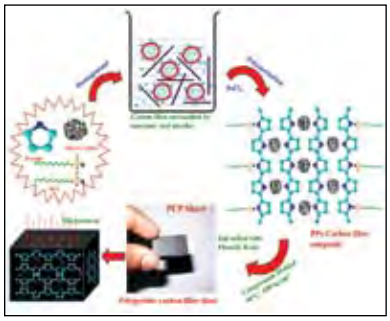


Fig. 2.10 Schematic representation of the formation of compression molded polypyrrole carbon fiber sheet (PCP) and interaction of microwave with the polymer sheet (Swati Varshney, K. Singh, A. Ohlan, S.K. Dhawan, Science of Advanced Materials, (2013) (I.F. 3.53))

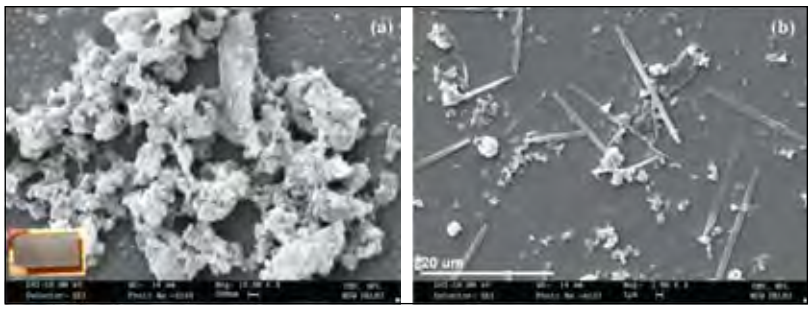


Fig. 2.11 Scanning electron micrographs of uncured (a) PPy (b) PCP3 sheet whereas inset to Figure 2.11(b) is a photograph of polypyrrole sheet

Morphology and the dispersion of carbon fibers in the PPy sheet has been analyzed by scanning electron microscope. Figure 2.11a & 2.11b demonstrates the SEM image of PP and PCP3 composite sheet respectively, whereas inset to Figure 2.11b is a photograph of PPy sheet. From the micrographs, it is observed that the PP exists in globular morphology whereas in PCP3 composite the PPy coated carbon fibers are distributed in the phenolic resin. From the facile method of in-situ oxidative polymerization of pyrrole along with carbon fiber, these fibers are thought to be surrounded by globular PPy molecules which lead to form multiparticle clusters and conducting channels in the composite sheet.

We have also functionalized graphene oxide matrix by incorporating amino group in the GO matrix and then polymerizing aniline in the presence of surfactant.

GO functionalized amino group polymerized along with aniline

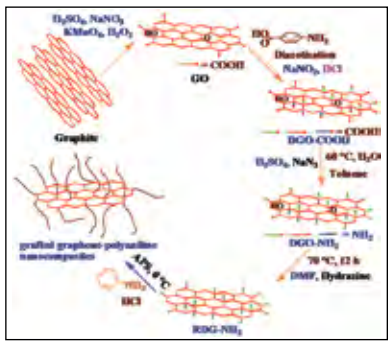


Fig. 2.12 Schematic representation of the synthesis of graphene-PANI nanocomposites

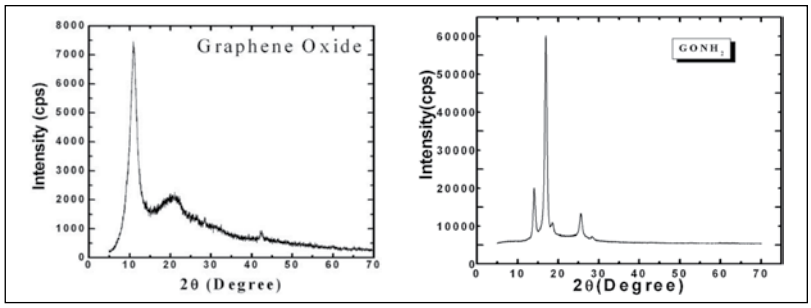


Fig. 2.13 XRD studies incorporation of amino group in the GO matrix which has also been confirmed by FTIR studies.

monomer moiety shows excellent shielding behaviour and more studies are being carried out.

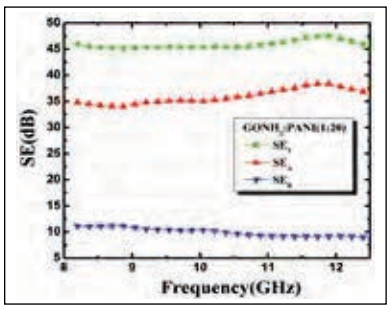


Fig. 2.14 Shielding effectiveness of functionalized GO with Polyaniline

Smart Coating of Polyaniline for Corrosion Protection:

Tafel polarization behaviour of mild steel in 3.5 % NaCl solution with uncoated, epoxy coated, PANI and HPSC coated mild steel have also been carried out. The studies revealed that novel designed polyaniline embedded with epoxy shows excellent corrosion preventive behavior even at a loading of 6 % when exposed to salt spray tests for 35 days under accelerated conditions.

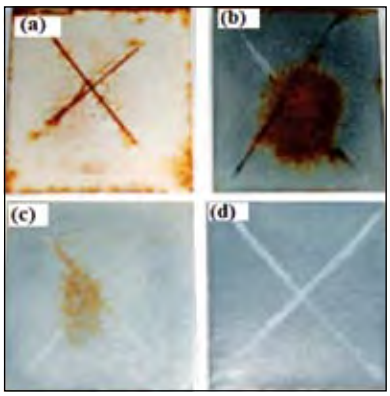


Fig. 2.15 Photograph of (a) epoxy coated (b) PANI (at 6 wt.% loading) coated (c) HPSC (at 1.5 wt. % loading) and (d) HPSC (6.0 wt. % loading) mild steel after 35 days of exposure to salt spray test.

Impedimetric Immunosensor for Cardiac Biomarkers

The use of cardiac biomarkers continues to play a major role in the diagnosis and management of patients suspected of having myocardial damage. Typical cardiac markers used for diagnostics of AMI are cardiac myoglobin, creatine kinase-MB and cardiac troponins I and T. Myoglobin (cMb) is one of the very early known markers that increase after acute myocardial infarction, and its rapid screening under acute physiological conditions is fundamental. Due to its small size (17.8 kDa), facilitating its quick release into circulation (as early as 1–3 h upon symptom onset), as well as its high sensitivity and high predictive value, cMb is considered as a valuable early screening test for AMI. The "cut-off" concentrations of Cardiac Myoglobin may vary from 50 ng mL^{-1} (Behring Diagnostics method, Nanogen cardiac STATus panel) and 56 ng mL^{-1} (Stratus CS STAT, for female) to 170–200 ng mL^{-1} (Triage cardiac panel) with majority of researchers holding the "cut-off" to about 100 ng mL^{-1}].

Electrochemical impedance spectroscopy (EIS) has recently received considerable attention in this field due to its sensitive, non-destructive, and rapid electrochemical sensing method and characterization of the electrical properties in biological interfaces.

We report the synthesis of ZnS(MPA) nanocrystals and their covalent attachment to self assembled monolayer (SAM) of 3-aminopropyltriethoxysilane (APTES) on an indium-tin-oxide (ITO) coated glass plate. These ZnS(MPA) modified ITO-glass plates were subsequently immobilized with protein antibody, Ab-Mb, through free carboxyl groups available on ZnS(MPA) nanocrystals by using N-(3-dimethylaminopropyl)-N'-ethyl carbodiimide hydrochloride

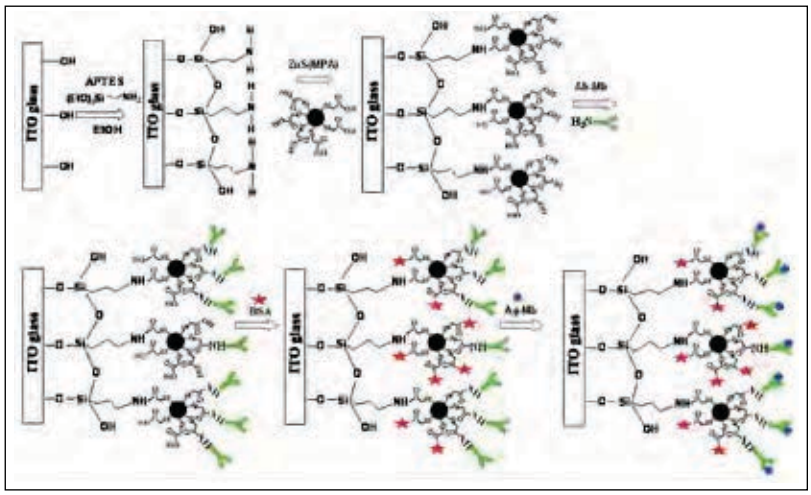


Fig. 2.16 Scheme1- Stepwise fabrication of bioelectrode

(EDC) / N-hydroxy succinimide (NHS) approach, for the fabrication of bioelectrode (Ab-Mb(BSA)/ZnS(MPA)/APTES/ITO-glass). The Ab-Mb(BSA)/ZnS(MPA)/ APTES/ITO-glass electrode was systematically characterized by spectroscopic techniques and it's immunosensing characteristic towards the quantitative estimation of target cardiac myoglobin, Ag-cMb, concentration was investigated by EIS using $[Fe(CN)_6]^{3-/4-}$ as a redox probe. The stepwise fabrication of the bioelectrode is shown in Figure 2.16.

Electrochemical impedance response studies of Ab-Mb(BSA)/ZnS(MPA)/APTES/ITO electrode to protein antigen, Ag-Mb, was carried out in 0.1 M KCl solution containing 2 mM $[Fe(CN)_6]^{3-}$/ $[Fe(CN)_6]^{4-}$ (pH 7.4), at the scanning frequencies from 1.0 to 10,000 Hz. The Nyquist plots of impedance spectra for different concentration of antigen, Ag-Mb, solution at the bioelectrode is shown in Fig. 2.17a. An increase in the diameter of Nyquist circle was observed with increasing concentration of added antigen, Ag-Mb, indicating an antibody–antigen interaction, at the electrode surface. The impedance modulus bode plot of the bioelectrode (Fig. 2.17b) demonstrates three distinct regions corresponding to the three types of elements in the equivalent circuit. The double layer capacitance region is in the low frequency range from 50 Hz to 1 kHz, whereas the frequency region below 50 Hz and above 1 κHz corresponds to charge transfer resistance and solution resistance, respectively.

The Ab-Mb(BSA)/ZnS(MPA)/ APTES/ITO-glass bioelectrode shows a well defined concentration dependence curve for protein antigen, Ag-Mb. Fig. 2.18 shows a linear relationship between the change in specific electron charge transfer resistance ($\Delta R_{et}=(R_{et})_{\text{after immunorecation}}-(R_{et})_{control}$) and logarithmic value of Ag-Mb concentration in the range of 10 ng to 1 μg mL^{-11} phosphate buffer solution (pH 7.4) with a R_{et} sensitivity of 117.36 Ω cm^2 per decade.

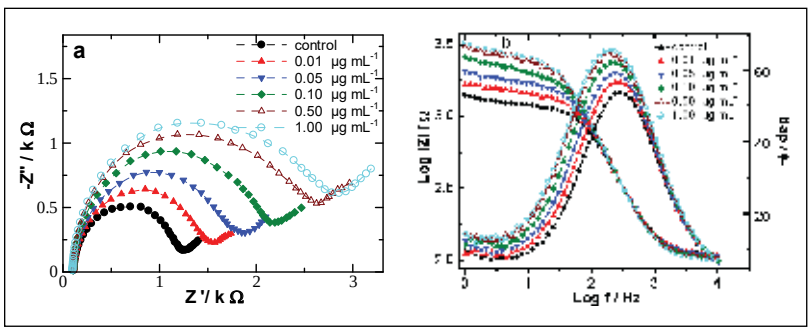


Fig. 2.17 (a)Nyquist plots obtained on Ab-Mb(BSA)/ZnS(MPA)/APTES/ITO electrode for control and different concentration of Ag-Mb in PBS (pH 7.4); (b) Corresponding bode plots

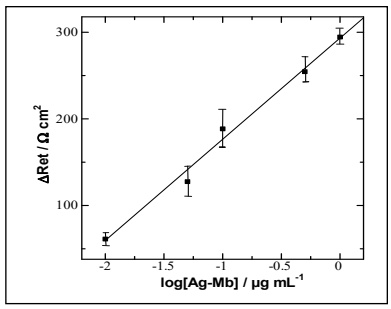


Fig. 2.18 Concentration dependent calibration curve of Ab-Mb(BSA)/ZnS(MPA)/APTES/ITO bioelectrode; The error bars represent the standard deviation from three separate experiments

We also report structural and ac impedimetric properties of a biofunctionalized conducting copolymer poly(pyrrole-co-pyrrolepropylic acid) (PPy-PPa) film electrochemically grown onto an indium-tin-oxide (ITO) coated glass plate. The copolymer film was bio-functionalized with myoglobin protein antibody, Ab-cMb, to form a bioelectrode. The ac impedance studies of the PPy-PPa copolymer film show both charge transfer resistance (Ret) and ions diffusion (WR) characteristics, at high and low frequency regions respectively, whereas the bioelectrode (Ab-Mb(BSA)/PPy-PPa/ITO) shows only Ret in a comparatively low ac frequency region with respect to the PPy-PPa copolymer film, indicating a good biocompatibility of the polymer electrode.

The impedance response of the Ab-cMb/PPy-PPa/ ITO-glass bioelectrode upon immunoreaction with myoglobin protein antigen, Ag-cMb, was measured in PBS (pH 7.4), containing 0.1 M KCl and 2 mM

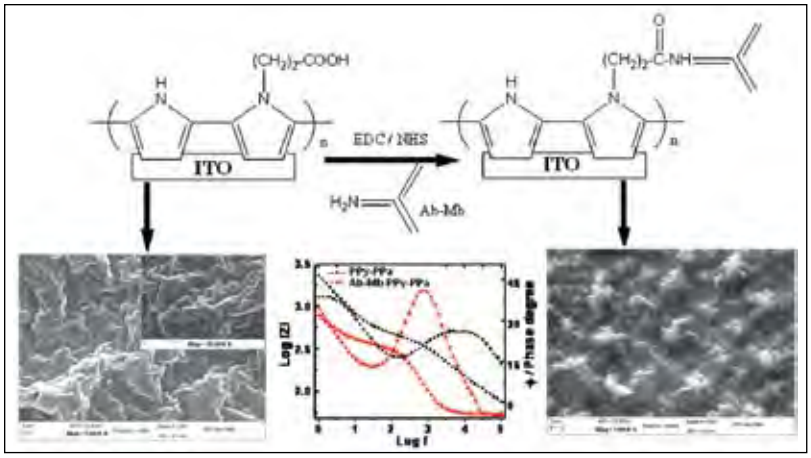


Fig. 2.19 SEM images of (a) PPy-PPa/ITO; (b) Ab-Mb/PPy-PPa/ITO-glass electrode and Bode plots corresponding to Impedance modulus and phase angle diagram vs frequency for PPy-PPa/ITO-glass and Ab-Mb(BSA)/PPy-PPa/ITO-glass electrodes (in between image)

$[Fe(CN)_6]^{3-/4-}$ as redox probe, at scanning frequencies from 1 to 100,000 Hz. The Nyquist plots of the impedance response of the bioelectrode with different concentration of myoglobin protein antigen, Ag-cMb, are shown in Fig. 2.20a, wherein a response for a solution with no Ag-cMb was taken as a control sample response. The immunoreaction of the Ab-cMb/PPy-PPa/ITO glass electrode towards Ag-cMb was further investigated by using frequency (f) dependent bode impedance and phase (ϕ) curves in order to ascertain the different constituent phases of the system. The impedance modulus bode plot (Fig. 2.20b) of the bioelectrode can be divided into four distinct frequency domains indicative of different kinetics dominant in those regions. The region above 10 kHz where no significant change is observed in impedance value is purely resistive and is representative of solution resistance, while in the region between 100 to 2000 Hz the capacitive behaviour of the immunoelectrode is dominant. The region from 10 to 100 Hz corresponds to R_{et} and below 10 Hz the process is primarily diffusion controlled in nature. It has been concluded that the mid frequency range is dominated by the capacitive portion of impedance, while the charge transfer resistance dominates at the lower frequency region in comparison to capacitive portion where maximum changes in the impedance magnitude were seen after immunoreaction.

The bioelectrode shows a Ret sensitivity (slope of the calibration curve) of 27.72 Ω cm^2 per decade of Ag-cMb having a correlation coefficient 0.991 (n=5) (Fig 2.21). Though the Ret sensitivity is comparatively smaller than the recently reported multistep fabricated ZnS nanoparticles based bioelectrode for the detection of Ag-cMb , the simple and one step, cost effective preparatory method of polymer as protein immobilizing matrix for constructing a bioelectrode makes it more advantageous.

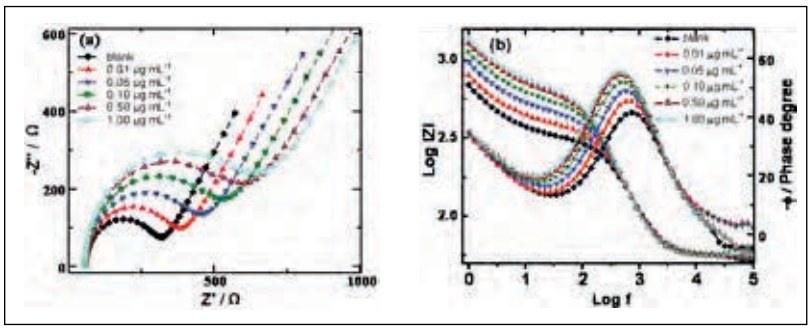


Fig. 2.20 (a) Nyquist diagrams for Ab-Mb(BSA)/PPy-PPa/ITO-glass electrode with different concentration of Ag-Mb in aqueous solution; (b) Bode plot for the corresponding response curve

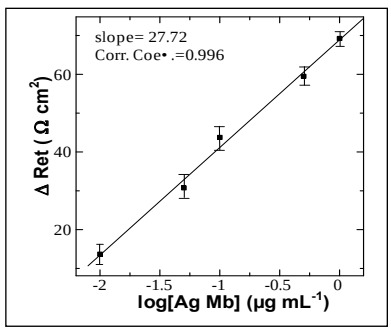


Fig. 2.21 Concentration dependence calibration curve for the Ab-cMb(BSA)/PPy-PPa/ITO bioelectrode

Physics and Engineering of Carbon

Development and demonstration of polymer electrolyte membrane Fuel Cell (PEMFC) stacks for stationary applications

NPL has successfully developed two important carbon components of the fuel cell viz. Porous conducting carbon paper and composite bipolar plate matching the performance of commercially available components. A 1kW polymer electrolyte membrane fuel cell (PEMFC) stack using NPL porous conducting carbon paper and NPL carbon composite bipolar plates is functional at CECRI.

Fig. 2.22 (a) 500 W PEM fuel cell stack with all indigenous components (b) NPL bipolar plate (c) Porous conducting carbon paper

NPL technology for porous conducting carbon paper goes commercial

- Carbon paper electrode has a critical role in the proper functioning of fuel cell. The carbon paper technology has been successfully developed at NPL and the process know how has been transferred to Ms. HEG, Bhopal.
- Following NPL technology M/s HEG has now come up with the carbon paper equivalent in performance with the commercial standard Toray paper of Japan and meeting the requirement of carbon paper for India's fuel cell program.

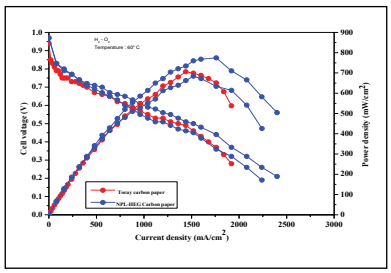


Fig. 2.23 Comparative performance of PEMFC with HEG and Toray carbon paper

An improved high performance Carbon Paper For cost efficient PEM Fuel Cell

- A novel technique has been used to develop CNT incorporated carbon paper to achieve high fuel cell performance without any additional set up or cost. The peak power density obtained from improved NPL carbon paper shows an increase of nearly 25% as compared to the commercially available standard Toray carbon paper (Japan) tested under similar conditions as shown in Fig. 2.24a.

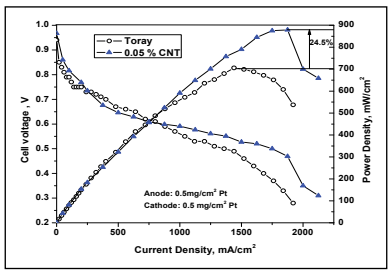


Fig. 2.24 (a) Comaparative performance of PEMFC using NPL and Toray paper (Catalyst; 0.5 mg/cm² Pt)

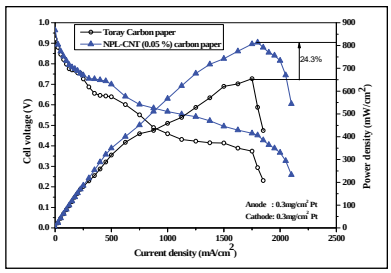


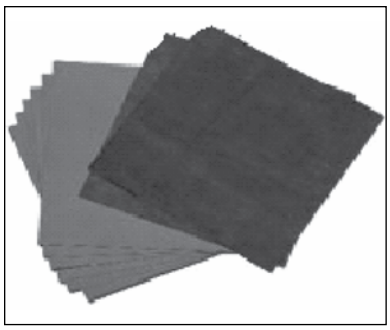
Fig. 2.24(b) Comparative performance of PEMFC using NPL and Toray paper (Catalyst: 0.3 mg/cm² Pt)

- Even after 40% reduced Pt loading the performance is better than Toray carbon paper thus making Indian technology cost competitive (Fig. 2.24b). The performance evaluation was done at CSIR-CECRI, Chennai.

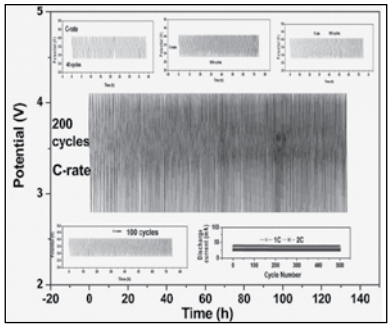
Development of Carbon based Anodes for Li-ion Batteries

Novel free standing anode materials have been developed at NPL, New Delhi with high aspect ratio carbon materials that include- Anode for Li-ion battery has been made from phenolic resin reinforced carbon fiber, followed by molding and heat treatment. The electrode gives consistent performance for more than 500 cycles.

MWCNTs have been synthesized at NPL using Chemical vapour deposition technique. Free standing, flexible anode for Li-ion battery has been prepared



Carbon fiber paper

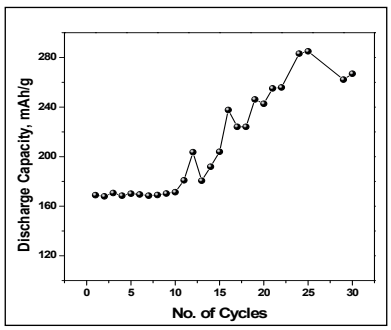


Discharge Capacity- 200mAh/g, No. of cycles > 500

Glowing solar lamp with Li-ion battery prepared from NPL anode and CECRI cathode

Fig. 2.25 Carbon fiber paper and its characteristies

Flexible MWCNT based anode



Cyclic performance

Glowing solar lantern with Li-ion battery prepared from NPL anode and CECRI cathode

Fig. 2.26 Free standing Multiwalled carbon nanotube (MWCNTs) based anode

which shows increasing capacity with successive cycles.

The studies have been carried out under the CSIR-TAPSUN project "Innovative Solutions for Solar Energy Storage".

Dispersion and alignment of CNTs and development of CNT reinforced composites:

The studies were continued under the DRDO Sponsored project to carbon nanotubes based High Performance composites for applications in Airframes, Heat shields, Rocket Motor Casings and futuristic missile system. Experiments were performed to optimize the dispersion conditions of MWCNT in the epoxy resin matrix. The maximum value of flexural strength which could be achieved for CNT/ epoxy composites with existing dispersion technique was ~ 115 MPa and flexural modulus ~2-3 GPa with 0.5-1% CNT loading. It was also observed that amine functionalized tubes shows improved better properties than the acid functionalized tubes based composites. The improvement in the mechanical properties of the resin by 60% following reinforcement of CNTs provides a useful insight to use such modified resin for carbon fibre/CNT-Epoxy mulltiscale composites. The values fall in the range of the global trend.

Carbon Foam Light Weight Engineering Material

Carbon foams are next generation sponge-like high performance structural engineering materials. The electrical conductivity of CF derived from different organic and inorganic precursor can be tailored by controlling processing parameters. NPL is engaged in developing the carbon foam from coal tar pitch by simple and low

cost sacrificial template technique, in which the polyurethane foam is used as template. We at NPL are putting continuous effort to improve the mechanical, thermal, electrical and Electromagnetic interference (EMI) shielding effectiveness of carbon foam to use as shielding and thermal interfacing material in aerospace and aircraft to protect from electromagnetic radiation as well avoid the electronic systems from overheating. To improve the overall properties of carbon foams two approaches are adapted i.e. incorporating or decorating carbon foam by nanosize organometallic (ferrocene) compound and by carbon nanotubes. In another approach, carbon foam has been decorated with multi-wall carbon nanotubes (MWCNTs) by two different routes to improve its electromagnetic interference (EMI) shielding effectiveness and mechanical properties. Apart from EMI shielding material it will be used as anode material for lithium ion batteries and light weight electrode for lead acid batteries. Figure 2.27 (b) shows the effect of different content of organometallic compound on the electromagnetic interference shielding of carbon foam. The EMI Shielding effectivness -81 dB of was achived with 10 wt % of ferrocene. Beside, compressive strength, electrical/thermal conductivity and thermal stability also increases.

Single /double layer Graphene synthesis

Studies were carried out on the synthesis of graphene by chemical route and chemical deposition technique. The new approach was adapted to deposit single or multiple graphene layers on a copper foil. An experimental set up was designed and fabricated to grow graphene sheet on any substrate. Experiments are in progress to grow large size high purity graphene sheets followed by characterization by Raman spectroscopy.

Luminescent Materials and Devices

Development of nanophosphors with enhanced down and up-conversion luminescence efficiency for solar cells, synthesis of doped nanocrystals and quantum dots for enhanced blue luminescence for display devices, core-shell nanophosphors for solar spectrum modification, novel nanophosphors for LEDs and luminomagnetic nanophosphors for bio-related applications are the current thrust of the group.

Highly Luminescent–Paramagnetic Nanophosphor Probes for In Vitro High-Contrast Imaging of Human Breast Cancer Cells

We have successfully synthesized and characterized the non-agglomerated highly luminescent–paramagnetic ultrafine $Y_{1.9}O_3:Eu_{0.1}^{3+}$ nanophosphor with millisecond PL lifetime by a modified sol–gel method, which can be produced on a large scale. We have demonstrated that the $Y_{1.9}O_3:Eu_{0.1}^{3+}$ nanophosphor possesses the essential features required for in vitro high-contrast bioimaging applications. The nanophosphor has colloidal stability and optical transparency in water, highly efficient hypersensitive red emission of Eu^{3+} peaking at 610 nm ($^5D_0$ – $^7F_2$) upon 246 nm UV light excitation with characteristically sharp spectral lines in the visible region, paramagnetic properties, and low cellular toxicity. Thus, this novel approach enables high-contrast cellular and tissue imaging with high sensitivity, magnetic tracking capability and low toxicity.

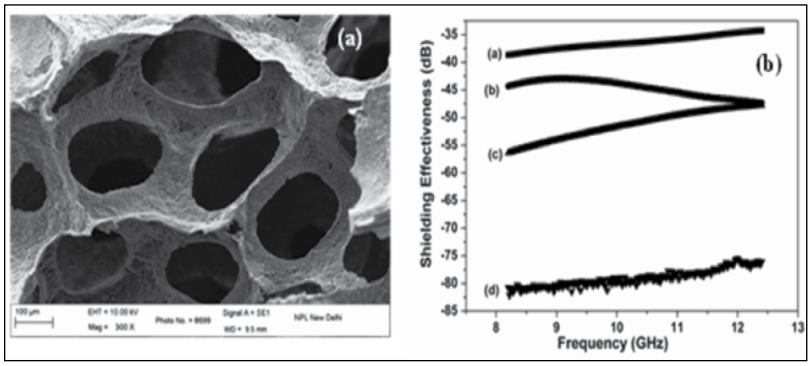


Fig. 2.27 (a) SEM of c-foam (b) Shielding effectiveness of c-foam

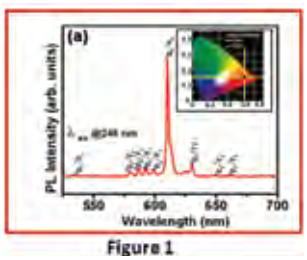


Figure 1

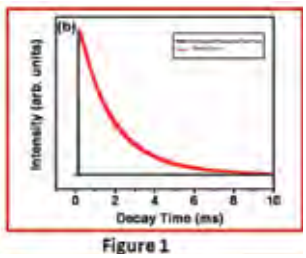


Figure 1

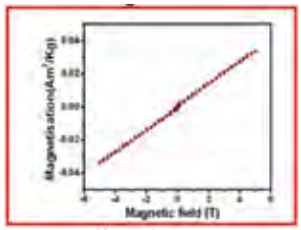


Figure 2

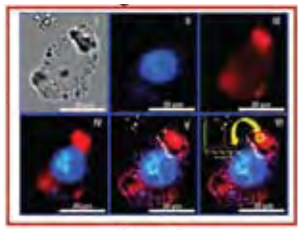


Figure 3

Fig. **2.28.1**) PL emission spectrum of $Y_{1.9}O:Eu_{0.1}^{3+}$ nanophosphor recorded at 246 nm excitation showing a sharp, intense, hypersensitive red emission peak with maximum at 610 nm ($^5D_0 - {}^7F_2$) at room temperature. The inset shows the color coordinates of red emission; x = 0.5941, y = 0.3039. b) TRPL decay profile of $Y_{1.9}O:Eu_{0.1}^{3+}$ nanophosphor recorded at room temperature while monitoring the emission at 610 nm at an excitation wavelength of 246 nm. Fig. **2.28.2**) Room-temperature M (H) curve of $Y_{1.9}O:Eu_{0.1}^{3+}$ nanophosphor Fig. **2.28.3)** In vitro fluorescence microscopy images of T47D cells incubated with $Y_{1.9}O:Eu_{0.1}^{3+}$ nanophosphor (50 µg mL^{-1}) for 4 h. Sequential images show: I) phase contrast of T47D cells; II) an individual nucleus stained blue with 4′-6-diamidino-2-henylindole(DAPI); III) red fluorescence staining by $Y_{1.9}O:Eu_{0.1}^{3+}$ nanophosphor; IV) overlapped images of blue DAPI and red $Y_{1.9}O:Eu_{0.1}^{3+}$ nanophosphor; V) overlap of phase contrast, blue, and red, from (I–III), respectively; and VI) in vitro localized PL images of $Y_{1.9}O:Eu_{0.1}^{3+}$ nanophosphor from (V). Inset: localized PL spectra taken from level cells (red).

Hybrid 2D Nanomaterials as Dual-Mode Contrast Agents in Cellular Imaging

We have demonstrated a 2D hybrid nanostructure-based nanofluid that can be used as a contrast agent in a dual mode imaging process, and that allows one to easily combine two complementary techniques (T2 MRI and optical fluorescence imaging) in cellular imaging. An interfacial energy transfer mechanism has been identified for the PL of GO-F. The time-resolved spectroscopy measurements reveal nanosecond decay for hybrid GO-F fluid, indicating its potential applications in biological systems. The hybrid GO-F fluid showed good cell viability with different cancer cell lines. This nanofluid exhibited an enhanced thermal conductivity

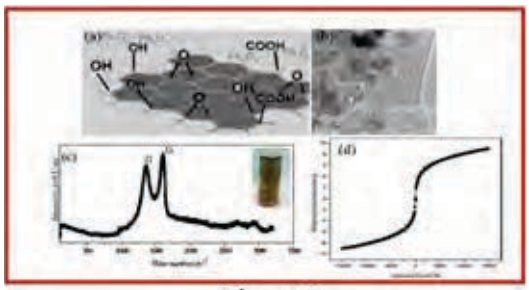


Figure 1

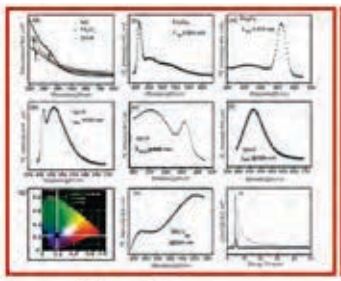


Figure 2

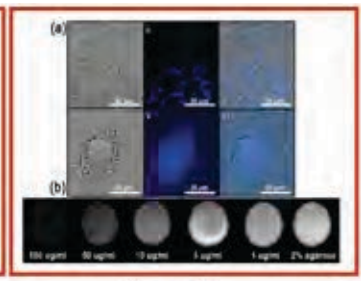


Figure 3

Fig. **2.29.1**) Schematic of the hybrid GO-F. Fe_3O_4 nanoparticles are covalently attached to the graphene plane through oxygen functionalities. b) Transmission electron microscopy (TEM) image of GO-F showing the Fe_3O_4 nanoparticles distributed throughout GO. c) Micro-Raman spectrum. Graphitic order and disorder (G and D) Raman modes are marked. Photograph: GO-F suspension in water. d) Room temperature magnetization curve of GO-F powder. The S-like M (H) loop shows the superparamagnetic nature of the GO-F powder. Fig. **2.29.2**) UV-vis absorption spectra of Fe_3O_4, GO, and GO-F fluids. b) Room temperature PL emission spectrum of Fe_3O_4 nanoparticles at 365 nm excitation. c) PL excitation spectrum at 416 nm emission of Fe_3O_4 nanoparticles. d) PL emission spectrum of GO-F nanofluid at 365 nm excitation. e) PL excitation spectrum at 416 nm emission of GO-F nanofluid. g) The color coordinate of the blue emission. h) PL emission spectrum of GO at 324 nm excitation. i) TRPL decay profile of GO-F nanofluid recorded at room temperature while monitoring the emission at 469 nm at an excitation wavelength of 371 nm. j) The lifetime data and the parameter generated by the exponential fitting. Fig. **2.29.3**) In vitro fluorescence microscopy images of T47D cells treated with GO-F (50 µ g mL^{-1}) for 24 h. i–iii) Low magnification images of T47D cells: i) Phase contrast picture, ii) fluorescence images of GO-F, and iii) overlay of images (i) and (ii). iv–vi) High magnification images of an individual T47D cell: iv) phase contrast picture of an individual T47D cell, v) fluorescence image of GO-F, and vi) overlay of images (iv) and (v). The overlay of the phase contrast and fluorescence images clearly demonstrates the localization of GO-F in the cellular cytoplasm, suggesting its suitability for bioimaging. b) T2-weighted MR image showing strong T2 contrast in agarose phantoms. It shows alginate phantoms doped with different concentrations (as shown) of GO-F. The T2-weighted image was acquired in a 7T scanner with multi-slice multi-echo sequence. The T2 relaxivity was 297.06 mM^{-1} s^{-1}

and the nanoparticles of GO-F were found to penetrate the cell cytoplasm, making it viable for intra-cellular magnetic hyperthermia applications. The surface functionalities in GO provide a good platform for large loading of aromatic drug molecules, thereby avoiding "drug burst" effects associated with bare SPIONs.

Fabrication and Electro-optic Properties of Multi-walled Carbon Nanotube Driven Novel Electroluminescent Lamp

We present a novel, cost-effective and facile technique, wherein multi-walled carbon nano-tubes (CNTs) were used to transform a photoluminescent material to exhibit stable and efficient electroluminescence (EL) at low-voltages. As a case study, a commercially available ZnS:Cu phosphor (P-22G having a quantum yield of 65±5%) was combined with a very low (~0.01 wt.%) concentration of CNTs dispersed in ethanol and its alternating current driven electroluminescence (AC-EL) is demonstrated as shown in Figure 2.30. The role of CNTs has been understood as a local electric field enhancer and facilitator in the hot carrier injection inside the ZnS crystal to produce EL in the hybrid material. The mechanism of EL is understood as an internal field emission, intra-CNT impact excitation and the recombination of electrons and holes through the impurity states.

Rare-earth Free Yellow-Green Emitting $NaZnPO_4$:Mn Phosphor for Lighting Applications

We have focused on the development of mercury-free inexpensive phosphor materials that are eco-friendly with improved luminous efficacy, energy-saving, long-lifetime, and low-power consumption characteristics. A new rare-earth free phosphor, $NaZnPO_4:Mn^{2+}$ ($NZP:Mn^{2+}$) with ultra-violet to visible absorption (300-470 nm), exceptional yellow-green (543 nm) broad-band photoluminescence (PL) and appreciable colour co-ordinates (x=0.39, y=0.58) was identified. It has a crystal structure consisting of discrete PO_4 tetrahedra linked by ZnO_4 and NaO_4 distorted tetrahedral such that three tetrahedra, one of each kind, share one corner. The XRD profile of the $NZP:Mn^{2+}$ phosphor is shown in Figure 2.31a. The presence of UV sensitive Zn-O-Zn bonds and their efficient energy transfer to Mn^{2+} ions resulted in brightest PL and external quantum yield of 63% at 418 nm. For all excitations, PL emission is centered at ~543 nm, which is attributed to spin forbidden d-d transition ($^4T_1 \rightarrow {}^6A_1$) of Mn^{2+} ions as shown in Figure 2.31b. Our experiment demonstrated the possibility of producing relatively inexpensive UV -converted white-light emitting diodes for future. The novel phosphor could also be useful for many display and lighting devices. Compared to the commercial sulfide phosphor (P-20), our $NZP:Mn^{2+}$ nanophosphor showed enhanced brightness and efficiencies and can be a favourable choice for incrementing white LED technology. The factors influencing the brightness, Mn^{2+} PL, reaction atmosphere, concentration of dopant etc. were studied in detail and optimized. Under this in-house activity a commercial UV LED (with 375 nm emission) was successfully coated with the present nanophosphor that showed the light emission very close to the 'ideal white' site of the chromaticity diagram.

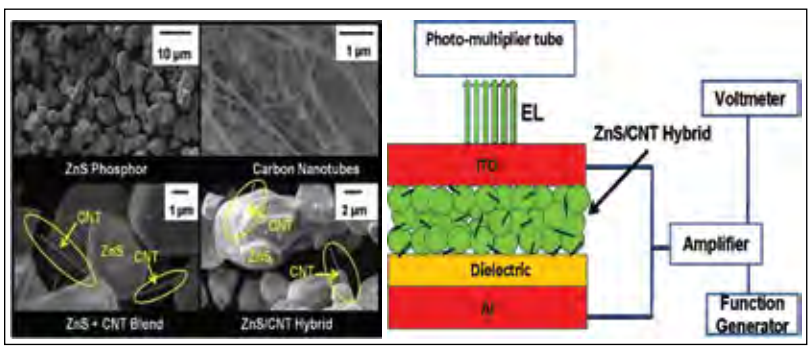


Fig. 2.30 a) SEM images show morphology of ZnS phosphor, carbon nanotubes, ZnS+MWCNT blend and ZnS/MWCNT hybrid material after annealing b) a schematic of the ZnS/MWCNT hybrid material-based AC-EL smart lamp structure.

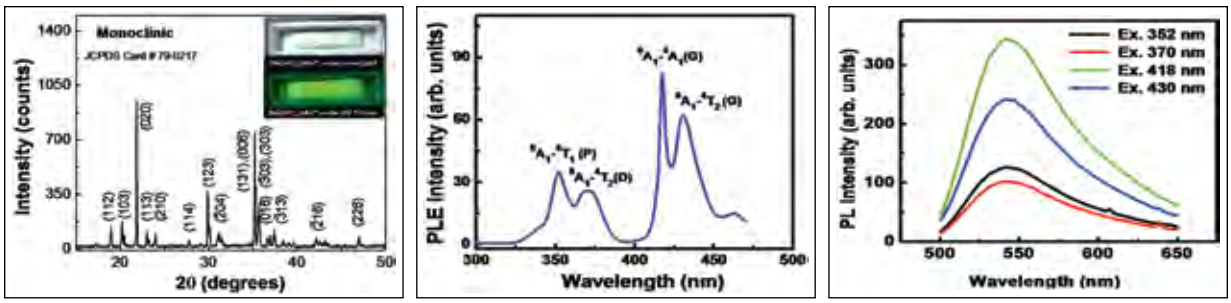


Fig. 2.31 (a) XRD profile of $NaZnPO_4$:Mn phosphor with the inset showing the phosphor under room light and UV 370 nm excitations (b) Photoluminescence excitation spectrum of the $NaZnPO_4$:Mn phosphor monitored at 543 nm emission and (c) Bright yellow-green photoluminescence recorded under various excitations mentioned in the figure.

Multiferroics & Magnetics

Magnetic Metrology

Calibration and testing for industries equipment have been undertaken and issued 41 certificates, earning an ECF of ₹ 6.5 lakhs. We have established low field magnetic measurement facility in the range 100 μT-1000 μT using standard Helmholtz coil as the field source and a triaxial Helmholtz coil system for cancellation of the ambient magnetic field and its variations. The magnetic field measurements were conducted using triaxial and single axis fluxgate magnetometers. The effective noise compensation in the E-W direction has been reduced to 20 nT by constructing coaxial cylinders of mu metal shields around Helmholtz coil along with lids on them, while in the N-S and vertical direction it is around 60 nT.

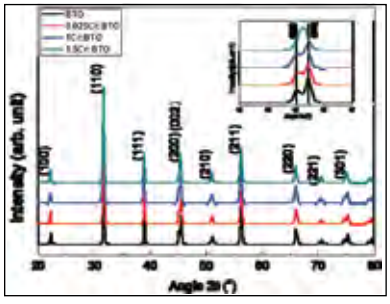


Fig. 2.32 XRD of pure and Cr doped BTO

Multiferroics, Humidity Sensing & Spin Hall Effect – SHE for Spintronics

Engineering of new multiferroic materials:

Transition metal Cr doped $BaTiO_3$ synthesized by a simple and inexpensive MOD method through a new approach to induce magnetoelectric coupling in BTO. Pure BTO exhibited tetragonal structure which transformed into distorted cubic phase by Cr doping confirmed by XRD and Raman spectra analysis. Ferroelectricity of pure BTO decreased by Cr doping but consequently it induced ferromagnetism in BTO. Deterioration in ferroelectric nature with distorted cubic phase has been observed by lowering of saturation polarization and Curie temperature.

Cr-doping induced the ferromagnetism and distorted cubic structure in BTO, whereas Cr ions involved in bonding mediate the exchange interaction via oxygen vacancy among the local spins resulting into ferromagnetism. Dynamic ME coupling coefficient value of 13 $mVcm^{-1}Oe^{-1}$ confirmed single-phase ferroelectric based magnetoelectric compound.

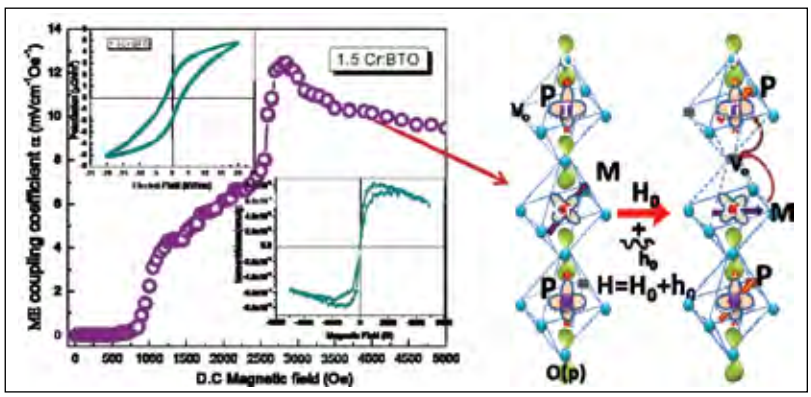


Fig. 2.33 Structural distortion of 1.5Cr: BTO with reduced polorization leads to 13 $mVcm^{-1}$ Oe^{-1} magnetoelectric coupling at room temperature

Physisorption in porous Magnesium Ferrite:

Fig. 2.34 SEM image showing porous micro-structure of $MgFe_2O_4$ pellet

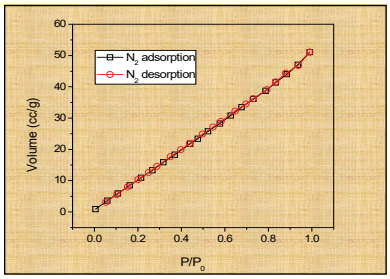


Fig. 2.35 BET Isotherm of $MgFe_2O_4$ powder

- No condensation even at higher N_2 pressure hence no hysteresis appeared.
- Absence of knee in isotherm at lower pressure represents weak adsorbate-adsorbent interaction.
- Small volume of N_2 adsorbed at all pressure indicates less interaction between adsorbate and adsorbent. Weak interaction of N_2 with magnesium ferrite may be due to non-polar character of N_2 molecule as compared to polar water molecule.

For describing the process of adsorption the isosteric heat of adsorption is an important parameter. The isosteric heat of sorption is a measurement of the energy or intermolecular bonding between water molecules and absorbing surfaces. It is difficult to measure the thermal properties of adsorption process therefore heats of adsorption of gases are usually derived from adsorption isotherm using Clausius-Cleyperon heat equation. Adsorption isotherms (coverage (conductance in this case), versus pressure at a constant temperature) can be used to calculate heats of adsorption.

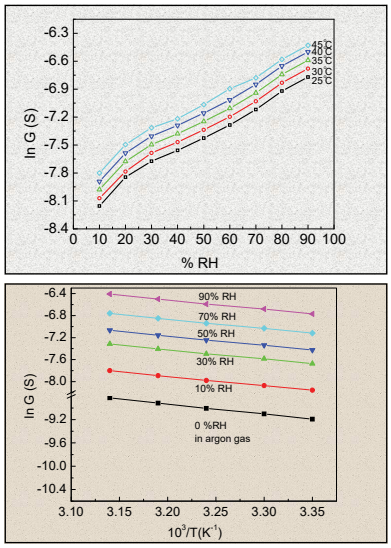
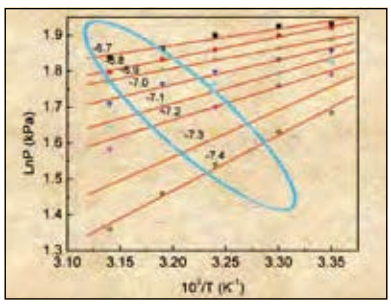


Fig. 2.36 Conductance value with respect to different inverse temperature at fixed %RH

Applying Clausius Clapeyron Equation to Isoconducting curve



$$Ln(P) = -\frac{q_{st}}{R}\left(\frac{1}{T}\right)$$

Fig. 2.37 Isoconductive piot between ln P(KPa) and $10^3/T(K^{-1})$

Here this compound followed the Freundlich isotherm with an exponential decrease in isotherm. This model assumes the multilayer adsorption. In addition, value of heat of adsorption is low 0.14 eV at low humidity 10%RH indicating binding between adsorbate-adsorbent is physical force (<0.1 eV). Moreover, physisorption from a gas phase does not involve activation energy while chemisorption involves as binding energy. For physisorption binding energy lies in the range 0.01 to 0.10 eV while for chemisorption between 1 to 10 eV. There is no chemisorption phenomenon in magnesium ferrite as it requires high interaction energy (>1 eV).

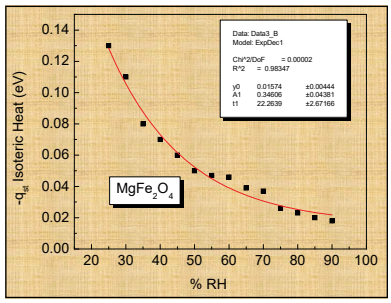
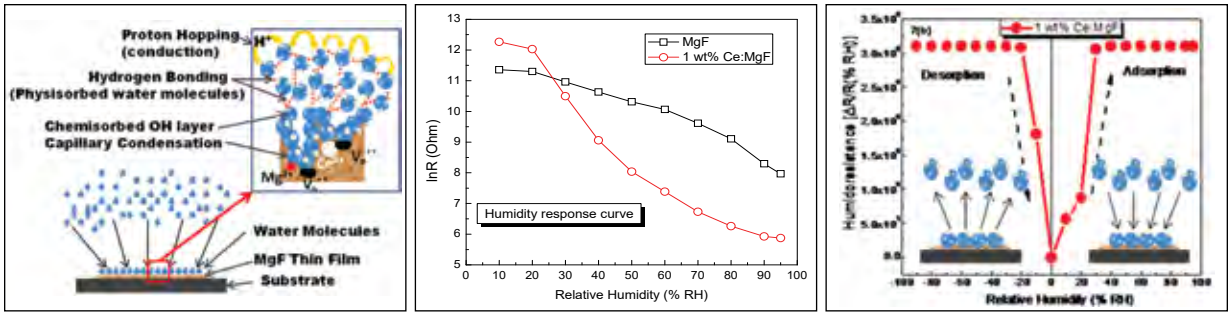


Fig. 2.38 Change in isosteric heat with the change in relative humidity for $MgFe_2O_4$

PLD thin films of Ceria added Magnesium Ferrite:

Giant magnetoresistance (GMR) in multilayer thin films by applying an external magnetic field brought a breakthrough in the area of magnetic read heads. A colossal change in resistance has been observed in thin films by exposing it in humidity present in atmosphere. This effect can be best exploited for new type of energy conservative colossal



➢ **Change in resistance is 0.1 Mohm/1%RH**

Fig. 2.39 Change in resistance with % RH of pure and 1 wt%ce added MgF thin film surface conduction mechanism due to water vapour adorption on thin film

humidoresistance (CHR) based device besides its established humidity sensor application.

The DC resistance of pure magnesium ferrite film was 256 GOhm at 0 %RH and it increased to 2.3 TOhm by ceria addition. Pure magnesium ferrite showed decrease in resistance from 230 GOhm at 10%RH to 184 MOhm at 95%RH. While 1 wt% Ce:MgF thin film resistance was 1.8 TOhm at 10% RH which decreased to 754 KOhm at 95 %RH exhibiting approximately a seven-order decrease in resistance.

Spin Hall Effect Measurements:

In this work, SHE voltage dependence on microwave frequency, power level, sweeping dc magnetic field and its direction with respect to film surface have been studied. The experimental results of microwave induced SHE; its frequency and amplitude dependence in Co/Pt bilayer thin film have been reported at room temperature.

The magnitude of dc voltage generated across bilayer thin film was 5.78 μV at 0.1 GHz, 1.36 μV at 0.5 GHz and 0.83 μV at 1.0 GHz for an incident microwave power of 10 mW corresponding to sweeping perpendicular magnetic field upto 0.2 T.

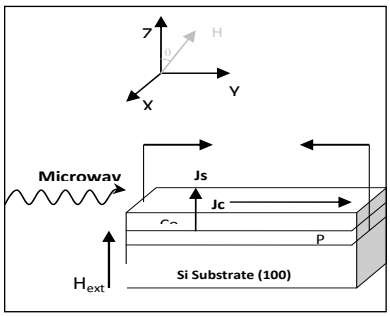


Fig. 2.40 The experimental setup we have used to demonstrate microwave induced SHE in Co/Pt film

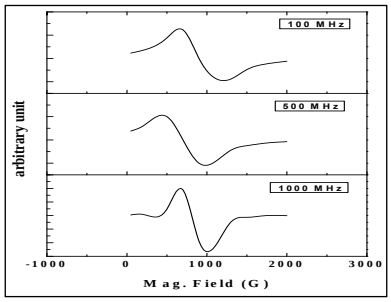


Fig. 2.41 FMR spectra of Co/Pt film at 0.1, 0.5 & 1.0 GHz

For power level dependence, output of microwave source was swept from 1 mW to 10 mW. Experimental results show dc voltage generated due to SHE across the Co/Pt film increases linearly with respect to the microwave power level. The linear fitting of the experimental data is shown in Fig. 2.42 with red colour.

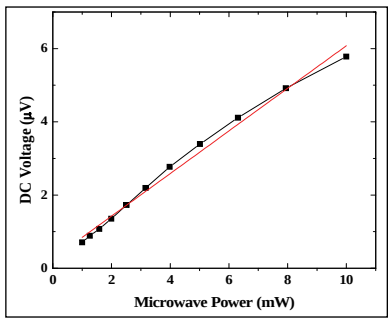


Fig. 2.42 Linear dependence of output dc voltage on incident microwave power in Co/Pt bilayer thin film

Biomedical Instrumentation

Technical Development of Cholesterol Device

Total cholesterol is a useful early indicator of cardiovascular problems; cholesterol contributes to the formation of arterial plaques. This work depicts a convenient analytical test (enzyme-linked) on paper to perform cholesterol detection as a result of Bio-chemical reaction

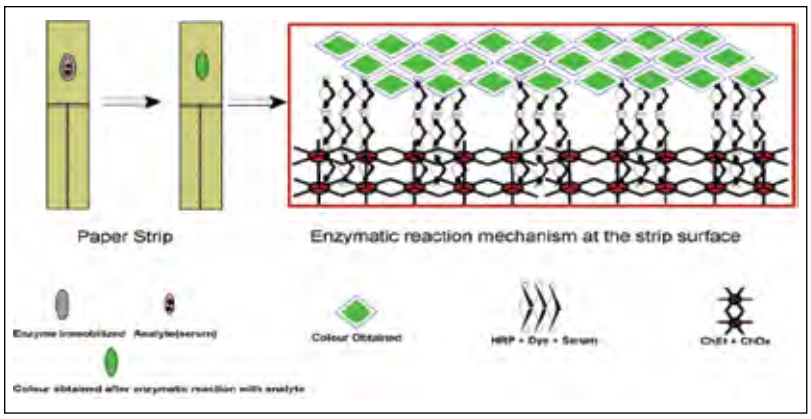


Fig. 2.43 Mechanism of functioning of cholesterol Bio Sensot

analysis of human serum/blood. Measuring cholesterol level is significant for coronary diseases, liver function, biliary function, intestinal absorption, etc. This drop test mechanism of colour formation is similar to lateral flow test methods currently available in the market for infectious & virus infected disease detection.

Technical development of Paper based Immunosensors

For the low resource settings, **WHO** developed the **ASSURED** (Affordable, Sensitive, Specific, User-friendly, Rapid, Equipment-free, and Deliverable) criteria to define the characteristics of an ideal diagnostic test. Non-conventional paper based ELISA techniques have been evolving for the detection of various biomolecules such as glucose, urea and proteins with comprising the ASSURED criteria. In the proteomic approaches for the detection of biomarkers, Immunosorbent assay (ELISA) systems gaining much attention due to its robust platforms with high analytical sensitivity.

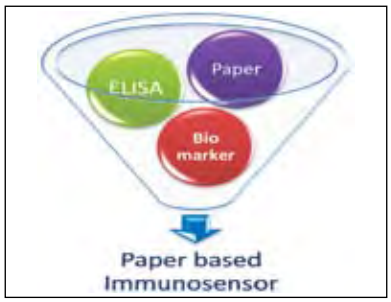


Fig. 2.44 Block diagram of paper based Immunosensor

In this context, the development of paper based sensors have attained lots of interest during recent years, not only because of their obvious advantages with respect to its chemical composition with conducive functional groups for the strong attachment of the sensing elements, but also because of the easy portability, lightweight (~10 mg cm^{-2}), and can be tailored according to the end use. Besides this, paper can be modified chemically to incorporate a wide variety of favourable functional groups such as hydroxyl, carboxyl, amino, that can be covalently bound to proteins, DNA, or small molecules. White Paper matrix for the colorimetric biosensor fabrication is advantageous and preferable, because it provides strong contrast with coloured substrates.

Biosafety management has also become one of the greatest concerns to prevent the transmission of infection. In this regard, fabrication of user friendly biodegradable diagnostic kits and diagnostic tools is urgently required for new generation biosensors. We have developed the low-cost, smart, intelligent paper based sensor for the qualitative and quantitative detection for cardiovascular disease (Troponin) and cancer.

Chitosan encapsulated quantum dots platform for leukemia detection

We report results of the studies relating to electrophoretic deposition of nanostructured composite of chitosan (CS)–cadmium-telluride quantum dots (CdTe-QDs) onto indium-tin-oxide coated glass substrate. The high resolution transmission electron microscopic studies of the nanocomposite reveal molecular level coating of the CdTe-QDs with CS molecules in the colloidal dispersion medium. This novel composite platform has been explored to fabricate an electrochemical DNA biosensor for detection of chronic myelogenous leukemia (CML) by immobilizing amine terminated oligonucleotide probe sequence containing 22 base pairs, identified from BCR–ABL fusion

gene. The results of differential pulse voltammetry reveal that this nucleic acid sensor can detect as low as 2.56 pM concentration of complementary target DNA with a response time of 60 s. Further, the response characteristics show that this fabricated bioelectrode has a shelf life of about 6 weeks and can be used for about 5–6 times.

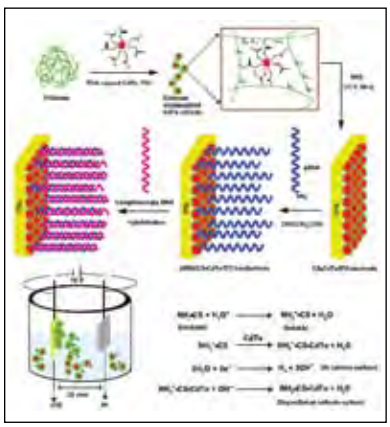


Fig. 2.45 schematic showing fabrication of NA/CS-CdTe/ITO bioelectrode and detail mechanism for EPD of Cs-CdTe colloids

Metals and Alloys

Development of novel thermoelectric material Bi doped Mg_3Sb_2 with a figure-of-merit ~ 0.6 at 750 K as an inexpensive thermoelectric material for power generation

A proof of principle has been established experimentally for a Zintl compound of Mg_3Sb_2 and its derivative of isoelectronically Bi doped Bi; $Mg_3Sb_{2-x}Bix$ ($0 \leq x \leq 0.4$) alloys in Mg_3Sb_2. Single phase p-type Mg_3Sb_2 compounds, with Mg and Sb powders as starting materials, have been prepared directly by spark plasma sintering (SPS) in a one step process. The structural refinements of this hexagonal Zintl compound by X-ray diffraction analysis (XRD) and high resolution transmission electron microscopy (HRTEM) investigation reveal that they are single phase devoid of any oxides or Sb precipitates. Transport measurements indicate low thermoelectric figure of merit ($ZT = 0.26$ at 750 K) for Mg_3Sb_2. However, an optimum doping of 0.2 at% with iso-electronic Bi ions at the Sb site enhances the ZT to 0.6 at 750 K, which is comparable with the present day industrial materials such as Bi based tellurides and selenides which are in this class of materials with appropriate doping.

An enhanced thermoelectric figure-of-merit (ZT) around 0.60 at 750 K is realized for the composition $Mg_3Sb_{1.8}Bi_{0.2}$ (figure 2.46). The computed valence band spectrum of Mg_3Sb_2 is in good agreement with the X-ray photoemission spectroscopy (XPS) data. Furthermore, angle dependence XPS was used to ensure that the surface composition of the alloy is same as in the bulk. On the other hand, the reduction in the thermal conductivity with Bi doping is attributed to mass fluctuation and grain boundary scattering. The measured thermal and electrical transport in these alloys can be correlated with the observed microstructures, as revealed by the transmission

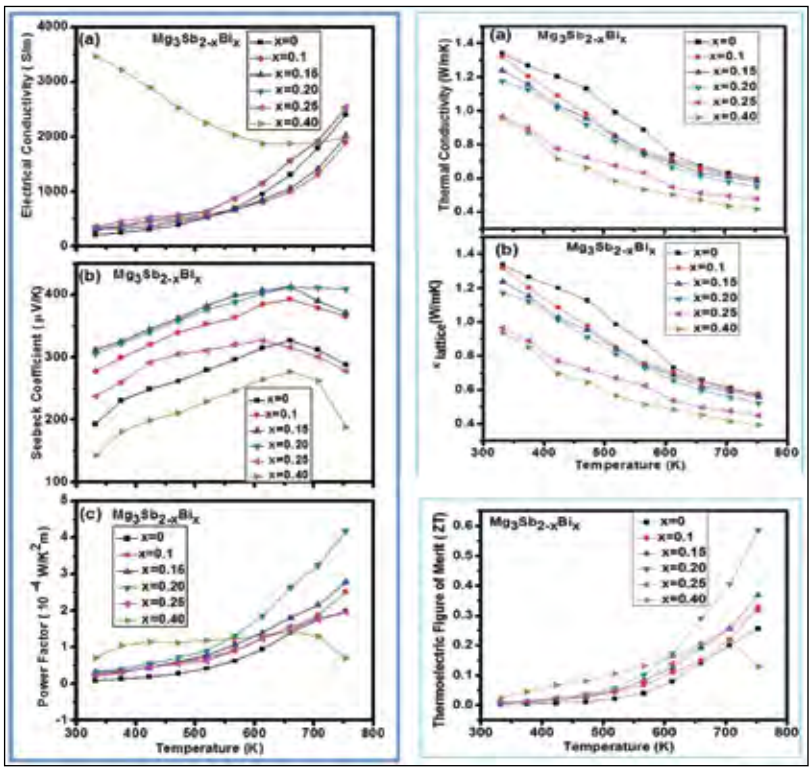


Fig. 2.46 Temperature dependence of the electronic properties of $Mg_3Sb_{2-x}B_x$ ($0 \leq x \leq 0.4$) -electrical conductivity σ(T), Seebeck coefficient S(T), power factor (σ^2S (T)), total κ (T) & lattice thermal conductivity κ_L (T)

microscopy investigations. The electronic structure of Mg_3Sb_2 as revealed by X-ray photo-emission spectroscopy and DFT based calculations render consistent features of the valence band spectrum.

Development of a p-type thermoelectric material Cu_2Se with a very high figure-of-merit

Nanostructuring followed by Spark Plasma Sintering (SPS) of Cu_2Se is shown to yield a thermoelectric figure-of-merit of ≥ 2, which is significantly higher than that reported for vacuum melt bulk samples. Our synthesis process involved high energy ball milling (HEBM) of the constituent elements mixed in stoichiometric proportion followed by consolidation employing SPS to realize a density of 99.8 % of its theoretical value. The average crystallite size of the HEBM nanopowders and SPS samples was ≈ 11 nm and 14 nm, respectively, which suggests that the nanoscale features introduced during ball milling are retained post-sintering. High Resolution Transmission Electron Microscopy (HRTEM) of the sintered nanostructured Cu_2Se revealed nanocrystallites with planes of varied interplanar spacings of monoclinic Cu_2Se which is also supported by the X-ray diffraction (XRD) analysis. Cu_2Se undergoes a monoclinic (α) to cubic (β) phase transition at ~ 140°C. This structural change

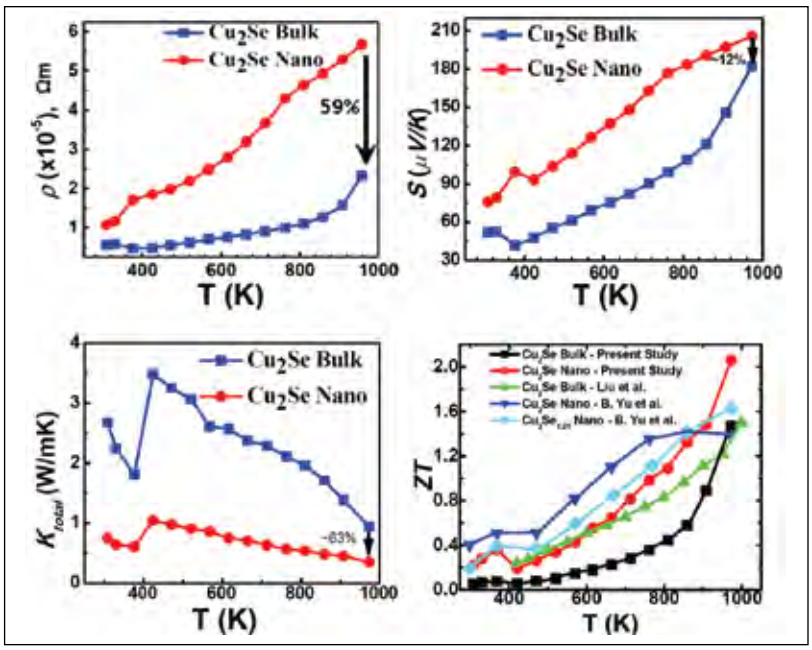


Fig. 2.47 Temperature dependence of resistivity, Seebeck coefficient, thermal conductivity and figure-of-merit of the synthesized nanostructured Cu_2Se compound

manifests itself prominently inspite of the nanoscale crystallite size in all electrical and thermal transport measurements carried out as a function of temperature and has also been established by high temperature XRD, HRTEM and differential scanning calorimetry (DSC) analysis.

The XRD results indicated no phase change on nanostructuring but a significant decrease in the crystallite size. The HRTEM results reveal that grains have an ultra-fine subgrain boundaries. Nanocrystallites with preferred planes of Cu_2Se – monoclinic crystal structure are dispersed homogeneously with an average size about 14 to 15 nm which is also supported by the XRD data of the same sample. These nanocrystals are either having interfacing with another crystals or trapped in thick boundaries of width between 1 to 2 nm. Tiny crystals with overlapped regions lead to an evolution of moiré fringes which again inferences for the existence of dense ultra-thin interfaces at the boundaries of several such nanocrystals. An enhanced figure-of-merit ~ 2.04 at 1000 K in nanostructured Cu_2Se has been obtained (Fig. 2.47), which is the second highest value obtained so far in bulk thermoelectric materials.

Synthesis of Rare Earth free Permanent Magnetic Material

The main objective of this project is to synthesize Rare-Earth Free Permanent Magnetic Material Mn-Al, Mn-Bi employing high energy ball milling, arc melting, conventional melting and spark plasma sintering techniques.

High energy ball milling and arc melting were used separately as well as in combination as a primary processing technique for synthesizing MnAl as a permanent magnetic material. Followed by primary processing high temperature (1150°C) solutionizing was done to obtain ε-phase (hcp structure) followed by water quenching. The ε phase transform to magnetic metastable τ phase by isothermal annealing at temperatures between 400 and 650°C in combination with varying annealing time. To achieve this transformation, annealing of water quenched sample was done for varying length of time ranging from 10 min. to 70 min. Annealing temperature was kept constant at 500°C for all the three conditions to study the dependence of annealing time on the final microstructure and to correlate it with the synthesis route. The samples were characterized by X-ray diffractometer and vibrating sample magnetometer.

Ball milled sample required maximum time of annealing as compared to arc melted sample or sample prepared using combination of ball milling and arc melting. Ball milled sample shows higher percentage of τ_2- and β-phases. However for the sample prepared employing ball milling and arc melting the hexagonal ε phase was completely transformed to metastable τ-phase although some amount of γ_2- and β-phases was found to be still present. Fig. 2.48 shows the magnetic hysteresis curves of τ-Mn-Al alloys for samples obtained from 3 different processing routes.

Work is presently underway to improve the magnetic properties of MnAl permanent magnetic material by employing different primary processing techniques optimizing their process parameter.

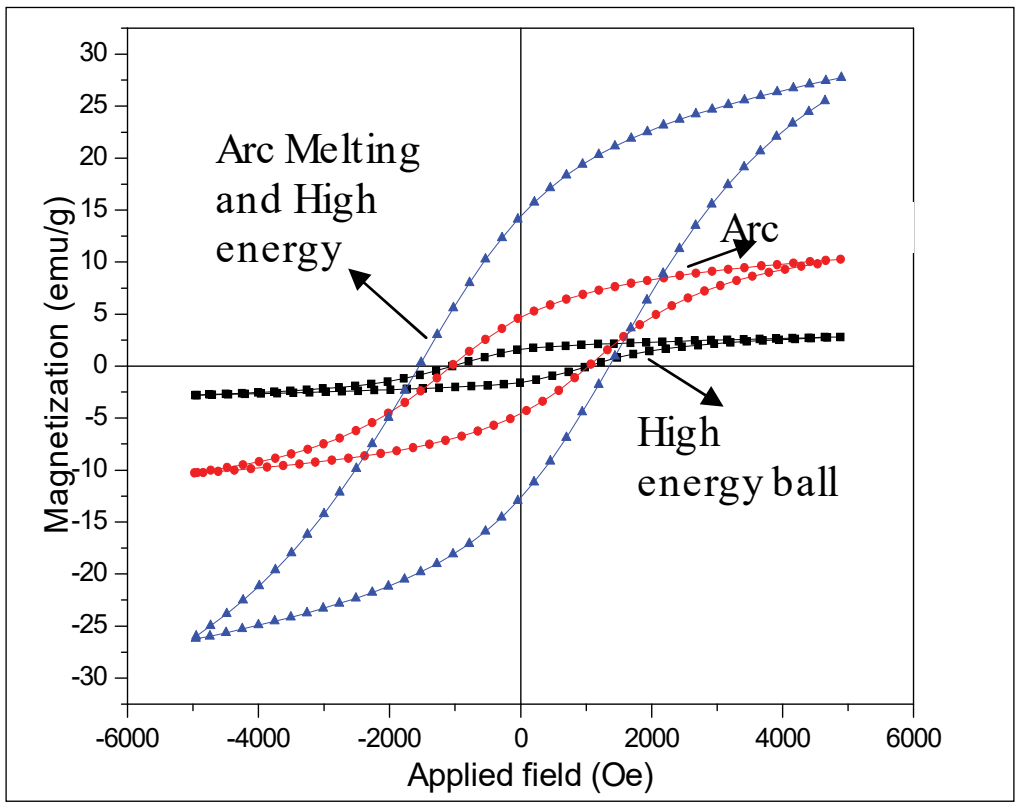


Fig. 2.48 Hysteresis curves of Mn–Al followed by annealing at 500°C (a) Ball milled sample annealed for 50min. (b) Arc melted sample annealed for 40min. (c) Combination of High Energy Ball Milled and Arc Melted sample annealed for 30min

रेडियो एवं वायुमंडलीय विज्ञान

Radio and Atmospheric Sciences

रेडियो एवं वायुमंडलीय विज्ञान

राष्ट्रीय भौतिक प्रयोगशाला का रेडियो एवं वायुमंडलीय विज्ञान प्रभाग (आरएएसडी) रेडियो विज्ञान तथा अनुप्रयोग, अंतरिक्ष मौसम और आयनमंडल, पृथ्वी के वायुमंडल का रसायनिक और भौतिक संगठन, वायुमंडलीय प्रदूषण और जलवायु परिवर्तन आदि के क्षेत्रों में राष्ट्र की वैज्ञानिक आवश्यकताओं की पूर्ति करता है। इस प्रभाग द्वारा (i) रेडियो विज्ञान, और (ii) वायुमंडलीय विज्ञान जैसे प्रमुख क्षेत्रों में अनुसंधान कार्य किए जाते हैं। वायुमंडलीय विज्ञान के अंतर्गत वायुमंडलीय रसायन विज्ञान, वायुमंडलीय स्पेक्ट्रम विज्ञान, वायुमंडलीय भौतिकी के अनुकार तथा प्रतिरूपण से संबंधित अध्ययन शामिल है।

रेडियो विज्ञान :

यह भारत में एक अद्वितीय समूह है जो रेडियो संचार, नौवहन और अन्य उन्नत अनुप्रयोगों में सुधार लाने की दृष्टि से रेडियो संचरण का प्रयोग करके आयनित, अनायनित क्षोभमंडलीय प्रक्षेत्र तथा पृथ्वी के निकट स्थित रेडियो पर्यावरण के अभिलक्षणों को ज्ञात करने के कार्य में संलग्न है। इसमें स्थिर तथा मोबाइल संचार के लिए रेडियो चैनल मापन और प्रतिरूपण, विभिन्न फ्रीक्वेंसी बैंडों में नए डेटा सेटों का सृजन, भारत के विभिन्न क्षेत्रों के ऊपर प्रतिरूपों का परीक्षण तथा प्रतिरूपों को विकसित करना तथा विभिन्न प्रयोक्ता एजेंसियों के साथ अन्योन्य संपर्क स्थापित करना शामिल है। भारत तथा ध्रुवीय क्षेत्रों के ऊपर जीपीएस, टोमोग्राफिक रिसीवरों, आयन सोंद, आदि सहित उपग्रह और भू–आधारित निगरानी प्रणालियों का उपयोग करके आयनमंडलीय/क्षोभमंडलीय पैरामीटरों से संबंधित निगरानी और मॉडलिंग से संबंधित क्रियाकलाप भी किए जा रहे हैं। हमारे अंतरिक्ष–मौसम क्षेत्रीय चेतावनी केंद्र (आरडब्ल्यूसी, एनपीएल, भारत) के माध्यम से विश्व भर के प्रयोक्ताओं के लिए आयनमंडल संबंधी पूर्वानुमान/समाचार प्रसारण से संबंधित कार्य किया जा रहा है तथा हमने प्रेक्षित आंकड़ों के साथ प्रतिरूप तुलना करके अंतर्राष्ट्रीय संदर्भ आयनमंडल (आईआरआई) प्रतिरूप में निरंतर सुधार भी किया है।

वायुमंडलीय विज्ञान :

वायुमंडलीय रसायन विज्ञान समूह विभिन्न स्रोतों से ग्रीन हाऊस गैसों के उत्सर्जन के संबंध में जानकारी हासिल करने, हमारे देश के ग्रामीण क्षेत्रों में प्रयोग में लाए जा रहे बायोमास ईंधनों से निकलने वाले कणिकामय पदार्थों और सूक्ष्ममात्रिक गैसों (सल्फर डाई ऑक्साइड, नाइट्रोजन ऑक्साइड और नाइट्रोजन डाई ऑक्साइड) तथा लैंडफिलों (कचरा डलाव स्थलों) और खेतों में लगी गेंहू एवं धान की फसलों से होने वाले उत्सर्जनों की मात्रा का आकलन करता है। यह समूह विभिन्न मॉडलों का प्रयोग करके और निगरानी के जरिए वायुमंडलीय ओजोन, इसके रासायनिक संगठन और इसकी गतिकी का अध्ययन भी करता है।

पराबैंगनी, दृश्य और एनआईआर–आईआर स्पेक्ट्रम रेंज में वायुमंडल का स्पेक्ट्रोस्कोपी मापन करके वायुमंडलीय ऐरोसोल, सूक्ष्म मात्रिक गैसों, सौर विकिरण और उनके प्रभावों के संबंध में व्यापक सूचना संगृहीत की जाती है। इनसे वायुमंडलीय ऐरोसॉल के प्रकाशीय और भौतिक अभिलक्षणों को ज्ञात करने तथा गैस सैम्पलों या वायुमंडलीय स्तंभ में उपस्थित सूक्ष्म मात्रिक रसायनों की रासायनिक संरचना को ज्ञात करने में सहायता प्राप्त होती है। इस प्रभाग द्वारा हाल ही में उच्च विभेदन विवक्त–पथ एफटीआईआर, सूक्ष्म–स्पंद एलआईडीएआर जैसे आधुनिक उपकरण अधिप्राप्त किए गए हैं जिनसे ऐरोसॉल की प्रकाशीय गहराई, ऐरोसॉल का ऊर्ध्वाधर प्रोफाइल, ऐरोसॉल के आमाप वितरण, ऐरोसॉल के प्रकीर्णन और अवशोषण गुणांकों, एकल प्रकीर्णन ऐल्बिडो (एसएसए), प्रकाशीय गुणों, रासायनिक गुण–धर्म आदि पर ऐरोसॉल की आकृति और इसके आमाप के प्रभाव के अध्ययन, आदि में सहायता प्राप्त होती है। मापन की अनुवर्तनीयता तथा अन्य प्रयोजनों हेतु इस प्रभाग में एक ओजोन मानक स्थापित किया गया है। गणितीय प्रतिरूपण इस प्रभाग के सभी क्रियाकलाप समूहों का एक अभिन्न भाग है।

Radio and Atmospheric Sciences

The Radio and Atmospheric Sciences Division (RASD) of NPL caters to the scientific need of the nation in the area of radio science and applications, space weather and ionosphere, chemistry and physics of the earth's atmosphere, atmospheric pollution, climate change etc. The major research areas : (i) Radio Science, and (ii) Atmospheric science. Atmsopheric science involves study of Atmospheric chemistry, Spectroscopy of Atmosphere, simulation and modeling for atmospheric physics.

Radio Science :

It is a unique group in India which is involved in the characterization of the ionized, non ionized tropospheric media and the near earth radio environment using radio wave propagation for the purpose of betterment of radio communications, navigation and other advanced applications. This consists of radio channel measurements and modelling for fixed and mobile communications, generating new data sets in various frequency bands, testing of models and development of models over various regions of India and interaction with various user agencies. Monitoring and modelling related to ionospheric / tropospheric parameters using satellites and ground based systems including GPS, Tomographic Receivers, Ionosonde, etc., over India and polar regions is also being carried out. Ionospheric forecasting/nowcasting is being provided to users worldwide through our space weather Regional Warning center (RWC, NPL-India) and have consistently improved the International Reference Ionosphere (IRI) model through model comparisons with observed data.

Atmospheric Sciences

The atmospheric chemistry group is engaged in developing the Greenhouse gas (GHG) inventory from different sources, emission estimates of particulate matter (PM) and trace gases (SO_2, NO and NO_2) from biomass fuels consumed in rural sector of our country, emissions from land fills and wheat and rice crop fields etc.. This group also investigates the atmospheric ozone, its chemistry and dynamics using various models and observations.

A wide range of information about the atmospheric aerosols, trace gases, solar radiation and their interactions is generated by conducting spectroscopic measurements of the atmosphere in the UV, Visible and NIR-IR spectral range. It enables the optical and physical characterization of the atmospheric aerosols and help in identifying the trace chemical constituents in the gas samples or in the atmospheric column. The high resolution Open-Path FTIR, micro-pulse LIDAR are the recent modern equipments that supplement the study of aerosol optical depth, vertical profile of aerosols, aerosol size distribution, scattering and absorption coefficients of aerosols, single scattering albedo (SSA), effect of aerosol shape and size on optical properties, chemical characterization, etc. An ozone standard has been added in the division for traceability of measurement and other purposes. Mathematical modelling is an integral part of all the activity groups in the division.

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Sh Sumit Kumar Mishra
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D 03.04 Simulation and Modeling for Atmospheric Physics

Dr (Ms) Meena Jain

Radio Science

Radio channel measurements and modelling for fixed and mobile communications

An experimental campaign was conducted in the urban, coastal, industrial region of Mumbai using WiMAX transmissions at 2.3 GHz, for seventeen base stations. The observed signal levels have been converted into path loss values and plotted as a function of distance. These were compared with various prediction methods like COST-231 Hata, ECC, SUI (Terrain B), ITU-R (P.1411-1) along with Least Square Regression method of measured data. A typical comparison for Harekrishna base station is shown in figure 3.1 Path loss exponents, mean errors, standard deviations and coefficient of determination of all the methods have been deduced and compared with observed values for terrain having partly dense urban, partly light dense urban, partly open with marginal coastal zones; partly urban, partly open, partly low density vegetation environment and partly light dense urban and partly industrial zone. The cdf values of prediction errors have also been compared. The COST-231 Hata and the ECC methods give a good agreement with the measured data than the other methods. These results can be utilized to predict the signal level, path losses in these regions and can be compared to future datasets, which will be generated in this region at various frequencies. The purpose of studying theoretical models and their comparison with measured data is to find a suitable propagation model in that region so that for future network planning, that specific propagation model can be used there or in a region of similar environment. This comparison can provide inputs to radio planning tools and the model tuning capabilities. Also the measured data can be utilized for fine tuning of the default propagation model of Radio Network Planning tool in different terrains . That way service provider can utilize the tuned propagation model for coverage predictions in a similar environment, which will save time and efforts for Radio Network Planning in a region.

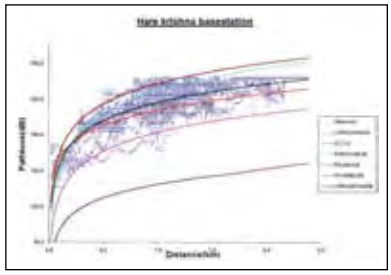

Fig 3.1 Comparison of observed results with those predicted from various models for Hare Krishna base station

Electromagnetic macro modelling of propagation in mobile wireless communication: Theory and experiment

The above work has been carried out in collaboration with Prof Tapan Sarkar's group of Syracuse University. The objective of this activity to illustrate that an

electromagnetic macro modeling can properly predict the path loss exponent in a mobile cellular wireless communication. This represents the variation of the path loss with distance from the base station antenna. Specifically, it has been illustrated that the path loss exponent in a cellular wireless communication is three preceded by a slow fading region and followed by the fringe region where the path loss exponent is four. The size of these regions is dependent on the heights of the base station antennas. Theoretically this is illustrated through the analysis of radiation from a vertical electric dipole situated over a horizontal imperfect ground plane as first considered by Sommerfeld in 1909. To start with, the exact analysis of radiation from the dipole is made using the Sommerfeld formulation. The semi-infinite integrals encountered in this formulation are evaluated using a modified saddle point method for field points moderate to far distances away from the source point to predict the appropriate path loss exponents. The reflection coefficient method is also derived by applying a saddle point method to the semi-infinite integrals and it is shown not to provide the correct path loss exponent. The various approximations used to evaluate the Sommerfeld integrals are described for different regions. It is also important to note that Sommerfeld's original 1909 paper had no error in sign. However, Sommerfeld overlooked the properties associated with the pole. Both accurate numerical analyses along with experimental data are provided to illustrate the above statements. Both Okumura's experimental data and extensive data taken from various base stations in urban environments generated by our group at National Physical Laboratory at two different frequencies have validated the theory. Experimental data reveal that a macro modeling of the environment using an appropriate electromagnetic analysis can accurately predict the path loss exponent for the propagation of radio waves in a cellular wireless communication scenario. A typical variation of path loss exponent at 1800 MHz for Omkarnagar sec-1 base station is shown in figure 3.2.

The above work helped to achieve the following goals:

1 to illustrate that if the Hertz potential are appropriately written as originally envisaged by Sommerfeld for fields at the interface, and the various expansions using appropriate approximations are carried out in a mathematically meaningful way, it may be concluded that the path loss exponent in a cellular wireless communication system is *three* and in the fringe areas is *four*,

2 to illustrate that experimental data also demonstrate that the path loss exponent in cellular wireless communication system is *three*,

3 to illustrate that if one uses an accurate numerical electromagnetic code like AWAS, then it is seen that in a cellular urban environment, the path loss exponent factor is 3 and in the fringe areas it is 4, and therefore it is sufficient to carry out a macro modeling of the environment

4 to illustrate that if a modified method of steepest descent is utilized to treat a pole near the saddle point for the field near the interface, then this characteristic field can be derived when using the appropriate form of the Green's function,

5 to illustrate that if experimental verification is carried out to measure the path loss exponent factor at 900 MHz and 1.8 GHz for various transmitters located in different urban environments, then the path loss exponent factor at moderate distances from the base station antenna settles down to a value of 3,

6 to demonstrate that there was no error in the sign in Sommerfeld's 1909 paper; the defect was that

Sommerfeld overlooked some mathematical subtleties associated with the pole while computing his asymptotic development of the branch cut integral,

7 to state that physics based macro modeling is sufficient to predict the propagation path loss in a cellular urban environment and a detailed micro modeling of the environment is an overkill.

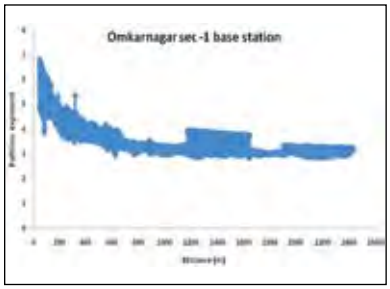

Fig 3.2. Variation of path loss exponent with distance for OM-1 base station (1800 MHz).

Ionospheric F2 - region: Variability and sudden stratospheric warmings

The ionospheric F2 – region is known to show a large day to day and hour-to-hour variability. This variability has recently been linked to sudden stratospheric warmings (SSWs). We have investigated the extent of ionospheric changes following SSWs of years 2007, 2008 and 2009 using ionosonde data from six different stations in the Asian zone thus covering a broad latitudinal range from 8.63°N to 45.1°. We find that ionospheric F2-region shows some significant variations following stratospheric warming within a week or two from the day of the peak event. However characteristics of these variations vary from event to event and from station to station. We have also examined the data on equatorial electrojet strength (EEJ) and find there are significant changes in EEJ strength during the SSW events. A counter electrojet (CEJ) coincident with the start of warming was also observed for the event of 2008.

We then compared this SSWs linked variability observed in the normal day-to-day and hour-to-hour variability seen in the ionospheric data. It is seen that even during times when there are no SSWs and solar and magnetic indices are quite stable and close to their minimum values, the ionospheric variability is comparable and sometimes larger than the variability attributed to these warmings. Further, it seems that it is difficult to quantify with precision the changes in foF2, as well as in the response times involved, in these events. Deviation (ΔfoF2) in critical F2 layer frequency from average of pre warming period (3-12 January 2009) at different Japense stations along with the spectral periodicity analysis are shown in Fig 3.3 and 3.4 respectively.

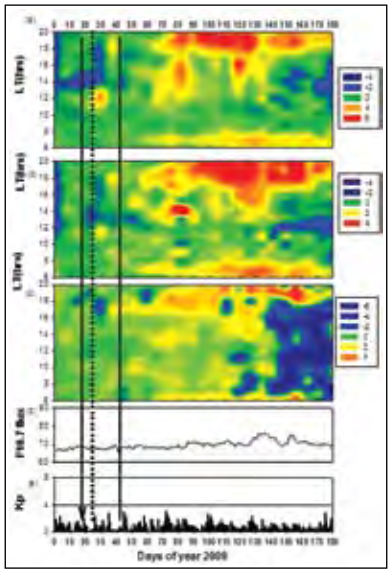

Fig 3.3. Plots of deviation (ΔfoF2) in critical F2 layer frequency from average of pre warming period (3-12 January 2009) at (a) Okinawa, (b) Yamagawa and at (c) Kokubunji. Plots of F10.7 (d) and Kp indices(e) with days of the year 2009. Dark black lines denote the SSW period and the dotted line the peak of SSW warming.

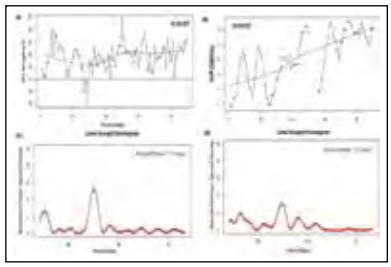

Fig3.4. (a) EEJ and (b) foF2 over Bhopal during January to March 2007 and (c, d) their Lomb-Scargle spectral analysis.

Daytime additional F-layer stratification over low-mid latitude station of the Indian sector under geomagnetic disturbed conditions

Observations of additional F-layer stratification are seen in a region which is situated at the outer edge of equatorial ionization anomaly (EIA) zone. The digital ionosonde data observed over Delhi (28.6° N, 77.2° E, dip 42.44° N) during March-April, 2001 has been used to carry out the present work. The observational period was geomagnetically disturbed

and represents the high solar activity phase of 23rd solar cycle. The additional transient cusp is frequently observed in the considered months before the noon hours; however, in this study only five prominent cases are presented. From the analysis of ionograms, it is observed that the transient additional cusp is formed between the pre-existing F1 and F2 layer; hence, named as the cusp of F1.5. Study reveals that the Traveling Atmospheric Disturbances (TADs) along with the vertical expansion of F layer provides the necessary condition for the existence of this transient feature. The intensification of F1 layer along with increased altitude immediately after the disappearance of additional stratification remains one of the fascinating features of the present results. The present investigation demonstrates that the daytime F1 and F2 region over low-mid latitude station is strongly modulated by the passage of TIDs, originating at high latitudes or by atmospheric disturbances of local origin during the high solar activity period. The concurrent presence of TADs and the associated disturbance composition appears to be plausible reason behind the present observations. Sequential ionograms on March 31, 2001 showing the presence of additional cusp is shown in Figure 3.5.

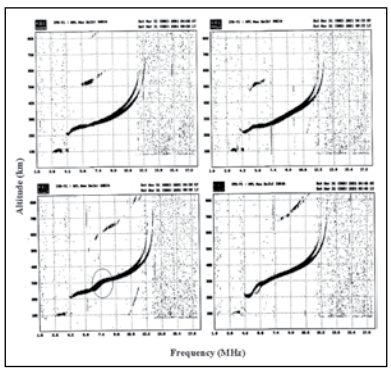

Fig. 3.5 Sequential ionograms on March 31, 2001 showing the presence of additional cusp which is marked by the circle

Antarctica Activity

Radio & Atmospheric Sciences Division, CSIR-NPL participated in 31st Indian Scientific Expedition to Antarctica and successfully carried out some scientific experiments in the field of Space weather and Climate Changes.

The primary objective of this activity is to study the effects of varying solar activity conditions on the southern polar region ionosphere. The study is based on the simultaneous observation of bottom side ionospheric parameters and Ionospheric Total Electron Content (ITEC) along with L-band scintillation observation by Global Ionospheric Scintillations and TEC monitoring system. The above instruments are operational at Indian Permanent Research Base "Maitri", Antarctica (70.43°S, 11.43°E) since 2008. The investigation showed that the minor changes in space weather conditions affect the polar region ionosphere severely.

The results (Figure 3.6) reveals that the enhancement in TEC values are closely associated with an increase in particle precipitation on the polar cusp region. It is observed that the Ionospheric TEC increases for a short duration as soon as proton density increases near the Earth as recorded by ACE satellite. Apart from this the result shows that the enhancement in ITEC is very much positively correlated with Z-component of

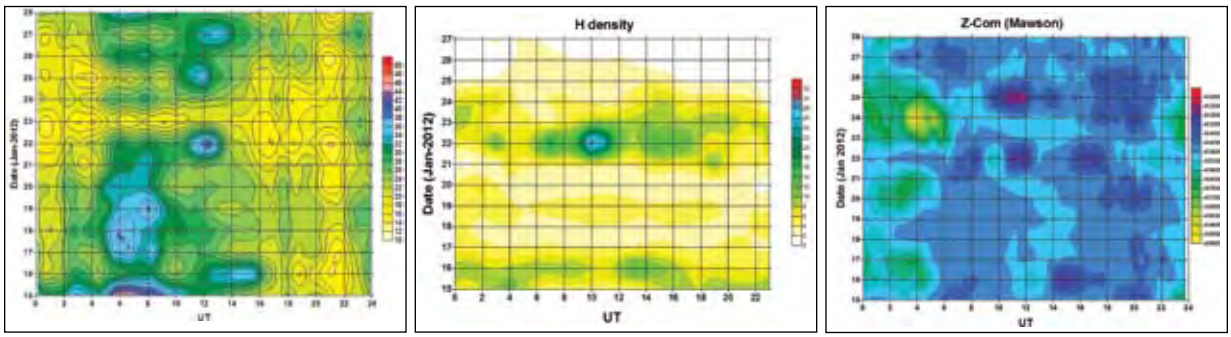

Fig. 3.6 (a): Diurnal variation of Ionospheric TEC variation over Maitri, Antarctica, (b): Diurnal variation of proton density near earth space environment, (c) : Diurnal variation of Earth's geomagnetic Z-component at southern hemisphere.

Earth's magnetic field which is recorded at Australian Antarctic Base "Mawson" (67.60° S, 62.86° E).

Atmospheric Chemistry

Assessment of Energy Generation Potentials of MSW in Delhi under Different Technological Options

The Municipal Solid Waste (MSW) being dumped into the landfills are the important source of methane which could be harnessed as a potential energy source. This would also contribute to the climate change mitigation efforts. Delhi has three landfills namely Ghazipur (GL), Bhalswa (BL) and Okhla (OL). The methane emission potentials of these landfills have been estimated using LandGEM model. The results of the model show the potential methane emissions as 14, 12 and 8 Gg CH_4 from GL, BL and OL respectively from the dumping of segregated MSW which is the current practice. The potential methane emissions could have been 33, 27, 23 Gg CH_4 from GL, BL and OL respectively in case the waste is deposited without pre-seggregation (i.e. bulk waste) in these landfills. The calorific values have been found to be 0.058-0.078 kW/kg for segregated MSW and 0.092-0.126 kW/kg for the bulk waste (MSW) being deposited in Delhi's landfills. The MSW deposited in Delhi's landfills have been subjected to composition analysis which revealed that its major constituent is readily decomposable material, followed by recyclable material and moderately decomposable material. It has also been found that almost 50% of the recyclables were being removed prior to the MSW reached to the landfill sites. To assess the energy generation potential from the MSW reaching to Delhi's three landfills, two situations have been hypothesised; (i) bulk MSW waste is subjected to five available technologies namely biomethanation, incineration, gasification/pyrolysis, refused derived fuel (RDF) and plasma arc gasification and (ii) the segregated waste reaching to the landfill sites is subjected to five technologies for waste to energy generation, namely biomethanation, incineration, gasification/pyrolysis, refused derived fuel (RDF) and plasma arc gasification.

The result of this study shows that different technologies for harnessing the energy from the MSW have different potentials. It has also been found that the segregation process reduces the energy production potential by 40-60% compared to bulk MSW. The plasma arc gasification technology shows the highest potential for energy generation in the ranges of 17-35, 16-32 & 11-28 MW/day from GL, BL and OL respectively as compared to the other technologies like gasification/pyrolysis technology (17-32, 16-29 & 11-25 MW/day from GL, BL and OL respectively), incineration process (17-32, 16-29 & 11-25 MW/day from GL, BL and OL respectively), RDF process (9-19, 8-18 & 6-15 MW/day from GL, BL and OL respectively), biomethanation process (3-10, 3-8, 2-8 MW/day from GL, BL and OL respectively). Thus, the plasma arc gasification seems to have highest energy generation potential but a number of other factors like installation cost, handling of by-products, environmental regulations etc. are required to be considered for identifying the most viable technology for WTE. The values derived in this study are based on theoretical ideas which provide indicative potential values that may differ from actual field measurement values due to the number of factors which influence the methane generation process.

Urban Heat Island Study in Delhi :

Many urban areas experience higher temperatures compared to their suburban or outlying rural surroundings due to urban heat island (UHI) effect. Urban heat islands are caused by development and changes in radiative and thermal properties of urban infrastructure. Elevated temperatures due to UHI, particularly during the summer months in India, can affect the region's environment and quality of life. Most of the impacts of UHI are negative and include:

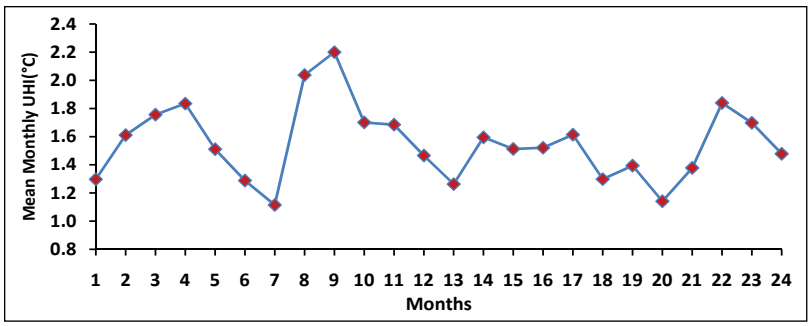

Fig. 3.7 Mean Monthly UHII for Sufdurjung region compared to NPL region during the period of 2010 and 2011

- Increased energy consumption
- Elevated emissions of air pollutants and greenhouse gases
- Compromised human health and comfort

To study the causes and impacts of UHI, a study has been initiated for Delhi region under which meteorological data for the two sub-regions, namely National Physical Laboratory (NPL) region and Safdarjung region have been collected for the years of 2010 & 2011 from the NPL and IMD meteorological stations respectively. It has been found that the temperatures at Safdarjung area was higher than the NPL area during this period. The computation of Urban Heat Island Index (UHII) for these two regions is given in following figure-3.7:

The mean monthly UHII has been found to be always greater than 1°C, throughout the study period and also shows periodical fluctuations with lower values during monsoon season. An analysis of wind speed showed lower values of UHII during strong wind conditions which facilitates the dispersal of accumulated heat in the structures in the region. A detailed analysis of landuse pattern of an area of about 6.46 km^2 around the two stations, derived from satellite images (Table-3.1) shows that NPL area has about 61% area under vegetation and 39% area under construction compared to 18% and 82% areas under vegetation and construction respectively in Safdarjung area. This differene is responsible for observed Urban Heat Isalnd Effect (UHII) in Safdarjung area higher compared to NPL area. Further work is in progress to analyse the impacts of UHII on local environmental parameters.

Table 3.1: Vegetation and construction areas in NPL and Safdarjung derived from Landuse map

S. No.	Station Name	Total Area (km^2)	Area Under Vegetation (km^2)	Area Under Vegetation (%)	Area Under Construction (km^2)	Area Under Construction (%)
1	NPL	6.46	3.92	60.6%	2.54	39.3%
2	Safdarjung	6.46	1.16	17.9%	5.30	82.1%

Updating of Greenhouse Gas (GHG) emission inventories for the energy sector:

An updated inventory of greenhouse gas emissions from the energy sector in India comprising of emissions from thermal power plants, road transport, railways, aviation and marine transport has been prepared for the period of 2001-02 to 2009-10 using the guidelines provided by the Intergovernmental Panel on climate Change (IPCC). The salient observations of this updated GHG emission inventory are as follows:

- The increased number of vehicles and increased demand of electricity has increased the consumption of fossil fuels in which coal consumption shows the annual growth rate of 6.4% while diesel and gasoline shows the growth of 4.9% and 9.4% respectively.
- From energy sector CO_2 emission shows the annual growth rate of 5.5%, CH_4 6.8% and N_2O 5.5%.
- From total CO_2 emission in energy sector 81% is from thermal power plants and 18% from transport sector while in total CH_4 74% is from transport and 26% is

from electricity generation and N_2O total emission 10.5% is from transport while 89.5% is from electricity generation.

- The GHGs emissions from railway have increased at the rate of 41% CO_2, 44% CH_4 and 50% N_2O because of the increase of huge amount of diesel oil in this sector.
- Emissions of CO_2, CH_4 and N_2O in aviation sector have increased at the rate of 100%, 66%, 100% respectively.
- In marine navigation, GHGs emission have increased at the rate of 149% CO_2, 160% CH_4 and 200% N_2O because of the huge increase in the consumption of fuel oil and diesel oil in marine navigation.

Chemical properties of PM10 over Indo Gangetic Plain (IGP) of India

Spatial variability of organic carbon (OC), elemental carbon (EC) and water soluble inorganic ionic components (WSIC) of PM10 were studied over Chandigarh, Delhi, Varanasi and Kolkata of Indo Gangatic Plain (IGP) of India during the period of January to December 2011. The annual average of PM10 mass concentration was found to be maximum at Delhi (205.6 ± 91.3 µg m^{-3}) followed by Varanasi (203.5 ± 88.7 µg m^{-3}), Kolkata (174.3 ± 63.6 µg m^{-3}) and Chandigarh (149.4 ± 25.2 µg m^{-3}) (Fig. 3.8).

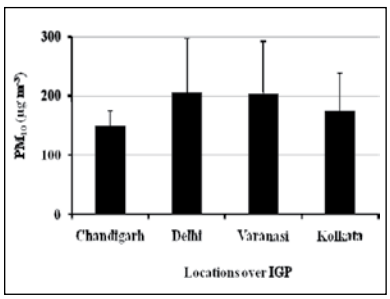

Fig. 3.8 Annual mean concentration of PM_{10} mass over IGP of India

A similar pattern was also recorded in the case of OC and EC concentrations over Delhi (OC: 26.7 ± 9.2 µg m^{-3}; EC: 9.9 ± 3.4 µg m^{-3}), Varanasi (OC: 17.4 ± 9.9 µg m^{-3}; EC: 8.0 ± 6.5 µg m^{-3}), Kolkata (OC: 15.7 ± 8.4 µg m^{-3}; EC: 7.7 ± 6.3 µg m^{-3}) and Chandigarh (OC: 13.9 ± 2.2 µg m^{-3}; EC: 7.2 ± 2.1 µg m^{-3}). The maximum mean concentration OC and EC of PM10 mass were recorded as 26.7 ± 9.2 µg m^{-3} and 9.9 ± 3.4 µg m^{-3}, respectively over Delhi whereas the minimum at Chandigarh (Fig.3.9). A significant positive correlation between OC and EC over the study sites are indicative of their common sources like vehicular traffic.

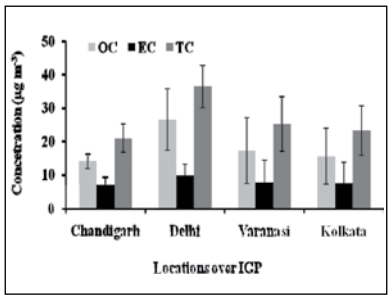

Fig. 3.9 Annual mean concentration of OC, EC and TC of PM_{10} mass over IGP of India

Figure 3.10 shows the spatial variation of NH_4^+, NO_3^-, SO_4^{2-} and WSIC-rest of PM_{10} mass over different locations of IGP, India. During winter, NH_4^+ positively correlated with SO_4^{2-} and NO_3^- at all the locations. Positive correlation of SO_4^{2-} and NO_3^- with NH_4^+ over IGP, India indicates the possibility of the formation of secondary aerosol [$(NH_4)_2SO_4$ and NH_4NO_3] during winter. An analysis of HYSPLIT seven days back-trajectories, suggested that during winter the approaching air mass at receptor sites are mainly of continental type and transported from the local (IGP), Pakistan, Afganistan and its surrounding areas. However, during monsoon season mixed type (continental and marine) air mass flow is recorded at the observational sites.

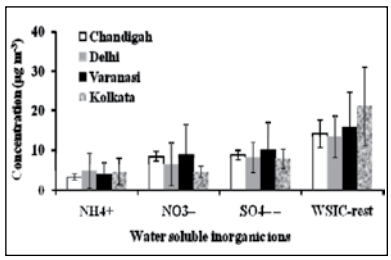

Fig. 3.10 Annual mean concentration of WSIC of PM_{10} over IGP of India

Biological properties of aerosol over IGP of India

Aerosol (PM_{10}) samples were collected from Delhi, Chandigarh and Kolkata of IGP using particle sampler for their biological characteristics. This study was focused on the microbial influence or its content in the formation of aerosols.

The 16S rRNA gene of the isolates was amplified by PCR using universal primers 8-27f (5'-AGAGTTTGATCCTG GCTCAG-3') and 1492r (5'-TACGGYTACCTTGTTACGACT T-3'). The PCR product was purified using the QIAquick PCR purification kit (Qiagen, Germany). The purified amplicon was sequenced using the Big Dye Terminator cycle sequencing kit and an ABI PRISM model 310 automatic DNA sequencer (Applied Biosystems, USA). The total count of bacteria was taken as colony formation units (CFU) from different dilutions where individual colonies observed. Morphologically different colonies were purified by streaking them on fresh plates with similar medium and preserved at -70°C as 10% glycerol stocks for further study. Among the isolates few strains with differences in morphology were analyzed by 16S rRNA gene sequencing and BLAST analysis to confirm their species status (Table 3.2).

The isolates exhibiting high similarity with the species belonging to genera like Mycobacterium and Staphylococcus are to be studied in detail as many species of these genera are found to be opportunistic pathogens. However, there are few strains that exhibited low similarity at 16S rRNA gene sequence with the existing species, indicating that they could be of novel. Other strains involved in nitrogen fixation, reduction nitrate and nitrite are being studied in detail for their characterization including their role in the formation of NH_3.

Polyphasic taxonomy studies are being made to establish their taxonomic status. Studies are being made to establish the role of these microbes in the formation of aerosols in these environments. The samples obtained from Kolkata were subjected to dilution to isolate the culturable bacteria. Up to 10^{-3} dilutions were plated on different media including nutrient agar, tryptose soy agar and plate count agar to obtain the maximum microbes into culturable form. Maximum count was observed over PCA in the sample collected from air filters obtained after 30 min and 60 min. Among the isolates, most of them were found to be species of the genus *Bacillus* based on the morphological features. After isolation, 8 cultures have been preserved at -70°C as glycerol stocks for further studies.

Unique morphotypes were selected from the isolates and were sequenced using universal bacterial 16S rRNA gene primers. The sequence analysis revealed that the isolates obtained by anaerobic culturing technique, mostly belong to the genus *Clostridium* and those obtained by aerobic culturing technique mostly belong to the genera *Mycobacterium, Caulobacter, Sphingopyxis*. Samples obtained from Chandigarh were plated out on different media as mentioned above and the number of colonies formed on plate count agar was taken into consideration. Among the isolates 31 colonies with varying colony morphology have been preserved as -70°C glycerol stocks. Few isolates exhibiting nitrate reduction and nitrogen fixation activities are being studied.

Table 3.2 : Identification of isolates based on 16S rRNA gene sequence BLAST analysis.

Strain designation	Identity	% similarity
NPL 120 P-3	*Mycobacterium aubagnense*	99.33
NPL-30-P-4	*Mycobacterium phocaicum*	100
NPL-120-P-2	*Enterobacter cloacae subsp. dissolvens*	99.85
NPL-T-1	*Staphylococcus auricularis*	100
NPL-VI	*Paenibacillus puldeungensis*	97.4

Abundance and sources of atmospheric carbonaceous and bioaerosols in Delhi region

The carbonaceous aerosols which include black carbon (BC) and organic carbon (OC) are recent focus of research as important chemical pollutants which affect human health and climate. Fig. 3.11 shows the percent contribution of various chemical components of total suspended

particulates (TSP) at Delhi. At this site, carbon accounts for maximum weight percent (~60%) followed by other elements. The presence of carbon may be as black carbon, organic carbon and carbonates. Most of the scattering and absorption of light in the atmosphere at urban sites in India may be due to carbonaceous aerosols which are contributed mainly by combustion of fossil fuel and biomass burning.

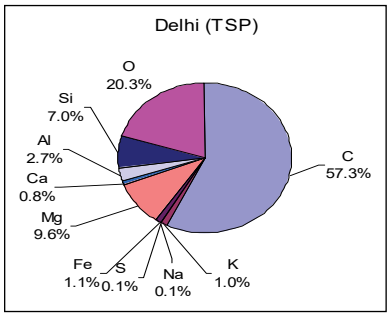

Fig. 3.11 Elemental distribution in total suspended particulate matter at Delhi

Bioaerosols may be found in the atmosphere as bacteria, fungi etc. These airborne microorganisms can be toxigenic, allergenic and infectious. The most significant sources of bioaerosols are soils, plants, vegetables, water bodies, sewage sludge, animal feeding, fermentation process, agricultural activities and human beings etc. Fig. 3.12 shows bacterial abundance in Total Suspended Particulate (TSP) during monsoon and winter seasons. The average concentrations of bacteria during monsoon and winter seasons are 2.37×10^7 and 0.57×10^7 CFU/m^3 respectively indicating four times higher concentrations during monsoon season than in winter season. Higher concentrations of airborne bacteria during monsoon season could be due to higher degradation of living or dead materials surrounding the buildings along with favourable meteorological conditions.

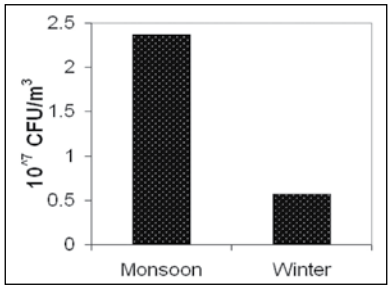

Fig. 3.12 Bacterial abundance (CFU/m^3) during monsoon and winter seasons at Delhi.

Chemical, physical and isotopic properties of aerosols over India

Detailed chemical, physical and isotopic characterization of atmospheric aerosols over India are done using different state of the art analytical facilities of NPL such as CF-IRMS, OP-FTIR, SEM-EDX and XRF. Using different air samplers of different size range of atmospheric particles, we collected atmospheric aerosols from a selected locale and do in-depth investigations using all the aforementioned analytical tools for obtaining comprehensive chemical morphological information. To inordeneto characterize mineral dust aerosols from the vicinity of Thar Desert, a field campaign was conducted in the Jaipur city, during the peried of 19-25 February, 2012. To collect atmospheric PM_5 particles (and a few bulk particles; TSPs) using low volume air sampler at seven locations with varying heights from ground (~10-1000 MAGL; Fig.3.13). The selection of locations is based on the nature of aerosols of local origin characterizing background mineral dust. Aerosol particles were collected on Teflon filters (?37 and ?25 mm) size for bulk chemical analyses using micro-volume air sampler (Fig. 3.13 (inset) with nominal flow rate of

Fig. 3.13: *Site locations of collected atmospheric dust samples from hill regions of Rajasthan (Indian Desert). Right inset shows the micro-volume sampler used for sample collection.*

1.2 lpm. For individual particle morphology and elemental composition, particles were collected on pure Tin substrates (~1×1 mm^2), placed on Teflon filters. Individual particles were imaged and chemical compositions were assessed using Scanning Electron Microscope equipped with Energy Dispersive X-ray (SEM-EDX) facility of NPL. Whereas, bulk chemical compositions of PM_5 particles were determined using X ray fluorescence (XRF) technique at NPL.

PM_5 mass concentrations ranged from 34.7 to 499.8 ?$g.m^{-3}$ (Figure 3.14). Crustal elements, Si, Al, Ca, Mg and Fe were found in abundance e.g. however, maximum variability was shown by Fe. Individual particle images revealed occurrence of highly non-spherical particles rich in Si, Al, Fe, Ca and Mg, supporting the dominance of mineral background dust component in ambient PM_5. Non-crustal elements e.g. Cu, S, C, Ag and Pb were found only over main city at ground level (Birla Temple; 26.89?N, 75.82?E). PM_5 and TSP particles over Kukas hill and Kukas NH-8 highway showed highest Fe mass fractions (maximum up to~43%). Presence of Fe rich mineral dust is of significant importance as Fe is a key element in form of hematite (Fe_2O_3) for incoming solar (visible) energy absorption. Average elemental ratios of Mg/Al, Si/Al, K/Al, Ca/Al, Mn/Al, Fe/Al were found as 0.44±0.22, 1.96±0.90, 0.65±0.22, 1.52±0.40, 0.84 and 1.54±1.67 respectively (Figure 3.14). Higher Ca/Al ratios are consistent with reported Ca rich dust over the Arabian Sea originated from the Thar Desert region. Similar elemental ratios, as found in this study, were also observed in aerosols over Bay of Bengal during late inter-monsoon season, when calcareous mineral dust originating from the Thar Desert is expected to be major contributor of crustal elements. Important to mention here, individual particle chemical compositions measured by spot-EDAX were found to be in good agreement with bulk level chemical compositions.

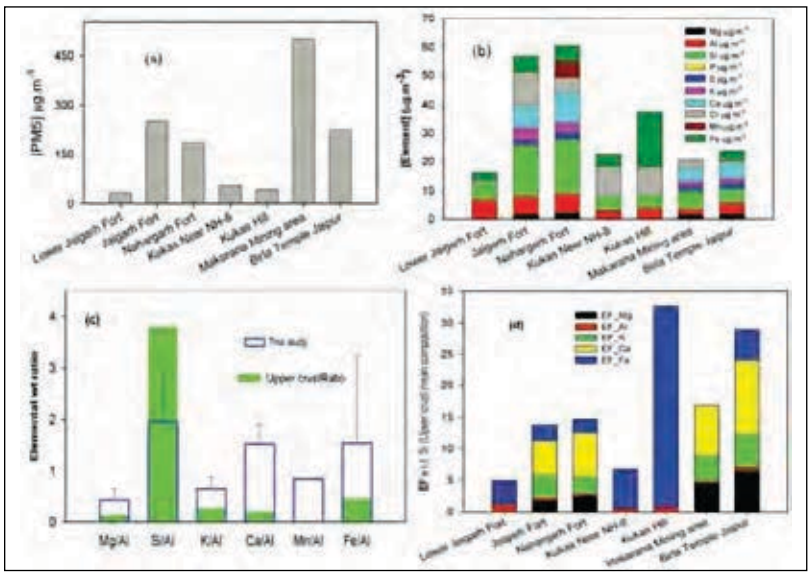

Fig. 3.14: *(a) Spatial variability of particle mass concentrations over all the sites. (b) Variability in measured elemental concentrations in PM_5 particles for all sites, as determined by XRF analyses. (c) Observed enrichment factors of element with respect to Si.*

Morphological analyses of particles revealed predominance of "Layered" (calcite and quartz rich), "Angular" structures (quartz rich) and "Flattened" particles over all the sites (nomenclature based on NIST morphological database). The generated database is highly required for numerical estimation of regional optical/ radiative forcing by mineral dust and to use them as a tracer to identify origin of dust storms that are frequent during inter-monsoon season in northern India. More such works are required (carrying out detailed chemical composition and morphology of individual mineral dust particles), to accomplish detailed classification of dust particles from the source region.

In addition to bulk level chemical composition we also investigated individual particle shape size (morphology) and elemental composition as has been shown for just one site in Figure 3.15. It has been planned to carry out such detailed physic-chemical investigation of bulk as well

as individual particle level of aerosols over typical aerosol producing regions of India such as northwestern India (Punjab) where in pre-winter season agricultural crop residue burning is regular practice and central part of Indo-Gangetic plains such as Kanpur, Varanasi where high loading of aerosols during winter is observed.

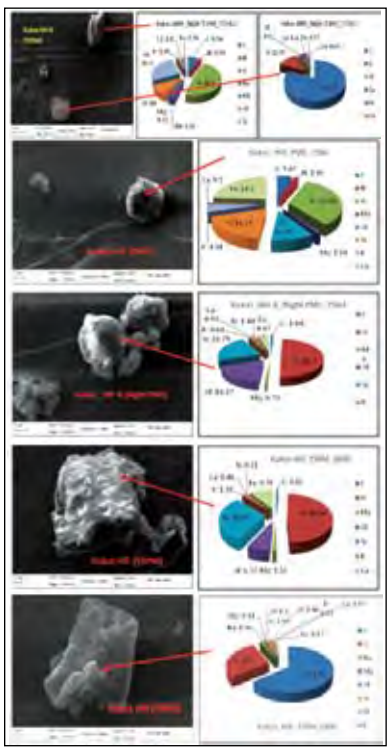

Fig. 3.15: SEM images and chemical compositions of individual mineral dust particles over Kukas hill and Kukas highway (Delhi-Jaipur).

Spectroscopy of Atmosphere

Studies on the altitude distribution of lower Tropospheric Aerosols and Clouds over New Delhi using Lidar

Altitude distribution of aerosols is an important factor influencing atmospheric stability through radiative heating, modifying cloud properties, Earth's radiation budget and consequent changes in the weather and climate of the Earth-atmosphere system. Atmospheric residence time as well as long-range transport of aerosols is primarily governed by the altitude distribution. Atmospheric circulation along with the aerosol properties and altitude distribution provide a handle for inferring the source regions. Furthermore, the aerosol radiative forcing strongly depends on the altitude distribution of aerosols with respect to that of the clouds.

The EZ-Leosphere lidar has been operated during 2009-2010 which has a capability to determine the vertical profiles of aerosol extinction/ backscattering, depolarization ratio and Planetary Boundary Layer (PBL) height. EZ lidar is an elastic Lidar whose light source is a tripled Neodymium-YAG laser that emits a pulse of duration of 10ns at 355nm with maximum energy of 16 mJ and repetition rate of 20Hz. The Lidar is completely eye-safe and reaches full overlap at 300m.

The variation of altitude structure of aerosols, the data corresponding to the monsoon, post-monsoon, winter and spring period from July 2009 to March 2010 were analysed. The lidar signal averaged for 30 minute is first corrected for background noise and then range normalized. Then the aerosol extinction coefficient (AEC) and particle depolarization ratio (PDR) is derived using Fernald's method. It is observed that, below 1.5 km, the AEC values are relatively high during the post-monsoon season and low during the winter season. The PDR values are high during the spring season and low during the monsoon season. The low value of PDR shows the relative abundance of spherical water droplets.

In order to understand the long range transport of aerosols, a case study has been performed. A dust layer has been observed

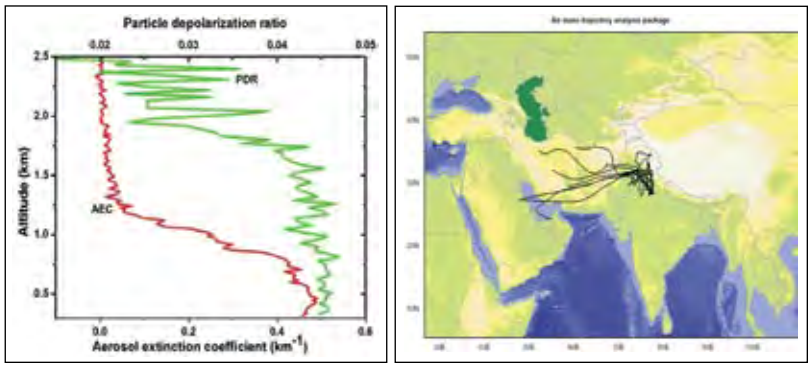

Fig. 3.16 (a) Aerosol extinction coefficient and Particle depolarization ratio (b) Hysplit back trajectory during the period of March 2010

in the height region of 0.4 km to 1.1km on March 12, 2010 and the layer persisted for about four days. The extinction value of the layer range from 0.46 to 0.12 km^{-1} (Figure 3.16 (a)). The particle depolarization value range between 0.045 to 0.041 shows that the layer contains the dust in the lower troposphere mixed with local pollutants. The Hysplit back trajectory analysis (Figure 3.16(b)) shows that the air mass transported to the station from the arid west Asian regions.

In order to study the interaction of aerosols in the low altitude rain clouds a case study has been made using the data obtained during the monsoon season (26th August, 2009). The rain clouds appeared in the altitude range of 0.6 to 0.9 km and precipitate after 12:30hrs (IST) and the rain stops at 14:00 hrs. The low values of the particle depolarization ratio confirm the presence of water droplets in the cloud. After the rain, a cloud layer has been formed below 0.6 km with a delay of 30-40 minutes. It shows that the scavenging of the CCN and recharging of the atmosphere with fresh CCN. Further studies have been made by considering the turbulence and meteorological parameters to bring more insight in to the role of aerosol on the precipitation characteristics of the rain clouds.

Aerosol Radiative Effect at Delhi due to an unusual dust storm of March 2012:

The aerosol direct radiative effects (DRE) in the ultraviolet, shortwave and longwave range due to an unusual dust storm during March 21, 2012 have been quantified from surface measurements of aerosol optical depth (AOD) and radiation fluxes at Delhi, a western Indo Gangetic Plain station (Figure 3.17). The intrusion of dust over Delhi caused an increase in daily average AOD at 500nm from 0.6 to 0.8 with a corresponding decrease in Angstrom Exponent from 0.4 to sub-zero value. The dust severely affected the incoming solar radiation flux in the UV, shortwave and longwave region. The DRE at surface in the UV and shortwave decreased from -4.6 to -5.9 Wm^{-2} and from -68 to -86 Wm^{-2} respectively, while the longwave DRE have increased from 27 to 45 Wm^{-2}. The decrease in UV and shortwave DRE are mainly attributed to the dust storm intrusion, whereas the increase in longwave DRE also seems to be due to change in temperature and humidity (Figure 3.18).

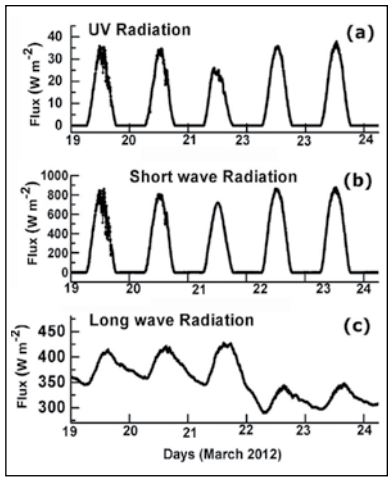

Fig 3.18: Temporal variation of the surface fluxes at (a) Ultra violet (b) visible and (c) long-wave region from 19th to 23rd March 2012 at Delhi

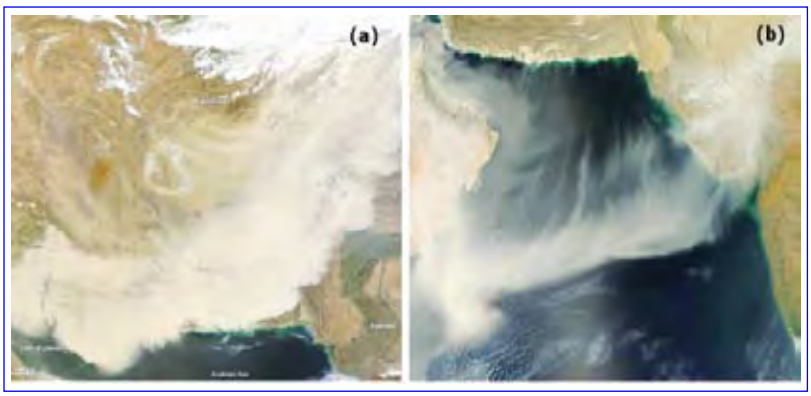

Fig 3.17: (a) Moderate Resolution Imaging Spectroradiometer (MODIS) dust storm across Iran, Afghanistan, and Pakistan on 19th March 2012 and (b) the image on 21st March showing the transport of dust plume across Arabian Sea to reach India.

Planetary scale modulations in aerosol properties over Indo Gangetic Plainstation Delhi

The timeseries data during December 2001 to May 2012 is observed to be a complex function of four dominant periodicities varying from intra-seasonal to inter-annual time scales. The annual (periodicity of ~ 12 months) and semi-annual oscillations (~ 6 months) in the

aerosol optical depth (AOD) as well as Angstrom parameters are found to contribute substantially to the mean pattern with a combined contribution of ~ 40% and are attributed to the changes in the prevailing meteorological conditions which are conducive for either production, transport and/or size transformation processes. Another important observation from the long-term database is that the presence of a much-longer periodicity of ~ 4-5 years (Quasi Triennial Oscillations), in significant amplitude (~ 8%) associated with the ENSO variability in the tropical pacific region. While the intra-seasonal fluctuations (~ 2-3 months) observed are associated with the eastward propagating Madden Julian Oscillations in the lower troposphere, the Quasi-Biennial periodicity (QBO) is related with circulation anomalies in the upper atmospheric region (Figure 3.19)

Simulation and Modeling for Atmospheric Physics

Importance of season, QBO and ENSO in temporal variation of Aerosols Optical Depth

The observational data of Aerosol Optical Depth (AOD) at 61 AERONET stations around the globe is studied to find the relative importance of season and the atmospheric parameters QBO and ENSO in the temporal variation of AOD. A mathematical model of AOD having components of contributions from trend, 6- and 12-month periodicities caused by season and regression with QBO and ENSO is used to quantify the contributions from the considered sources. The contributions from seasonal cycles of 6- and 12-month are found to be dominating and those from regressive parameters QBO and SOI (representing ENSO) insignificant at all stations. The magnitude of importance varies with latitude and longitude. The contribution from season matches in phase and amplitude with AOD anomalies, the variation of AOD with time excluding the trend, at American and Australian stations indicating that the AOD variation is due to seasons. At most of European, African and Asian stations the amplitudes of contributions from seasons do not match exactly with the peaks of AOD anomalies and the cause of this region not falling in line with that of America and Australia may be the pollution at these stations. The contribution from 12-month cycle is significantly high for African and Asian stations as compared with the most of the American, European and Australian stations. The contribution from 6-month cycle is comparable with 12-months cycle in the region (10°–30°N, 80°-120°E) comprising India, Bangladesh, Nepal, Burma, Thailand, Myanmar and South China.

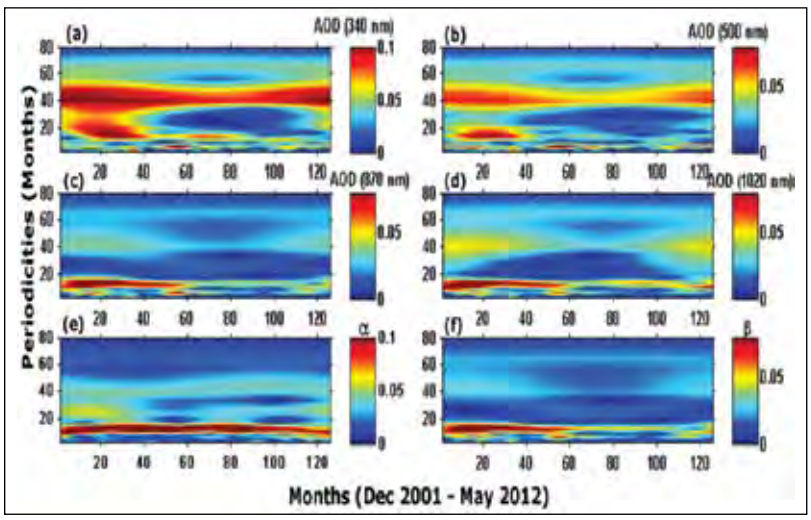

Fig. 3.19 Wavelet spectra of the time series of spectral AODs and Angstrom parameters for the period December 2001- May 2012.

Temporal variation of methane over Indian sub-continent

Methane is the most important anthropogenic greenhouse gas (GHG) after carbon dioxide, causing both direct and an indirect radiative forcing and climate change. The anthropogenic sources include waste decomposition, paddy fields, wet lands, domestic ruminant, biomass burning etc. Because of the biodiversity and

economic conditions the emission rates of the pollutant gases like methane are different over different regions in India. Hence it is important to find hotspots for the abundance of methane over Indian region. SCHIAMCHY (Scanning Imaging Absorption Spectrometer for Atmospheric Cartography) data (level 3) for methane for the period 2003-2009 is obtained to pinpoint hotspot for increasing methane over Indian sub-continent. The column average methane data is available at latitude, longitude mesh grid of 0.5° x 0.5°. The data is retrieved at all grid point over Indian sub-continent which includes around 2000 data files. The monthly averages of SCHIAMACHY data from 2003 to 2009 is found to be more over Indian region compared to other neighboring countries. The methane abundance is significantly high in Indo-Gangatic Plains (IGP) and some regions of Andra Pradesh.

To find the temporal rate of change in methane abundance over India, trend is calculated using following regressive model

$$Z(t) = \mu_0 + \omega * t + ?\alpha_i \sin(2\pi(t+\tau_i)/p_i) + ? \eta_j * V_j + N_t \quad (1)$$

where μ_0 is a base level constant value for Z(t); ω the slope of the trend in Z with time; p_i, α_i, and τ_i the period, amplitude and phase difference corresponding to the ith seasonal cycle taken in the analysis; ηj, and Vj, the coefficient of regression and value of the jth regressive variable such as QBO and N_t the noise term. The unknown constants μ_0, ω, α_i, τ_i and η_i in the model representative function of time for the observed parameter Z(t) in (1)) are found out by the least square fit technique. The cyclic variations caused by seasonal cycles of 3, 6 and 12 months are included in the model. The variations caused by El Niño/ La Niña-Southern Oscillation (ENSO) which is a quasi-periodic climate pattern that occurs across the tropical Pacific Ocean at irregular intervals of 3–7 years with an average period-length of 5 years and lasts nine months to two years is also taken in the model. The Southern-Oscillation Index (SOI) as a proxy for ENSO is used in the model. The trend in methane is found to be significantly high in western IGP.

Major Facilities Established

Establishment of new Stable isotope ratio mass spectrometer coupled with Elemental Analyzer (CF-EA-IRMS) as new R&D facility at Radio & Atomospheric Science Division

A major facility called stable isotope ratio mass-spectrometer (Isoprime 100) coupled with Elemental Analyzer (Pyro-cube) in a continuous flow mode (CF-EA-IRMS) has been procured and installed successfully for measuring concentrations as well as stable isotopes of Carbon (C), Nitrogen (N) and Sulfur (S) in a flash combustion mode and concentrations as well as stable isotopes of Hydrogen (H) and Oxygen (O) in pyrolysis mode. Figure 3.20 shows the installed instrument in Room No 108 of TEC building while accuracy and precision checks are described in Figure 3.21 & 3.22.

Salient features/ capabilities of the established CF-EA-IRMS are-

- Capable of measuring C, N, S, H and O isotopic analyses of particulate matter (e.g. Atmospheric dust, Soil, Sediment, biogenic products)
- Stable isotopic data of C, N, S are vital for deciphering contributing source-characterization and secondary processes involved in chemical processing of particulate matter.
- H, O isotopes of particulate matter can provide insights to degree as well as source of moisture during natural particle formation.

Fig. 3.20: Pyro-Cube (Elemental Analyzer) coupled with Isoprime 100 Stable isotope mass-spectrometer installed in Room no. 108 of RASD.

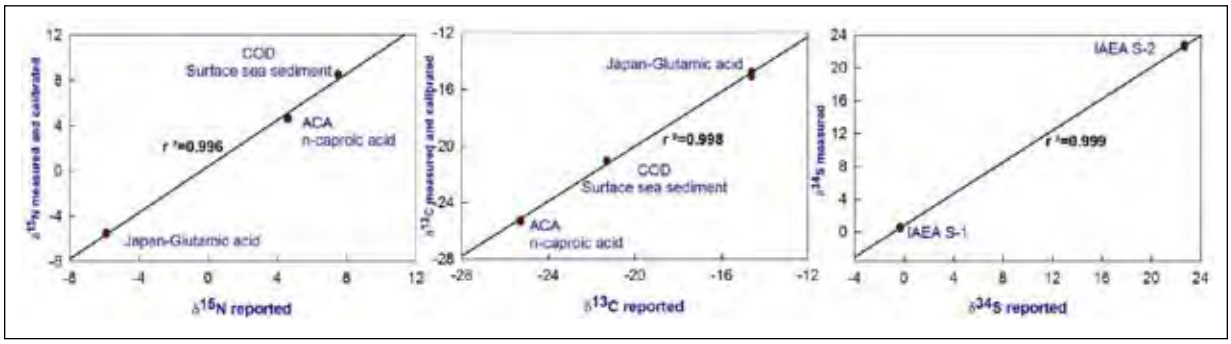

Fig. 3.21: Accuracy of CF-EA-IRMS as determined using combination of international and national analytical isotopic standards.

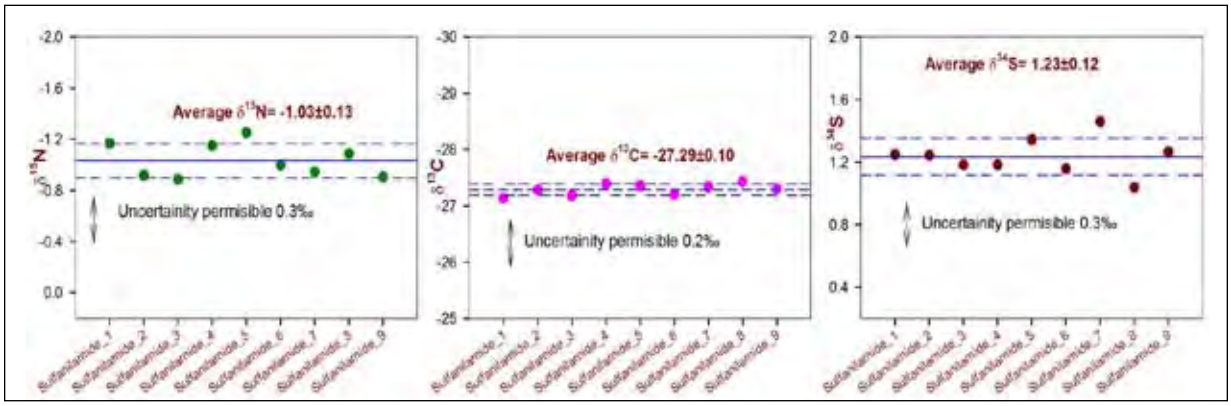

Fig. 3.22: Reproducibility obtained by running nine aliquots of Sulfanilamide (a laboratory standard) is well within expected range of uncertainty known for these isotopic measurements.

❑

समय और फ्रीक्वेंसी मानक

Time & Frequency Standards

समय और फ्रीक्वेंसी मानक

समय तथा फ्रीक्वेंसी प्रभाग द्वारा निम्नलिखित क्रियाकलापों का निष्पादन किया जाता है:

❖ सूक्ष्म तरंग फ्रीक्वेंसी मानक

- *सीज़ियम फाउंटेन – I तथा सीजियम फाउंटेन – II*
- *अंतरिक्ष अनुप्रयोग हेतु रूबिडियम परमाणु घड़ी*

❖ ऑप्टिकल फ्रीक्वेंसी मानक

- *एकल प्राप्त इटर्बियम आयन ऑप्टिकल फ्रीक्वेंसी मानक*

❖ परिशुद्ध समय मापन प्रणालियां

- *भारतीय मानक समय, आईएसटी का अनुरक्षण*
- *समन्वित भूमंडलीय समय यूटीसी का स्थानीय आधार पर यूटीसी (एनपीएलआई) के रूप में मापन*
- *अंतर्राष्ट्रीय परमाणु समय स्केल (टीएआई) में योगदान*
- *समय का प्रसार*
- *अंशांकन तथा परीक्षण*

हमारा प्रभाग भारत में उच्चतम स्तर के समय तथा फ्रीक्वेंसी मापन, भारतीय मानक समय (आईएसटी) के अनुरक्षण, इसका प्रसार तथा अति–परिशुद्ध उपग्रह लिंकों का प्रयोग करके इसे अंतर्राष्ट्रीय बाट तथा माप ब्यूरो (बीआईपीएम) द्वारा निर्धारित मानकों के अनुरूप बनाए रखने के लिए उत्तरदायी है। यह प्रभाग परमाणु घड़ियों तथा फ्रीक्वेंसी स्रोतों के लिए अंशांकन सेवाएं भी उपलब्ध कराता है। हम परमाणु फ्रीक्वेंसी मानकों अर्थात अंतरिक्ष अनुप्रयोग हेतु रूबिडियम परमाणु घड़ियों, सीजियम परमाणु फाउंटेन तथा एकल प्राप्त इटर्बियम आयन घड़ियों के क्षेत्र में अनुसंधान तथा विकास क्रियाकलापों में भी संलग्न हैं।

Time and Frequency Standards

Time and Frequency division is focusing on the following areas :

❖ **Microwave Frequency Standards**

- *Cesium Fountain-I and Cesium Fountain-II*
- *Rubidium Atomic Clock for Space Applications*

❖ **Optical Frequency Standard**

- *Single Trapped Ytterbium Ion Optical Frequency Standard*

❖ **Precise Timing Systems**

- *Maintenance of Indian Standard Time, IST*
- *Local realization of Coordinated Universal Time, UTC as UTC (NPLI)*
- *Contribution to International Atomic Time Scale, TAI*
- *Dissemination of Time*
- *Calibration and Testing*

Our division is responsible for the highest level of time and frequency measurements in India, maintenance of IST, its dissemination and keeping it traceable to the International Bureau of Weights and Measures (BIPM) using ultra-precise satellite links. The division also provides calibration services for atomic clocks and frequency sources. We pursue R&D activities on atomic frequency standards namely Rubidium atomic clocks for space applications, Cesium atomic fountain and Single trapped Ytterbium ion clock.

Dr Amitava Sengupta
Outstanding Scientist
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D 04.01 Ultrastable Atomic Frequency Sources

Dr Amitava Sengupta
Sh Kavindra Pant
Dr Ashish Agarwal
Dr (Ms) Poonam Arora

D 04.02 Precise Timing Systems

Dr Amitava Sengupta
Ms Arundhati Chatterjee
Ms Pranalee Premdas Thorat
Sh Anil Kumar Suri

Ultrastable Atomic Frequency Sources

I) Microwave Frequency Standards

Cesium Fountain Frequency Standards

Cesium fountain clocks provide very precise and accurate measurements of time and frequency. Most of the developed countries have developed such clocks which are already operating as primary standards. T & F division at CSIR-NPL started efforts to realize India's first fountain clock only few years back. The first cesium atomic fountain (India-CsF1) frequency standard is now completely assembled and operational.

In 2011, NPLI has started a project to design and build a second Cs fountain (NOVOCEF) with special design features that enable us to carefully investigate the systematic errors in order to enhance the accuracy of our frequency standard to a few parts in 10^{16} – which would be at the level of the best in the world.

First Cs Fountain: India CsF1

The first cesium atomic fountain (India-CsF1) frequency has a (0, 0, 1) geometry of the magneto-optical trap (MOT) for cooling and launching operations. In this geometry, four out of the six cooling beams are in horizontal plane and other are going up and down, respectively. The atoms are first loaded and cooled in MOT followed by further cooling in optical molasses (OM). They are launched using moving molasses (frequency detuning of vertical beams) and cooled further with polarization gradient cooling. It is possible to trap about 10^7 Cs atoms, cool them to about 7 μK by both magneto-optical trap (MOT) and polarization gradient cooling (PGC) and launch them up by moving molasses method. The atoms are tossed up to 75 cm above the trap center and the return signals are detected in the detection zone. In the detection zone, we have two beams; the upper beam detects atoms in F=4 state and the lower beam detects atoms in F=3 state. The fluorescence signals detected at the large area photodiodes are collected via an NI-DAQ and processed in a Labview program. The labview program has two versions; one version is used for getting Ramsey fringes and the other one is used for frequency locking and analysis of the fountain as shown in Fig. 4.1.

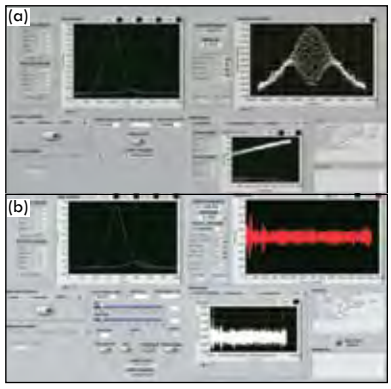

Fig. 4.1: Screenshot of the Labview based data acquisition program for (a) Ramsey fringes and (b) frequency analysis.

At present, the fountain is fully operational and we have got the preliminary results viz. Ramsey fringes, C-field mapping, frequency locking, stability analysis and estimation of systematic shifts. During last one year, major task was to optimize all the operational parameters and to improve the signal to noise ratio in the detected signals. With the new microwave synthesizer in place, the state-selection has been activated. With state-selection, all the atoms interacting with the microwaves are in the mF=0 state and hence transition probability values change from 0 to 1 when microwave frequency is tuned. It is now possible to observe Ramsey fringes with more than 90% contrast as shown in Fig. 4.2.

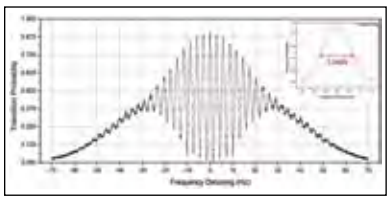

Fig. 4.2: Ramsey fringes with more than 90% contrast for a toss height of 65.4 cm; Ramsey time of 325 ms. Inset: Enlarged central fringe.

The Allan deviation, $\sigma_y(\tau)$ is a measure of the frequency instability of the fountain and is mostly limited by the S/N ratio of the detected atomic flux. The noise in the detected signals comes from various sources such a change in powers of repumping and cooling beams, scattered noise in the detection region and technical or electronic noise. The old repump laser was recently upgraded to have higher and stable repump powers for cooling and detection. The result is increase in the detected atomic flux and reduced shot-to-shot noise. The large area photodiodes used for florescence collection in detection were replaced with another model which has lower terminal capacitance in order to reduce high-frequency noise components in detected signals. The other components in the detection hardware such as resistors and capacitors were also replaced with low-noise components. The Fourier analysis of the detected signals was also performed to test the new detection photodiodes and hardware. The S/N ratio has been improved from 50 to 300. The Allan deviation (with improved S/N ratio) of the frequency difference between the fountain and the H-Maser is shown in Fig. 4.3.

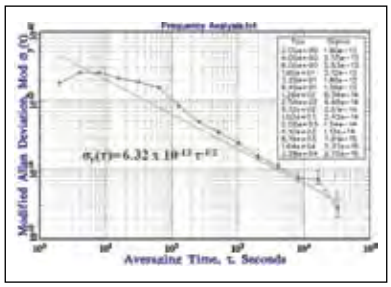

Fig. 4.3: Allan deviation of the frequency difference between the fountain and the H-Maser as a function of the averaging time.

The fountain is at the stage of complete frequency evaluation. It is possible to run the fountain continuously for days without major interruptions provided the temperature of the room is stable. Initial estimation of various systematic shifts to the fountain frequency has been done. The magnetic field mapping was done repeatedly to estimate second order Zeeman shift. The temperature of the flight tube was monitored to calculate the blackbody radiation (BBR) shift and gravitational red-shift was calculated from the estimated height of the microwave cavity above the geoid. The values of biases and uncertainties are reported in Table 4.1. Currently, the fountain frequency evaluation and comparison with PTB is being planned.

Second Cs Fountain: NOVOCEF

Novel Optically-pumped Cesium Fountain (NOVOCEF) project started in 2011 with an aim to build fountain clock with special design features to enhance the accuracy of our frequency standard to a few parts in 10^{16} – which would be at the level of the best in the world. Most of the planning and design of crucial

Table 4.1: The preliminary uncertainty budget for INDIA-CsF1.

Effect	Bias (x 10-15)	Uncertainty (x 10-15)
2nd order Zeeman	50.8	0.1
AC Stark (BBR)	-16.5	0.2
Collisions	to be calculated	1.0 (approx)
Gravity	19.4	0.1
Other effects	To be calculate	0.1 (approx)
Total, uB		1.0

components has been completed for this fountain. CsF2 will have (1, 1, 1) geometry of the magneto-optical trap for cooling, trapping and launching of atoms. The Physics package and the optical set-up of the fountain has been planned as shown in Fig. 4.4. The vacuum parts have been designed and procured. The Ramsey cavity as shown in Fig. 4.5 has been designed in collaboration with NPL, UK and has the features to reduce the cavity related phase shifts. It is also planned to use optical pumping to increase the number of cold atoms interacting with the microwaves. The theoretical calculations for finding optical pumping parameters are underway. Most of the electronics subsystems have been designed and manufactured. The assembly of the fountain will be done in the Metrology building at NPLI.

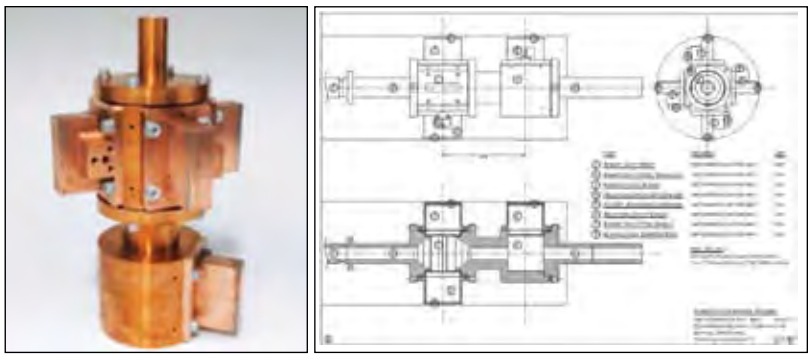

Fig. 4.5: Schematic layout (left) and picture (right) of the 4-feed microwave cavity.

Rubidium Atomic Clock for Space

It is the endeavour of CSIR-NPL to support the national strategic sector programs in a big way. NPL is contributing to India's strategic space programme by developing navigational space clocks. It has developed and transferred the critical technology of Rubidium atomic clock to ISRO. Initial model has been developed at NPL and is undergoing further developments at Satellite Applications Center before being integrated in the payload of the Indian Regional Navigation Satellite system.

Further critical process for development of glass technology of Rubidium bulbs and cells is under development at NPL for making the indigenization of space clocks complete. For this process, a rare, highly enriched, isotope of Rubidium has been extracted in the lab. This has been achieved by a chemical reaction under ultra-high vacuum at 700° C. A modified ultra-high vacuum system is being developed for making the quantum devices required for making a stable atomic clock.

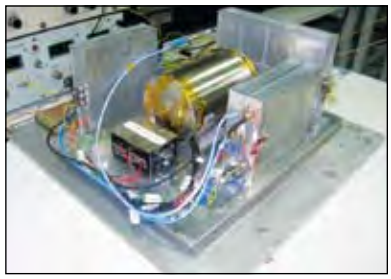

Fig. 4.6. First model of Rubidium Atomic Clock jointly developed by ISRO and NPL

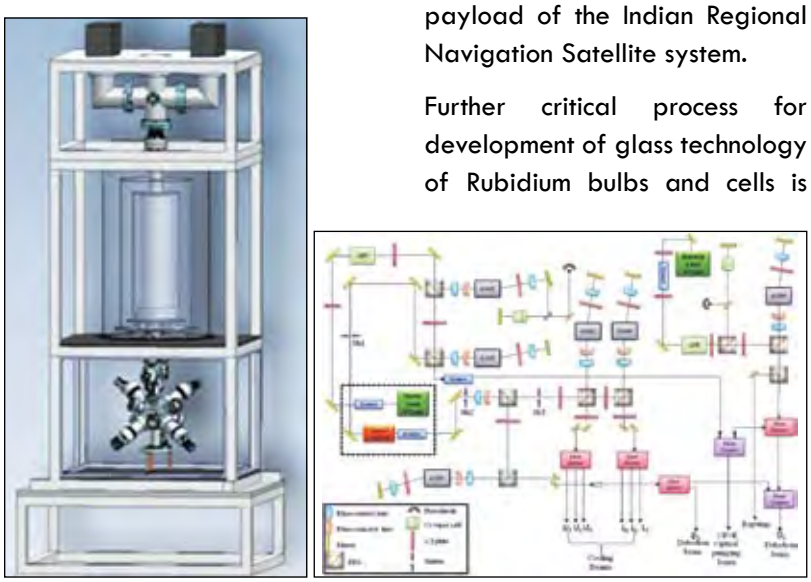

Fig. 4.4: Planned layout of the Physics package and the optical set-up of the second fountain at NPLI.

Fig. 4.7 Development of Indigenous Rubidium Bulbs and Cells

II) Optical Frequency Standard

Single Trapped Ytterbium (Yb) Ion Optical Frequency Standard (STIOS):

We have recently started research and development on a secondary frequency standard at optical wavelength as a Supra-institutional project in the 12th five year plan. Conceptually, this frequency standard consists of probing frequency of an ultra-narrow transition driven by atom-photon interaction. The variance of the measurement, Allan deviation, is inversely proportional to the energy carried by each photons and proportional to the linewidth of the interrogated transition. An optical transition operates at few hundred *THz*, which is four orders of magnitude higher than the operational frequency of the Cesium frequency standard, i.e., 9192631770 Hz between two energy levels of ^{133}Cs atom. This makes the optical clocks 100-1000 times better than the microwave clocks. There are some atoms e.g., ^{199}Hg, ^{171}Yb and ^{87}Sr having narrow $^1S_0 \rightarrow {}^3P_0$ hyperfine induced transitions are potential candidates for optical clocks with trapped atoms in an optical lattice. These clocks are very accurate (fractional accuracy ~ 10^{-18}) due to large signal coming from ensemble of atoms; however they have relatively poor long term stability dominated by collisional shifts. On the other hand optical transitions of $^{199}Hg^+$ (quadrupole transition at 282 *nm*), $^{171}Yb^+$ (quadrupole and octupole transitions at 435.5 *nm* and 467 *nm*), $^{88}Sr^+$ (quadrupole transition at 674 *nm*), $^{43}Ca^+$ (quadrupole transition at 729 *nm*) and $^{27}Al^+$ (hyperfine induced transition at 267 *nm*) provide much better long term stability with a fractional frequency uncertainty < 10^{-17}. In this case single trapped ions are free from Coulomb interaction and also collisions with their chemical homolog vanish. At NPLI work is in progress towards trapping of single $^{171}Yb^+$ in a Paul trap (Fig. 4.8) and aiming to interrogate its qudrupole transition at 435.5 *nm* (corresponds to 688 358 979 309 307.5 *Hz*).

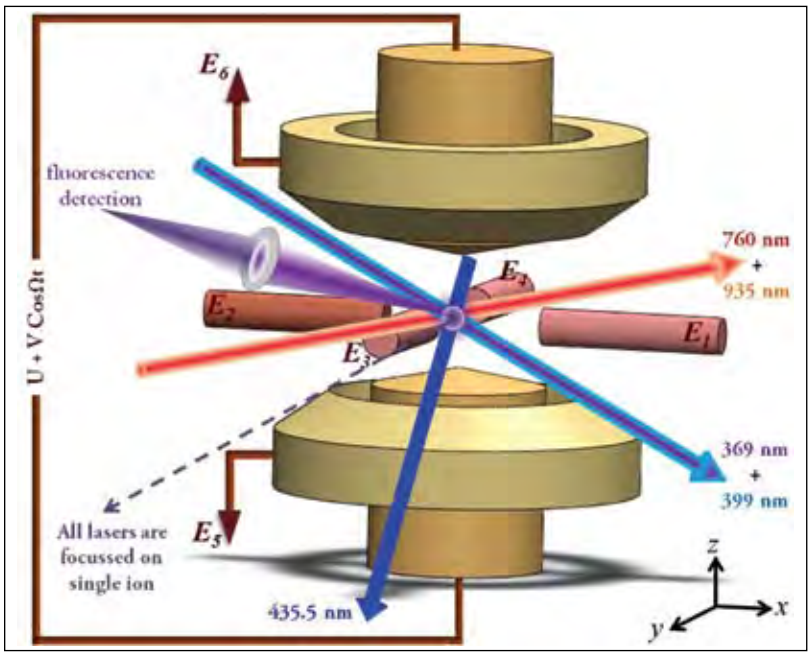

Fig. 4.8: Paul trap with end cap geometry for trapping single $^{171}Yb^+$ ion at NPLI. Electrodes along the z-axis carry radio-frequency and the concentric ring along with the two pairs of electrodes in the x-y plane pushes the ion at the geometric center of the trap. Five laser beams of diameter ~ 50 μm need to be overlapped on the single ion for laser cooling and driving the clock transition. The weak florescence from that ion will be collected by a high numerical aperture lens for detection.

Atoms coming out of a hot effusive oven will be photoionized to Yb^+ using combination of lasers at wavelength of 399 *nm* and 369.5 *nm*. We will start with trapping of few ions in the Paul trap and then gradually throw them one by one except the very last one. Laser cooling will be implemented to reduce temperature of that ion at few hundred *micro-Kelvin*. That will confine the ion within the optical wavelength (Lamb-Dicke regime) which reduces experimental uncertainty by orders of magnitude. A closed laser cooling scheme using the strong cooling transition at 369.5363 *nm* can be realized by implying two additional lasers at 935.1879 *nm* and 760.0767 *nm* for repumping (Fig. 4.9). Finally the ultra-cold ion will be

interrogated using a very narrow linewidth (~1 Hz) lasers at 435.5 *nm* to drive the $^2S_{1/2}$ (F = 0, mF = 0) - $^2D_{3/2}$ (F = 2, mF = 0) clock transition. Finally the weak fluorescence radiated by the single ion at 369.5363 *nm* will be detected by photomultiplier tube as well as by CCD camera using electron shelving technique.

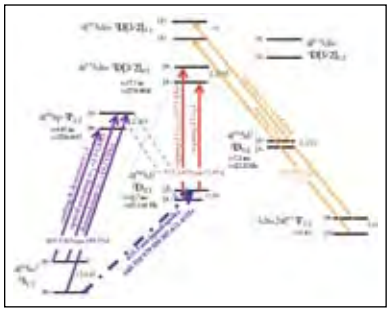

Fig. 4.9: Energy level diagram of $^{171}Yb^+$. Laser cooling and the detection include the lasers at wavelengths 369.5363 *nm*, 935.1879 *nm* and 760.076 *nm*. Light at 435.5 *nm* will drive the quadrupole transition for the clock operation.

Currently we are engaged in designing the ion trap, the ultra-high vacuum vessel, optical setup for all the lasers, ultra stable clock laser and the detection system. We are building an inductively coupled helical resonator for an efficient delivery of radio-frequency $V\ Cos\Omega t$ to the trap electrodes as shown in Fig. 4.8. A narrow bandwidth and high quality factor resonator is near completion. We are theoretically optimizing the trap potentials that will minimize the unwanted energy shifts of the atomic energy levels. We are also developing many electronics in house which will be associated in the experiment. The experiment is planned to setup at the upcoming Metrology building at NPLI.

Precise Timing Systems

National Physical Laboratory is the Time Keeper of the Country and is responsible for highest level of time and frequency measurements in India at par with the international standards. The major activities in timekeeping comprise the following:

Maintenance of Indian Standard Time (IST) with the help of a five Cesium (Cs) atomic clocks and a Hydrogen Maser with stringent environment control and clean uninterrupted power. The IST is inter-compared with international time scale using precise time transfer links with BIPM. **For the first time, an uncertainty u_a of time transfer link has reduced to 0.5ns.** This has been facilitated by the introduction of dual frequency GPS receivers, which are capable of phase tracking a GPS carrier and processing the data by the precise point positioning technique.

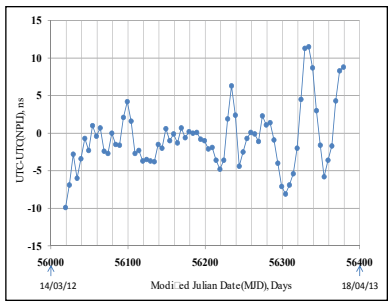

Fig. 4.10. UTC-UTC (NPLI) from April 2012 to March 2013. UTC (NPLI) was given time step of +190 ns on MJD 56351.

Contribution to International Atomic Time Scale, TAI, has been achieved for the first time by the division in this year. **Five of NPL cesium clocks and a Hydrogen Maser have been contributing to TAI since 30 October, 2012.** This has been achieved by combination of (a) precise, regulated, automated inter comparison of clocks (b) precise satellite links, and (c) automated upload of data to BIPM daily. BIPM calculates TAI by assigning weights to more than 600 clocks from 65 laboratories including NPLI. The weightage assigned is decided by the stability of a

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BUREAU INTERNATIONAL DESPOIDS ET MESURES

INTERNATIONAL ATOMIC TIME

RELATIVE WEIGHTS (IN PERCENT) OF THE CLOCKS
FOR INTERVALS OF ONE MONTH ENDING AT THE GIVEN DATES
(*****DENOTES THAT THE CLOCK WAS NOT USED

		29-10-2012	28-11-2012	28-12-2012	27-01-2013	26-02-2013	28-03-2012
LAB	CLOCK	56229	56259	56289	56319	56349	56379
NPLI	35.1324	0.000	0.338	0.259	0.232	0.157	0.169
NPLI	35.140	0.000	0.038	0.035	0.046	0.055	0.047
NPLI	40.5201	0.000	0.001	0.001	0.002	0.002	0.002
NPLI	35.2245	0.000	0.237	0.369	0.387	0.382	0.459
NPLI	35.57	0.000	0.082	0.070	0.039	0.032	0.031
NPLI	35.2796	0.000	0.330	0.497	0.384	0.470	0.351

Fig. 4.11. Weights allocated to clocks of NPLI by BIPM for calculation of International Time Scale (TAI). Source: BIPM (URL: ftp://ftp2.bipm.org/pub/tai/publication/cirt.303).

clock. BIPM assigns maximum of .696% weight to a clock. One of the NPL clock has already achieved a weightage of .497% in the month of December 2012 as shown in Fig 4.11.

An Alternate Clock inter-comparison system has been established with a view to provide redundancy to the existing clock inter-comparison based on the measurements of 1 pps output. The system comprise of a multichannel phase comparator (8-channels) that is fed by 5 MHz outputs of all the five cesium clocks and the Hydrogen Maser as shown in Fig 4.12.

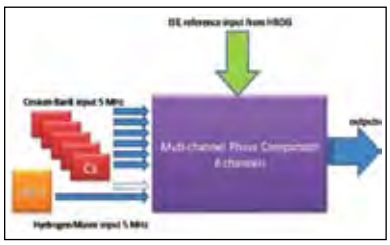

Fig. 4.12. The schematic of the alternate clock inter-comparison system using Phase Comparator. HROG is a micro phase stepper.

Dissemination of Time and frequency to users is being done using two techniques:

Teleclock Service:

The system developed by NPLI for transmission of digital time data via telephone line is an innovative one. This time service via telephone lines is called as Teleclock Service. This unique time service may be accessed by a very inexpensive system called Teleclock Receiver which has been developed by NPLI. The synchronization accuracy of this service is well within ± 1 second.

Internet Time Service: A new Network Time Protocol time service over the internet has been recently started by which any computer world-wide can be synchronized to UTC (NPLI) within 10 ms. The URL for this service is time.nplindia.org. To make the system redundant, two Stratum 1 NTP servers have been connected in parallel. An experiment conducted at NPL showed that using NTP service of NPL, it is possible to get time synchronization within 10 ms. Results of time synchronization accuracy are plotted in Fig 4.13.

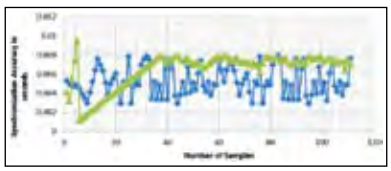

Fig. 4.13 Results of synchronization of NTP server on link www.time.nplindia.org. Two data series (green and blue) refers to two different occasions of measurement.

Time transfer using Ultra stable Time links is being done by NPL to contribute to International Time Scale and maintain the National Time Scale. Following systems have been developed for this purpose:

(a) ***Two Way Satellite Time & Frequency Transfer System*** (TWSTFT) is one of the most precise link to compare time and frequency of two remotely located clocks. Regular time and frequency transfer sessions are being conducted with seven timing laboratories participating in Eu-Asia network using Russian satellite AM-2 at different frequencies & time slots which includes the measurement of clock difference of the two labs at a time.

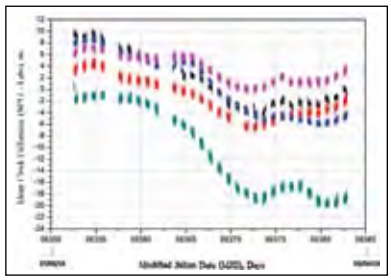

Fig. 4.14. Variation of NPLI time scale with respect to NICT Japan (Black), NIM China (Red), PTB Germany (Blue), TL Taiwan (Green), SU Russia (Pink). Measurements done during the time period of 1st March 2013 to 31st March 2013 by TWSTFT with Jitter, σ = 0.3ns.

(b) ***Precise Point Positioning*** (PPP) is generally used for determination of precise position of a GPS receiver. This technique also allows comparison of atomic clocks with precision at the level of a hundred picosecond. At NPL-India, we are in process of establishing a PPP technique for upgrading our precise time transfer links using some of the internationally available softwares for this purpose. The basic inputs for this technique are the Rinex files generated from the GPS and the IGS files are required as an input for

post processing of the data.

Fig. 4.15. The PPP comparison of NPLI w.r.t to PTB.

Calibration and Testing of secondary frequency standards, clocks and timers has been modernized. During the year calibration was done of different time and frequency instruments like Frequency counters with Rubidium Base oscillator and TCXO, digital timers, master clocks, teleclocks, volt second generator and stop watches. These calibrations were done for Indian industries, namely, HAL, ERDA, Shriram Institute for industrial Research, CRIS (Centre for Railways Information System), National Council for Cement and Building Material, ERTL(W), and Hindustan Petroleum Corp. Ltd. An internal audit of the quality system has been completed in the year.

Major Facilities developed/created/established

Fig. 4.16. NTP internet time service

Extraordinary Research Highlights of work done in the division

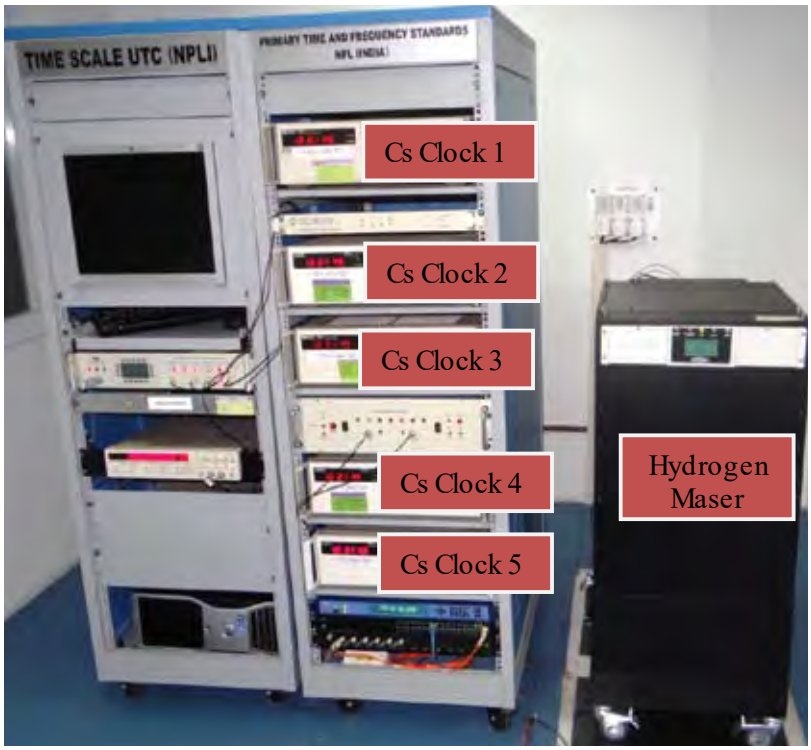

Fig. 4.17 Cesium Clocks started contributing to the International Atomic Time Scale. Weightages to 5 Cesium Clocks and 1 Hydrogen Maser has been assigned by BIPM for the first time in the history of NPL Time and Frequency Division.

शीर्ष स्तरीय मानक एवं औद्योगिक मापिकी

Apex Level Standards & Industrial Metrology

शीर्ष स्तरीय मानक एवं औद्योगिक मापिकी

इस प्रभाग को अंगीभूत समूहों के संगत मानकों को स्थापित करने, अनुरक्षण तथा उन्नयन करने और अंतर्राष्ट्रीय आधार पर समतुल्य राष्ट्रीय अनुमार्गणीयता प्रदान करने का अधिदेश सौंपा गया है जिससे इन मापनों से संबंधित उत्पादों तथा प्रक्रियाओं को अंतर्राष्ट्रीय स्वीकार्यता सुनिश्चित होती है। इस प्रभाग द्वारा मापन क्षमताओं के संवर्धन हेतु अंशांकन सुविधाएं उपलब्ध कराई जा रही हैं तथा प्रमुख एनएमआई के साथ उनकी समतुल्यता स्थापित की जा रही है। यह प्रभाग संदर्भ मानकों के अंशांकन, उत्पाद विकास, परामर्शदात्री सेवाएं, प्रशिक्षण प्रदान करने, आदि के लिए उद्योगों, एनएबीएल द्वारा प्रत्यायित अंशांकन प्रयोगशालाओं तथा अन्य प्रयोक्ता संगठनों को तकनीकी सहायता भी उपलब्ध करा रहा है।

विगत वर्ष इस प्रभाग के लिए अत्यधिक सफल वर्ष रहा है क्योंकि इस वर्ष प्रोफेसर वी.एस. रामामूर्ति (निदेशक, एनआईएएस, बंगलूरु) की अध्यक्षता में 30 मार्च, 2013 को सीएसआईआर–एनपीएल में संपन्न सीएसआईआर के भौतिक विज्ञान समूह (नवोन्मेषी भौतिकी तथा उन्नत इलेक्ट्रॉनिक्स) के अंतर्गत सेक्टोरल मॉनीटरन समिति की चौथी बैठक के दौरान 11वीं पंचवर्षीय योजना के अंतर्गत चलाई जा रही परियोजना "मापिकी के क्षेत्र में प्रगति" – (सीएसआईआर/एनडब्ल्यूपी–45) को अतिरिक्त निधि उपलब्ध कराते हुए 31 मार्च, 2014 तक विस्तारित कर दिया गया है। इस परियोजना का एक सर्वाधिक महत्त्वपूर्ण लक्ष्य मापिकी भवन का निर्माण करना तथा उसे पूरा करना है। एनडब्ल्यूपी–45 परियोजना को निष्पादित करने के परिणामस्वरूप (i) नई तथा अद्यतन सुविधाओं के साथ अंतर्राष्ट्रीय इंटर–कम्पैरिजन की प्रतिभागिता में वृद्धि हुई है, और साथ ही (ii) अंशांकन मापन क्षमता (सीएमसी) बढ़कर 246 हो गई है जिन्हें bipm.org वेब पृष्ठ पर प्रमुख कम्पैरिज़न डेटाबेस (केसीडीबी) में प्रकाशित किया जाता है।

वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद् (सी एस आई आर) की 12वीं पंचवर्षीय योजना नेटवर्क परियोजना में "विज्ञान तथा प्रौद्योगिकी के क्षेत्र में मापन से संबंधित नवप्रवर्तन (एम आई एस टी) (सी एस आई आर परियोजना कोडः सी एस आई आर/पी एस सी 011)" नामक एक नई परियोजना को एस एफ सी/सी एस आई आर की श्रेणी के अंतर्गत प्रत्यय पत्र (25 करोड़ से भी अधिक का) प्राप्त हुआ है। सी एस आई आर–एन पी एल भौतिक माप संबंधी मानकों के क्षेत्र में तथा उभरते हुए नए रासायनिक माप संबंधी मानकों (अर्थात खाद्य पदार्थ, नाशीजीवमारक रसायनों, पर्यावरण, औषधियों तथा खनिज पदार्थों) के क्षेत्र में सी एस आई आर की अन्य सहायक प्रयोगशालाओं के साथ मिलकर एक नोडल प्रयोगशाला के रूप में कार्य करेगा। इस परियोजना के अंतर्गत सभी स्टेकहोल्डरों के साथ अन्योन्य संपर्क स्थापित करने के लिए आयोजित की गई पहली बैठक सी एस आई आर–एन पी एल के निदेशक प्रोफेसर आर. सी. बुधानी की अध्यक्षता में 15 मार्च, 2013 को आयोजित की गई। इस बैठक में सी एस आई आर–एन पी एल तथा प्रतिभागी प्रयोगशालाओं (सी एस आई आर–सी एम ई आर आई, दुर्गापुर, सी एस आई आर–सी डी आर आई, लखनऊ, सी एस आई आर–आई आई टी आर, लखनऊ, सी एस आई आर–एन एम एल, जमशेदपुर, सी एस आई आर–सी एफ टी आर आई, मैसूर; और सी एस आई आर–एन ई ई आर आई, नागपुर) के वैज्ञानिकों ने भाग लिया।

प्रभाग द्वारा किए जा रहे क्रियाकलापों को प्रदर्शित करने के लिए **"भारत में राष्ट्रीय परिशुद्ध मानक तथा अंशांकन एवं परीक्षण का अभिरक्षक"** नामक एक पोस्टर का चयन सी एस आई आर के 70 पोस्टरों में किया गया और उसे 26 सितंबर, 2012 को आयोजित सी एस आई आर के स्थापना दिवस पर प्रस्तुत किया गया।

जापान के अर्थव्यवस्था, व्यापार तथा उद्योग मंत्रालय (एम ई टी आई) तथा वहां के उन्नत औद्योगिक विज्ञान तथा प्रौद्योगिकी से संबद्ध राष्ट्रीय संस्थान (ए आई एस टी) एवं जापान मेजरिंग इंस्ट्रूमेंट्स फेडरेशन (जे एम आई एफ) से एक उच्च स्तरीय जापानी शिष्टमंडल ने उभरते हुए क्षेत्रों– ऑटोमोबाइल विनिर्माण तथा संबंधित समस्याओं के बारे में वैज्ञानिकों के साथ विचार–विमर्श करने के लिए विमीय तथा वैद्युत मापविज्ञान प्रयोगशालाओं का दौरा किया।

Apex Level Standards and Industrial Metrology

The mandate of division is to establish, maintain and upgrade the respective standards of the constituent groups and to provide national traceability, having international equivalence, which ensures international acceptance of the products and processes involving these measurements. Emphasis of the division is on providing the calibration facilities, to enhance the measurement capabilities and establishing their equivalence with leading NMIs. The Division is further engaged in providing technical support to industry, NABL accredited calibration laboratories and other user organizations in calibration of reference standards, products development, consultancy, providing training, etc.

Last year was very successful year for the Division - 11th Five year Plan project "Advances in Metrology" – (CSIR/NWP-45) has been extended up to 31st March, 2014 with additional fund during Fourth Meeting of Sectoral Monitoring Committee under the Physical Science Cluster of CSIR (Innovative Physics and Advance Electronics) which was held at CSIR-NPL on 30th March, 2013 under the Chairmanship of Prof V S Ramamurthy (Director, NIAS, Bangalore). One of the most important targets of this project is the construction and completion of the Metrology Building. The execution of the NWP-45 project has resulted (i) Increased participation of the international inter-comparisons with new and updated facilities, and also (ii) Calibration Measurement Capabilities (CMCs) have gone up to 246 which are published in Key Comparison Data Base (KCDB) of bipm.org web page.

In the 12th Five-Year Plan Network Project of CSIR, a new project entitled "Measurement Innovation in Science & Technology (MIST) (CSIR Project Code: CSIR/PSC 0111) has obtained the crédence under the categories of SFC/CSIR (more than 25 Crore). CSIR- NPL will be nodal laboratory networking with the other sister CSIR laboratories in the field of Physical Measurements Standards and emerging new Chemical Measurements Standards [namely food, pesticides, environment, drugs and minerals]. The first interaction meeting of this project with all the stake holders was organized on the 15th March 2013 under the chairmanship of Prof. R.C. Budhani, Director, CSIR-NPL. Scientists from CSIR-NPL, and partner laboratories (CSIR-CMERI - Durgapur, CSIR-CDRI – Lucknow, CSIR-IITR – Lucknow, CSIR-NML – Jamshedpur, CSIR-CFTRI – Mysore, and CSIR-NEERI – Nagpur) attended the meeting.

A poster entitled **"Guardian of National Precision Standards and Calibration and Testing in India"** containing the divisional activities was selected as one of the 70 posters of CSIR and presented at the CSIR foundation day on 26th September, 2012.

A high Level Japanese delegation from the Ministry of Economy, Trade and Industry (METI) and the National Institute of Advanced Industrial Science and Technology (AIST) and Japan Measuring Instruments Federation (JMIF) visited the Dimensional and Electrical Metrology Laboratories to have interaction with the scientists in the field of emerging sectors - Automobiles manufacturing and related problems.

Dr Ashis Kumar Bandyopadhyay
Chief Scientist
Email : akband@nplindia.org

D 05.01 Mass Standards

Sh Anil Kumar
Dr Sanjeev Sinha
Sh Gautam Mandal
Sh Mahargha Baran Das

D 05.02 Standards of Dimension

Dr K P Chaudhary
Ms Girja Moona
Sh Virendra Babu
Sh Ravi Khanna
Sh Mukesh Kumar

D 05.03 Temperature and Humidity Standards

Dr Yesh Pal Singh
Mr Dilip Dhondiram Shivagan
Sh Jagdish Kumar Gupta
Sh Gurcharanjit Singh
Sh Bhikham Singh
Sh Rasik Behari Sibal

D 05.04 Optical Radiation Standard

Dr H C Kandpal
Dr (Ms) Ranjana Mehrotra
Sh Virendra Kumar Jaiswal
Dr Parag Sharma
Sh K N Basavaraju
Sh Sudama
Dr Bharat Kumar Yadav

D 05.05 Force and Hardness Standards

Dr Sushil Kumar Jain
Dr S Seela Kumar Titus
Sh Rajesh Kumar
Sh Harish Kumar
Sh Vikram

D 05.06 Pressure and Vaccum Standards

Dr Ashis Kumar Bandyopadhyay
Dr Pardeep Mohan
Sh D Arun Vijayakumar
Dr Sanjay Yadav
Dr (Ms) Nita Dilawar
Sh Om Prakash
Sh Harish Kumar
Sh Virendra Kumar Gupta

Mass Standards

Re-calibration of NPK-57 at BIPM, Paris

National Prototype Kilogram No. 57 (NPK-57) is the primary standard of mass in India and as per Weights & Measures Act. 2009, it is a mandatory requirement to get calibrated NPK-57 every 10 years at BIPM, Paris for re-affirmation of its mass value. Accordingly, the NPK-57 has been re-calibrated in the year 2012 at BIPM, Paris. The artifact was hand carried with the help of ATA carnet. The report has also been received. The mass value of NPK-57 will be disseminated to the Govt. organizations and Private organizations through NPL transfer standards and working standards.

Fig. 5.1 Certificate of NPK-57

Development of Watt Balance

It is well known that out of seven SI base units in the International System (SI) of units; only "kilogram" is still an artifact and defined by International Prototype Kilogram (IPK), which is kept at International Bureau of Weights and Measures (BIPM).

The NPL Mass Standards Group has taken initiative to develop *Watt Balance* for the redefinition of *kilogram* by *Plank constant*. It is an inter-disciplinary project.

Investigations of the Silicon for Avogadro constant

For last few decades, a lot of R&D works are going on to redefine the kilogram through a physical constant and one important approach is determination of Avogadro constant by atom counting of pure silicon. Atoms are counted by exploiting their ordered arrangement in the spheres and calculating the ratio between sphere and the unit-cell volumes.

The Mass Standards Group has started investigations of the property of silicon for determining Avogadro constant using existing facilities at CSIR-NPL. Silicon sphere was used in this project. Mass of the sphere was determined in air by substitution method using mass standards and diameter of the sphere was determined using CMM. For determining purity of the silicon, EDS Pattern and XRD Pattern of the same silicon sample were studied after cutting, grinding, polishing, dimpling and ion milling and it is found that almost 95 % silicon and rest is carbon. For the lattice parameter, TEM images as well

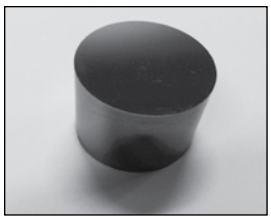

Fig. 5.2 Silicon sphere

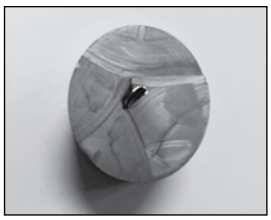

Fig. 5.3 Silicon sphere after cutting for property analysis

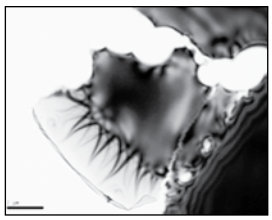

Fig. 5.4 Electron Microscopy study of silicon

as Electron Diffraction Pattern of the silicon sample were taken of the corresponding area those are showing single crystal of silicon having cubic structure. We have achieved the Avogadro's number 6.154×10^{23} i.e. within 2 % deviation from the reference value.

International inter-comparisons

International inter-comparison on Mass Standards [SAARC-PTB Program]

An inter-comparison among the SAARC countries has been conducted for mass by the Mass Standards. Initially Four SAARC countries – Bangladesh, Sri Lanka, Nepal and Pakistan are participating in this inter-comparison. This program is funded by PTB, Germany and is piloted by CSIR-NPL, India (Mass Standard). The standard weights of different denominations – 100 mg, 20 g and 1 kg have been first calibrated at Mass Standard and then sent to the participating SAARC countries for their end. The inter-comparison is under process and the results will be discussed once reports from the participating nations received.

In addition to this, the SAARC countries are being supported technically and their personnel are provided in-depth training on Mass Standards.

International inter-comparison on Viscosity Standards

Also, the group has participated in an international comparison CCM.V-K3 on viscosity piloted by NMIJ, Japan. The oil samples were calibrated at Mass Standard and report has been submitted to the pilot laboratory. The results are awaited.

Fig. 5.5 Standard Liquid A

Fig. 5.6 Standard Liquid B

NPL-NABL Proficiency Testing Program on Mass

A proficiency testing program on mass was conducted by Mass Standard. Four standard weights of nominal values 1 g, 10 g, 200 g and 1 kg and one non-standard weight of nominal value 124 g were used as artifacts. This program was conducted among 27 NABL accredited laboratories for the verification of technical competency. Two loops were designed for timely execution of the proficiency testing program.

Now, the proficiency testing program has been completed and the report has been communicated to NABL, New Delhi after rigorous evaluation of the results submitted by the participant laboratories.

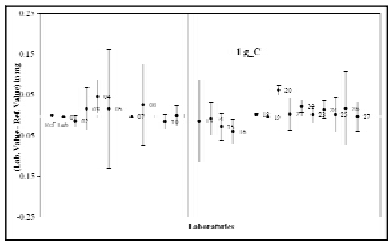

Fig. 5.7 Conventional mass_1 g

Traceability to SAARC Nations

Though the CSIR-NPL, India has mandate to provide apex level calibration facilities in India, but it has been now providing to the SAARC nations to strengthen their metrology programs. The SAARC countries like Sri Lanka, Nepal, Bangladesh and Bhutan have been sending their artifacts to Mass Standard and maintaining their traceability thereafter.

Strengthening the Strategic Sectors

The Mass Standard has been strengthening the strategic sectors of the country and providing the calibration facilities to the defense, aerospace sector of the country. Continuing the previous services, the high capacity weights of 500 kg of Indian Space Research Organization (ISRO) has been provided, which is only available in India. In addition

D 05.07 Acoustics, Ultrasonic, & Vibration Standards

Dr Ashok Kumar
Dr Mahavir Singh
Sh Naveen Garg
Sh Gurbir Singh
Ms Reeta Gupta
Dr Yudhisther Kumar Yadav

D 05.08 Fluid Flow Measurement Standards

Sh Shiv Kumar Jaiswal
Sh Ishwar Singh Taak

D 05.09 LF & HF Impedance & DC Standards

Sh Anil Kishore Saxena
Dr Sher Singh Rajput
Sh Ajeet Singh
Sh Rajbeer Singh
Sh M A Ansari
Sh Satish
Sh Kul Bhushan Ravat
Sh Mohammad Saleem
Sh Avdhesh Kumar Goel

D 05.10 LF & HF Voltage, Current & Microwave Standards

Sh Anil Kumar Govil
Sh Pramendra Singh Negi
Sh Saood Ahmed
Sh Bijendra Pal

D 05.11 AC High Voltage and AC High Current Standards

Sh H R Singh
Sh Sridhar Lingam

D 05.12 AC Power & Energy Standards

Sh Mukesh Kumar Mittal
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to foundry industries have been provided traceability for weight of nominal capacity of 100 kg, 200 kg and 500 kg.

Standards of Dimension

Proposed a Research Project entitled "Development of patentable technology to calibrate diameter with nanometer range uncertainty of measurement".

SIM – LK1 : Gauge Blocks by Interferometer – Report Received.

APMP LK – 3 : Angle Gauge and polygons – Report Received.

Bi-lateral Comparison (APMP.L-K5) with NMI Japan for 1000 mm Step Gauge.

APMP LK S – 1: Gauge blocks by comparator – Report Received.

APMP LK – 8 : Surface Roughness – Report Received

Temperature and Humidity Standards

The temperature scale at NPL is defined by realizing fixed points called the equilibrium states of pure substances i.e. Ar, Hg, H_2O, Ga, In, Sn, Zn, Al and Ag measured by the platinum resistance thermometers covering the range from 84K to 1234K and realizing Ag and Cu points in blackbody cavities by spectral photoelectric radiation pyrometer, LP4 and thus extends the temperature range from 1234 K to 3500 K. Thermocouples of Type-S/R are directly traceable to ITS-90 by calibration on the fixed points of In, Sn, Zn, Al, Ag, Cu, Au and Pd, covering a range from 273 K to 1873°C. The total radiation thermometers are also traceable to international standards through comparison of blackbody source (up to 3000 K) and tungsten strip lamps using standard radiation pyrometer.

The **humidity standard** is maintained through a temperature-pressure humidity generator, Thunder Scientific, USA capable of generating humidity in the range from 10%Rh to 95% RH with a precision of 0.1% RH. The temperature and pressure indicators used in the Chamber are traceable to NPL.

Based on the **APMP Key comparison** at aluminum point (660.323°C), one more CMC is likely to be cleared and thus five CMCs in temperature parameter have been published in the Appendix-C of key comparison database (KCDB) of BIPM. Other remaining 27 CMCs are under reviewing process at APMP level.

This Section is providing **apex level calibration** to a large number of NABL accredited laboratories, govt. departments and user industries for all types of temperature and humidity measuring standards and instruments. A large number of instruments namely SPRTs, RTDs, LIGTs, Liquid baths, Dry-block Calibrators, Sensor based digital Indicators, thermocouples

(S&R), optical and IR-pyrometers, Thermal imagers, tungsten strip lamps and blackbody sources were calibrated during this period. A significant amount of ECF has been generated through calibration of these instruments.

In-house calibration-In addition to the above mentioned calibration work for outside customers, a significant number of in-house temperature instruments and humidity indicators, RTDs, freezers and furnaces were also calibrated for various groups of NPL.

APMP key comparisons - This year our Group has prepared the experimental facilities for participation in two APMP key comparisons, one in Pt/Pd thermocouples at Co-C eutectic fixed point (1324°C) and the other for LIGT (-40°C to 250°C). The comparison has been completed at silver point for a set of two Pt/Pd thermocouples received from KRISS Korea (Pilot Lab) and measurements are in the process at Co-C point.

We have established the primary standard of high temperature by realizing the silver and copper fixed points in blackbodies using recently procured and installed Photo-electric linear pyrometer, LP4 from M/s K. E. Technologies, Germany. Presently, a set of two numbers of tungsten strip lamps which are used transfer standards for high temperature have been calibrated against the Ag-blackbody and pyrometer LP4 in the range from 1073 K to 2473 K.

Fixed point of silver with new set-up installed this year has been utilized to calibrate HTPRTs. The results on experimental runs taken on the fixed point have improved the precision and uncertainty in the measurement of the Ag-point. The facility has been utilized for calibration of SPRTs ad HTPRTs of in-house and international standards. One such calibration requirement has been received from Sri Lanka Standards Institution (SLSI), Sri Lanka.

For the **12th Five Year plan** we have formulated an innovative project entitled "Determination of Boltzmann constant and realization of thermodynamic temperature by acoustic gas thermometry". We are working on the preliminary experimental requirements for this project.

Collaboration with NABL

Our group is associated with NABL activities by organizing proficiency testing programs in LIGT and TC comparison among accredited calibration laboratories in order to support quality assurance in temperature metrology. Expertise is provided to NABL for laboratory assessment in the field of thermal calibration. Expertise is also provided for the Accreditation Committee meetings related to the thermal area.

International Collaboration of NPL-PTB Project for SAARC Countries

Under the extended phase of NPL-PTB Project for strengthening metrology among SAARC member countries, Temperature metrology is one of the areas of the above project in which the inter-laboratory comparison has been organized by our group among the four SAARC countries namely Bangladesh, Nepal, Pakistan and Sri Lanka. The meeting was financially supported by PTB, Germany.

Optical Radiation Standards

Luminous Intensity (APMP. PR-K3.a)

Preparation is carried out to participate in APMP Key Comparison for Luminous Intensity (APMP. PR-K3.a). Twelve countries including NPLI are participating in this key-comparison.

Force and Hardness Standards

Stability studies on the realized forces using the new 1 MN FSM were carried out over the first two years of its installation. High precision force transfer

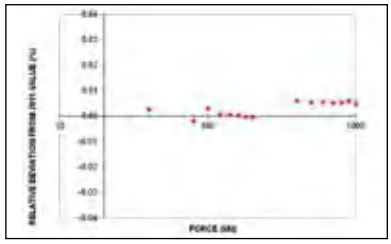


Fig. 5.8 Stability of force realization in 1 MN FSM

Division 5

transducers having repeatability better than 20 ppm in the range 1 – 1000 kN were used. The force values measured on transfer standards were within the claimed CMCs (Fig.5.8).

Stability of force realization in 1 MN FSM

The CMC of HMS force machine was reduced from ± 0.025% to ± 0.02% (k=2). This could be possible due to lowering of measurement uncertainty of the transfer standards, which were calibrated on the new 1 MN force standard machine. These transfer standards were then used to evaluate the CMC of the HMS force machine. Due to the decrease in the CMC value to 0.02%, the HMS force standard complies with the requirement of ISO 376:2011for calibration of force transducers of accuracy class up to 0.5.

The CMC of the new Torque Comparator Machine (TCM) (Fig. 5.9(a)), which was installed with flexible coupling to eliminate effect of cross forces on the torque transducers, was established as ± 0.05% (k=2) for calibration of torque transducers up to capacity 1000Nm (Fig. 5.9(b)). This machine shall be an improvement over the existing unsupported lever torque machine, as it is free from the effect of the cross forces on the DUC and hence shall be used as secondary standard to provide traceability in torque to NABL accredited calibration laboratories and other users.

A comparative study of new calibration standard of force proving instruments, ISO-376:2011, vis-à-vis the existing standard, IS 4169:2004 (reaffirmed) was initiated. The points of differences between the two standards were identified. A few force proving instruments (both load cells and integral rings) were calibrated following the two standards to study the effect on the measurement uncertainty. Preliminary results showed that overall measurement uncertainty of the instrument, or its class in some cases, is likely to go up.

The uncertainty of the applied force in 3 MN force calibration machine, using the 2.1 MN build-up system in extended range up to 3 MN, was evaluated using the 3 MN force transfer standard having traceability from PTB, Germany to be within ± 0.05% (k=2). The force machine thus fulfills the requirement of IS 4169/ISO 376 for accuracy class 1 and is being used to provide traceability up to 3 MN force to NABL accredited calibration laboratories and other users as per their demand.

The final report of the APMP key comparison in Rockwell Hardness scales HRA and HRB, (Calibration on the artifact standard blocks received from the pilot laboratory, NIMT, Thailand was done in 2010-11) was published in *Metrologia*. The deviation from the key comparison reference value (KCRV) and the normalized error of the participating laboratories are shown in Fig. 5.10. NPL (I) results show the degree of equivalence with the other NMIs.

Fig. 5.9(a) Torque comparator machine using flexible coupling

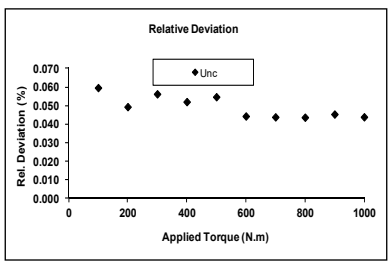
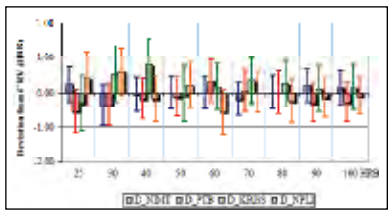


Fig. 5.9(b) Uncertainty (k=2) of applied torque in TCM coupling



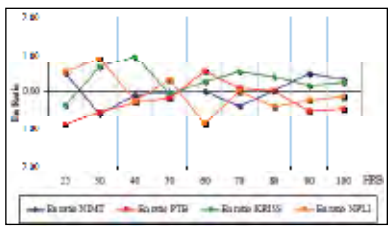


Fig. 5.10 Deviation of HRA from KCRV and the normalized error of participating laboratories in APMP. M.H.-53

Secondary hardness standardizing machines of Brinell, Rockwell (including superficial Rockwell), Vickers and micro-Vickers hardness

were evaluated for the applied force and were found to conform to the requirement of the international standards ISO 6506/7/8 – part-3. The CMC values of the hardness machines were established. Calibration of standard hardness blocks from NABL accredited laboratories and other users were carried out providing the traceability in the hardness scales including the newly introduced micro-Vickers hardness (25 gf – 0.5 kgf).

The group is working on feasibility of developing and establishing low force measurement facilities in the mN and μN range. The group had developed loading hanger for the realization of 0.5N using dead weight system and recently a sub-Newton force actuation system using piezo-force actuation with a mechanical amplifier was set up. Forces down to 0.1 N were realized with an accuracy of 1%.

Vacuum and Pressure Standards

Pneumatic Pressure

In addition to the above mentioned activities, the group is also engaged basic research which include investigation of materials under high pressure using Raman spectroscopy as well phonon behaviour at liquid He/N_2 temperatures. The results have been published in international reputed journals. The group also collaborates with groups within and outside NPL for Raman characterization of strategic materials and assists in the analysis of the data.

A proficiency testing program in pneumatic pressure range up to 50 bar was also completed in which seven labs all over India participated. The final report for the proficiency exercise was sent to NABL in later 2012.

Hydraulic Pressure

Establishment of a New Oil Operated Controlled-Clearance Piston Gauge (CCPG) Type Compact Primary Pressure Standard at NPL, India in the Pressure Range up to 100 MPa

The Pressure Standards Group of NPLI is developing its new oil operated controlled clearance piston gauges (CCPGs) for establishing primary pressure scale. The CCPG type primary pressure standard in high pressure range up to 1.0 GPa has already been established. The work on the establishment of mid and low range CCPGs is being carried out. During the current year under report, a new CCPG100 has been developed and characterized with the aim of improving the measurement uncertainty in the pressure range 10 to 100 MPa. Basically two experiments were performed. In one of the experiments, CCPG100 was characterized using the Heydemann and Welch model (HW model) and pressure dependence of the effective area and associated uncertainty were evaluated. In another experiment, the pressure dependence of the effective area for NPL100MPN was determined by cross floating it against CCPG100. Two parameters in this model, the jacket pressure coefficient and the zero clearance jacket pressure, were then determined from

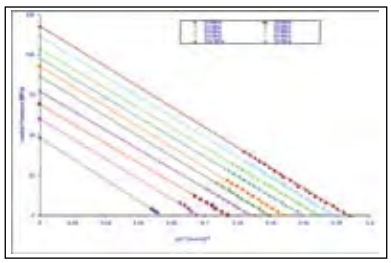


Fig. 5.11(a) $v^{1/3}$ as a function of p_i at different pm

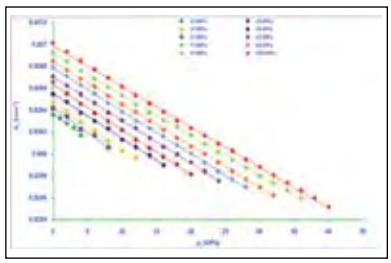


Fig. 5.11(b) Effective area, A_e of CCPG100 from cross-float against NPL100MPN

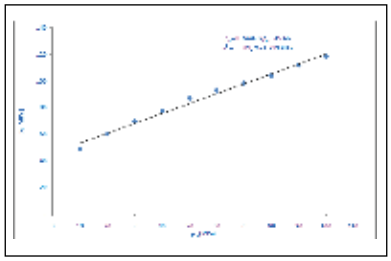


Fig. 5.11(c) p_z as a linear function of *pm*

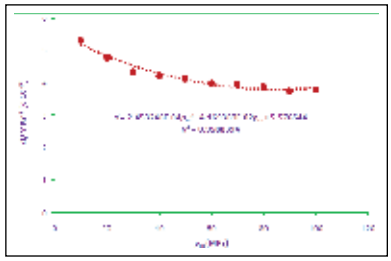


Fig. 5.11(d) Jacket Pressure Coefficient (*d*) of the CCPG100

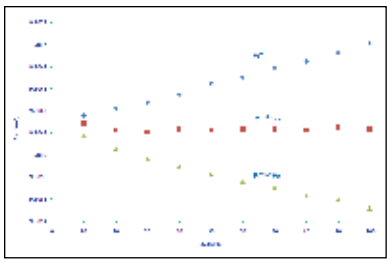


Fig. 5.11(e) The distortion coefficient deceases with increase in p_j and Ae is found operated at almost negligible distortion at p_j = 0.2 *pm*

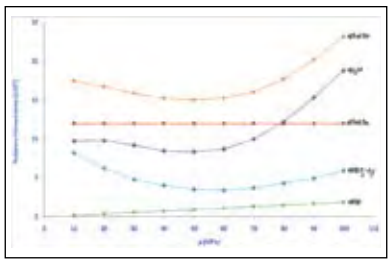


Fig. 5.11(f) Estimated Measurement Uncertainty Contributions of various Parameters of CCPG100

characterization experiments. Then, the pressure dependence of the effective area and its uncertainty were calculated. The characterization results are shown briefly in Fig. 5.11.

Fall rate data was recorded in increasing pressure mode at 10 MPa, 20 MPa, 30 MPa, 40 MPa, 50 MPa, 60MPa, 70 MPa, 80MPa, 90 MPa and 100MPa at different jacket pressure values. In order to examine the stability and repeatability of the measurements, the fall rate measurements were repeated 3 times at all *pm* in a similar fashion. Following the HW model, the average of cube root of fall rate of all the 3 observations is then plotted as a function of *pj* and extrapolating the linear portion of the curve to zero fall rate or zero clearance which provided us the values of *pz* at different *pm* as shown in Fig. 5.11(a). From the *pz* at different *pm*, we have determined the zero clearance between the piston and cylinder as shown in Fig. 5.11(b).

As is evident from the plots, almost linear curves are obtained which satisfy the HW model having coefficient of determination of linear fitting from 0.99 to 1 at all 10 *pm*. Other results on relative change in effective area of CCPG100 and determination of 'd' are shown in Figs. 5.11(c) and (d), respectively. Fig. 5.11(e) depicts the behavior of *Ae* as a function of applied pressure highlighting that *Ae* is almost unchanged at *pj* = 0.2 *pm*, which further reveals that distortion coefficient decreases with increase in *pj* and it is almost negligible at *pj* = 0.2 *pm*. Different uncertainty contributions estimated are shown in Fig. 5.11(f). The overall relative uncertainty associated with measurements is found to be better than 23×10^{-6} at a coverage factor k = 1 with the scope of further improvements, specially dimensional measurements of the piston cylinder assembly.

Re-affirmation of National Hydraulic Pressure Standards up to 500 MPa through In-house Intercomparison Exercise

An extensive in-house laboratory intercomparison exercise carried out on various national hydraulic pressure standards, designated as NPL20MPA, NPL28MPA, NPL50MPA, NPL100MPN, NPL100MPA, NPL140MPA, NPL200MPN, NPL280MPA, NPL500MPN, NPL500MPA using method of cross-floating of pressure balances. The compatibility, uniformity and reaffirmation of the recent results obtained during 2011 and 2012, is re-established by comparing them with the values obtained in several calibrations over the years. The main parameters compared are Effective area (A_e), zero pressure effective area (A_0) and distortion coefficient (□). The metrological characteristics thus obtained establish a very good agreement of all the standards within their claimed uncertainties.

The deviations in the values of A_0, from the most recent results during 2011 for NPL500MPN and NPL500MPA and 2012 for rest of the standards are studied as a function of calibration year. It is observed that all the standards remained very much stable over the years. The values of □ are studied in details. The values of A_0 and □ are found to be consistent. The deviations of A_0 are found to be well within 25×10^{-6} for all the standards except one value each for NPL500MPN, NPL500MPA and NPL20MPa as 46×10^{-6}, 85×10^{-6} and 38×10^{-6} ppm, respectively. These deviations are basically from the manufacturer data and it is assumed that manufacturer data may not be that reliable. However, if manufacturer data is ignored in the comparison,

the deviations are well within $25x10^{-6}$ for NPL500MPa and within $15x10^{-6}$ for rest of the standards.

The estimated relative standard measurement uncertainties are also plotted as a function of measurement range and compared with the approved Calibration and Measurement Capabilities (CMCs) of NPL in Appendix-C of Key Comparison Data Base (KCDB) of BIPM. It is found that measurement uncertainties of all the standards are well within the approved CMCs (Fig. 5.12).

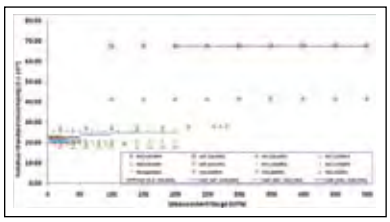


Fig. 5.12 Comparison of Relative measurement uncertainties of all the standards with approved CMCs

Ultra High Vacuum

Recently we have installed the ferroelectric/multiferroic test station, capable of doing the measurement on different aspects of electrocaloric and flexoelectric effect. We have started an extensive research in these two areas. We have significant development in these areas; electrocaloric materials/systems will produce low power cooling devices for nanoelectronics whereas flexoelectric will deal with the design of nanoelectronics for sensors and actuators.

Acoustics, Ultrasonics and Vibration Standards

- Maintenance and upgradation of primary standards of sound pressure and vibration amplitude
- Reverberation Chamber Testing for development of high insulative materials having high sound transmission loss for noise abatement
- Development of Acoustic device for the object detection for divers.
- Design and study of Electro-magnetic Acoustic Transducer for non-contact testing of conducting material
- Development of fully automated ultrasonic power measurement system (Primary standard).
- Development of ultrasonic C-scan system for immersion testing of materials.
- Microcontroller programming and associated circuit design.
- Development of GUI using National Instruments Lab View Software: for acquisition of data through NI DAQ and control of devices
- In-house PCB development for custom developed circuits.

Fluid Flow Measurement Standards

The Fluid Flow Measurement Standards group has the mandate to provide apex level testing and calibration services for the different types of domestic and industrial water flowmeters. The group has a Water Flow Calibration Facility (i.e. Primary Standard of Flow) comprising of two Test Rigs of sizes DN50 and DN200 for calibration of different types of water flowmeter as per ISO 4185 standard. Since the present facility is obsolete now, therefore, its upgradation using latest instrumentation and controls was planned. For this purpose, Rs. 1.65 Crores has been sanctioned in XII-Five Year Plan (2012-17) under MIST project.

The group also has a Water Meter Testing Facility (i.e. Secondary Standard of Flow), for testing of domestic/ industrial water meters of sizes 15 mm to 50 mm as per IS 779, IS 6784 and ISO 4064 standards. The internal audit of this facility was successfully completed. An interlaboratory comparison of this facility was performed with M/s. Institute for Design of Electrical Measuring Instruments (IDEMI), Mumbai (Ministry of Micro, Small and Medium Enterprise) using water meter of 50 mm size. The result of this comparison was found satisfactory.

LF, HF Impedance and DC Standards

Re-establishment of High Value Capacitor calibration facility (10 µF to 10 mF)

Fig. 5.13 Calibration set-up for high value capacitance standards

This Facility was established at NPL in year 1986. However this facility was discontinued in Year 2008 due to no demand from the customers. Now many organizations are demanding calibration of capacitors from value 10 µF to 10 mF.

So, this facility is now re-established for calibration of

i) 10 µF & 100 µF at frequencies 120 Hz, 400 Hz & 1 kHz

ii) 1 mF & 10 mF at frequencies 120 Hz & 400 Hz

Measurement of High Value Inductors using Capacitance Bridge

The simulated reference standards of values 100 H, 1 kH, 10 kH and 100 kH were developed at NPL The value of these high value inductors have been determined by precise capacitance measurement using High Precision Capacitance Bridge (Andeen - Hagerling make).

Fig. 5.14 Simulated high value inductors of 100 H, 1 kH, 10 kH and 100 kH

The measured values are better than 0.1% agreement with calculated values

APMP Comparison of 6½ Digit Multimeter (DMM)

NPL is a Pilot Lab and coordinating the inter-comparison (*P1-APMP.EM-S8*) of 6½ Digit Multimeter (DMM) under Asia Pacific Metrology Programme (APMP), in which 16 countries are participating. The participating countries are Australia, Hong Kong, Sri Lanka, Kazakhstan, Egypt, South Africa, Thailand, New Papua Guinea, Vietnam, Jordan, Mangolia, Philippines, Malaysia, Indonesia, Syria and India (Pilot Lab).

The inter-comparison is being carried out in two circulation schemes for countries covered under ATA Carnet system and for other countries. Both circulation schemes have two loops.

The first loop schemes for countries covered under ATA Carnet system started in Dec 2011 as per schedule and covered five countries (Thailand, Hong Kong, Malaysia, Sri Lanka & Australia), which completed in Sep 2012.

Similarly, the second loop of circulation scheme for countries not covered under ATA Carnet system, started in June 2012 with Kazakhstan as 1st participating country, other countries are Egypt, Syria & Jordan. To be completed in April 2013

The DC measurements are carried by our group and ac measurement by D#5.10. Measurements, data consolidation and analysis are being carried out.

To Conduct Inter-Laboratory Proficiency Testing amongst the NABL Accredited Laboratories in India (CLP 003732)

Under this Project, our group is co-ordinating two Proficiency Testing (PT) Programmes for Capacitance Measurements:

(i) 1 µF (NABL – E – Capacitance - 003)

(ii) 10 pF & 100 pF (NABL – E – Capacitance - 004)

The first circulation loop completed in the month of July 2012. The eight participating labs in first loop are ERTL (N), ETDC – Mohali, C & I Systems-Rajasthan, ETDC - Jaipur, IDEMI – Mumbai, EQDC - Vadodara, EQDC - Gandhinagar, NCQC – Ahmedabad.

The second circulation loop started from Sep. 2012 and completed in Jan 2013. This circulation scheme includes nine participating labs viz. PMMPL - Noida, ECIL -Hyderabad, BDL - Hyderabad, BEL - Bangalore, Transcal - Bangalore, ETDC-

Bangalore, ERTL (E), ERTL (S) and Karandikar Lab-Mumbai.

The analysis of the measured data is being carried out and interim report is under preparation.

Evaluation of 4 terminal pair standard air capacitance using resonance method

The standard air dielectric capacitor series, four-terminal-pair (4TP) used as reference and working standards for the calibration of impedance standards. The frequency characteristics of the standard air capacitors have been evaluated upto 30 MHz. The 4TP network could be used to measure precise admittance and impedance standard described by Cutkosky.

$$Z_{4TP} = \frac{1}{Y_{4TP}} = Z_{21}Z_{34} - Z_{24}Z_{31}$$

The evaluation of air capacitance standard has been done using the equivalent circuit of the capacitors from 1 pF to 1000 pF. The components of the equivalent circuit has been measured or computed to get the effective capacitance. The series and parallel resonance of the air capacitances could be determined by measuring two-port s-parameters.

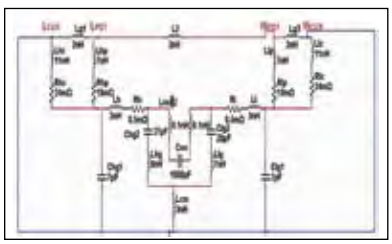


Fig. 5.15 Equivalent Circuit Model; 1000 pF at 10 MHz

The equivalent circuit model of the standard air capacitor, 1000 pF (HP16380A) has shown in Fig. 5.15.

CSIR-NPL, India has been evaluating the standard capacitances (1pF, 10pF, 100pF & 1000 pF)) using series and parallel resonance of the standards. A vector network analyzer has been used to measure the s-parameters of the respective standard and then impedance parameters computed to get the resonance.

The steps follows for the evaluation of 4TP air capacitances are given below:

1. Measurement of Capacitance (C0) at 1 kHz using AH Capacitance Bridge.
2. Measurement of high-to-ground capacitance (C_{HG}) and low-to-ground capacitances (C_{LG}) with 3TP measurement setup using GR 1616 Capacitance Bridge.
3. Determine the remaining residual inductive and capacitance components.
4. Measurement of two port s-parameters from vector network analyzer.
5. Convert s-parameter into z-parameters and find out the series and parallel resonance.
6. Compute the 4TP capacitance and uncertainty over the frequency range (1-30MHz).

Measurement of Residual Capacitances at 1 kHz

The measurements of capacitive residual components have been done using AH Capacitance Bridge by three-terminal-pair measurement setup as shown in Table 5.1.

Table 5.1 : Residual capacitance measurements

1000 pF		100 pF	
C @ 1kHz	1000.74	C @ 1kHz	99.99
C_{HG}, pF	C_{LG}, pF	C_{HG}, pF	C_{LG}, pF
33.5	35.3	31.2	32.42
10 pF		1 pF	
C @ 1kHz	9.998	C @ 1kHz	0.9999
C_{HG}, pF	C_{LG}, pF	C_{HG}, pF	C_{LG}, pF
25.5	29.5	17.4	49.2

The two port s-parameter has been measured using vector network analyzer to compute the series and parallel resonance of each standard capacitance.

Charge Measurement:

To provide calibration and traceability for low level electrical charge from 200 pC to 2 μC following two methods are used:

- **Constant Voltage Method (Q = CV):** In this method a voltage supply is connected across the terminals of a capacitor and the resulting charge stored by the capacitor is measured using an electrometer. This has been implemented by using DPDT switch (Double Pole Double Throw Switch).

Fig 5.16 shows the circuit diagram used and table 5.2 illustrates the measurement results.

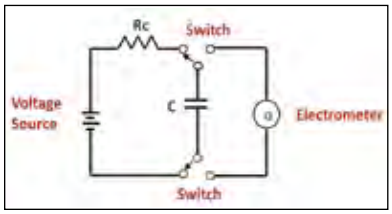


Fig 5.16: Circuit Diagram: Constant Voltage Method

Table 5.2 : Measurement Results by CV Method

Charge Range	Uncertainty Achieved
100 nC – 200 nC	0.5%
200 nC – 2 µC	0.5% -0.01%

- **Constant Current Method (Q = it):** In this method the current is allowed to flow for a specified period of time and the resulting charge developed is measured by the electrometer. This has been implemented by developing an automation program using LabVIEW. Table 5.3 illustrates the measurement results:

Table 5.3 : Measurement Results by CC Method

Charge Range	Uncertainty Achieved
1 nC – 20 nC	0.5%
20 nC – 200 nC	0.5% - 0.3%
200 nC – 2 µC	0.3% - 0.01%

We are in the process of improving the charge measurement set up by using relay and by controlling the whole measurement process by automation.

LF & HF Voltage, Current and Microwave Standards

Automation software based on LabView platform, has been developed for calibrating digital multimeter for LF Voltage & Current. which also performs uncertainty calculations for reporting calibration results.

An APMP Intercomparison P1-APMP. EM-S8 of $6^{1/2}$ digit DMM is being piloted by NPLI. Sixteen countries are participating. Compilation of comparison data is in progress.

Automation of Broadband attenuation measurement (1dB to 60 dB) facility has been performed, based on Labview platform. Step attenuators (10 MHz to 18 GHz) have been calibrated using automated system based on IF substitution technique and the automated results were compared with the manual calibration results. There is improvement in uncertainty by automation (Fig. 5.17).

Fig. 5.17 Automated Attenuation Measurement

Re-establishment of traceability of VM7 (transfer standards for attenuation) against WBCO(NPLI primary standard of attenuation) and its control chart.

A project proposal to establish standards of radiated power density (900 MHz to 6 GHz) have been submitted and approved. Feasibility study has been performed to establish this facility using available resources as shown in Fig 5.18.

Fig.5.18 Feasibility study for Radiated Power Density Measurements

An attempt has been made (de-embedding) to evaluate the S-parameters of a X-band Waveguide to coaxial adapter to calibrate W/G power standards using direct comparison technique by shifting the calibration reference plane from waveguide measurement to coaxial one as shown in Fig 5.19.

The preliminary measurements have been performed in X-band at 10 GHz to evaluate coaxial mismatch transfer standard.

Fig. 5.19 Evaluating an adapter for its S-parameters

A project to upgrade the existing Coaxial Microcalorimeter facility in microwave power from the present (7mm) 18 GHz to (2.4mm) 50 GHz in collaboration with LNE, France is under progress.

AC High Voltage and AC High Current Standards

This section is maintaining National Standards for AC High Voltage and High Current Ratios at power frequencies (50 Hz) by using Reference Standard High Voltage Ratio Measuring System and Reference Standard Current Transformers. Accordingly calibration services were provided for the calibration of Current Transformers, Current Transformer Testing Sets, Clamp Meters, CT Burdens, Voltage Transformers, Voltage Transformer Testing Sets, HV Probes, Electrostatic Voltmeters (ESVMs), HV Break Down Test Sets and Voltage Transformer Burdens etc. As many as 69 Calibration Certificates were issued to the electrical manufacturers and utilities in the country.

The National Standard of AC High Current Ratio Measuring System up to 5000A/1A, 5A is shown in Fig. 5.21.

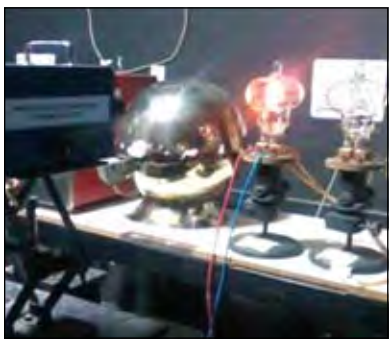


Fig. 5.20(a) Calibration of Strip Lamp against Photo-electric Linear Pyrometer, LP4

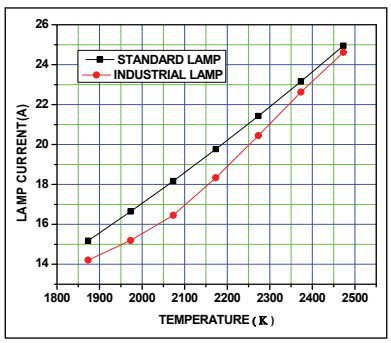
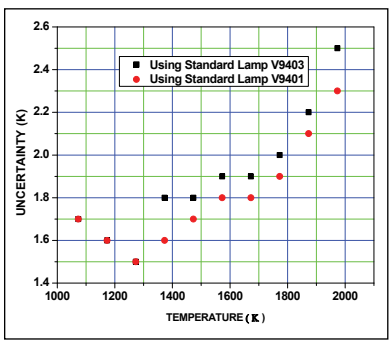


Fig. 5.20(b) Temperature vs. Lamp Current for calibrated Strip lamp, 1873-2473 K



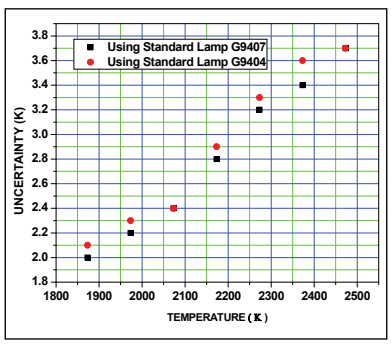


Fig. 5.20(c) Uncertainty Evaluated for calibrated Tungsten Strip Lamps

Fig. 5.21 The National Standard of AC High Current Ratio Measuring System up to 5000A/1A, 5A

The National Standard of AC High Voltage Ratio up to 100 kV/100 V comprising of the Compressed Gas Capacitor, Air Capacitor & the Electronic Voltage Divider (EVD) is shown in Fig.5.22

Fig. 5.22 The National Standard of AC High Voltage Ratio up to 100kV/100V comprising of the Compressed Gas Capacitor, Air Capacitor & the Electronic Voltage Divider (EVD)

Establishment of the National Standard for AC High Voltage Capacitance and Tangent Delta Measurement at NPL

AC High Voltage & High Current Standards have established the National Standards for the calibration and measurement of AC High Voltage Capacitance and Tan δ up to 200 kV at 50 Hz. This will also provide the measurement traceability to kV Meters, High Voltage Dividers, BDV Testers upto 200 kV. With the help of this facility insulation level of test objects like Transformers, Bushings and Cables etc. can be

Division 5

The ranges of the measurements of C & Tan δ are as follows:-

Applied Voltage & Frequency	Parameters	Ranges	Accuracy
5V – 200kV/50Hz	HV Capacitance Tan δ	≥0.01pF 0 – 100	± 0.011% ± 0.011%

measured with a high degree of accuracy.

National Standard for AC High Voltage Capacitance and Tan δ

Fig. 5.23 National Standard for AC High Voltage Capacitance and Tan δ

Extraordinary Research Highlights

Making use of the expertise and experiences available with the division, a new innovative idea of using the recently installed C and Tan delta facility as kV meter for measurement of voltages as high as upto 200 kV has been implemented in addition to the C and Tan delta measurement and calibration services This new idea has added a new dimension in our measurement capability by adding one more parameter of AC high voltage measurement services from existing 100kV to 200kV for High Voltage Sources, kV Meters and High Voltage Probes. This has been made possible by the induction of C and Tan Delta high precision measuring system.

AC Power and Energy Standards

- The activity is maintaining the primary standard of AC Power & Energy (PPCS) traceable to voltage, resistance and time. Working range is 10 V to 480 V/10 mA to 100 A/ PF:1 to 0.01(lag/lead) at frequency range 40 Hz to 400 Hz.
- One single phase and one three phase reference standards are calibrated against this PPCS and then used in our calibration benches for providing traceability to all power sector organization, other laboratories and energy meter manufacturers in India and in SAARC countries.
- Calibration of class 0.01 reference standard are being done in NPL now which were being sent to other NMI,s.

R & D Activity :

The Primary Power Calibration System (PPCS) is integrated in NPL India. The basic parts like voltage and current transformers have been calibrated by PTB Germany initially and in future the traceability will be in house with NPLI.

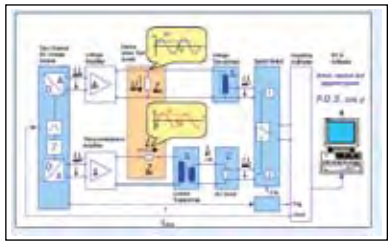


Fig. 5.24 Schematic diagram and working principle of Primary Power Calibration System (PPCS)

Working principle:

A two channel AC source generates sinusoidal voltages in digital form and converted to analog signal by D/A converter and the phase is introduced by time delay. Any phase difference +180° to -180° can be introduced and corrected if there is difference in the applied and measured value. One signal is for voltage and other for current. The voltage signal is amplified and the voltage amplifier supplies the voltage to the device under calibration and in parallel to the voltage transformer. The secondary side of the transformer is connected to DMM through a signal switch. The current is generated by the other signal and the current amplifier generates the test current which is applied to device under calibration and the primary side of the CT. The secondary of this CT is burdened with a shunt. The voltage drop across the shunt is measured by DMM through signal switch. The two signals are compared with generated voltages and the error is calculated. Synchronizing

errors are eliminated because of single clock signal used for generation as well as for measurement of both signals and also by the use of single voltmeter used for measurement of all the voltage signals. The measurement uncertainties are in the range of ± 30ppm to ± 40ppm at k=2.

- **Major Achievement:**

The CMC of the activity have been improved to ±50 ppm for single phase and ± 65 ppm for three phase active power and energy. These are being uploaded on BIPM Website. In the next peer review we plan to further improve to ±30 ppm for single phase and ± 50 ppm for three phase active power and energy.

Major Facilities created/ developed

Establishment of High Temperature Primary Standards

We have established the calibration facility for high temperature transfer standard strip lamps in the range from 1000 K to 2473 K using Photo-electric pyrometer, LP4. The facility is the result of the work of primary standard established in terms of Ag and Cu points in the form of metal-in-graphite blackbodies by using heat pipe blackbody source and the pyrometer, LP4. This facility is useful for providing traceability to industry by apex level calibration of tungsten strip lamps used as transfer standard sources in the significant range of non-contact thermometry. The measurement uncertainty has been evaluated in the calibration from ±1.0 K at 1000 K to ±2.3 K at 2500 K.

We have developed in-house fixed point cells of Co-C and Fe-C metal carbon eutectics for realization using vertical three zone heating furnace, TZF 16/610 procured from CARBOLITE, USA with bottom end closed. The graphite cells have been fabricated from CSIR-NPL workshop. For the accurate realization of the fixed point, it is desired that the zone of the furnace where fixed point cell is placed should be highly stable and uniform to provide homogeneous heating to fixed point cell. By measuring vertical thermal profile of the furnace using the Type-S TC, it was observed that the temperature stability in the middle zone of about 200 mm (100 mm from center) has a stability of better than ±1°C which is adequate to place melting cell of 110 mm height. The cell assembly and the complete equipment is as shown in the Fig 5.25.

Fig. 5.25 Fixed Point Cell assembly and the Measurement Equipment for Metal-carbon Eutectic

Pneumatic Pressure

A new Raman laboratory was established with state of the art equipment and accessories for Raman measurements at high pressures as well as low temperatures from 4K to 450 K.

A new Triple Raman spectrometer was installed in late 2012. The equipment is Horiba Jobin-Yvon, France made, model T64000 equipped with spectra-physics made, stabilite-2017 Ar ion laser. The detectors include a CCD detector as well as TE cooled PMT. The equipment provides high resolution with low wave-number measurements.

In addition a continuous flow Liquid helium cryostat from Janis, model ST-500, was also procured for low temperature phonon mode investigation of strategic materials. The cryostat was procured with a turbo pump for evacuation, a temperature controller for the sample, a 60 litre LHe dewar and a compatible liquid helium transfer line. In

Fig. 5.26 Triple Raman Spectrometer

Fig. 5.27 Microscopy Cryostat

addition, a diamond anvil cell for generating high pressures was also procured.

Ultra High Vacuum section

Fig. 5.28 Multiferroic Tester Installed:

Acoustics, Ultrasonics & Vibration Standards

Set-up for 24-Hrs Noise Monitoring System for Road Traffic Noise and Airport Noise Measurements

Development of measurement technique: A technique for measurement and evaluation of the relative pulse echo sensitivity (S_{rel}) developed and measurements made on 2.25 MHz broad band ultrasonic transducer. Results compared with frequency spectrum of the echo received from back wall of a standard reference block used in ultrasonic non destructive testing (NDT) of materials. The technique can be used for characterization of the ultrasonic transducer.

Set up of New Facility: Radiation Force Balance method uses a microbalance for low power (below 1 Watt) measurement. For higher measuring range and better sensitivity and uncertainty, Mettler Toledo XP-56 micro balance along with Labx-Direct software procured. This upgraded the facility of Primary standard on ultrasonic power measurement. Undertook training and demonstration on this model after installation of the balance.

Calibration facility for ultrasonic equipments like transducers and UFD.

Fluid Flow Measurement Standards

An automatic Water Flow Calibration Standard (i.e. Primary Standard of Flow) of size DN100 was developed in technical collaboration with M/s. Bharti Automation Pvt. Ltd., New Delhi. Presently, performance evaluation and establishment of traceability of this system are being carried out. Figure 5.29 shows the photograph of this new system.

Fig. 5.29 (a) Piping, Weighing Tanks and Support Structures (b) Weighing Tank, Drain Valve and Platform for Calibration of Tank

Fig. 5.29 (c) Flowmeters, flow control valve and current source (4-20 mA) (d) Circuit for automation of diverter and drain valves

Figure Photographs of a New Water Flow Calibration Standard

LF & HF Voltage, Current and Microwave Standards

Establishment of automated Power Ratio Technique for the calibration of lower value attenuators (0.1dB to 10 dB) for frequency range 10 MHz to 18 GHz. The calibration setup has been shown in Fig. 5.30.

Fig. 5.30 Automated Power Ratio Measurement

Extraordinary Research Highlights

Fig. 5.31 Standards of dimension

At NPL-India, external diameter of cylindrical shaped artifacts is measured using a Length Measuring Machine (OPAL 1000). This machine can measure diameter with an uncertainty

0.2 micron. **Pressure and Vacuum Division, Mass and Volume Standards Division** regularly demanding diameter measurement traceability for their cylindrical, spherical artifacts to participate in international inter-comparisons. These inter-comparisons require approximately 20 nm uncertainties for external diameter measurement. National Measurement Institutes e.g. PTB Germany, NPL UK and NIST USA has an expensive and sophisticated facility to measure external diameter with such a low measurement uncertainty.

In Standards of Dimension Division at NPL-India, a series of experiments are carried out to achieve 30 nanometer measurement uncertainties. An innovative measurement setup is fabricated using several components/fixtures from various old machines.

Temperature & Humidity Standards

We have established the high temperature primary standards by realizing silver and copper fixed points by metal-in-graphite blackbody cavities using Photo-electric linear pyrometer, LP4 which has been procured and installed recently. The pyrometer was procured from M/s K.E. Technologies, Germany. The Ag and Cu points were realized in the heat pipe furnace having arrangement for argon gas fusion all around the metal environment

Fig. 5.32 Measurement Set-up of Photoelectric Pyrometer, LP4.

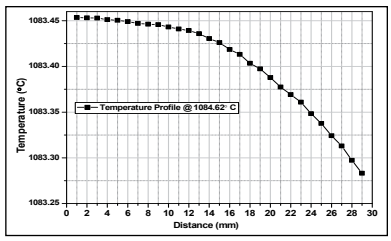
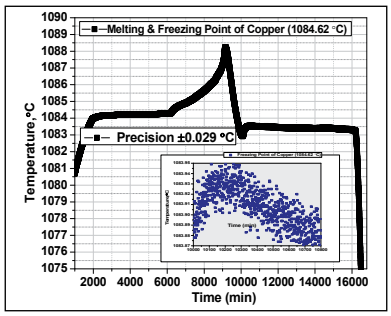


Fig. 5.34 Measured Profile of Blackbody Source at a temperature of 1358 K.



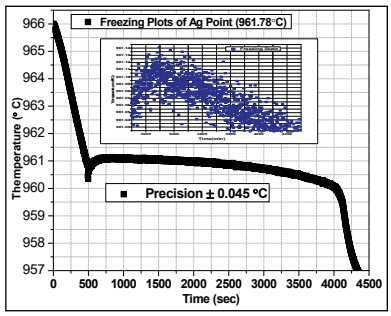


Fig. 5.33 Realization Curves for Ag & Cu Points by Photoelectric Pyrometer, LP4

to avoid the oxidation of Ag or Cu metal. Fig. 5.33 shows the realization of silver and copper along with precision of measurement. By establishing this facility it is now possible to calibrate the transfer standard strip lamps in the laboratory thereby saving a significant amount of calibration money invested on the calibration of these lamps from PTB. Germany.

Optical Radiation Standards

In last few years, the study on spectral switching based information processing (SSBIP) has emerged as an area of great interest for the researchers of science and engineering. Despite some experimental constraints, SSBIP has attracted considerable attention due to its unique features e.g., supporting nature for internal and external control mechanisms at transmission end, information hiding and multi-level information encoding possibilities, compatibility to exploit two popular information encoding techniques namely on-off keying (OOK) and frequency shift keying (FSK) and polychromatic light based fluctuating less free-space optical (FSO) communications in near field as well as in far field. Although the study on spectral switching for realization as a promising technology is still at initial stage and its introduction to FSO community is quite new but sooner a broad-band light (so-called white light laser) based FSO communication becomes feasible, then SSBIP might come out automatically a potential technology for the future requirements. It is evident that polychromatic light based optical networks are more popular these days than laser based optical networks as the former are more

human health friendly, especially in indoor FSO communications.

In our recent investigations, we explored SSBIP in different dimensions. We introduced interference-induced 1×N (1 input N outputs) and spectral switching technique and 1×N×M (1 input and N×M outputs) channel FSO links. The fan-out architecture of SSBIP shown in Fig. 5.35 indicates the spectral switching in the vicinity of dark fringe on interference pattern. This work has potential applications in FSO communications and to design spectral-selective optical interconnects.

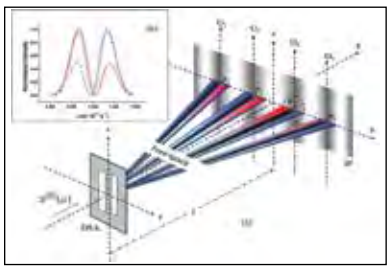


Fig. 5.35 Schematics to show fan-out architecture for interference-induced spectral switching.

Pressure & Vacuum Standards

Pneumatic pressure

In the area of pressure standards, our reference standard NPLI-4 was cross floated against the recently installed large diameter piston gauge with automated mass loader. The obtained results were compared with the traceability data against the ultrasonic interferometer manometer in the low overlapping pressure range. Excellent agreement of less than 2 ppm was achieved in these results which further strengthened our traceability for the zero pressure effective area. In addition, all our secondary standards were recalibrated and their traceability in pressure was reinforced.

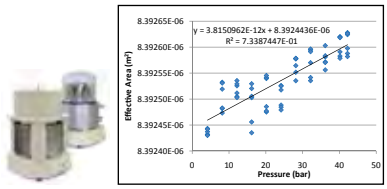


Fig. 5.36 Large diameter piston gauge with automated mass loader

Raman studies

After the recent installation of a new Raman spectrometer, studies have been initiated in the direction of low temperature phonon measurements and investigation of anharmonicity effects. At ambient Raman spectra were recorded for a number of samples which include $BiTe_2$, GaN, LACRA, Cu_2SeO_4, Cu_2ZnSnS_4, Doped LN single crystal, PZT, CZTS etc.

Raman spectra were recorded up to LHe and LN_2 temperatures for Gd_2O_3, Yb_2O_3, Sb_2Te_3, Cu_3SbSe_3, CZTS and CeO_2.

Raman studies at low temperatures

Gd_2O_3 under cryogenic temperature (~4.2 K) monitored through Triple Raman spectrometer. A slight shift in the predominating peak at 300 k with the decrease in temperature was observed. The asymmetric decay of I_3 and I_4 with temperature, consequently the increase of intensity of I_1 and I_2 is due to anharmonicity. The high pressure and the low temperature Raman studies have been correlated to deduce the phonon behavior of these materials. The mode Gruneisen parameters obtained from the shift in Raman frequencies with increasing pressures is used to estimate the quasi harmonic contribution to the phonon frequency distribution at low temperatures i.e due to the lattice contributions.

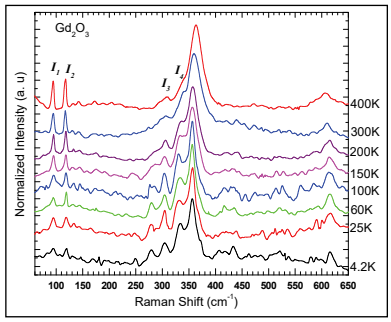


Fig. 5.37 Low temperature Raman study of Gd_2O_3

In addition, temperature dependent Raman studies on Sb_2Te_3, Cu_3SbSe_3 are being carried out as a part of two M.Tech. projects using LN_2. The effects of anharmonicity on the phonon modes were studied and the structural changes observed were analyzed.

Temperature dependent Raman study of Cu_3SbSe_3

Temperature dependent Raman spectra of Cu_3SbSe_3 in the range of 80-440K are shown in Fig 5.38. The 80K spectra show four peaks (A, B, C, and D) at 169.9, 187.5, 208.4 and 229.3 cm^{-1} corresponding to B_{3g}, A_g, A_g, and B_{1g} respectively. The mode

B_{3g} disappears at ~ 300K. The shoulder type peak C at 80K consistently becomes wider and finally merge with B at high temperature region. The modes D shifted towards lower frequency side and disappear at ~ 400K. The most intense mode B shifted towards lower frequency side and broadened with increasing temperature. The low frequency shift and broadening of optical phonon arises due to the quasi-harmonic thermal expansion effect and anharmonic phonon-phonon interaction.

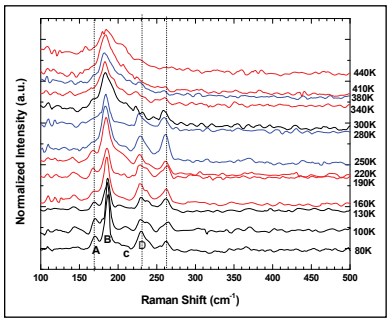


Fig. 5.38 Temperature dependent Raman spectra of Cu_3SbSe_3

High Pressure/Low temperature Raman Study of Yb_2O_3

In a unique effort, the high pressure Raman data was used to elucidate the behavior of the material at very low temperatures. In the case of Yb_2O_3, mode Gruneisen parameter was obtained from the pressure induced shifts in the phonon frequencies and the obtained values were used to estimate the anharmonicity effects in these phonon modes at low temperatures. Fig. 5.39 shows the frequency shift of Tg+Ag mode as a function of temperature.

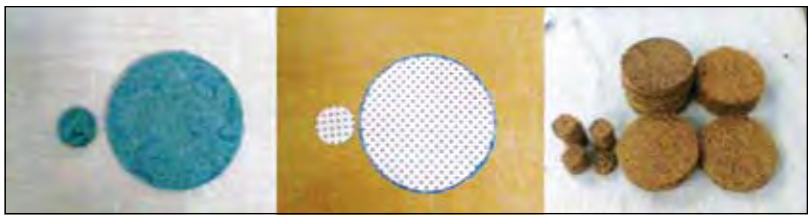


Fig. 5.40 Test samples (a) porous layer; (b) perforated panel; (c) rice husk.

The solid line represents the calculated frequency shift using the following equation and the inset shows the fitting of Tg+Ag mode at 80K using DHO model

$$\omega(T) = \omega_o + (\langle\Delta\omega\rangle)_{latt} + (\langle\Delta\omega\rangle)_{anh}$$

Where, ω_o is the harmonic frequency, which was obtained as 356.8 cm^{-1}, extrapolating the experimental data down to 80K; the quasi-harmonic term $(\langle\Delta\omega\rangle)_{latt}$ accounts for the lattice expansion contribution; and $(\langle\Delta\omega\rangle)_{anh}$ is the intrinsic (true) anharmonic contribution due to cubic and quatric anharmonicities.

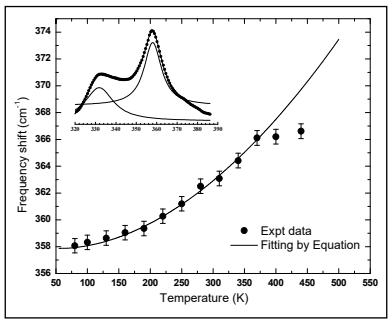


Fig. 5.39 Temperature Raman Study of Yb_2O_3

Acoustics, Ultrasonics & Vibration Standards

Development of New Rice Husk Material as an Absorber

Car boot liners made from woven cotton cloth were used as type of porous layer in the study. This material has been used widely in automotive industry. Perforated plate used was machined with perforation ratio of 0.20, thickness of 1 mm and hole diameter of 2 mm. The samples were tested at the acoustic lab of CSIR-NPL, New Delih, according to IS 8225-1976, Indian standards for sound absorption coefficient. Fig. 5.39 shows the test samples with porous layer, perforated panel and rice husk.

The experimental data indicates that porous layer backing can improve noise absorption coefficient at low and high frequencies with significant increasing. 20 mm thick layer rice husk with porous layer backing exhibit peak value at frequencies range 12500-4000 Hz with maximum value of 0.99 (Fig. 5.41). The experimental results also found that the rice husk with perforated plate gives higher value for lower frequencies range from 1250-2500 Hz. The

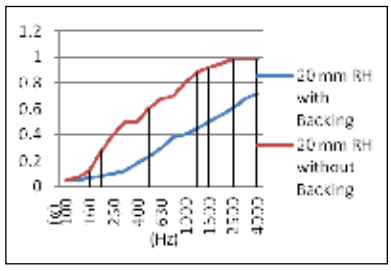


Fig. 5.41 Comparison of sound absorption coefficient versus rice husk, 20 mm thickness, with and without porous layer backing

optimum value for rice husk with perforated panel is around 0.94 for the frequency range 2500-4000 Hz (Fig. 5.42)

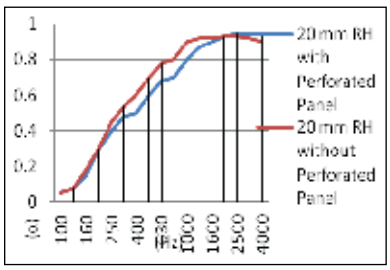


Fig. 5.42 Comparison of sound absorption coefficient of rice husk, 20 mm thickness, with and without perforated panel backin

Transverse motion characteristics of air-bearing shaker used for Primary Vibration Calibration using laser interferometer:

Undesirable shaker characteristics, such as excessive transverse motion and waveform distortion, adversely affect the accelerometer calibration results. Transverse motion limits are required by ISO 16063-11 to be less than 1% for frequencies below 10 Hz, less than 10% for frequencies below 1000 Hz and less than 20% for frequencies below 10 kHz. The transverse motion of the shaker PCB 396C11 causes the SUT (Sensor Under Test) to produce output proportional to the product of the accelerometer transverse sensitivity and the transverse motion of the shaker platform. Coupling of shakers transverse motion & accelerometer transverse sensitivity thus creates an error in sensitivity determination. The cross-axis measurement is quantified using a tri-axial accelerometer as shown in Fig 5.43. These investigations have been instrumental in characterizing the transverse motion characteristics and determination of uncertainty component in measuring the charge/voltage sensitivity of accelerometer.

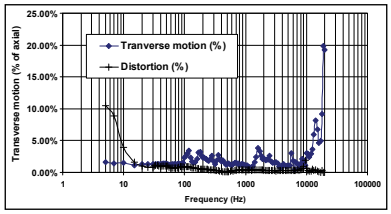


Fig. 5.43 Transverse motion (% of axial) & distortion measurement of air-bearing shaker of National Primary Vibration Calibration Standard

Underwater object detection device to be used by divers

Successfully developed underwater object detection device to be used by divers (Fig 5.44). The device has been tested for its functionality to detect objects up to the range of 130 meters with resolution of 12 mm. The developed system has many more improved features including distance variable gain for better detection.

Aeronautical Development Agency (ADA) Project: Certification of

Fig. 5.44 Developed Circuit for underwater object detection and its testing at Chennai.

blocks with flat bottom hole (FBH) used for certifying light combat aircraft for airworthiness. Number of Blocks with Flat bottom hole of diameter 1.2 mm and cylindrical diameter 50.8 mm received and calibrated for their ultrasonic response and dimensional accuracy.

Societal Benefits

Legal Metrology

Visit of the Officials of Legal Metrology under training IILM, Ranchi. on 13th July /2012 at 9.30AM.: CSIR-NPL arranged this mini training program with Apex

Fig. 5.45 Visit of the Officials of Legal Metrology under training IILM, Ranchi at CSIR-NPL

Level Standards and Industrial Metrology Division (ALSIM). The visits consists of two parts one 4 lectures by the scientists of CSIR-NPL. This time it was inaugurated by Dr. A.K. Bandyopadhyay talked about ALSIM, followed by Mr. Anil Kumar (Head, Mass Standards), Dr. K.P. Chaudhary (Head, Standards of Dimension) and Dr. Sanjay Yadav. (Pressure Standards). After the talks a visit was arranged in following specific area of interest: a) Demonstration on National Prototypes, b) Exhibitions of hierarchy of standards, c) Mass Measurement, d) Volume measurement and e) Length measurement.

Participation of BIPM/APMP activities:

Participation in the 8th meeting of the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV) (13 and 14 June 2012), BIPM (France)

The Consultative Committee of Acoustics, Ultrasound and Vibration met from 13 to 14 June 2012 and Dr. Mahavir Singh of NPL attended the meeting as NPL representative. The meeting started by following oral presentations of specific topics such as "Application of optics to acoustical metrology", "Calibrations for underwater sound level measurements" and "Development of characterisation methods of therapeutic ultrasound" concentrated on current trends in the AUV field. The work issued by the associated working groups was reported, activities carried out in the RMOs and the NMIs were communicated and particular questions concerning present and future planned key comparisons were discussed. In particular, the main issues of the outcome of the CGPM ad hoc working group were summarized, and the needs for a strategic planning process were emphasized. The essential actions and decisions arising from the 8th meeting of CCAUV 2012 can be obtained in the BIPM.org web page.

Fig. 5.46 Participation in the 8th meeting of the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV), BIPM (France)

Participation of the 27th Asia Pacific Metrology Program (APMP) – Developing Economy Committee (DEC), Technical Committees (TC), Executive Committee (EC) Meetings and General Assembly

Traditional areas of industry becoming more complex requiring broader measurement ranges and lower uncertainties, new areas of technology e.g. nano technology or biotechnology, areas in which of metrology is increasingly recognised e.g. chemistry, clinical analysis, food safety are critical. In order to discuss these critical issues among the NMI, APMP is conducting DEC, TC, EC meetings and finally, General Assembly (GA). As the division is responsible to establish, maintain and continually upgrade the National Standards of measurements related to above said activities and disseminate the standards by providing the apex level calibration services to the industry and institutions of the country and thus ensures the traceability to measurements made by these parameters, it is mandatory that CSIR-NPL should attend these meetings. A delegation of five scientists participated in the these meetings at Wellington, New Zealand from 25th – 30th November, 2012 and discussed the various issues like international intercomparison,

the calibration and measurement capabilities (CMCs) of the various groups. As a result, many CMCs related issues are sorted out and are available on BIPM website (www.bipm.org).

Fig. 5.47 Participation in the Technical Committee of Quality System TCQS-2012, New Zealand

Fig. 5.48 Participation in the General Assembly of APMP-2012, New Zealand [Prof. Barry Inglish, President, CIPM/BIPM, Dr. Robert Kaarls, Secretary General, CIPM, Prof. Yu Yudong, Chairperson, APMP, Dr. Tim Armstrong, Treasurer, APMP, Dr. A. Sengupta, CSIR-NPL etc.]

क्वान्टम परिघटना एवं अनुप्रयोग

Quantum Phenomena and Applications

क्वान्टम परिघटना एवं अनुप्रयोग

क्वांटम परिघटना एवं अनुप्रयोग प्रभाग (क्यू पी ए) में तनु फिल्म तथा उपकरण संविरचन तकनीक, क्वांटम ऑप्टिक्स के अग्रणी क्षेत्रों में अनुसंधान हेतु नए अति चालक पदार्थों के विकास से संबंधित अनुसंधान कार्य किए जाते हैं।

स्पंदित लेज़र निक्षेपण (पी एल डी) समूह द्वारा मैग्नेट्रॉन कण क्षेपण (डी सी तथा आर एफ दोनों), ऊष्मीय वाष्पीकरण, फोटो लिथोग्राफी, आर्गन आयन चूर्णन, आदि जैसे व्यापक रेंज के तनु फिल्म तथा उपकरण संविरचन तकनीकों को प्रयोग में लाया जाता है। इस समूह द्वारा किए जा रहे एक व्यापक अनुसंधान क्रियाकलाप के अंतर्गत संक्रमण धातु ऑक्साइड विषम संरचनाओं, स्पिनट्रोनिक्स और अति चालक/लौह चुंबक विषम संरचनाओं पर ध्यान केंद्रित किया जाता है। विभिन्न तनु फिल्म विषम संरचनाओं तथा उपकरणों जिनमें जोसेफसन जंक्शन, अति चालक एकल फोटोन संसूचक का संविरचन शामिल है, से संबंधित कार्य किए जाते हैं जिनमें तात्विक और साथ ही Nb, NbN, VN जैसे नाइट्राइड अति चालक पदार्थों को प्रयोग में लाया जाता है।

अति चालक पदार्थ समूह ने BiS_2 आधारित अति चालकों को विकसित करने के कार्य में उल्लेखनीय योगदान दिया। Fe आधारित निक्टाइड अति चालकों के संबंध में मौके पर मादन प्रभाव का अध्ययन करने, MgB_2 पदार्थ के गुणों पर (नैनो) योजकों के प्रभाव के अध्ययन का कार्य जारी रखा गया।

उच्च विभेदन चुंबकीकरण का विलक्षण निर्धारित करने स्क्विड आधारित ac सुग्राहयता तथा T = 1.8-400 K और B = 0-7 T के बीच प्रतिरोधकता ज्ञात करने के लिए एक स्क्विड आधारित 7 टेस्ला मैग्नेटोमीटर को संस्थापित किया गया।

नैनो स्केल मापन सहित विमीय मापन की अनुमार्गणीयता का प्रसार 633 nm पर आयोडीन फ्रीक्वेंसी स्थिरीकृत लेज़र प्रचालन की सहायता से जारी रखा गया। प्रोग्रामनीय जोसेफ वोल्टता मानक का बेहतर स्थायित्व तथा पुनरुत्पादकता हेतु पुनः अभिलक्षण निर्धारण किया गया है। एन पी एल में एल एफ, एच एफ और डी सी मानक समूह के बैंक ऑफ जेनर (वोल्टता हेतु एन पी एल के राष्ट्रीय मानक) का अंशांकन किया गया तथा "वोल्ट" मात्रक की अनुमार्गणीयता के अनुरक्षण हेतु प्रमाणपत्र जारी किए गए।

विवर्तित स्टोकास्टिक (प्रसंभाव्य) विद्युत चुंबकीय किरणपुंजों (एस ई बी) की स्पेक्ट्रमी विसंगतियों पर ध्रुवीकरण के प्रभाव के संबंध में सैद्धांतिक तथा प्रायोगिक अध्ययन के परिणाम सूचित किए गए हैं। प्रकाश संसूचकों की निरपेक्ष क्वांटम दक्षता के मापन हेतु एस पी डी सी की परिघटना पर आधारित एक सुविधा तथा क्वांटम सूचना प्रक्रमण में उनके अनुप्रयोग हेतु एक आधारभूत क्वांटम प्रकाशीय अध्ययन स्थापित किया गया है। संक्रामक ऊतकों का विश्लेषण करने तथा उनके सामान्य स्वतंत्र क्रियाकलापों से जैव रासायनिक विचलनों के मापन के लिए फूरिये रूपांतरण अवरक्त स्पेक्ट्रममापी तकनीक को प्रयोग में लाया जा रहा है। हम कुछ महत्त्वपूर्ण अवरक्त मार्करों की पहचान करने में सफल हुए हैं जो कोशिका की उपापचयी अवस्था से संबंधित हैं। डी एन ए तथा विभिन्न ऑलिगो न्यूक्लियोटाइडों के साथ कैंसर–रोधी औषधियों की अन्योन्यक्रिया की व्याख्या करने के प्रयास किए गए हैं।

इलेक्ट्रॉनिक्स तथा यंत्रीकरण प्रकोष्ठ ने 1 T स्पंद क्षेत्र चुंबक का एक प्रोटोटाइप तथा अत्युच्च गति से डेटा अधिग्रहण प्रणाली विकसित की है। इनका सफलतापूर्वक परीक्षण किया जा चुका है। स्पंद क्षेत्र चुंबक का अभिकल्प तैयार करने से संबंधित एक कार्यक्रम भी शुरू किया गया है तथा ज्ञात स्पंद फील्ड चुंबक के संबंध में प्राप्त परिणामों से तुलना करके इसका परीक्षण भी किया गया है।

Quantum Phenomena and Applications

In the division of Quantum Phenomena and Applications (QPA), the research interest ranges from thin film and device fabrication techniques, development of new superconducting materials to research in forefront areas of quantum optics.

The Pulsed Laser Deposition (PLD) group employs a wide range of thin film and device fabrication techniques such as Magnetron Sputtering (both DC and RF), Thermal Evaporation, Photo-lithography, Argon Ion Milling etc. A broad research activity of this group focuses on Transition metal oxide heterostructures, Spintronics and Superconductor/Ferromagnet Heterostructures. Fabrication of various thin-film heterostructures and devices, including Josephson junctions, superconducting single photon detector utilizing elemental as well as nitride superconductors such as Nb, NbN, VN.

Superconducting materials group contributed significantly to the new BiS_2 based superconductors. The on site doping effects were studied for Fe based pnictide superconductors. Studies on the effect of (nano) additives on the properties of MgB_2 material was continued.

A SQUID based 7 Tesla Magnetometer was installed to characterize high resolution magnetization, squid-based ac susceptibility and resistivity between T = 1.8 – 400 K and B = 0 – 7 T.

Dissemination of traceability, to dimensional measurement including nanoscale measurements, continued with the help of iodine frequency stabilized laser operation at 633nm. The Programmable Josephson Voltage Standard has been further characterized for better stability and reproducibility. The Bank of Zeners (National Standards of NPL for voltage) of LF, HF and DC standard group at NPL were calibrated and certificates were issued to maintain the traceability of unit 'volt'.

Theoretical and experimental studies are reported on the effect of polarization on spectral anomalies of diffracted stochastic electromagnetic beams (SEB). A facility based on the phenomena of SPDC for measurement of absolute quantum efficiency of photo-detectors and basic quantum optical studies for their application in quantum information processing was established. Fourier transform infrared spectroscopy technique was used to analyze malignant tissue and measure biochemical deviations from their normal forebears. We were able to identify some important IR markers, which are related to metabolic state of a cell. Attempts have been made to delineate the interaction mechanism of anticancer drugs with DNA and different oligonucleotides.

Electronics and Instrumentation Cell has developed a prototype of 1T pulse field magnet and very high speed data acquisition system. They have been successfully tested. A program for designing of pulse field magnet has also been developed and tested by comparing the results with the known pulse field magnet.

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D 06.01 Josephson Junctions and Single Electron Tunneling Physics

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Dr Veerpal Singh Awana
Ms Santhya Malikar Patel

D 06.02 Quantum Transport in Thin Film Heterostructures

Prof R C Budhani
Dr Vijay Kumar Gumber
Dr Hari Krishna Singh
Dr (Ms) Anjana Dogra
Dr Parveen Siwach

D 06.03 Nanoscale Measurements

Dr (Ms) Rina Sharma
Dr Vijay Kr. Toutam
Dr Ashok Kumar

D 06.04 Quantum Optics and Photon Physics

Dr Hem Chandra Kandpal
Dr Ranjana Mehrotra
Sh Virendra Kumar Jaiswal
Dr Parag Sharma

D 06.05 Superconductivity : Materials and Dissipation Physics

Prof R C Budhani
Dr (Ms) P L Upadhyay
Dr Anurag Gupta
Sh Rajendra Singh Meena
Dr Sudhir Husale
Dr Rajib Kr. Rakshit

D 06.06 Electronics & Instrumentation Cell

Dr Tushya Kumar Saxena
Ms Manju Singh
Ms Priyanka Jain
Ms Poonam Sethi Bist

Programmable Josephson Voltage Standard

The Programmable Josephson Voltage Standard, established at NPLI in the month of March 2012, has been further characterized for its optimal functioning to disseminate 'Unit' Volt at par to international level. This optimization in the characterization of the system has enabled/ensure us to operate the system consistently and with better stability and reproducibility. It shows the better and uniform margin around the 0 mA dither current. The Bank of Zeners (National Standards of NPL for voltage) of LF, HF and DC standard group at NPL were calibrated and certificates were issued to maintain the traceability. The uncertainty reported were ± 350 nV at 10 V and ± 200 nV at 1.018 V, inclusive of the noise of the Zeners.

Quantum Transport in Thin Film Hetreostructures

Transition metal oxide heterostructures

Focus is on engineering the thin film heterostructures of pure and doped $LaAlO_3/SrTiO_3$ and $LaTiO_3/SrTiO_3$ using Pulsed Laser deposition (PLD) using in-situ reflection high-energy diffraction (RHEED) gun that allows to monitor atomic layer-by-atomic layer growth of epitaxial film. Focus is also on the theoretical calculations of electronic states and its interplay with various properties of transition metal interfaces using Density Function Theory (DFT).

Superconducting – Ferromagnetic Heterostructures

Fabrication of various thin-film heterostructures and devices, including Josephson junctions, superconducting single photon

Fig. 6.1 : Photograph of the 'Programmable Josephson Voltage Standard' (PJVS) at 10 Volt at NPL-India

detector utilizing elemental as well as nitride superconductors such as Nb, NbN, VN.

Development of various magnetic tunnel junctions (MTJ) using magnetic alloys such as Co_2MnSi, Co_2FeSi, CoFeB and also elemental ferromagnets such as Co, Fe etc.

Nanoscale Measurement

Resistive switching random access memory (RAM) studies of Lanthanum Titanate ($LaTiO_3$)

$LaTiO_3$ films sandwiched between Pt and Ag, Au, bottom and top electrodes were studied under Conductive Atomic force microscopy and probe station for resistive switching behaviour.

Pin hole dominated electrical transport across $LaTiO_3/SrTiO_3$ polar hetero-junction

Electrode area dependent transport characteristics across LTO for Au/LTO/2DEG@STO were studied using CAFM. Gold electrode array was deposited on LTO/STO interface. 2DEG formed at LTO/STO interface was taken as the bottom electrode, forming metal-insulator-metal structure (MIM). The experiment was done for four different diameters of electrodes say 400, 200, 50 and 5 μm respectively.

VAMAS TWA-2 International Round Robin Test: Graphene layer number characterization by Kelvin Probe Force Microscopy (KPFM)

Graphene layers supported on well-characterized substrates are proposed as suitable CRMs for the quantification of KPFM for the quantitative measurement of CPD distribution.

Evaluation of depth distribution and characterization of nanoscale Ta/Si multilayer thin film structures

Si/Ta multilayer samples were prepared on a Silicon (100) single crystal wafer using double e-beam evaporation technique. A Kelvin probe force microscope was used for making a comparative study on the thickness of Si and Ta multi layers with other techniques like X-ray reflectivity (XRR) and Secondary ion mass spectroscopy (SIMS).

Quantum Optics and Photon Physics

In recent years, a lot of research has shown that the spectral degree of coherence and spectral degree of polarization may change on propagation of an electromagnetic Gaussian Schell model beam in free space and also in different media. The recently developed Wolf's unified theory of coherence and polarization provides an intimate relationship between coherence and polarization properties of an electromagnetic beam and can predict changes in the coherence and polarization properties of the beam as it propagates.

we have verified experimentally the theoretical prediction, that in general the degree of polarization of a Gaussian Schell model beam doesn't change on propagation in free space if the spectral correlation lengths δ_{xx}, δ_{yy}, δ_{xy} are equal to each other and the beam width parameters $\sigma_x=\sigma_y$. It is shown that the magnitudes of the four Stokes parameters at the center of the beam change with the distance of propagation but the magnitude of the normalized Stokes parameters and the degree of polarization remain unchanged. The study might be helpful in the area of free space optical communication (FSO) technology in which various polarization shift keying (PolSK) modulation schemes are used.

Theoretical and experimental studies are reported on the effect of polarization on spectral anomalies of diffracted stochastic electromagnetic beams (SEB). To the best of our knowledge we are the first to report experimental results that show the effect of the degree of polarization on spectral anomalies in diffracted SEB. The study might be useful in understanding the spectral behaviour of SEB near phase singularities. Moreover, it might provide a sophisticated control mechanism for spectral switching.

A facility for absolute quantum efficiency measurement of photo-detectors using SPDC is established at NPL India. KDP, BBO and lithium iodate ($LiIO_3$) nonlinear crystals respectively are used to create a pair of entangled photons, using high power CW Ar^+ ion laser. Entangled photons are detected using avalanche photodiodes

and their correlation is studied using photon correlator.

Recently, SPDC based absolute quantum efficiency measurement facility is extended for the wavelength 810 nm. Facility for generation of polarization entangled photon pairs at 810 nm based on SPDC, for the basic quantum optical studies and their application in quantum information was also established.

Fourier Transform IR Spectroscopy

Fourier transform infrared spectroscopy is potentially a powerful analytical method for identifying the spectral properties of biological tissues. It is a fast and reliable tool for distinguishing between normal and cancerous tissues without the need for laborious sampling procedures. Normal and malignant breast tissue samples from two hundred and eight patients of different age group were collected from Max super specialty hospital, New Delhi and analyzed. To characterize differences between the normal and cancerous tissue, specific regions of the spectra were analyzed to study variations in the levels of metabolites. The malignant tissue showed appreciable biochemical deviations from their normal forebears in all the cases. We were able to identify some important IR markers, which are related to metabolic state of a cell.

Amsacrine and carboplatin are two important anticancer drugs, which are used to treat different types of cancers. The present work is an attempt to delineate the interaction mechanism of these two anticancer drugs with DNA and different oligonucleotides, using spectroscopic techniques. The spectroscopic studies demonstrate that these drugs bind with DNA in entirely different ways. Dual mode of binding (intercalation and minor groove) is observed in amsacrine-DNA interaction whereas intrastrand cross-linked DNA adducts are formed in platination mechanism of carboplatin. Binding of these drugs with DNA results in conformational variation in DNA at local level. These structural and conformational variations in DNA are of high importance and play a major role in cytotoxicity mechanisms of these drugs. These results are vital in the discovery of the next generation of DNA-binding anticancer drugs.

The ability of a drug substance to form more than one crystalline form is called polymorphism. Different polymorphs possess different physiochemical properties, which affect solubility, dissolution, adsorption, melting point and stability, which in turn affect the bioavailability of the drug. We studied the hydration process of Ritonavir Sulphate, an anti HIV drug, using Raman spectroscopy and Atomic Force Microscopy. In the hydration process, the commercial anhydrous form of Ritonavir Sulphate was exposed to water atmosphere during different time intervals. After exposing the drug to different relative humidity Raman Spectra AFM image of the drug was collected and the results were compared.

Superconductivity: Materials and Dissipation Physics

The installation of "SQUID based 7 Tesla Magnetometer" at NPL was completed in May 2012. Extensive measurements of high resolution magnetization, squid-based ac susceptibility and resistivity between T = 1.8 – 400 K and B = 0 – 7 T were carried out. More than 200 different samples, typically (nano) powders, tailored thin films/ heterostructres, nano-wires and rings, single crystals and bulk magnetic and/or superconducting materials were measured.

A custom built setup capable of measuring both thermoelectric power (TEP) and resistivity of thin plates and films was tested to work in a temperature range 77 – 300 K. Variety of samples like Cu, Mo, $YBa_2Cu_3O_7$ superconductor and Bi_2Te_3 in thin plate and film forms were employed. The system can be easily adapted to lower temperatures down to 4.2 K.

Effect of excess Mg (5 wt.%) and nano-additives Ag (3 wt.%) and SiC (10 wt.%) on

the superconducting properties of weakly connected bulk ex-situ MgB_2 was studied. It was found that additives have varying effects on the critical current density, whereas, several other properties like microstructure, superconducting onsets, thermopower and the parallel upper critical field etc. stay largely unaffected. We tried to understand these results quantitatively in terms of changes in connectivity, pinning and anisotropy driven percolation in the samples.

During the period substantial contribution was made towards discovery of new BiS_2 based superconductor $Bi_4O_4S_3$ (J. Am. Chem. Soc 134, 16504 (2012). This work is highlighted by RSC (Royal society of chemistry).

Major Facilities created/ developed

Ebeam lithography facility and fabrication of ferromagnetic nano rings

- **Extra modules for AFM analysis** a). Conductive AFM for I-V charateization, patterning and conductivity mapping. b). Scanning capacitance microscopy for charge determination and concentration studies in semiconductors.
- **Keithley 2612A Source measure unit for MIM junctions and FET characterization.**
- **AFM Lab in Room No: 17, TEC Building.**

Ion Milling

Wire Bonder

Cryogenic Micro Manipulated Probe station

Fig 6.2a. Facility for the ebeam pattern writing

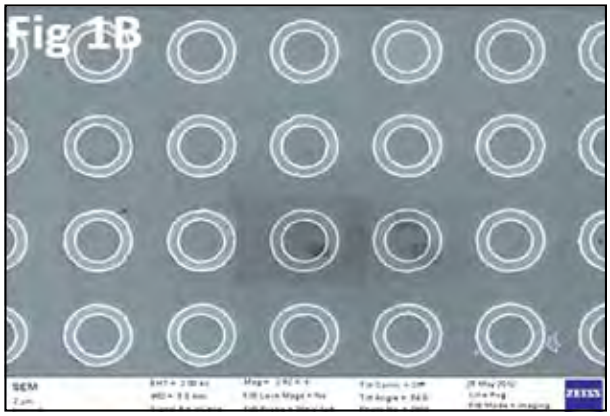
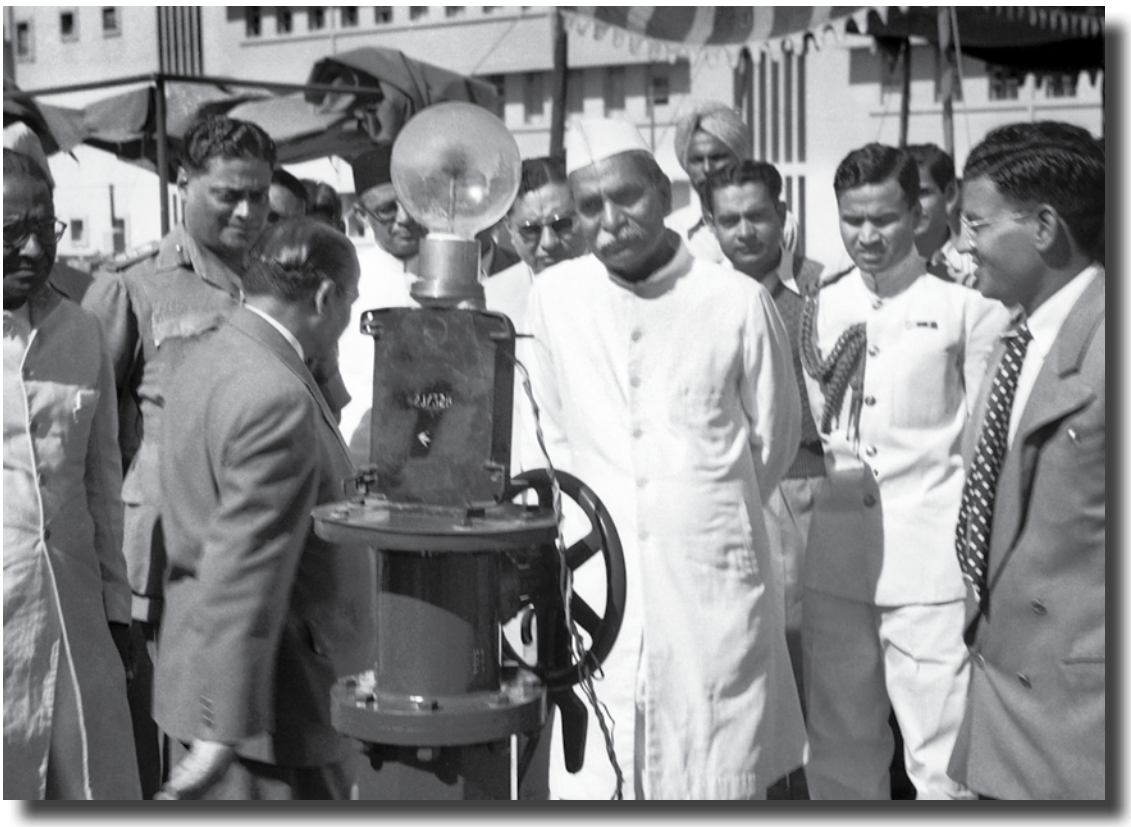


Fig. 6.2b: Nanofabrication of ferromagnetic nanorings

अतीत के सुनहरे पल ...



Dr Rajendra Prasad
Visiting NPL Exhibition

परिष्कृत और विश्लेषणात्मक उपकरण

Sophisticated and Analytical Instruments

परिष्कृत और विश्लेषणात्मक उपकरण

पदार्थ, जो अनुसंधान तथा अनुप्रयोगों हेतु सभी आधुनिक प्रौद्योगिकियों के संरचनात्मक घटक हैं, कड़ी विनिर्दिष्टियों के अनुरूप होने चाहिए। पदार्थ का संघटन, शुद्धता संरचना तथा क्रिस्टलीय पूर्णता पदार्थ के गुणों को नियंत्रित करने वाले बुनियादी अभिलक्षण हैं। अभिलक्षणन पदार्थ की सभी तीनों अवस्थाओं अर्थात ठोस अवस्था, द्रव अवस्था और गैसीय अवस्था से संबंधित है। इन कार्यों को करने के लिए अपेक्षित विशेषज्ञता अत्यधिक उन्नत है तथा इसके लिए आवश्यक सुविधाएं अत्यधिक परिष्कृत हैं।

राष्ट्रीय भौतिक प्रयोगशाला में स्थित परिष्कृत और विश्लेषणात्मक उपकरण प्रभाग पदार्थ की अकारिकी, रासायनिक संघटन, शुद्धता, संरचना (त्रुटियों सहित), क्रिस्टलीय पूर्णता से संबंधित अभिलक्षणों को ज्ञात करने एवं ठोस पृष्ठीय तनु परतों तथा अंतरापृष्ठों के अध्ययन हेतु उच्च कोटि की सुविधाओं से युक्त है। यह इस प्रयोगशाला में उपलब्ध कराई गई एक मुख्य सुविधा है।

एक उल्लेखनीय तथ्य यह है कि इन सुविधाओं के अनुरक्षण तथा विकास के कार्य में जुड़े वैज्ञानिक न केवल संगठन के अन्य प्रभागों को ये अभिलक्षणन सुविधाएं उपलब्ध करा रहे हैं बल्कि वे उन्नत क्षेत्रों में अपने स्वयं के अनुसंधान कार्यों में भी काफी सक्रियता से जुटे हुए हैं जिसके कारण यह प्रभाग इस क्षेत्र में हुई नवीनतम प्रगतियों से अवगत बना रहता है तथा साथ ही नई जानकारियों के सृजन में भी अपना महत्त्वपूर्ण योगदान देता है। इस प्रभाग में एक्स–किरण विश्लेषण, इलेक्ट्रॉन तथा आयन सूक्ष्मदर्शी, ई पी आर तथा आई आर स्पेक्ट्रमविज्ञान एवं विश्लेषणात्मक रसायन विज्ञान के क्षेत्र में कार्य कर रहे समर्पित समूह शामिल हैं।

Sophisticated and Analytical Instruments

Materials, the building blocks of all modern technologies for research as well as for applications have to conform to strict specifications. Basic material characteristics which control material properties are composition, purity, structure and crystallographic perfection. Characterization is concerned with all the three phases mainly solid, liquid and gases. The expertise needed to carry out these tasks are very advanced and the facilities required are very sophisticated.

The Sophisticated and Analytical Instuments Division at NPL houses high quality facilities for characterization of materials for morphology, chemical composition, purity, structure (including defects), crystallographic perfection and the study of solid surface thin films and interfaces. This is the central facility for the laboratory

It is worth mentioning that scientist involved in the maintenance and development of such facilities are not only providing these characterization facilities to other groups of the organization but are very actively engaged in their own research programe in advanced areas thus enabling the group to remain close to the latest development in the field and to contribute towards generation of knowledge.

The division comprises of dedicated groups working in the field of X-Ray Analysis, Electron and Ion Microscopy, EPR Spectroscopy and Analytical Chemistry.

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X-ray Analysis

Crystal Growth and X-ray Characterization of advanced materials

Due to stringent properties of modern devices, the composition, purity, crystal structure, and crystalline perfection including defects and interfaces are to be evaluated very accurately. X-ray methods have been well proven for these studies because of their accurate, non-destructive and convenient nature. The X-ray analysis group at NPL has variety of sophisticated X-ray analysis techniques namely: (i) X-ray florescence spectrometer for the elemental analysis for wide variety of elements with atomic numbers ranging from 5 to 92 either in liquid or solid form, (ii) Powder X-ray diffractometer for structural and phase analysis of crystalline materials either in the form of polycrystals or thin films, (iii) a double crystal X-ray diffractometer specially meant for X-ray topography to see pictorially the macroscopic deviation of the structure for large size single crystals/ wafers/thin films, (iv) a high-

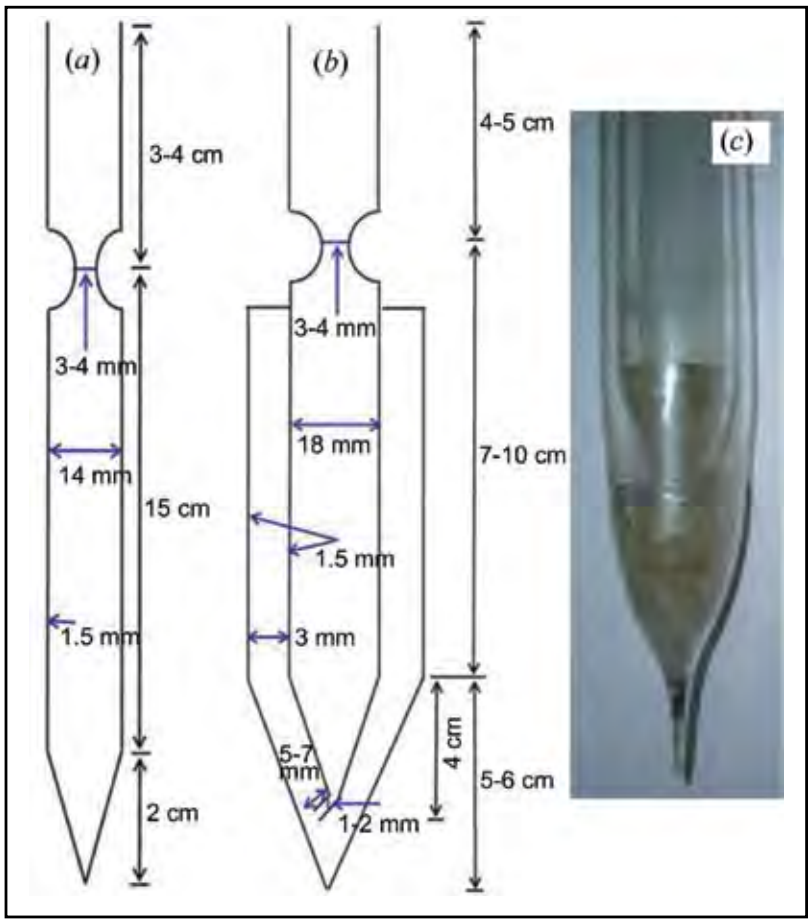


Fig. 7.1 Schematics of the ampoules: (a) single wall and (b) double wall. (c) A double-wall grown BMZ single crystal within the ampoule.

resolution X-ray diffractometer cum reflectometer specially established for characterization of nano-epitaxial or amorphous films, quantum structures and their devices like light emitting devices etc. for determination of various parameters like composition, thickness, roughness of surfaces and interfaces and (v) an in-house developed state-of-the art level multicrystal X-ray diffractometer for high-resolution XRD, diffuse X-ray scattering, crystallographic orientation, curvature measurements to get the full understanding about the structural perfection at microscopic level in a non-destructive way. This section is also having variety of bulk single crystal growth systems by melt and solution methods and involved in the growth of variety of technologically important single crystals like pure and/ or doped LN, KDP, BMZ, ZTS, LA, LAP, LAM, GPI, ninhydrin etc. The current major activities are to characterize GaN based LED devices for solid state lighting and to develop powder XRD Certified Reference Materials (CRMs) as part of the CSIR Network Projects like NWP-025, NWP-045 and Measurement in Science & Technology (MIST) and to grow topological and multiferroic single crystals for energy conversion/ saving and sensor applications.

In this financial year along with Ph.D. students and collaborators, this group has been achieved a remarkable R&D output, which is published in 53 SCI journals with high impact factors (five papers have IF > 4). On the basis of citations, in the recent book of "70 years of outstanding scientific contributions of CSIR", released by CSIR on 26th Sept. 2012, two of the articles published by this group are listed in the top 70 outstanding scientific contributions. A few of the significant published investigations in the current financial year are described briefly in the following.

- Good quality benzimidazole (BMZ) single crystals were successfully grown by the vertical Bridgman technique (VBT). The unavoidable thermal-induced structural grain boundaries formed in the normal VBT growth of these crystals with low melting point were controlled by using a double-wall ampoule. The grown single crystals were subjected to high-resolution X-ray diffraction (HRXRD) to assess their crystallinity. Ref.: J. Appl. Cryst.46 (2013)276-8, IF=5.15.
- Single crystals of glycine phosphite (GPI), a potential ferroelectric material, doped with rare earth metal ions (Ce, Nd and La) were grown from aqueous solution by employing the solvent evaporation and slow cooling methods. Crystalline perfection of doped GPI crystals was determined by HRXRD. Influence of the dopants on the optical properties of the material was determined. Paraelectric to ferroelectric transition temperature (Tc) of doped GPI crystals were identified using DSC measurements. Piezoelectric charge coefficient d_{33} was measured for pure and doped GPI crystals. Mechanical and ferroelectric properties of doped crystals were found to be improved with doping of rare earth metals. Ref.: J, Cryst. Growth 362 (2013) 343–348.
- Single crystal growth of ninhydrin by unidirectional Sankaranarayanan Ramasamy (SR) method by using a glass ampoule for nonlinear optical applications. The good quality seed crystal has been prepared by conventional solution growth technique using double distilled water as the solvent. The lattice dimension of the grown specimen was identified from the powder X-ray diffraction analysis and found that it crystallized in monoclinic system with non-centrosymmetric space group $P2_1$.

  CrystEngComm, 15 (2013), 2127-2132. (IF=4.1)
- The effect of dopants,

Division 7

namely s-, p-, d- and f-block elements (Mg, Sb, Pd and La) on the growth process, crystalline perfection, NLO properties etc. of KDP crystals grown by the slow evaporation solution growth technique has been systematically investigated. The HRXRD studies reveal many interesting features on the ability of accommodating the dopants by the crystalline matrix. The second harmonic generation (SHG) efficiency is enhanced considerably when the concentration of the dopant is low while depressed activity is observed with poor crystalline perfection at high concentrations irrespective of the nature of the dopants. CrystEngComm, 14 (2012), 3813-3819. (IF=4.1)

- The effect on crystalline perfection, second harmonic generation (SHG) efficiency, optical transparency and mechanical properties due to Mn(II) doping in KDP single crystals grown by slow evaporation solution technique by adding different quantities of $MnCl_2$ in the solution has been investigated. The influence of Mn(II) doping on the crystalline perfection by HRXRD revealed that the grown crystals could accommodate Mn(II) in the interstitial positions of the crystalline matrix of KDP only up to some critical concentration (1 mol%), and above this NLO properties also deteriorated along with crystalline perfection. Applied Physics A, (2012) Materials Science & Processing. DOI 10.1007/s00339-012-6773-1.

- A large (20 mm diameter and 80 mm length) single crystal of l-arginine phosphate monohydrate (LAP) has been grown for the first time by the unidirectional Sankaranarayanan–Ramasamy method. HRXRD study reveal that the quality of the grown single crystal is quite good and the indepth studies along different directions show that the crystal contains a low density of edge-type dislocations formed along the growth direction. The thermal stability, hardness and dielectric studies were carried out and found that that the grown bulk single crystal is suitable for device applications. J. Appl. Cryst. 45(2012) 679–685 (IF=5.15).

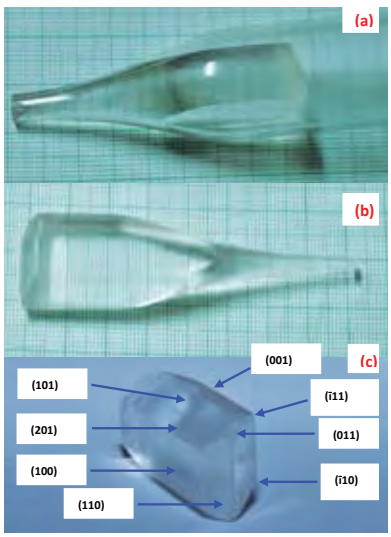


Fig. 7.2 LAP single crystal: (a) inside, (b) outside of the SR ampoule and (c) hkl indexing of the naturally grown facets.

- A multilayer thin film structure of ten alternate Ta and Si layers with approximately 18 nm thickness for the combined (Ta+Si) layer, was evaluated to explore the individual layer thickness and the interface mixing behavior using different surface characterization techniques like Time-of-Flight Secondary Ion Mass Spectrometry (TOFSIMS), X-ray Reflectometry (XRR) and Kelvin Probe Force Microscopy (KPFM). These results were compared with measurements performed earlier using cross section Transmission Electron Microscopy (TEM). The XRR observations however reveal better agreement with the cross section TEM data and the results are published in Thin Solid Films 520 (2012) 6409–6414.

- The $Sm_{0.5}Sr_{0.5}MnO_3$ thin films deposited by DC magnetron sputtering on $LaAlO_3$ (LAO) and $SrTiO_3$ (STO) substrates were characterized. The film on LAO, which is under compressive strain, undergoes paramagnetic–

ferromagnetic (PM–FM) transition at TC ~116 K and shows insulator-metal transition (IMT) at T_{IM} ~115 K. The film on STO is under tensile strain and has TC ~112 K; and shows IMT at T_{IM} ~110 K. The structure/microstructure was characterized by high resolution X-ray diffraction rocking curve (θ-2θ and ω-scan) and the results are published in Appl. Phys. Let. 102 (2013) 032402 (IF=3.844).

AcSIR

The Division is also actively involved in AcSIR. A Course # Eng(NPL)-2-873 entitled "Advanced Materials Characterization Techniques" for the Second Batch of PGRPE on Advanced Materials Physics & Engineering is successfully taught with six practicals. The theme of the course is "An advanced level introduction on characterization techniques for the analysis of composition, purity and structure including defects, surface and interface analysis." The course contains twelve X-ray related techniques and 12 other techniques along with their basic theory and analysis of the results.

Scientific Support and R&D Collaborations: This group is actively involved in providing scientific support to various groups of NPL and various outside laboratories through R&D collaborations by characterizing variety of samples by in-house developed multicrystal X-ray diffractometer, Bruker AXS D8 Advance Powder X-ray Diffractometer and the recently established XRF and HRXRD cum XRR systems. Variety of samples have been characterized for purity including phase analysis, structure and perfection for various projects at NPL including the CSIR network projects NWP-025 and NWP-045 on materials development/metrology. Many thin films of different materials like HfO_2, $LaCrO_3$, $LaAlCrO_3$, FePt, PSMO, LAO, V_2O_5, NbGe, GaN, NBN, CFS etc. have been characterized by HRXRD technique. Some multilayer LED structures of AlGaN/InGaN/GaN films made by CEERI have also been characterized. No. of samples characterized to various NPL groups and collaborators: (i) by multicrystal HRXRD: ~ 150, MRD system ~ 365, Powder XRD: ~575, XRF~75 whose notional cost is around Rs. 40 lakhs/-.

Major important technical achievements

A newly procured Vertical Bridgeman Crystal Growth system has been installed successfully to grow bulk single crystals.

Electron & Ion Microscopy

Electron & Ion microscopy facilities are being utilized at NPL as the central facility for the characterization of materials. This group is equipped with state of the art and most modern equipments such as TOF-SIMS, SEM, AFM/STM, TEM and high resolution TEM with EDS and STEM attachements. Different types of samples in the form of thin films, powders, and composites prepared by various techniques have been received from different groups of NPL working on the development of new and advanced materials. These samples have been characterized for their particles shape, size, distribution of particles, phase identification and crystallographic structure etc., using these facilities.

Many industrial units and other scientific organizations also made use of this facility for different type of materials characterization and testing for quality improvement of their products, which has resulted in generation of considerable ECF to the laboratory. Responsibilities included maintenance, up gradation and operation of the microscopes together with carrying out studies and investigations of new trends in the field of nano-materials have been the major work of the group. Electron & Ion microscopy group is doing basic research towards shape and size control of nanostructures as well as their synthesis using different methods: chemical as well as physical routes. Collaboration with some very prominent groups in the field of nano-science in NPL, user industries and other research institutions has been

another activity of the group.

Some of the samples are gold nano particles prepared through chemical route at 4°C, 10°C and room temp., Silicon Nanowires on Si and quartz, Te doped InSb thin thin films at Rt and annealed at 200°C , ZnO powder doped with Na (2 and 10 %) and Li 2%, CNT prepared by CVD technique, Fe_3O_4 ferrofluid with different PH values, Fe_2O_3 powder Indian as well as Imported, NiS and MnS powder magnetic materials in nano form, TiO_2 films pure and doped with 1.0 and 1.6% Fe, Cd ferrite, Si/Mn/Si prestine as well as irradiated, Electrochromic Device based on CNT Functionalized poly methylpyrol synthesized in hydrophobic ionic liquid medium. In figure 7.3 TEM bright field image represents the core shell structure of Au-ZnO recorded under HRTEM operated at 300KV at magnifications of 790KX and 490KX.

About 110 samples were received from the various groups of NPL working on the development of new and advanced materials. These samples were characterized by using TEM. This facility was also extended to various industries.

Scanning Electron Microscopy and Energy Dispersive Spectroscopy is another central facility of the laboratory which is extensively used by various R & D groups of NPL, other scientific R & D institutes and Industrial organizations for characterization of materials for surface microstructure and chemical compositional measurement. More than 1600 samples were received from various R&D groups of NPL as well as from industries have been examined by SEM and EDS for surface microstructure and compositional analysis.

SEM and EDS facility is also used by the industry for carrying out different type of testing and analysis work. During the period different samples were received from industry for particle size, shape, surface structure, fracture analysis, thickness and chemical compositional analysis. Some of the industries for which SEM/ EDS analysis were carried out are M/s. Oriental Carbon and Chemicals Ltd., New Delhi, M/s. Mindarika Pvt. Ltd., Gurgaon, M/s. MNIT, Jaipur, M/s. Ranbaxy R&D Lab. Gurgaon, M/s. NTPC, R&D centre Noida, Central Road Research Institute New Delhi, M/s. MoserBaer Photovoltaics Ltd., Gautam Budh Nagar, M/s. KPS Consultant & Impex Pvt. Ltd. New Delhi.

Some of the materials characterized by using SEM are Al-Si powder samples, Mg-Al Alloys, Oxidase coatings, metal doped polymer films, polymer powders and films with and without enzyme and DNA, Gold nanoparticles with and without enzymes, High Tc Superconducting Bi2223 multifilaments samples Bi2223 doped with Eu and Tb dopings, Y123 with Pr doping, MgB_2 Pure and with SiC, Mg ferrite and Li-Mg Ferrite samples, Pr-Ba-MnO_3 Composites with different additives, SAM layers with PPY, PNA and DNA, PANI plane, protein immobilized with and without DNA, PANI+CNT composites, LDPE films, CdSeTe Alloys of different ratios and at different temps, Particulate matter/filter paper collected from different locations, Au film/ ITO, gold nanoparticles with enzyme and gold nanoparticles with pyrol, Lithium-Ce Ferrite Samples, PECVD grown TiO_2 films/Si, TiO_2 films on different substrates etched with HF and

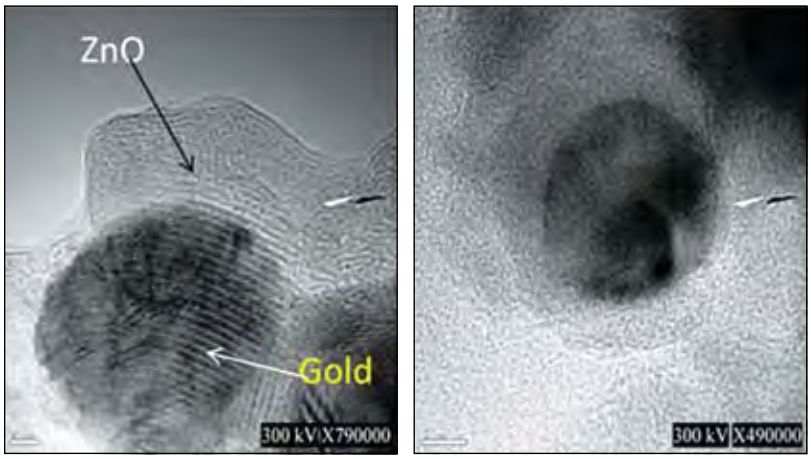


Fig. 7.3 TEM images of Au-ZnO Core-Shell

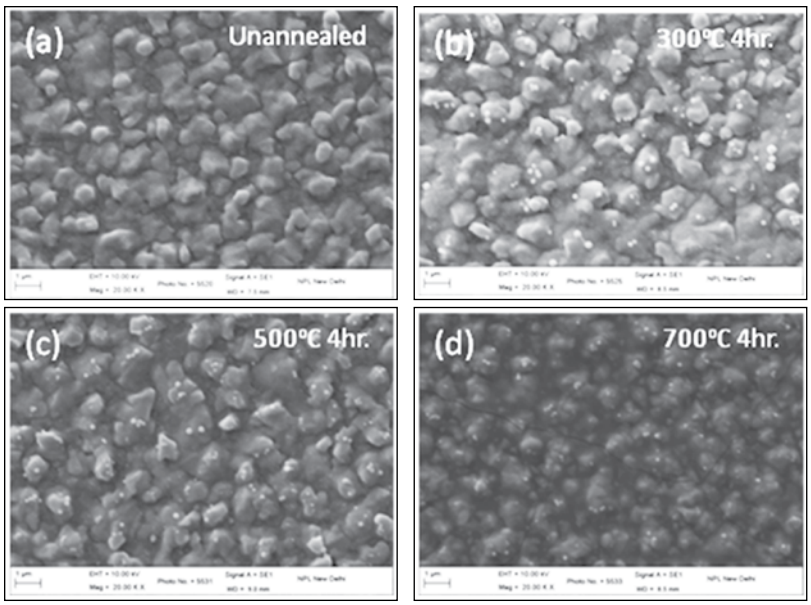


Fig. 7.4 SEM images of indium deposited thin films on quartz substrate, annealed at 300, 500 and 700°C for 4 hr. under oxygen atmosphere depicting recrystallization growth

NaOH treated, MgB_2 Pure and with 10% SiC samples annealed at different temperatures, Graphite composites with mixing of Chitosan polymer, Al, Al_2O_3, $Al+Al_2O_3$ powders ball milled, La-Sr-MnO_3 films/$SrTiO_3$ substrate prepared by DC magnetron sputtering technique, Alkaline and acid texturised micro crystalline Silicon, Porus Silicon samples. Humidity response of Li- substituted magnesium ferrite has been studied in detail. Indium thin films deposited at room temperature annealed at 300, 500 and 700°C for 4 hr. under oxygen atmosphere depicting recrystallization growth as shown in fig. 7.4. Annealing at higher temperature (700°C) for 4hr leads towards the diffusion of particles because of gaining thermal energy. A uniform matrix is formed after annealing at 700°C for 4hr. and the growth of the particles have taken place along the direction of electron beam. Presence of some nano cracks in the film was observed due to thermal stress in the film at 700°C.

Scanning Probe Microscope (SPM) is the central facility of NPL and is extensively used by different R & D Groups of Laboratory for the surface characterization in the field of Thin Film Technology. SPM includes Atomic Force Microscopy (AFM) and Scanning Tunnelling Microscopy which are generally used for the study of surface characterization and electron density profiles at molecular /atomic levels. NPL has Multimode-V (NS-V) which has other advanced modes techniques i.e. Magnetic Force Microscopy (MFM) (used for measuring spatial variation of magnetic forces over the sample), Electric Force Microscopy (EFM) (used for measuring electric field gradient above the sample), Nanolithography which is one of the nanoscale technologies for the fabrication of nanometer scale structures, Nanoindentation, which can be used for the study of mechanical properties and modification on the surface at nanoscale.

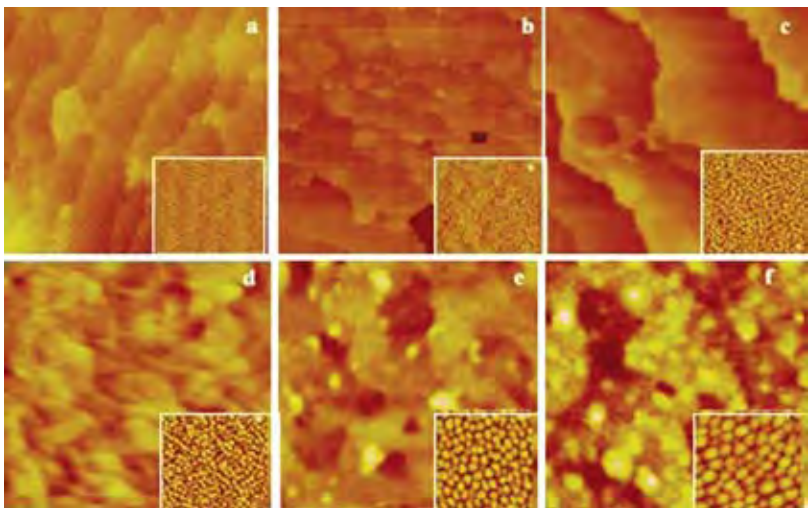


Figure 7.5 (A) AFM surface topography (1x1 μm²) of post-deposition annealed (inset: as grown) (a) 5 nm (b) 12 nm (c) 35nm (d) 70 nm (e) 150 nm and (f) 200 nm $Pr_{0.60}Sr_{0.40}MnO_3$ films on $LaAlO_3$ substrates.

Atomic Force Microscope, or Scanning Probe Microscopy (AFM/SPM), is an extremely accurate and versatile technique for measuring surface topography at the nanoscale. A very fine sensor tip mounted to the end of a small deflecting cantilever is brought into contact with the sample surface to be investigated. The sensor tip is moved across the surface in numerous line scans, which produces a high resolution image. Figure 7.5 shows the modifications in the surface topography of $Pr_{0.60}Sr_{0.40}MnO_3$ (PSMO) PSMO thin films (thicknesses in the range 5 – 200 nm) deposited on $LaAlO_3$ (001) single crystal substrates by DC magnetron sputtering. The inset shows the AFM images of as grown sputtered thin films. The surface of as grown films generally consists of densely packed granular features whose size is observed to increase with increasing film thickness. Annealing in flowing O_2 at 900°C for 12 hrs drastically modifies the surface features. At lower film thickness (5 – 70 nm) step terrace like features representing epitaxial nature are clearly visible. As the film thickness increases further the step terrace like features appear to get disordered suggesting the termination of the epitaxial growth. The results suggest that the film growth in this case remains epitaxial up to about 70 nm and beyond that the epitaxy is destroyed gradually. This effect is clearly visible in AFM images.

EPR & IR Spectroscopy

R & D Activities

Ferrofluids have emerged as an active area of research due to their enhanced thermal, rheological and magnetic properties over the base fluids. These fluids move as whole in the direction of applied magnetic field and offer an excellent property for sensor & actuations. This makes them very attractive in variety of applications like sensors, biomedical, energy and magnetic data storage, etc. During this period, we have prepared nanomagnetic particles of mixed ferrites dopd with rare earth e.g. Gd, Pr etc., and investigated their physical properties like structural, morphological, rheological and magnetic by XRD, FTIR, SEM, HRTEM, AFM, VSM, SQUID, Magnetorheometer and EPR spectroscopic techniques. These investigations have helped us in developing stable and suitable ferrofluid for device based applications. Some of the results of our investigations are as:

Low Temperature FMR investigations on water based ferrofluids

FMR measurements were performed on FF sample kept in a fine cylindrical quartz capillary. A typical FMR spectra at room temperature constitutes a broad ferrimagnetic signal ~3100 Oe superimposed by a sharp signal at ~3400 Oe due to a superparamagnetic phase which is similar to the previous reports. The low temperature FMR measurements were performed in Zero-field cooled (ZFC) and Field-cooled (FC) procedures. Figure 7.6 shows selected FMR spectra recorded via ZFC and FC procedure with a defined 3D coordinate axis system of Ferromagnetic nanoparticles (FNPs) under study.

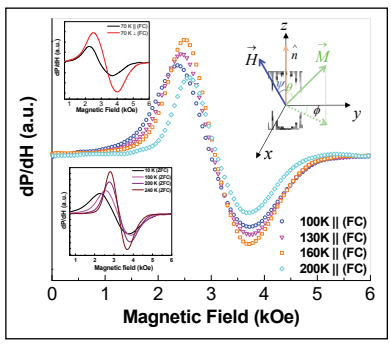


Fig. 7.6 FC-ZFC FMR Spectra at different orientations

These measurements on the sample were carried using 9.54 GHz microwave frequency with the power of 1.03 mW. In ZFC measurements, the sample was cooled down from 298 K in zero magnetic field to 4 K and the spectra were recorded while raising the temperature. For the FC measurements, the sample was cooled in magnetic field (H_{cf}) of 1 T and spectra were recorded during warm up cycle (4 K - 298 K) at different angular orientations at each specified temperature. The applied field of 1T is chosen intentionally so as to create the environment where $H_{cf} >> H_A$, H_A is anisotropy field. In our sample H_A is found to be 340 Oe at 4 K. So, the applied field will simply align all moments

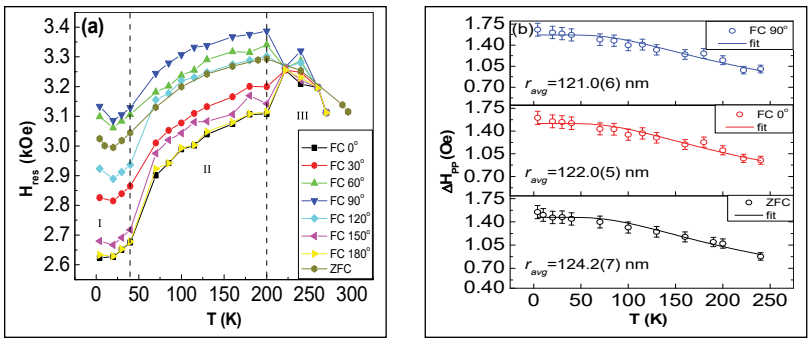


Fig. 7.7 (a) H_{res} vs T for ZFC and FC measurements (4K-298K), (b) observed peak-to-peak linewidth (ΔH_{pp}) values for ZFC and FC (0° and 90°) measurements and the fit of eq. (1).

in one direction thus minimizing orientational distribution function leading to the saturation of applied-field dependent shift in H_{res} while performing FC measurements. Fig. 7.7(a) & (b) shows the variation of resonance field (H_{res}) and linewidth with temperature in the range from 4 K – 298 K for ZFC and FC measurements.

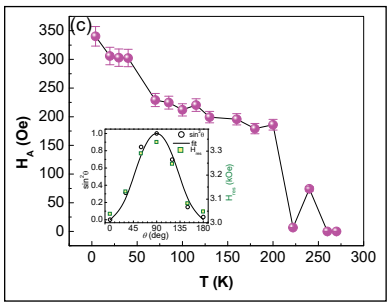


Fig. 7.8 Temperature dependence of anisotropy field, H_A. The inset shows the angular variation of uniaxial anisotropy filed (opened symbols) and the $\sin^2\theta$ fit (solid line) to the observed data of H_{res}.

On the other hand, ΔH_{pp} did not show any angular variation in FC measurements, but rather a consistent temperature dependent decrease is observed in ZFC and FC measurements. Similar decrease in linewidth of ZFC for two different sized FNPs, but with different slopes has been reported by Hsu et al [23]. The temperature dependency of linewidth in a system composed of MNPs can be described by

$$\Delta H_{PP} = \left(\frac{5g\beta nS}{r_{avg}^{3}}\right)\tanh\left(\frac{\Delta E}{kT}\right), \qquad (1)$$

where, g is splitting factor, β is Bohr magneton, n is the total number of magnetic centers inside each grain, S is the effective spin, r_{avg} is the average interparticle distance and ΔE is energy barrier which consist of terms like dipole field energy (E_m), dipole-dipole energy (E_{dd}) and anisotropy energy (E_a). Temperatuure dependent peak-to-peak linewidth measurements along with the theoretical fit based on eq. 1 are shown in fig 7.7(b) and from these fits, the average interparticle distance comes out to be 124.2(7) nm, 122.0(5) nm and 121.0(6) nm for ZFC, FC (0°) and FC (90°) respectively. The variation in interparticle distance can be explained as the effect of magnitude of applied field in ZFC and FC measurements, respectively. This also gets further support from different ΔE values of 4.8(2) X 10^{-21} J and 4.5(1) X 10^{-21} J for 0°, 90° both FC and ZFC measurements. Such enhanced ΔE value in FC as compared to ZFC can be related to increased dipolar field energy between FNPs. The number of magnetic centers obtained from FC and ZFC fit (i.e. 7.2(3) X 10^3) corresponds to 9.9(1) nm particle size when one assumes spherical particles with 8.32 Å unit cell dimension. This is again found in anticipation to the sizes obtained from XRD, TEM and VSM results.

In ZFC, resonance field shows a non-monotonic behaviour with a maximum at 200 K. The corresponding FC data also retained this behaviour but reveal more interesting features with in plane angular rotation which has been quantitatively discussed here. The variation of H_{res} at different angles as shown in Fig. 7.8 for all FC spectra were found to have a good fit with $\sin2\theta$ function ($H_{res} \propto EA = K_u V \sin2\theta$, where E_A is uniaxial anisotropy energy of system, K_u is uniaxial anisotropy constant and V is volume of particle) for all temperatures except at 260 K onwards, where the melting of carrier liquid takes place.

Exchange bias effect in $CoFe_2O_4$-Fe_2O_3 nanocomposite based ferrofluid

Nanocomposite of $CoFe_2O_4$-Fe_2O_3 core-shell nanoparticles having average particle size of 10±1 nm was prepared by chemical co-precipitation method and finally suspended into water to make ferrofluid. Structural

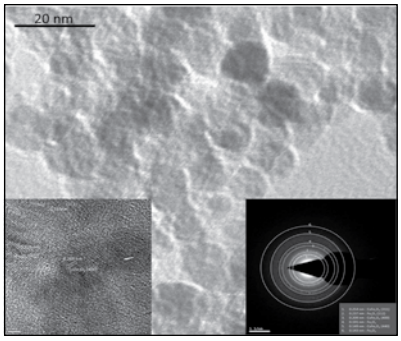


Fig. 7.9 HRTEM image of $CoFe_2O_4$ nanoparticles

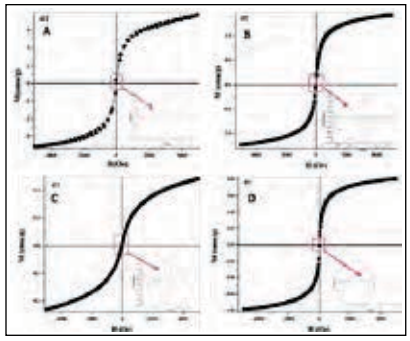


Fig. 7.10 M-vs-H curves of $CoFe_2O_4$

characterizations by X-ray diffraction (XRD), Transmission Electron Microscope (TEM) show highly crystalline phase of the nanocomposite. High resolution TEM images show distorted and modified grain boundary region. Magnetic properties were studied by Vibrating Sample Magnetometer (VSM) and Electron Paramagnetic Resonance (EPR) spectrometer. $CoFe_2O_4$-Fe_2O_3 nanocomposite show excellent negative exchange bias effect after zero fields cooling (ZFC). VSM measurements shows the superparamagnetic (SP) behaviour of nanocomposite at room temperature and ferromagnetic at low temperature. EPR spectra show the co-existence of α-Fe_2O_3 and $CoFe_2O_4$ phase upto 250 K but after 250 K, it shows only the γ-Fe_2O_3 phase.

JCPDS file, No. 22-1086 confirms the formation of $CoFe_2O_4$ spinel structure. The broadened diffraction peaks can be attributed to the reduced particle size of the water based cobalt ferrofluid (WCFF). TEM observation was used to investigate the morphology and size of the as-prepared $CoFe_2O_4$ ferrofluid. They reveal that the nanocrystals of WCFF was nearly monodisperse and spherical-shaped with an aspect ratio of about 1 and a diameter 10±1 nm.

The magnetic properties of the WCFF were evaluated by a vibrating sample magnetometer (VSM) from 80-300 K. The magnetization curve measured at 300 K demonstrates a typical super paramagnetic behaviour with a coercivity of 35 Oe and remanence 0.24 emu/g as the field is cycled between –5 and 5 kOe. The saturation magnetization was found to be ~3.4 emu/g which is not saturates in a maximum field of 5 kOe.

Magneto-rheological studies on Ferrofluid based MR Fluid

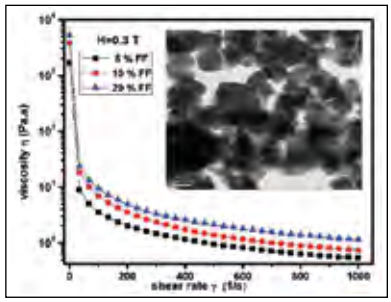


Fig. 7.11 Viscosity variation with shear rate

Fe_3O_4 based ferrofluid (FF) was prepared by using co-precipitation method while MR fluids was prepared using micron sized Fe_3O_4 powder commercially available from Sigma-Aldrich, with <5 μm particles. The particles were ball milled for two hrs to reduce the size. For MR fluid preparation, particles were ultrasonicated by adding oleic acid and kerosene.

Average particle size for FF and MRF are found to be 10 nm and 250 nm using HRTEM technique and shown in Fig. 7.11 (inset). The rheological and viscoelastic

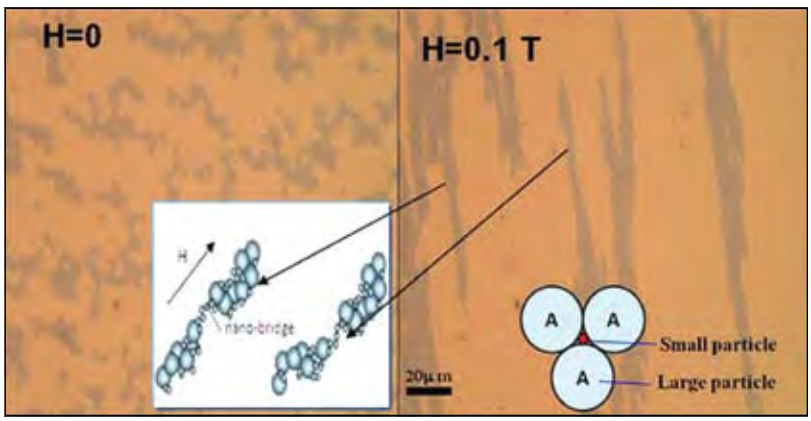


Fig. 7.12 Rheo-microscopy image of FF and MR fluid

properties of MR fluids mixed with different volume concentration of ferrofluid 5, 10 & 20%, were investigated by using Rheometer (MCR301 Anton Paar) at 25°C. Figure 7.11 shows shear dependent viscosity of all the samples in presence of magnetic field (0.3 T). The viscosity for 5% FF nanoparticles decreases with increasing shear rate and it shows a shear thinning behaviour. It is attributed to the fact that the lower shear rate is unable to break the magnetically induced structures but as the shear rate increases these structures breaks and fluid flows easily. Thus, the viscosity of the fluid decreases rapidly with increasing the shear rate. The similar trend has been observed for 10 and 20%. In presence of magnetic field, magnetic particles come closer and form clusters and creates micron-sized cavities within these structures. These cavities are filled by nano particles of ferrofluid. These nano particles are attached to the ends of MR particles and form a long chain like structures and also make a colloidal nano bridge between the clusters of micron-sized particles. Such fluids will have potential application in fine polishing.

Analytical Chemistry

The Analytical Chemistry group has been working for characterization of materials for their chemical composition, purity assessment and conformity requirements needs for challenges in NPL & in MiC & CRM activities, including R&D for method development for challenging problems in water and air quality. The activities in the metrology in chemistry (MiC) and certified reference materials (CRM) for SI 'mole', are to help provide traceability at apex level in chemical measurements through a network of MiC partners, under CSIR network project 'measurement for innovation in science & technology (MIST)', in various sectors impacting quality of life and international trade. Its mission is helping showcase CSIR-NPL & partners chemical metrology services in equivalence with international NMIs; interaction and close cooperation with national (BIS, NABL, QCI, CPCB, IMD, ICAR, MoEF, ISRO-GBP and Universities) & international (BIPM-CCQM-APMP, CITAC, ISO, PTB/BAM Germany, NIST USA etc) stakeholders for dissemination of SI traceability, quality data and spreading MiC awareness/ education.

R & D Activities

The group has carried out R&D in method development in speciation for toxic heavy metals, elemental purity analysis, aerosol chemistry and related metrology, greenhouse gases emission factor development in waste sector and data analysis for proficiency testing (PT) schemes for iron ore/ coal with NML Jamshedpur and pesticide solutions with IITR Lucknow for Indian testing labs. MiC & CRM activity R&D in gas-aerosols, elemental solutions and pH at NPL by utilizing the advance instrumental techniques like ICP-HR-MS, F&GF-AAS, GC with FID/ TCD/ ECD & PDHID, IC, UFLC, SMPS, gas analyzers and the high precision balances/ comparators. Gravimetric preparation, validation, certification and dissemination of reference materials as per ISO standards in the field of aqueous elemental/ ionic solutions for water quality and standard gas mixtures are done. During this period under gas metrology activities, efforts were made for cylinder preparation/ processing for primary GHG gas standard mixture for international comparison. These gas standards are prepared by gravimetric methods followed by rigorous quality control and quality assurance procedures for verification. Such standards may then be used for disseminating SI traceability to all stakeholders. The group carryout consultancy and R&D for societal issues viz. for purification of water for toxic contaminants like pesticides, arsenic, chromium, cyanide, mercury, poly-aromatic hydrocarbon, microbes etc using nano-materials, and for NATCOM-TNC, Industry etc. A process for improving water quality contaminated by pesticides has been developed and filed for patent.

A study has been carried out for the development of new methods to determine trace level of As^{5+} and Cr^{3+} and Cr^{6+} by Ion Chromatography (IC) system and their validation according to the IUPAC and EURACHEM approaches. The method developed is a reliable and simple for the determination of As(V) and Cr (III)/ Cr(VI) (Figure 7.13) up to 25 µg/kg, 2 mg/kg and 40 µg/kg respectively in aqueous solution.

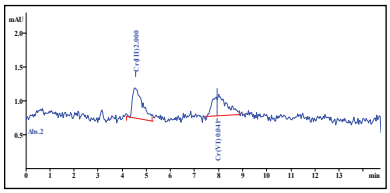


Fig. 7.13 Chromatogram of Cr (III) and Cr (VI)

Under MiC in gas metrology-aerosol metrology, a novel approach to calibrate condensation particle counter (CPC) is developed. This approach is based on the comparison of particle mass derived from scanning mobility particle sizer (SMPS) with corresponding particle mass collected on filter and determined by gravimetric method. Ammonium sulfate particles were generated by aerosolization and dried using diffusion dryers. These particles were introduced to a differential mobility analyzer (DMA) where size segregation was done based on the particles electrical mobility, and then particle number concentration was measured by CPC, which has to be calibrated. A filter holder (47 mm) was placed in between DMA and CPC to simultaneously collect particles on quartz filter. Based on particle counts measured by CPC for different sizes and density of ammonium sulfate particles, CPC driven particle mass was calculated. This mass was then compared with filter based mass determined by gravimetric method. Particle mass comparison results show relative difference mainly below 15% for a wider particle size range, i.e. 14 - 615 nm in this study. This approach can be applied to calibrate/ correct the particle counts of a CPC at the laboratory scale.

1. CRM preparation of elemental solutions

Three new elemental aqueous certified reference materials i.e. Bharatiya Nirdeshak Dravyas (BNDs/ or CRMs) namely Arsenic (100 mg/kg), Mercury (100 mg/kg) and NO_3 (100 mg/kg) were prepared and certified according to quality management system based on ISO/IEC-17025 and Guide 34/35. Certified values are assigned by gravimetric primary method (traceable to SI through CSIR-NPLI mass).

2. Quality System and International Peer-review on CRM activity

Quality management system (ISO/IEC-17025) in aqueous elemental solution analytical capability after their preparation (as per ISO Guide 34/35) under inorganic analysis CRM activity has been implemented which had been peer-reviewed internationally. During this period internal audit had been completed successfully on 6th February 2013.

3. Participation in International Inter-comparison studies

Participation has been initiated in inorganic, gas and electrochemical analysis areas for three international inter-comparison studies i.e. as speciation, total As & Cd in rice powder/ and for CH_4 in nitrogen and pH of borate buffer.

Table 7.1 : International inter-comparison participation underway by NPLI

Inter-comparison	Matrix	Analyte/ component	Technique used
APMP.QM-P21	Rice flour	Total As, As^{3+}, As^{5+} and Cd	IC, AAS, HR-ICPMS
APMP.QM-S5	Nitrogen	CH_4	GC-FID/TCD Gravimetric
APMP.QM-K19	Borate buffer using glass electrode	pH	pH meter with glass electrode

A recent result of international APMP.QM-P18 comparison for zinc in herbal material is shown in figure 7.14.

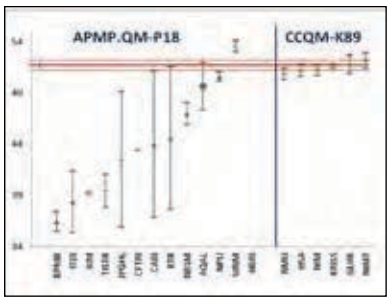


Fig. 7.14 APMP.QM-P18-Zinc measurement results and uncertainties (Final Report: jan. 2013)

Note: *Participants' results are displayed with error bars representing reported standard uncertainties. The solid horizontal line in red is the KCRV from CCQM-K89 and the dashed lines show the standard uncertainty of the KCRV*

Major Facilities established during the year 2012-13

Equal arm balance (Model-Raymor HCE-25G; M/s Raymor Tool Co., Inc., USA) facility having 25 kg capacity with sensitivity 1 mg, for gravimetric preparation of gas standard mixture at CSIR-NPL has been established. A moisture analyzer (Model-LaserTrace, M/s Tiger Optics, PA USA) based on CRDS principle has been established for <500 ppb level of trace moisture impurities in high purity gases.

❑

अतीत के सुनहरे पल ...

Pandit Jawaharlal Nehru, Prof M S Thacker and Dr K S Krishnan at NPL

वैज्ञानिक एवं प्रशासनिक सहायक सेवाएं

Scientific and Administrative Support Services

Planning, Monitoring and Evaluation Group
Sh T Raghavendra
Sh V D Arora
Sh Ashok Kumar
Ms Anita Sharma

Industrial Liaison Group
Dr (Ms) Jyoti Lata Pandey

Human Resource Development Group
Dr Rajeev Chopra

International Science and Technology Affairs Group
Dr V K Gumber
Sh Ashwani Kumar Suri

Knowledge Resource Centre
Sh N K Wadhwa
Sh Abhishek Sharma
Sh Jagdish Prasad
Sh Rajpal Zamaji Walke
Ms Neetu Chandra

Central Workshop
Dr R K Kotnala
Sh Ravi Khanna
Sh P Srinivasan
Sh Jai Pal Singh
Sh Amar Singh

Computation & Network Facility
Dr Ravi Mehrotra
Mr Ashish Ranjan
Ms Deepti Chaddha
Mr Nitin Sharma
Ms Anjali Sharma
Mr Trilok Bhardwaj
Mr Kanwaljit Singh
Mr Vijay Sharma

Quality Management System
Dr Rakesh Kumar Garg

Planning, Monitoring and Evaluation Group (PME)

Contract R & D Projects, as Sponsored, Collaborative and Grant-in-Aid Projects are undertaken by the Laboratory with funding from External Agencies. Before submission of the project proposals to the outside agencies they are evaluated by the Group based on various criteria and conditions. Monitoring and developing of complete database for report generation on projects are done and project files are created and maintained. Similarly Major Laboratory Projects and other In-house Projects funded by CSIR & NPL, undertaken in NPL, are also monitored. Fund allocation and processing of indents is an important activity undertaken by this group. The report on completed projects and refund of unspent balance to the funding agencies at the end of project are made by the group.

PME prepares Annual Plan and Five Year Plan for NPL. It organizes Research Council meetings and coordinates the Management Council meetings, organized by administration. Time to time PME disseminates information on projects, performance reports and ECF reports to CSIR. PME is also involved in monitoring of Networking Projects and XII five year plan projects. PME developed manpower data and maintains staff positions and disseminates the information to various authorities. The group also maintains and regulates the appointments of project staff under various externally funded projects.

PME has the additional responsibility of getting feedback on degree of customer satisfaction in a prescribed format from funding agencies who are funding the different contract research projects in NPL. The process is done at the end of each project. This function has been initiated by CSIR under the supervision of Customer Satisfaction Evaluation Unit (CSEU) at CSIR Headquarter, Rafi Marg, New Delhi – 110 001. The feed-back received from the funding agencies are sent to CSEU, CSIR.

PME prepares many types of reports on Manpower in different formats as required from time-to-time and also does different type of Analysis for manpower planning of the laboratory.

Publication of Annual Report is another important activity of PME. On receiving inputs from various Divisions & other concerned groups, Text and Apendices of Annual Report are compiled, corrected and published in the form of Annual Report each year.

Industrial Liaison Group (ILG)

The Industrial Liaison Group (ILG) is responsible for the commercialization of research and knowledge developed by

the NPL scientists and researchers. Our focus is to foster and develop collaborative work environments between researchers, industry partners and funding agencies. We want to ensure that the relationships created through the commercialization of a technology continue to add value for all partners; leading to ongoing research projects for the inventor and the industry partner and to the commercialization of complementary technologies. In addition, this group also undertakes consultancy, technical services and dissemination of science and knowledge base. This group is responsible for all matters connected with business development. It also helps in organizing "Technology Day" and "World Metrology Day" function where all licensees are invited to interact and deliberate with scientists concerned with development of the technology. It also helps in organizing "Open Day" function, wherein few thousand school and college students with their teachers are invited to see the various scientific and technical activities at NPL. This group further carries out the dissemination of science through publication in CSIR News, CSIR Annual report, business and industrial magazines and their websites and through advertisements in newspapers, conferences, symposiums, various other events and their souvenirs and also through participation in exhibitions. Processing of applications for the awards pertaining to technology or consultancy services is rendered. This group also undertakes distribution of royalty, premia and intellectual fee pertaining to consultancy, technical services and technology know transferred. It further updates industries, licensees and scientists for any CSIR/DST entrepreneurship/ funding schemes for applying for awards/ projects. It updates scientists about scientific and technical exhibition, events. It acts as bridge in resolving scientific and technical issues raised by industries/clients for providing them solution through technical and consultancy services. This group also takes care of the management of S & T outputs with other funding agencies viz. DST, CSIR, NRDC, CDC, FICCI, etc. This group interacts with FICCI and loads technology inventions at their website for wider exposure, collaborative work, market search and entrepreneurship demand. During the year, the group disseminated Knowledgebase / Technology during India-Africa Exhibition held in Vigyan Bhawan, Taj Palace and at 100th Indian Science held during January 3 -7 2013 at Kolkata. It also extended support to M/s NISCAIR, New Delhi who made documentary film on CSIR-NPL. This group initiated its efforts for possible knowledge alliance with Sensor Technology Pvt. Ltd., Prabhatam Radisafe Limited, New Delhi, Reinste Nano Ventures Pvt. Ltd, Noida, Jyoti Cero Composite, Jamshedpur, GTC Technologies, Houston USA in the area of carbon composite, energy, sensor electronics, solar energy biological instrumentation water purification, EMI shielding, radiation safety etc. A registration certificate for setting-up of NPL Technology Innovation Center (NTIC) under Sec-25 company act was received on 22th May 2012 (2012-13). This group coordinated with CSIR HQs for Scientific Enterprise scheme in the area of ECG-plug-In device. This group resolved the issue of silver recovery from inedible ink waste which was accumulated/ generated by M/s Mysore Paints & Varnish Ltd, Mysore over the years and this may be taken up as consultancy project in future.

Human Resource Development Group (HRDG)

The HRD Group represents the central group of the laboratory providing several activities in various areas of core competence of the lab and also related to research scholars / students. The basic objective behind all these activities is to make the Human Resource better informed, knowledgeable and highly skilled & trained so that it can prove to be more competitive, productive and useful to the society. All these eventually lead to the generation of trained S&T manpower in the country.

The group is involved in various activities, such as, Organisation

of Industrial Training in Metrology/Standards, help & support to Research Scholars, Students' Training for M.Tech./ MCA/M.Sc. and other equivalent degree courses, Institutional Visits, Deputation of NPL staff members to attend conferences, AcSIR related activities (Ph.D.& M.Tech.) etc,.

International Science and Technology Affairs Group (ISTAG)

Inputs from ISTAG for annual report for the year 2012-2013

The International Science and technology affairs group deals with collaboration of CSIR-NPL with prestigious scientific institutions of the various countries of the world. It facilitates the cooperation by signing Memorandum of Understanding between CSIR-NPL and other reputed institutes of various countries. In the year 2012-2013, a MOU was signed between CSIR-NPL and INMETRO, Brazil for undertaking Joint research in the area of metrology. The scientific delegations and visitors from South Africa, UK, France, Botswana, Australia, South Korea, Japan, Canada, Tanzania, Germany and USA visited CSIR-NPL for exploring scientific and technological cooperation with CSIR-NPL. Scientists of CSIR-NPL visited various countries to take part in Joint scientific research and to attend international seminars, symposiums and scientific meetings.

Knowledge Resource Centre (KRC 2012-13)

NPL Knowledge Resource Center (KRC) has been providing library and information support to scientists for R & D pursuits.

Over the years, it has developed a rich collection of scholarly books and journals for the purpose, especially in the field of physics and related sciences.

During the current year, KRC subscribed to 61 scholarly journals *(43 foreign journals and 18 Indian journals)* and added 342 books, out of which 104 were S&T books, 238 were Hindi books. KRC serves the NPL community with services like Reprographic service, Electronic Document Delivery service, Inter Library Loan service, Reference service, Literature Search service etc.

NPL-KRC offers online access to more than 6000+ **full text journals under the e-consortium** project of NKRC (CSIR+DST). The project facilitates access to electronic content from various publishers such as Elsevier, Springer, AIP (American Institute of Physics), APS (American Physical Society), AGU (American Geophysical Union), Wiley - Blackwell, Oxford University Press, Royal Society of Chemistry, American Chemical Society etc as well as the archives of few publishers on concession rates.

KRC is also providing access to intranet edition of **Indian Standards**.

The shift in technology achieved with the installation of improved routers helped in attracting the R & D personnel in large number to make use of NPL-KRC and leads to optimize the use of the subscribed/ entitled e-resource as well as internet resources.

On continuous basis, KRC maintains its site on the NPL intranet to provide latest information on its activities such as additions to its collection, current subscribed journals, new journals received during the week, links to electronic libraries, publishing houses, and papers published by NPL researchers.

NPL-KRC also maintains NPL website (http://www.nplindia.org) on Internet to inform others about the activities of NPL such as its role towards the society, thrust area of research, facilities, services and achievements.

Further, to improve the quality, speed and effectiveness of services, KRC has completed the retro-conversion of books. With this, end users of KRC would avail the value added services associated with the NPL-KRC Information System (NKIS).

In the direction of providing free worldwide access to the intellectual outputs of NPL in form of journals articles, research papers, conference papers, technical reports, preprints, and other scholarly communication and also to support the concept of open access initiative, NPL-KRC

has established the Institutional Repository (IR@NPL) http://npl.csircentral.net/ and till date, around 940 records has been added.

Central Workshop

Central Workshop has successfully completed 731 jobs related to R & D and maintenance work costing approximately ₹ 60 Lakhs (Rupees Sixty Lakhs only). The jobs included designing , drawing, fabrication and development of various components required by the several scientists for their activities. Most of them are highly sophisticated components related to various R & D works.

In the Glass Technology Unit, we completed 75 jobs of different sections in NPL It included the sealing of quartz ampoules, making of reactors B-45, Bubbler B24, distillation plant, condenser, covering of filaments in quartz tubes and electro chemical cells.

Due to good preventive maintenance, most of the machines in workshop are in good working condition.

Computation & Network Facility (CNF)

The Computation & Network Facility (CNF) caters to the spcialized computing and communication needs of the laboratory. It configures, administers and maintains various servers, a campus LAN and internet connectivity as required. Most of the solutions are integrated in house and deployed on linux based servers.

Major facilities include email, web hosting on intranet and internet, webcast, database, security solutions and high performance computing. A completely new and efficient email solution has been integrated and deployed in this year using a host of open source packages.

A major laboratory wide effort has been started to implement the CSIR-ERP soultion at CSIR-NPL. A 20TB SAN and database and application servers have been installed in the Data Centre to connect to the CSIR-ERP network as soon as it is deployed by the CSIR. The exercise to familiarize all across the laboratory and populate the ERP database has been started.

In the area of research and education, CNF staff teaches Advanced Computaional Physics to M.Tech. students under the AcSIR programme. Under a DST sponsored project "Innovative Product Development Centre", low cost medical instrumentation is being developed. The ECG device developed earlier won the DST – Lockheed Martin Gold Medal for the year 2012. Other devices are in various stages of development.

Quality Management System

This group maintains Quality System in NPL, based on the international standard IS/ISO/IEC 17025:2005, in the area of Test and Calibration. All the test/calibration areas of NPLI are periodically audited to confirm the continued compliance to the international standard.

The Quality Manual was revised time to time, depending upon reorganization of the different activities.

A delegation from NPL participated in APMP General Assembly and related meetings held in New Zealand. Laboratory Report of NPL was prepared and submitted to APMP in its General Body meeting. The QMS annual report was also submitted in APMP QS TC meeting.

This group is also organizing a special training course on "Quality Management System – Laboratory Management, Need for Calibration / Accreditation as per IS/ISO/IEC-17025". Special training course was also conducted for the staff of Department of Legal Metrology on their demand.

अतीत के सुनहरे पल ...

Dr S S Bhatnagar, Pandit Jawaharlal Nehru, Sanjay Gandhi, Rajeev Gandhi, and Smt. Vijay Laxmi Pandit at NPL

Pandit Jawaharlal Nehru Addressing the Gathering at the Inauguration of NPL

राजभाषा कार्यान्वयन

Rajbhasha Unit

राजभाषा यूनिट

राजभाषा यूनिट दिन–प्रति–दिन के सरकारी कार्यों में राजभाषा हिन्दी के प्रगामी प्रयोग को बढ़ाने का कार्य करती है। राजभाषा यूनिट का मुख्य उत्तरदायित्व संघ सरकार की राजभाषा नीति, राजभाषा अधिनियम के उपबंधों तथा आदेशों से प्रयोगशाला के वैज्ञानिकों/अधिकारियों/कर्मचारियों को अवगत कराना, अनुपालन कराना एवं अनुपालन हेतु सहायता प्रदान करना है।

राजभाषा यूनिट के उत्तरदायित्व :

1. कार्यान्वयन :

- संघ सरकार की राजभाषा नीति, राजभाषा अधिनियम के उपबन्धों तथा आदेशों से प्रयोगशाला के वैज्ञानिकों/अधिकारियों/कर्मचारियों को अवगत कराना, अनुपालन कराना एवं अनुपालन हेतु सहायता प्रदान करना।
- प्रत्येक तिमाही में निदेशक, एन पी एल की अध्यक्षता में राजभाषा कार्यान्वयन समिति की बैठक का आयोजन, कार्य सूची एवं कार्यवृत्त तैयार करना। बैठक में लिए गए निर्णयों पर अनुवर्ती कार्रवाई करना।
- प्रयोगशाला की राजभाषा कार्यान्वयन प्रगति सम्बन्धी तिमाही प्रगति रिपोर्ट तैयार कर सी एस आई आर मुख्यालय भेजना।
- हिन्दी दिवस/हिन्दी सप्ताह/हिन्दी पखवाड़ा/हिन्दी मास मनाना।
- प्रत्येक तिमाही में हिन्दी कार्यशालाओं/व्याख्यानों का आयोजन करना।
- राजभाषा विभाग, गृह मंत्रालय, भारत सरकार से प्राप्त वार्षिक कार्यक्रम में निर्धारित लक्ष्यों को प्राप्त करने हेतु उचित कार्रवाई करना।
- संसदीय राजभाषा समिति के निरीक्षण सम्बन्धी कार्य तथा समिति को दिए गए आश्वासनों को पूरा करने हेतु कार्रवाई करना।
- प्रत्येक वर्ष विज्ञान विषयों पर हिन्दी में दो दिवसीय राष्ट्रीय संगोष्ठी का आयोजन।

2. प्रशिक्षण एवं प्रकाशन :

- हिन्दी प्रशिक्षण (प्रबोध, प्रवीण एवं प्राज्ञ पाठ्यक्रम)।
- हिन्दी टंकण/आशुलिपि एवं कम्प्यूटर पर हिन्दी में कार्य करने का प्रशिक्षण दिलाना।
- प्रत्येक छमाही में हिन्दी समीक्षा पत्रिका का प्रकाशन।
- प्रयोगशाला की वार्षिक रिपोर्ट तथा अन्य महत्त्वपूर्ण प्रकाशनों में हिन्दी अंश का संपादन।

3. अनुवाद :

- प्रयोगशाला में प्रयुक्त सभी प्रपत्रों (फार्मों), मानक मसौदों का द्विभाषीकरण।
- अंग्रेजी से हिन्दी और हिन्दी से अंग्रेजी में अनुवाद कार्य।
- राष्ट्रीय भौतिक प्रयोगशाला के वार्षिक प्रतिवेदन के महत्त्वपूर्ण अंशों का हिन्दी अनुवाद।
- प्रयोगशाला की वेबसाइट का हिन्दी अनुवाद।

कार्मिक :

1. **मंजु** (हिन्दी अधिकारी)
2. **जय नारायण उपाध्याय** (हिन्दी अधिकारी)
3. **विजय सिंह** (वरिष्ठ आशुलिपिक (हिन्दी))

हिन्दी पखवाड़ा रिपोर्ट

राजभाषा विभाग, गृह मंत्रालय, भारत सरकार की हिन्दी पखवाड़ा सम्बन्धी व्यवस्थाओं को ध्यान में रखते हुए प्रयोगशाला में दिनांक 01 सितम्बर, 2012 से 14 सितम्बर, 2012 तक हिन्दी पखवाड़ा मनाया गया। प्रयोगशाला में स्टाफ सदस्यों को हिन्दी में अधिक से अधिक कार्य करने के लिए प्रोत्साहित एवं प्रेरित करने के उद्देश्य से हिन्दी पखवाड़ा मनाए जाने से पूर्व एवं पखवाड़ा के दौरान विभिन्न प्रतियोगिताओं का आयोजन किया गया। प्रत्येक वर्ष की भाँति इस वर्ष भी जो प्रतियोगिताएं आयोजित की गयी वे इस प्रकार से हैं :–

इन सभी प्रतियोगिताओं में प्रयोगशाला के स्टाफ सदस्यों ने उत्साहपूर्वक भाग लिया व अत्यधिक रूचि प्रदर्शित की। प्रयोगशाला के

हिन्दी दिवस समारोह में अतिथि व्याख्यान देती हुई प्रो. रीतारानी पालीवाल, निदेशक, मानविकी विद्यापीठ इग्नू

सभागार में दिनांक 14.09.2012 को मुख्य समारोह आयोजित किया गया। इस अवसर पर गेस्ट लेक्चर देने के लिए प्रो. रीता रानी पालीवाल, निदेशक, मानविकी विद्यापीठ, इंदिरा गांधी राष्ट्रीय मुक्त विश्वविद्यालय, नई दिल्ली को आमंत्रित किया गया था। प्रो. रीता रानी पालीवाल ने हिन्दी दिवस के अवसर पर प्रयोगशाला के सभागार में उपस्थित स्टाफ सदस्यों को दैनिक सरकारी कामकाज में हिन्दी का प्रयोग करने के लिए प्रेरित एवं प्रोत्साहित करते हुए 'राष्ट्रभाषा बनाम राजभाषा' विषय पर अत्यन्त सारगर्भित एवं विवेचनात्मक व्याख्यान प्रस्तुत किया। डा. ए के बंधोपाध्याय, चीफ साइंटिस्ट ने कार्यक्रम का शुभारंभ किया। इस अवसर पर उन्होंने प्रयोगशाला के स्टाफ सदस्यों को हिन्दी में अधिक से अधिक कार्य करने के लिए प्रेरित करते हुए अपना संदेश दिया। समारोह के अंत में हिन्दी पखवाड़ा मनाए जाने के दौरान आयोजित की गयी प्रतियोगिताओं में भाग लेने वाले विजेता प्रतिभागियों को पुरस्कार प्रदान किए गए।

क्रम सं.	प्रतियोगिताएं	दिनांक
1.	साइंस क्विज़ प्रतियोगिता	6 अगस्त, 2012
2.	निबन्ध प्रतियोगिता	9 अगस्त, 2012
3.	हिन्दी टिप्पण एवं आलेखन प्रतियोगिता (डेस्क प्रतियोगिता)	14 अगस्त, 2012
4.	टंकण प्रतियोगिता	28 अगस्त, 2012
5.	वर्ष के दौरान हिन्दी में किया गया अधिकतम कार्य एवं हिन्दी डिक्टेशन	3 सितम्बर, 2012
6.	शब्दावली एवं अनुवाद प्रतियोगिता	6 सितम्बर, 2012
7.	काव्य पाठ प्रतियोगिता	7 सितम्बर, 2012

रेडियो एवं वायुमण्डलीय विज्ञान के विभिन्न आयामों पर परिचर्चा पर राष्ट्रीय संगोष्ठी, 7 – 8 नवम्बर, 2012

मानव जाति के लिए जीवन की गुणवत्ता में सुधार लाने तथा पृथ्वी के वातावरण प्रक्रियाओं को समझने में 'रेडियो एवं वायुमण्डलीय विज्ञान' का महत्त्व संदेह से परे है। जहां एक ओर रेडियो तरंगों का उत्पादन और अनुप्रयोग उपग्रह संचार, माइक्रोवेव रिमोट सेंसिग, दृष्टि की रेखा में संचार, ट्रोपोस्कैटर संचार, मोबाइल संचार आदि से लेकर जैव चिकित्सा अनुप्रयोगों में व्यापक रूप से हो रहा है; वहीं दूसरी ओर वायुमण्डलीय विज्ञान जलवायु परिवर्तन, सामुदायिक स्वास्थ्य, प्रदूषण, पारिस्थितिकी आदि प्रमुख मुद्दों को समझने और विनियमित करने में अहम भूमिका निभाती है। राष्ट्रीय भौतिक प्रयोगशाला के वैज्ञानिक उपर्युक्त क्षेत्रों में महत्त्वपूर्ण शोध–कार्य कर रहे हैं।

ऐसा माना जाता है कि विज्ञान एवं प्रौद्योगिकी किसी भी समाज की समृद्धि और विकास का द्योतक होते हैं और यदि इसका प्रचार–प्रसार राजभाषा हिन्दी में हो तो यह समाज और राष्ट्र के लिए स्वाभिमान और आत्म सम्मान की बात होती है। राष्ट्रीय भौतिक प्रयोगशाला इस दिशा में सतत्

राष्ट्रीय संगोष्ठी का शुभारंभ करते हुए प्रो. रमेशचन्द्र बुधानी, निदेशक, राष्ट्रीय भौतिक प्रयोगशाला

राष्ट्रीय संगोष्ठी में उपस्थित वैज्ञानिक समुदाय को सम्बोधित करते हुए प्रो. रमेशचन्द्र बुधानी, निदेशक, राष्ट्रीय भौतिक प्रयोगशाला

प्रयत्नशील रही है कि विज्ञान एवं प्रौद्योगिकी के अधिक से अधिक कार्य राजभाषा हिन्दी में किए जा सकें। इसी संदर्भ में, राष्ट्रीय भौतिक प्रयोगशाला हर वर्ष कम से कम एक वैज्ञानिक एवं प्रौद्योगिकी संगोष्ठी हिन्दी भाषा में आयोजित करती रही है। राष्ट्रीय भौतिक प्रयोगशाला में 7–8 नवम्बर, 2012 को 'रेडियो एवं वायुमण्डलीय विज्ञान के विभिन्न आयामों पर परिचर्चा' विषय पर राजभाषा हिन्दी में दो दिवसीय राष्ट्रीय संगोष्ठी का सफल आयोजन किया गया।

संगोष्ठी में रेडियो एवं वायुमण्डलीय विज्ञान के विभिन्न आयामों पर परिचर्चा हेतु देश भर के विभिन्न संस्थानों एवं विश्वविद्यालयों के वैज्ञानिकों एवं शोधकर्त्ताओं को आपस में विचार–विमर्श करने और अपने अनुभवों के आदान–प्रदान हेतु आमंत्रित किया गया। इस संगोष्ठी के मुख्य अतिथि डा. अजित त्यागी जी, पूर्व महा निदेशक, मौसम विज्ञान विभाग, पृथ्वी विज्ञान मंत्रालय थे।

संगोष्ठी का शुभारंभ प्रो. रमेश चन्द्र बुधानी, निदेशक, राष्ट्रीय भौतिक प्रयोगशाला के स्वागत भाषण एवं आशीर्वचनों से हुआ। निदेशक महोदय ने मुख्य अतिथि डा. अजित त्यागी एवं सभागार में उपस्थित वैज्ञानिक समुदाय का अभिनंदन करते हुए एन पी एल में रेडियो एवं वायुमण्डलीय विज्ञान के क्षेत्र में हो रहे शोध कार्यों के बारे में बताया। मुख्य अतिथि डा. अजित त्यागी ने 'जलवायु परिवर्तन व भारत पर इसका संभावित प्रभाव' शीर्षक पर मुख्य अभिभाषण दिया। आपने अपने अभिभाषण में जलवायु परिवर्तन के विभिन्न आयामों पर प्रकाश डाला और इस वैश्विक समस्या के निदान हेतु सभी स्तरों पर सहभागिता सुनिश्चित करने के लिए कुछ कारगर उपाय सुझाए।

इस संगोष्ठी में छह तकनीकी सत्र थे, जिनमें नौ आमंत्रित वार्ताएं तथा 55 मौखिक वार्ताएं प्रस्तुत की गयीं। इन वार्ताओं में रेडियो एवं वायुमण्डलीय विज्ञान से संबद्ध विभिन्न विषयों जैसे जलवायु परिवर्तन और इसके प्रभाव, शहरीकरण एवं वायुमण्डलीय परिवर्तन, दूरसंवेदन, एरोसोलः रासायनिक तथा भौतिक अभिलक्षण, ग्रीन हाउस, ट्रेस गैस तथा कृषि एवं वनोपजों पर प्रभाव आदि पर लेख प्रस्तुत किए गए एवं गहन विचार–विमर्श किया गया। इस प्रकार राजभाषा हिन्दी में आयोजित यह दो दिवसीय राष्ट्रीय संगोष्ठी रेडियो एवं वायुमण्डलीय विज्ञान से जुड़े विभिन्न पक्षों के लिए अत्यंत प्रासंगिक रही।

व्याख्यान

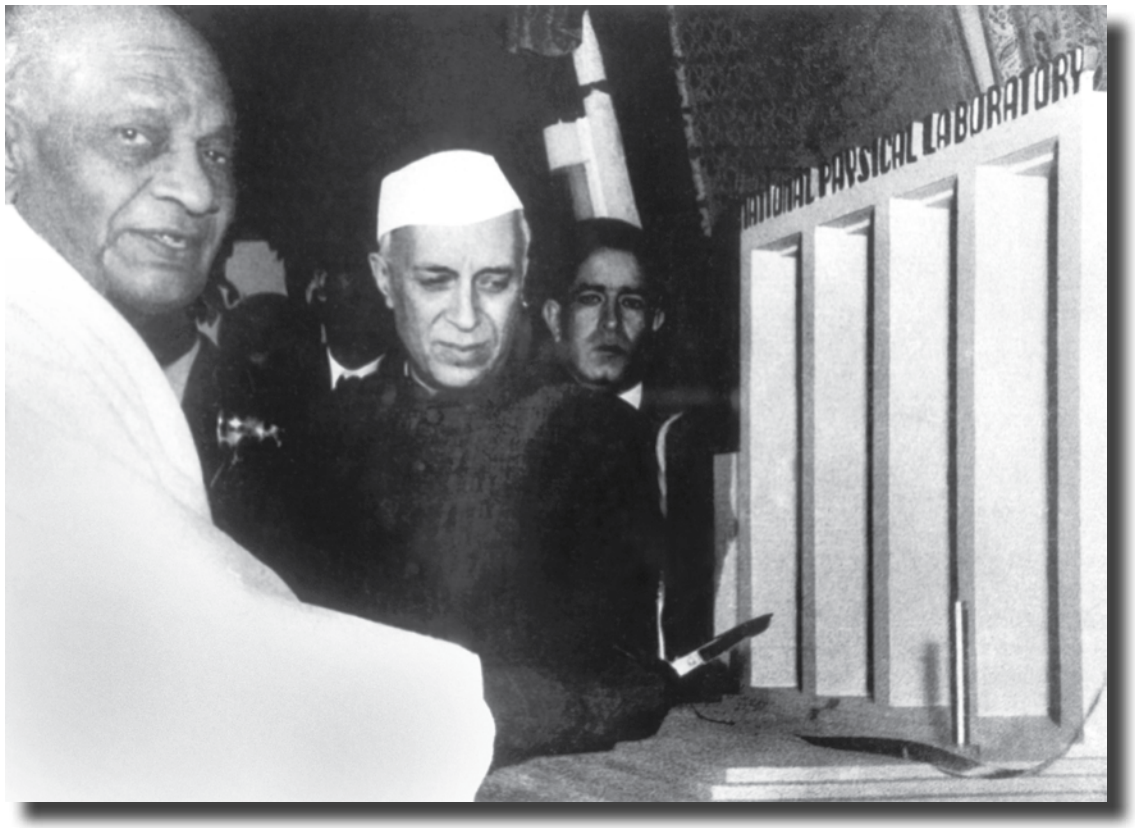
राजभाषा विभाग, गृह–मंत्रालय, भारत सरकार के निर्देशानुसार राजभाषा हिन्दी के प्रचार–प्रसार के लिए प्रयोगशाला के वैज्ञानिकों, प्रशासनिक अधिकारियों/कर्मचारियों के लिए प्रत्येक तिमाही में कार्यशाला/व्याख्यान का आयोजन किया जाता है जिसमें जनोपयोगी एवं सूचनात्मक विषयों को शामिल किया जाता है। इसी क्रम में प्रयोगशाला के स्टाफ सदस्यों

के लिए दिनांक 29 नवम्बर, 2012 को 'डायबटीज' (Diabetes) विषय पर एक व्याख्यान का आयोजन किया गया। व्याख्यान देने के लिए डा. अजय कुमार अजमानी, सीनियर कंसलटेंट एण्ड हैड डिपार्टमेंट ऑफ एंडोक्रिनोलॉजी, डायबटीज, बी एल कपूर सुपर स्पैशिलिटी हॉस्पिटल को विशेष रूप से आमंत्रित किया गया। डा. अजमानी ने डायबटीज पर महत्वपूर्ण एवं अद्यतन जानकारी देते हुए बताया कि ग्रामीण इलाकों के मुकाबले शहरों में डायबटीज ज्यादा तेजी से पाँव पसार रहा है। जहां ग्रामीण इलाकों में 4 से 8 प्रतिशत लोगो को डायबटीज होती है वहीं शहरों में 10 से 15 फीसदी लोगों में यह बीमारी हो रही है। डायबटीज की बड़ी वजह हाई ब्लडप्रैशर की शिकायत है। राजधानी दिल्ली में बड़ी संख्या में लोग डायबटीज की चपेट में हैं और हर साल यह तादाद बढ़ रही है। बीमारी की पहचान, उसकी रोकथाम पर फोकस करते हुए डा. अजमानी ने बताया कि सही जीवन शैली को अपनाना और डायबटीज के लिए आसान लेकिन प्रभावी तरीकों का इस्तेमाल करना अत्यन्त आवश्यक है। डा. अजमानी ने उपस्थिति श्रोताओं द्वारा पूछे गए प्रश्नों का भी समाधान किया। इस व्याख्यान में प्रयोगशाला के वैज्ञानिकों/अधिकारियों एवं स्टाफ सदस्यों ने बड़ी संख्या में भाग लिया।

कार्यशाला

राष्ट्रीय भौतिक प्रयोगशाला राजभाषा हिन्दी के व्यापाक प्रचार–प्रसार के लिए निरन्तर प्रर्यत्नशील है और प्रयोगशाला द्वारा भारत सरकार के दिशा–निर्देशों के अनुपालन में प्रत्येक तिमाही में कार्यशाला/व्याख्यान का आयोजन किया जाता है। इसी अनुक्रम में प्रयोगशाला के सभी स्टाफ सदस्यों विशेषकर वैज्ञानिकों के लिए 'पॉपुलर साइंस' पर दिनांक 29 जनवरी, 2013 को टी ई सी कांफ्रेंस–रूम में एक व्याख्यान का आयोजन किया गया। आमंत्रित वक्ता डा. मनोज कुमार पटैरिया, निदेशक/वैज्ञानिक–एफ राष्ट्रीय विज्ञान एवं तकनीक संचार परिषद्, विज्ञान एवं प्रौद्योगिकी विभाग, भारत सरकार ने 'विज्ञान और समाज सम्बन्ध–वैज्ञानिकों की भूमिका' (Connecting Science to Public–A Scientist Agenda) विषय पर व्याख्यान दिया। डा. पटैरिया ने उपस्थित वैज्ञानिक समुदाय को सम्बोधित करते हुए कहा कि 'जन भागीदारी वाले लोकतंत्र में देश के समग्र विकास के लिए विज्ञान विषयों के साथ–साथ समाज के लिए आवश्यक विषयों पर खोज करके जानकारी देना वैज्ञानिकों का उत्तरदायित्व है। जन संचार माध्यमों में वैज्ञानिक मुद्दों पर गहन, विश्लेषणात्मक और रोचक विषय वस्तु को पर्याप्त स्थान दिए जाने की आवश्यकता है ताकि जन सामान्य को वैज्ञानिक दृष्टि से जागरूक और आचार–व्यवहार में विवेकपूर्ण और वैज्ञानिक प्रवृत्ति से परिपूर्ण बनाया जा सके। डा. पटैरिया ने उपस्थित श्रोताओं द्वारा पूछे गए प्रश्नों पर भी अपने विचार रखे। इस प्रकार यह व्याख्यान अपने उद्देश्य में अत्यंत सफल रहा। ❑

अतीत के सुनहरे पल ...



Sardar Vallabbhai Patel and Pandit Jawaharlal Nehru at the Opening Ceremony of NPL (1950)

APPENDIX - 1

Papers Published by NPL Researchers in SCI Indexed Journals During April 2012 to March 2013

1. Agarwal, A., and Sen Gupta, A. "Frequency and Intensity Control of Lasers to Cool and Control Caesium Atoms." Mapan-Journal of Metrology Society of India27 (Sep 2012): 169-173.
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APPENDIX - 2

PATENTS
(01.04.2012 – 31.03.2013)
Patents Filed in India

Sr. No	Title	Filing Date	Application No.	Inventors
1	Improvement in power conversion efficiency in conjugated polymer modified ptb7- pc60bm based bulk heterojunction solar cells	27/08/2012	2650del2012	Gupta Vinay, Bharti Vishal, Chaudhary Neeraj, Chand Suresh
2	Light weight carbon foam as electromagnetic interference (emi) shielding and thermal interface material for aerospace applications	26/11/2012	3615del2012	Sanjay Rangnath Dhakate, Rajeev Kumar, Rakesh Behari Mathur, Parveen Saini
3	Development of specific method to identify inorganic phosphate (used as an adulterant) in milk	01/06/2012	1582del2011	Ajit Kumar Sarkar, Niranjan Singh, RC Sharma
4	Lithium metal quinolates and process for preparation thereof as good emitting, interface materials as well as n-type dopent for organic electronic devices	27/06/2012	1746del2011	Kamalasanan M.N., Srivastava Ritu, Amit Kumar, Ishwar Singh, Dhawan S.K., Bawa S.S.
5	A low cost compact mixed flow relative humidity generator	14/12/2012	3859del2012	Ashok Kumar, Hari Kishan, Bhikham Singh
6	Mixed flow relative humidity generator	7/12/2012	3769del2012	Hari Kishan, Bhikham Singh, Ashok Kumar, Shiv Dutt Sharma
7	Light weight high electromagnetic interference (emi) shielding material based on carbon nanotubes reinforced polymer composites	21/06/2012	1793del2011	Singh Bhanu Pratap, Garg Parveen, Pande Shailaja, Mathur Rakesh Behari, Saini Parveen, Dhawan Sundeep Kumar

Patents Filed Abroad

Sr No	Title	Country	Filing Date	Application No.	Inventors
1	Lithium metal quinolates and process for preparation thereof as good emitting, interface materials as well as n-type dopent for organic electronic devices	US	21/06/2012	13/529815	Kamalasanan Modeeparampil Narayanan, Srivastava Ritu, Amit Kumar, Ishwar Singh, Dhawan Sandeep Kumar, Bawa Sukhwant Singh

Sr No	Title	Country	Filing Date	Application No.	Inventors
2	An improved process to deposit diamond like carbon as protective coating on inner surface of bottles	EP	30/01/2013	13000454.2	Kumar Sushil, Dixit Prakash Narain, Rauthan Chandra Mohan Singh
3	A process for the removal of arsenic and chromium from water	Rep. of South Africa	27/7/2012	2011/00701	Nahar Singh, Rashmi, Sukhvir Singh,Daya Soni, Renu Pasricha, Prabhat K. Gupta

Patents Granted in India

Sr No	Title	Grant Date	Patent No.	Inventors
1	Monoclinic $CeTiO_2O_6$ thin film and a sol-gel process for the preparation thereof	08/08/2012	253634	Verma Amita, Agnihotry Suhasini Avinash, Bakshi Ashok Kumar
2	A process for the preparation corrosion protection copolymer coating of iron based surfaces	07/09/2012	253963	Dhawan SK, Singh N
3	A proces for the preparation of improved fibrous activated carbon useful for the filtration of carcinogenic vapours in tobacco based smoking devices	18/09/2012	254077	Jagan Nath Bohra, Ranjan Koyhari, Rajiv Kumar Saxena, Ranbir Singh, Erode Subramanian Raja Gopal

Patents Granted Abroad

S. No	Title	Country	Grant Date	Patent No.	Inventors
1	Monoclinic $CeTiO_2O_6$ thin film and a sol-gel process for the preparation thereof	JP	18/05/2012	4995839	Verma Amita, Agnihotry Suhasini Avinash, Bakhshi Ashok Kumar
2	A novel method for joining oxide-superconducting tubes with a superconducting joint	JP	18/05/2012	4995284	Ekbote Shrikant Narayan, Padam Gursharan Kaur, Arora Narendra Kumar, Sharma Mukul, Sethi Ramesh
3	Device useful as a master/ slave clock for transmitting standard time over a telephone network and a telephone network incorporating the device for transmitting and receiving standard time	EP	13/06/2012	0851324	Banerjee P

S. No	Title	Country	Grant Date	Patent No.	Inventors
4	Device useful as a master/ slave clock for transmitting standard time over a telephone network and a telephone network incorporating the device for transmitting and receiving standard time	FR	13/06/2012	0851324	Banerjee P
5	Device useful as a master/ slave clock for transmitting standard time over a telephone network and a telephone network incorporating the device for transmitting and receiving standard time	DE	13/06/2012	0851324	Banerjee P
6	Device useful as a master/ slave clock for transmitting standard time over a telephone network and a telephone network incorporating the device for transmitting and receiving standard time	SE	13/06/2012	0851324	Banerjee P
7	Device useful as a master/ slave clock for transmitting standard time over a telephone network and a telephone network incorporating the device for transmitting and receiving standard time	IT	13/06/2012	0851324	Banerjee P
8	Device useful as a master/ slave clock for transmitting standard time over a telephone network and a telephone network incorporating the device for transmitting and receiving standard time	GB	13/06/2012	0851324	Banerjee P
9	Conducting copolymer ferromagnetic composite and a process for the preparation thereof	US	02/10/2012	8277690	Dhawan; Sundeep Kumar, Singh; Kuldeep, Sobti; Nikhil, Ohlan; Anil, Saini; Parveen, Gupta; Beena, Pant; Rajendra Prasad, Kotnala; Ravinder Kumar, Hari; Kishan, Kothari; Prafulla Chandra

S. No	Title	Country	Grant Date	Patent No.	Inventors
10	Sol-gel process for the preparation of nanocrystalline ceti2o6 powder	US	08/01/2013	8349284	Verma; Amita, Agnihotry; Suhasini Avinash
11	A novel method for joining oxide-superconducting tubes with a superconducting joint	US	06/11/2012	8304372	Ekbote Shrikant Narayan, Padam Gursharan Kaur, Arora Narendra Kumar, Sharma Mukul, Sethi Ramesh
12	Process for the preparation of low contact resistant contact on a high transition temperature superconductors	US	06/11/2012	US8306590	Shrikant Ekbote, Gurusharan Kaur Padam, Narendra Kumar Arora, Mukul Sharma, Ramesh Sethi, Mrinal Kanti Banerjee
13	Development of thick film ceramic gas sensor:lpg gas sensor	AP	22/10/2012	AP2499	Vipin Kumar, Jain Kiran, Lakshmikumar S T, Raghavendra T
14	A simulation circuit layout design for low voltage, low power and high performance type ii current conveyor for analog signal processing applications	JP	22/06/2012	5021866	Rajput S S, Jamur S S
15	A process for joining a pair of tubes of oxide superconductors	JP	18/05/2012	4995284	Ekbote Shrikant Narayan, Padam Gursharan Kaur, Arora Narendra Kumar, Sharma Mukul, Sethi Ramesh
16	Process for the preparation of a low contact resistance on high transition temperature superconductors" (a product patent)	US	06/11/2012	8306590	S N Ekbote, G K Padam, N K Arora, M Sharma R Sethi and M K Banerjee
17	An automated dead weight force machine useful for calibrating strain gauge load cells	DE	07/03/2013	10 2007 036 214	K K Jain, HP Poddar, RP Singhal

APPENDIX - 3

R & D Collaborations

Collaborating Institute	Research Area
ISRO, Dept of Space	Development of Rubidium Atomic Clock
Department of Physics, ARSD College, University of Delhi (South Campus), New Delhi-110021, India	Degenerate gases: a new tool for frequency detection
LNE-SYRTE, Paris, France (LNE International Technical Collaboration Program)	Atomic fountains
NPL, UK	Atomic fountains
Bharti Automation Pvt. Ltd., New Delhi	Water flow measurement
LPEM, France	Two dimensional electron gas physics in oxide heterostructures
SINP, Kolkatta	Superconducting & Magnetic Materials
CNR/INFM-LAMIA, Genova, Italy	Superconducting Materials
JNU, New Delhi	Superconducting Materials
MAX Super Specialty Hospital, New Delhi	Tumor Diagnosis
Anna University, Chennai – CAP-14 (PI)	Crystal Growth and Characterization
Crystal Growth Centre, SNN College of Engg., Chennai, CAP-18 (PI)	Crystal Growth and Characterization
Jamia Millia Islamia, CAP-24. (PI)	Crystal Growth and Characterization

APPENDIX - 4

Sponsored/Supported R & D Projects

Sr. No.	Title of the Project	Agency/Client	Amount Received (₹ in Lakhs)
1	Development & characterization of bulk aluminium-alumina (Al-Al_2O_3) nano-composites-study of their nano-sintering with respect to densification & grain growth	DST, New Delhi (Indo-Hungary)	3.244
2	Development of grain Ferroelectric Nanocomposites and Investigation of size effect on various Ferroelectric Parameters	DST, New Delhi	9.20
3	Preparation and characterization of ferrofluids for energy conversion applications	DST, New Delhi	320.00
4	Two dimensional electron gas physics in oxide heterostructures	Indo-French Centre Promotion of Advanced Research (IFCPAR)	8.723
5	Enhancement of solar cell effciencies using tapered ZnO nanorod-CdTe polycrystalline thin film structure (Under SERC fast Track Scheme)	DST, New Delhi, (SERB)	16.50
6	Fellowship for INSPIRE Faculty	DST, New Delhi	19.00
7	DAE-SRC Outstanding Investigator Award Fellowship	Department of Atomic Energy (DAE)	61.82
8	Fellowship for INSPIRE Faculty	DST, New Delhi	19.00
9	Fellowship for INSPIRE Faculty	DST, New Delhi	19.00
10	Fellowship for INSPIRE Faculty	DST, New Delhi	7.00
11	Synthesis and characterisation of nanostructured electroluminescent materials for improved performance of optoelectronics devices and allied technologies	DST (Under Women Sci. Scheme A WOS-A)	6.600
12	Studies of electron correlations at low temperatures and high magnetic fields in tailored interfaces and heterostructures	DST, New Delhi	459.50
Total			**949.587**

APPENDIX - 5

Consultancy Projects 2012-13

Sr. No.	Project Code	Client	Title	Contract Value (₹ in Lakhs)
NEW*				
1	CNP120132	Emerald Jewel Industry India, Coimbatore	Recovery of Gold and Silver from process waste	2.24
NEARING COMPLETION**				
1	CNP050232	Regional Reference Standard Laboratory (RRSL), Ahmedabad	Design, Fabrication and installation of load cell testing machine	16.44
2	CNP051032	CPCB, Agra, Lucknow Zone	Inversion/mixing height studies at CPCB, Agra	9.99
3	CNP060632	MN Dastur & Co. Ltd, Kolkatta	Mixing height determination at Paradeep, Orissa	2.76
4	CNP070432	Regional Reference Standard Laboratory (RRSL), Guwahati	Setting up of torque standard machine at RRSL, Guwahati	14.29
5	CNP070932	Regional Reference Standard Laboratory (RRSL), Bangalore	Design, develop and fabricate torque primary standards from 2 Nm-200Nm within uncertainty of 0.05 %	31.00
6	CNP071132	Regional Reference Standard Laboratory (RRSL), Ahmedabad	Design, primary and secondary torque measuring facility at RRSL, Ahmedabad	14.29
7	CNP071232	Regional Reference Standard Laboratory (RRSL), Bhubaneswar	Supply of one number of secondary torque measurement facility at RRSL, Bhubaneswar	14.29
8	CNP071332	MN Dastur & Co. Kolkatta	Mixing height determination at Keonjhar, Orissa	5.25
9	CNP071732	Tata Steel, Jamshedpur	Inversion study for Tata Steel Plant at Jamshedpur	4.10
10	CNP090332	Raipur Tar Product, Raipur, Chhattisgarh	General consultancy relating to reduction of QI from high QI coal tar pitch	0.98
11	CNP100132	SIMCO Calibration Laboratory, Hyderabad	Guidance in Implementing of quality system dimensional parameters as per ISO 17025	1.37
12	CNP100532	Rajesh & Rajesh Std. Lab, Konark Apartment, Ta Panvel, Dist. Raigad (Maharashtra)	Set-up of laboratory of mass measurement for NABL accreditation	2.49
13	CNP110132	ABB Limited, 32, NIT, Faridabad	Weighing scale validation project	4.33
14	CNP110232	Electronics Regional Test Laboratory (North), New Delhi	Metrological characterization of a dual range piston gauge	3.26

15	CNP110332	Electronics Test and Development Centre, Guwahati	Determination of metrological parameters of hydraulic and pneumatic dead weight testers	5.40
ACCOMPLISHED* **				
1	CNP050932	Coal Chem, Bhilai	QI free coal tar pitch from coal tar	0.80
2	CNP060432	DMRCL, New Delhi	Consultancy services for studying noise impact of Delhi Metro Operation	5.32
3	CNP070132	ERTL, New Delhi	Characterization of dead weight tester	2.46
4	CNP070232	Regional Reference Standard Laboratory (RRSL), Bhubaneswar	Design and fabrication of the transfer standards of 100 kg, 200 kg and 500 kg full scale confirming to class A over the range 20-100 % at RRSL, Bhubaneswar	2.23
5	CNP070332	CSIO, Chandigarh	Quality system implementation in geoseismic and medical instrumentation in accordance with ISO/IEC 17025 : 2005	0.00
6	CNP070532	Regional Reference Standard Laboratory (RRSL), Faridabad	Design, fabrication and installation of primary torque measurement machine at RRSL, Faridabad	31.00
7	CNP070632	Bangalore Metro Rail Corporation Ltd. (BMRCL), Bangalore	Noise and vibration study in and around proposed Bangalore metro trains/stations near historic monuments	11.23
8	CNP070732	Aparna Carbon Pvt. Ltd, Kolkatta	General consultancy to improve the QI free coal tar-pitch	02.00
9	CNP071032	Regional Reference Standard Laboratory, (RRSL) Bangalore	Design, erection and commissioning of dead weight force machine at RRSL, Bangalore	101.25
10	CNP071432	Urban Waste Management Ltd, New Delhi	Performance checking of high pressure hose	0.34
11	CNP071532	General Motors India Ltd, Bangalore	Recrystallization and grain refinement mechanism during extrusion of magnesium alloys	65.96
12	CNP071632	HEG Ltd, Noida	To check feasibility/ suitability of HEG Ltd works at Mandideep to manufacture nuclear grade graphite	0.99
13	CNP071832	Jindal Steel & Power Ltd, Raigarh (MP)	Ultrasonic response from hall and notches in reference test rails and theirs correlation with dimensions	05.46
14	CNP080132	UP Samaj Kalyan Nagar Nigam Ltd, Lucknow	Acoustic of multipurpose hall at Bhagidari Bhawan, Gomati Nagar, Lucknow	01.73
15	CNP080232	Regional Reference Standard Laboratory, (RRSL) Ahmedabad	Design, develop & fabricate secondary force standards upto 50 kN by comparison of 0.05 %	22.29

16	CNP080332	Regional Reference Standard Laboratory, (RRSL) Bhubaneswar	Design, develop & fabricate secondary force standards upto 50 kN by comparison of 0.05 %	22.29
17	CNP080432	Regional Reference Standard Laboratory, (RRSL) Guwahati	Design, develop & fabricate secondary force standards upto 50 kN by comparison of 0.05 %	22.29
18	CNP080632	Regional Reference Standard Laboratory, (RRSL) Faridabad	Design, develop & fabricate secondary force standards upto 50 kN by comparison of 0.05 %	22.29
19	CNP080832	Yantrika Instrument Pvt Ltd, New Delhi	Characterization of Yantrika dead weight tester Model YW1307HBO/04 Sr. No. T8M311	3.48
20	CNP090132	Electronic Regional Test Laboratory (North), New Delhi	Metrological characterization of dual range piston gauge	3.269
21	CNP090232	Maple Consultants, Gurgaon	Noise and vibration impact study for proposed Taj Hotel in Dwarka, New Delhi	2.02
22	CNP090432	Moser Baer Photo Voltaic Ltd, Greater Noida	Measurement of minority carrier life time in multi-crystalline silicon wafers	4.24
23	CNP090532	Archaeological Survey of India, Chennai Circle, Chennai	Investigation of induced vibrations due to acoustic excitation from sound show at Brihadisvara Temple Thanjavur	4.49
24	CNP090632	Archaeological Survey of India, Chennai Circle, Chennai	Investigation on effect of Light show at Brihadisvara Temple, Thanjavur	4.47
25	CNP090732	Assam Tourism Dev. Corp. Ltd, Guwahati	Investigation of induced vibrations due to acoustic excitation from sound show at Talatal Ghar, at Shiv Sagar, Assam	4.49
26	CNP090832	Assam Tourism Dev. Corp. Ltd, Guwahati	Investigation on effect of Light show at Talatal Ghar, at Shiv Sagar, Assam	4.47
27	CNP100232	Electronics and Quality Development Centre, Gandhinagar	Metrological Characterization of a Dual RANGE Hydraulic Piston Gauge	3.38
28	CNP100332	Electronics Test and Development Centre, Chennai	Evaluation of Metrological Characteristics of a Pressure Balance	3.58
29	CNP100432	Fenesta Building Systems, Plot No. 52, Sector 32, Institutional Area, Gurgaon	Investigation on sound Insulation properties of Single, Double and triple window glazing	2.75
CONTINUING *****				
1.	CNP070832	Aeronautical Development Agency (ADA), Bangalore	Certification of reference blocks of various materials as per 1,2mm FBH standards of ASTM E 127-PV3/PV5 (59/704)	9.36
			TOTAL	**502.41**

Pl. note: * New Projects during 2012-13;
** Nearing Completion (Intellectual fee yet to be distributed);
*** Accomplished (Intellectual fee distributed);
***** Continuing during the year 2012-13.

APPENDIX - 6

Earning from Calibration & Testing

A. Apex Level Standards & Metrology			
Sub-division No.	**Sub-division Name**	**Charges or Actual Amount Received (inclusive of All Taxes) (₹ in Lakhs)**	**No. of Reports**
D5.01	Mass Standards	81.78	283
D5.02	Standards of Dimension	42.63	233
D5.03	Temperature & Humidity Standards	28.46	96
D5.04	Optical Radiation Standards	83.58	484
D5.05	Force & Hardness Standards	101.19	767
D5.06	Pressure & Vacuum Standards	30.39	83
D5.07	Acoustics, Ultrasonics, Shock and Vibration Standards	18.19	124
D5.09	LF & HF Impedance & DC Standards	16.80	64
D5.10	LF & HF Voltage, Current & Microwave Standards	27.23	64
D5.11	AC High Voltage & AC High Current Standards	9.69	21
D5.12	AC Power & Energy Standards	19.88	69
	Total (A)	**459.82**	**2288**

B. Time and Frequency			
Sub-division No.	**Sub-division Name**	**Charges or Actual Amount Received, inclusive of All Taxes (₹ in Lakhs)**	**No. of Reports**
D4.03	Precise Timing Systems	2.57	10
	Total (B)	**2.57**	**10**

C. Materials Physics & Engineering.			
Sub-division No.	**Sub-division Name**	**Charges or Actual Amount Received, inclusive of All Taxes (₹ in Lakhs)**	**No. of Reports**
D2.01	Polymer & Soft Material	0.27	01
D2.04	Multiferroics and Magnetics	5.85	34
D2.06	Metals & Alloys	0.84	04
D2.07	Piezoelectric Sensors & Actuators	0.51	16
	TOTAL (C)	**7.47**	**55**

D. Josephson Junctions, QHR Standards & Nanoscale Measurements			
Sub-division	**Sub-division Name**	**Received, inclusive of All Taxes (₹ in Lakhs)**	**No of Reports Generated**
D 6.03	Nanoscale Measurements	0.67	2
	Total (D)	**0.67**	**2**

Summary			
Sub-division No.	**Sub-division Name**	**Amount Received, inclusive of All Taxes (₹ in Lakhs)**	**No. of Reports Generated**
D 2	Materials Physics & Engineering	7.47	55
D 4	Time and Frequency	2.57	10
D 5	Apex Level Standards & Industrial Metrology	459.82	2288
D 6	Josephson Junctions, QHR Standards & Nanoscale Measurements	0.67	2
	Grand Total	**470.53**	**2355**

Notional Cases Only			
Division	**Division Name**	**Charges (₹ in Lakhs)**	**Number of Reports**
D 2	Materials Physics & Engineering	1.43	11
D 3	Atmospheric Chemistry	0.11	1
D 4	Time and Frequency	0.95	8
D 5	Apex Level Standards & Industrial Metrology	127.63	344
D 6	Josephson Junctions, QHR Standards & Nanoscale Measurements	6.40	13
	Grand Total	**136.52**	**377**

D. Josephson Junctions, QHR Standards & Nanoscale Measurements			
Sub-division	**Sub-division Name**	**Received, inclusive of All Taxes (₹ in Lakhs)**	**No of Reports Generated**
D 6.03	Nanoscale Measurements	0.67	2
	Total (D)	**0.67**	**2**

Summary			
Sub-division No.	**Sub-division Name**	**Amount Received, inclusive of All Taxes (₹ in Lakhs)**	**No. of Reports Generated**
D 2	Materials Physics & Engineering	7.47	55
D 4	Time and Frequency	2.57	10
D 5	Apex Level Standards & Industrial Metrology	459.82	2288
D 6	Josephson Junctions, QHR Standards & Nanoscale Measurements	0.67	2
	Grand Total	**470.53**	**2355**

Notional Cases Only			
Division	**Division Name**	**Charges (₹ in Lakhs)**	**Number of Reports**
D 2	Materials Physics & Engineering	1.43	11
D 3	Atmospheric Chemistry	0.11	1
D 4	Time and Frequency	0.95	8
D 5	Apex Level Standards & Industrial Metrology	127.63	344
D 6	Josephson Junctions, QHR Standards & Nanoscale Measurements	6.40	13
	Grand Total	**136.52**	**377**

APPENDIX - 8

Recognitions, Honours and Awards

- Dr. Poonam Arora received CSIR Young Scientist Award 2012 in "Physical Sciences including Instrumentation". The award consists of a citation, a cash prize of Rs. 50,000 and a plaque.

- Dr. Priyanka Heda Maheshwari received CSIR Young Scientist Award 2012 in "Engineering Sciences". The award consists of a citation, a cash prize of Rs. 50,000 and a plaque.

- Prof. R.C. Budhani, Director, CSIR-NPL, was conferred with "IIT Delhi Distinguished Alumni Award 2012", at the convocation of IIT Delhi held on 28th October, 2012, in recognition of his "Outstanding Contributions as Researcher and Educator". In addition, Prof. R.C. Budhani was felicitated by the IIT Delhi Alumni Association at a special function held on the same day.

- Dr. Sanjay K. Srivastava was deputed at Max Planck Institute for the Science of Light (MPL), Erlangen, Germany under BOYSCAST Fellowship 2010-11 programme of Department of Science and Technology (DST), Govt. of India. For 12 months (10 Aug 2011-09 Aug. 2012).

- Dr. Rajesh Agnihotri received M.S.Krishnan Gold Medal for the year 2012 by Indian Geophysical Union, Hyderabad.

- Dr M V S N Prasad received IETE-N V Gadhadhar Memorial award (2012) for his contributions in the area of radio channel modeling and measurements for fixed and mobile communications.

- Dr. Naseema Begam, RA, has been awarded young Associate of India Academy of Sciences -Bangalore award.

- Dr. Rupesh M. Das, Scientist, participated as Leader for 31st Indian Scientific Expedition to Antarctica for New Research Station, Bharati, National Centre for Antarctic and Ocean Research (Ministry of Earth Sciences), Goa.

- Dr. O. S. Panwar - External member of Research Council (RC) of R& D Centre at Central Electronic Limited (CEL), Sahibabad.

- Dr. A. M. Biradar received Material Research Society of India (MRSI) medal lecture award for the year 2013 at Indira Gandhi Centre for Atomic Research, Kalpakkam, Chennai.- MRSI, India

- Dr. K. P. Chaudhary- Chairman, Engineering Metrology Sectional Committee, PG 25, Production and General Engineering Department and Expert, PG 32, PGDC, Bureau of Indian Standards (BIS),

- Dr. Mahavir Singh- Principal Member, LITD 07, MED28, Bureau of Indian Standards (BIS).

APPENDIX - 9

Foreign Visitors

- Delegation from NPL, Teddington, UK, compriseing of Dr. Theodorus J. B. M. Janssen & Dr. Timothy Richard Prior (March 30, 2012 to April 5, 2012)
- Prof. Ahmed C. Bawa, Vice Chancellor & Principal, University of Technology, Durban (April 10, 2012)
- Under the sponsorship of Ministry of External Affairs, Government of India, for its Indian Technical & Economic Cooperation (ITEC) & Special Common Wealth Assistance for African Programme (SCAAP), following delegations visited CSIR-NPL during their training prgramme :
  - 41 participants from developing countries attending International Training Programme on "Standardisation and Quality Assurance for Developing Countries" organized by National Institute of Training for Standardization (NITS) of Bureau of Indian Standards.(BIS) under Min. of Consumer Affairs, Food & Public Distribution (April 18, 2012)
  - 20 delegates from 12 countries under "Management Development Programme on Operation, Maintenance and Repair of Bio Medical Equipment" at CSIO, CSIR Complex, New Delhi (September 28, 2012)
  - 9 delegates from 6 countries under "Management Development Programme on Operation, Maintenance and Repair of Optical/ Ophthalmic Equipment" at CSIO, CSIR Complex, New Delhi (January 2, 2013)
  - 23 participants from developing countries attending International Training Programme on "Standardization and Quality Assurance for Developing Countries" organized by National Institute of Training for Standardization (NITS) of Bureau of Indian Standards (BIS) under Min. of Consumer Affairs, Food & Public Distribution (March 3, 2013)
- 4 member Tanzanian delegation from Department of Weights & & Measures Agency, Republic of Tanzania (June 4, 2013)
- 9 Members delegation led by Ms. Lesego M Motoma, Director, Research, Science & Technology from Botswana (June 25, 2012)
- Delegates from South African Bureau of Standards (SABS) and Brazilian Association of Technical Standards -ABNT (August 8, 2012)
- 5 member Korean, IPET delegation led by Dr. Chan HO CHOI, Regional Director, International Cooperative Alliance-Asia & Pacific (September 12, 2012)
- French delegation from Institute of Physics CNRS-INP led by Prof. Jean-Francois PINTON, Scientific Director (October 30, 2012)

French Delegation at NPL

- Australian delegation from University of Wollongong led by Prof. Paul Wellings CBE, Vice Chancellor (December 2, 2012)

Australian Delegation at NPL

- Canadian delegation from University of Toronto led by Prof. Judith Wolfson, Vice President (January 14, 2013)

Canadian Delegation at NPL

- A high Level Japanese delegation of 15 participants from the Ministry of Economy, Trade and Industry (METI) and the National Institute of Advanced Industrial Science and Technology (AIST) and Japan Measuring Instruments Federation (JMIF)(February 18, 2013)

Japanese Delegation at NPL

APPENDIX - 10

Ph. D awards based on the research work done at NPL

Sr. No.	Title	Awardee	University/Institute	Guide(s)
1	Synthesis and Characterization of Metal and Metal Oxide nanoparticles and their Bioapplications	Ms. Prachi Joshi	Jamia Millia Islamia, Delhi	Dr. Virendra Shanker (CSIR-NPL) Dr. Z.Ansari (JMI)
2	Group II-VI Semiconductor Nanocrystals for Photo and Electroluminescence Applications	Ms. Sonal	Jamia Millia Islamia, Delhi	Dr. D. Haranath (CSIR-NPL) Prof. M.Hussain (JMI)
3	Effect of nanomaterials on the alignment & memory behaviour	Mr. Ajay Kumar	University of Delhi	Dr. A.M. Biradar (CSIR-NPL) Dr. Poonam Silotia (DU)
4	Sound Transmission Through Panels	Mr. Dharam Pal Singh	CCS Meerut University, Meerut	Dr. Mahavir Singh (CSIR-NPL) Dr. R. S. Upadhayay (CCSMU, Meerut)
5	Vibrational spectroscopic studies on interaction mechanism of anticancer drugs with deoxyribonucleic acid	Mr. Deepak Kumar Jangir	University of Delhi, Delhi	Dr. Ranjana Mehrotra (NPL) Dr. Suman Kundu (DU)
6	Experimental studies of ZnSe, ZnTe chalcogenide and LPCCM, LAM, KDP, GP non-linear compounds	Mr. Mohd. Shakir	Jamia Millia Islamia, Delhi	Dr. G. Bhagavannarayana (CSIR-NPL) Prof. M.A. Wahab (JMI)
7	Growth and investigation for crystalline perfection *vis-à-vis* physical properties of pure and doped $LiNbO_3$, benzophenone and ZTS NLO single crystals	Mr. S.K. Kushwaha	University of Delhi, Delhi	Dr. G. Bhagavannarayana (CSIR-NPL) Dr. Binay Kumar (DU)

APPENDIX - 11

HUMAN RESOURCE DEVELOPMENT GROUP

The various activities of the Group are as follows:

1. Organisation of Industrial Training Courses

Organisation of Training Courses on various physical parameters in the area of Metrology / Standards, as well as on other specialized topics is an important activity of the HRD Group. These courses are primarily meant for the personnel belonging to various industries, Testing & Calibration laboratories and other S&T organisations. However, the NPL staff members are also encouraged to attend these courses, where ever found fit.

The Training Courses consist of theory lectures on various scientific & technical aspects of the training course, followed by practical demonstration and hands-on training on the related instruments / apparatus / machines.

Nine (09) Training Courses on different subjects were organised by NPL during the period from 1st April 2012 to 31st March 2013., the details of which are as follows :

S. No.	Name of Training Course	Date	No. of Participants
1	Training Course on Mass, Volume & Length Measurements	24-27 April 2012	26 (Legal Metrology)
2	Workshop on advanced Material Charecterization techniques	10-13 July 2012	8 + 13 (NPL)
3	Training Programme on Quality System	22-24 August 2012	13+10 (NPL)
4	Training Programme on Blood Pressure, Force Measuring Instruments and Clinical Thermometers	27-29 August 2012	42 (Legal Metrology)
5	Training Programme on Mass Metrology	3-5 September 2012	19 + 02 (NPL)
6	Workshop on Electrical Metrology & Low level DC Measurements	17-19 October 2012	20
7	Training Programme on IP with Special Reference to Patent Search & Drafting Specification	2nd November 2012	29 (NPL)
8	Training Programme on Temperature Standards and Metrology	6-9 November 2012	11
9	Training Programme on Pneumatic & Hydraulic Pressure Measuring Instruments & their calibration	17-18 January 2013	15

This activity of HRD Group led to an ECF generation of ₹ 30.04 lacs.

2. Placement, Ph.D. Registration and other Support to Research Fellows

One of the most prominent activities of the NPL is to provide help and support to Research Fellows (JRFs / SRFs), starting from the time they join NPL till the time they leave NPL. This includes their placement in a suitable Division / Group and helping them in getting Hostel accommodation, if required. This also includes their Ph.D. registration, assessment for continuance / upgradation, deputation to attend conferences, etc. Sometimes, the help to the Research Fellows starts even before they join NPL. This refers to the cases wherein they are invited and inspired to join NPL for their Ph.D. programme.

During the period from 1st April 2012 to 31st March 2013, 26 research fellows (JRFs/SRFs) were inspired to join NPL, resulting in a total strength of Research Fellows (JRFs+SRFs) in NPL to be 97 as on 31.03.2013.

3. Organization of Institutional Visits to NPL

Organization of institutional visits involving students / teachers / faculty members / personnel belonging to schools / colleges / universities / technical institutes / S&T organisations is an important activity of the NPL. The basic objective is to provide the visitors a glimpse of the NPL activities and achievements, and thus enhance visibility of NPL in the society.

During the period from 1st April 2012 to 31st March 2013, Six (06) institutional visits were organised by NPL, which involved around 200 persons from different institutes and colleges.

4. Organisation of Students' Training at NPL

NPL provides Training (6 months & above) to students pursuing M.Sc./M.Tech./MCA, or their equivalent degree programmes, at different educational institutions spread all across the country, in the areas of research activities being carried out at NPL. The basic objective is to provide the students a feel and importance of the various activities, as well as to motivate them towards scientific research as the career.

During the period from 1st April 2012 to 31st March 2013, 96 students were provided training oriented towards the fulfillment of their academic degree requirements in different areas of research under the guidance of senior scientists.

This activity of HRD Group led to an ECF generation of ₹ 4 lacs.

5.Deputation of NPL Staff Members to Attend Conferences / Similar Events

NPL encourages and supports its staff members, including the students like JRFs, SRFs, PAs, RIs, RAs, SRAs, etc., to attend and present papers at national / international conferences / symposia / seminars / workshops, organised by different agencies in areas relevant to research activities being carried out at NPL. This is primarily meant to enable the staff members to put forward their views and research results before the leading national / international experts and interact with them on the latest developments in their research areas.

During the period from 1st April 2012 to 31st March 2013, 458 cases of NPL scientists and other staff members including research scholars, were nominated to participate in various conferences / similar events and different Training Courses held across the country.

6. AcSIR and M.Tech. Programme Related Activities

All activities related to M.Tech programme for Advanced Material Physics & Engineering and AcSIR Ph.D Students including Interviews, Admission Process, Classes (theory/tutorial/ practical), Examinations and Evaluation are handled by the HRD Group in consultation with the AcSIR-NPL Coordinator.

During the current year Nine (9) M. Tech students joined NPL for "Advanced Material Physics & Engineering" Course.

7. Organisation of National Science Day Function

National Science Day was celebrated at CSIR-National Physical Laboratory, New Delhi on 28th February 2013. On that occasion, Prof. S.D. Mahanti, University of Michigan, USA delivered the 'Science Day Lecture' at NPL auditorium. Director, NPL welcomed and introduced the chief Guest to the audience. All staff and students from NPL attended the lecture and interacted with the speaker. After the lecture, there was a poster session by NPL students (JRF, SRF, PA and RI) during 2:30-4:30 PM. More than 92 students from different R&D groups presented their results. A team of five eminent scientists acted as the Jury. The committee members visited all the posters and interacted with the students. Out of these, five posters were selected for the best poster awards.

APPENDIX - 12

IMPORTANT CONFERENCES, SYMPOSIA, WORKSHOPS AND EVENTS

Date	Conferences, Symposium, Workshops and Events
24 April, 2012	Training program on Legal Metrology
21 May, 2012	World Technology and National Metrology Day
25 June, 2012	NWP 54 CSIR TAPSUN Meeting
27 June, 2012	Invited Talk by Dr Rahul Masker of NIST
29 June, 2012	Invited Talk by Dr D P Bhatt of NPL
10 July, 2012	Training on Advanced Material Characterization
20 July, 2012	PGRPE Interview
27 July, 2012	Distinguished Scientist Lecture by Prof. R. Rajaraman of JNU Delhi
06 August, 2012	Invited Talk by Dr Vindya Arora of Gunanak Dev University, Punjab
06 August, 2012	Science Quitz
15 August, 2012	Independence Day Celebration
22 August, 2012	Training Program on Calibration, Quality System and Laboratory Management
27 August, 2012	Training on Legal Metrology
07 September, 2012	Kavita Path on Hindi
13 September, 2012	Hindi Pakhwada Celebration
14 September, 2012	Distinguished Scientist Lecture by Prof Balram Bhargav of AIIMS, New Delhi
16 September, 2012	Competition of Painting and Essay
21 September, 2012	Invited Talk by Prof Anjan Kumar Gupta of IIT Kanpur
26 September, 2012	CSIR Foundation Day Celebrations
27 September, 2012	Workshop on Nano Metrology
11 October, 2012	Invited Talk by Dr. Sanjay Kumar Srivastava of Physics of Energy Harvesting
17 October, 2012	Workshop on DC Current of Electrical
30 October, 2012	Symposium on Ultrasonic Society of India
06 October, 2012	Training Program on Temperature Std and Metrology
07 October, 2012	National Conference on Various Aspect Radio and Atmospheric Science (in Hindi)
19 November, 2012	Pledge on Quomi Ekta
29 November, 2012	Hindi Unit Meeting
30 November, 2012	Distinguished Scientist Lecture by Prof Mukunda Prasad Dash of Australian National University
04 December, 2012	1st TAPSUN Conference
14 December, 2012	Research Council Meeting
15 December, 2012	Steering Committee Meeting
01 January, 2013	New Year Message by Director, NPL
05 January, 2013	13th International Conference on Magnetic Fluids
20 February, 2013	Admet 2013
25 February, 2013	Seminar on Nano Science
25 February, 2013	National Seminar of Indian Science
06 March, 2013	DG CSIR Meeting with Foreign and NPL Scientists
11 March, 2013	Krishnan Memorial Lecture
31 March, 2013	57th RC Meeting of NPL

APPENDIX - 13

CSIR-NPL Colloquium Series

S. No.	Date	Speaker & Affiliation	Title of the talk
1	April 4, 2012	Dr. Jan-Theodoor Janssen, National Physical Laboratory, UK	Universality test of the quantum Hall effect using epitaxial graphene
2	May 16, 2012	Prof. Subodh R Shenoy, Indian Institute of Science Education and Research, Trivandrum	Martensite domain growth after a deep quench: Golf holes and entropy barriers
3	June 27, 2012	Dr. Rahul Mhaskar, NIST, Boulder, CO, USA	Chip-Scale Atomic Magnetometry: Fundamentals and Applications in Biomagnetism
4	June 27, 2012	Prof. R Rajaraman JNU, New Delhi	The discovery of the higgs boson and its significance (Distinguished Scientist Lecture)
5	June 29, 2012	Dr. D P Bhatt, Intellectual Property Rights Management Group, NPL	Pre-patenting & other IP related issues (in house Lecture)
6	August 03, 2012	Prof. Guglielmo M Tino University of florence, Italy	Cold atom interferometers and optical clocks
7	August 06, 2012	Dr. Bindiya Arora Guru Nanak Dev University, Amritsar	Uncertainity budget for atomic and optical frequency standards
8	September 14, 2012	Prof. Balram Bhargav AIIMS, New Delhi	Challenges and opportunities for healthcare innovation in india (Distinguished Scientist Lecture)
9	September 21, 2012	Prof. Anjan Kumar Gupta, IIT KANPUR	Hysteresis in superconducting weak links and micron size SQUIDs
10	October 11, 2012	Dr. Sanjay Kumar Srivastava CSIR-NPL, India	Silicon Nanowire Arrays for solar cell applications (In house Lecture)
11	November 30, 2012	Prof. Mukund P Das, Australian National University, Australia	Superconductivity for everyone: 101 years for its discovery (Distinguished Scientist Lecture)
12	January 10, 2013	Prof. Jagadeesh S Moodera MIT, Cambridge, MA, USA	Spin Filtering, internal exchange interaction at the molecular level (Distinguished Scientist Lecture)
13	February 15, 2103	Prof. Klaus Jungmann, University of Groningen, The Netherlands	A Single Ra+ Ion to Measure Atomic Parity Violation and as an Oscillator of an Atomic Clock (Distinguished Scientist Lecture)

APPENDIX - 14

Invited Talks and Lectures by CSIR-NPL Scientists

S No	Speaker's Name	Topic	Event and Venue
1	Dr Sushil Kumar	Plasma Processing of Thin Film	Refresher course on physics and electronic at Department of Physics and Astrophysics, Delhi University, October 03, 2012.
2		Environmental Issues & Sustainable Development: R&D in Harnessing of Solar Energy	Refresher course on physics and electronic at Department of Physics and Astrophysics, Delhi University, October 03, 2012.
3		R&D on thin film solar cells	Refresher course on physics and electronic at Department of Physics and Astrophysics, Delhi University, October 03, 2012.
4	Dr S Sudhakar	Boron doped hydrogenated micro/ nano Crystalline Si thin films by PECVD	International workshop on crystal growth and characterization of advanced materials and devices, at Anna University, Chennai, December 16, 2012.
5	Dr S K Srivastava	Silicon nanowire arrays for solar cell applications	R & D Conclave on New and Renewable Energy-Prospects for Cross Cutting Technologies, organized by MNRE at Vigyan Bhawan, August 09, 2012
6		Silicon nanowire arrays for photovoltaic applications	National Seminar on 'Materials and Energy Security' (NSMES-2012), December 31, 2012, Department of Physics, Banaras Hindu University (BHU)
7		Silicon nanowire arrays for photovoltaic applications	In-house Lecture in NPL Colloquium Series, October 11, 2012, National Physical Laboratory, New Delhi.
8	Dr D Haranath	Photoluminescence – Theory, Measurements and Applications	UGC sponsored Refresher Course, held at Department of Physics, Jamia Millia Islamia, New Delhi, May 18, 2012.
9		Nanotechnology-Small Science, Plenty Applications	Invited Guest Lecture held at Khalsa College, University of Delhi, New Delhi, June 01, 2012.
10		Quantum Dots and Doped Nanocrystals for Energy Saving Applications	National Workshop on Luminescence Materials, Devices and Applications held at Department of Applied Physics and Electronics, M. S. University, Vadodara, November 26-27, 2012
11		Luminescent Quantum Dots for Next Generation Displays	National Conference on Next Generation Applications, held at Department of Applied Physics, Punjab University, Firozepur, December 18, 2012.

S No	Speaker's Name	Topic	Event and Venue
12	Dr D Haranath	Quantum Dots and Nanocrystals for Better Tomorrow	National Conference on Nanomaterials: New Horizon for Betterment of Mankind, held at R.T.M. Nagpur University, Nagpur, February 28, 2013
13		Nanotechnology of Multifunctional Materials for Energy Saving Applications	National Seminar on Multifunctional Materials-2013 held at Department of Physics, Banaras Hindu University, March 06, 2013.
14	Dr Bipin Kumar Gupta	Importance of Chemistry in Nanotechnology and Life Sciences	National Conference on Chemistry and Life, held at Dept. of Chemistry, CMP Degree college, University of Allahabad, Allahabad during September 16-17, 2012.
15		Future Prospects of Advanced Nanomaterials in Strategic Applications	HEAM CAM 2012, A national level workshop on Characterization of Advanced Materials held at Department of Chemistry, University of Kerala, Thiruvananthapuram during October 11- 12, 2012.
16		Future Prospects of hydrogen fuel in India : Alternative energy sources	HEAM SCIENTIST 2012, A national meet of young scientists of Hydrogen Energy and Advanced Materials held at Department of Chemistry, University of Kerala, Thiruvananthapuram during December 13-14, 2012.
17		Future Prospects of Advanced Luminescent Nanomaterials for Strategic Applications	1st International workshop on Nanomaterials (IWoN): Engineering Photon and Phonon Transport held at School of Materials Science and Nanotechnology, Jadavpur University, Kolkata during December 13-14, 2012.
18		Future Prospects of Hydrogen Energy as a Green Freedom Fuel For India	National Seminar on Materials and Energy Security (NSMES) 31 held at Dept. of Physics BHU, Varanasi during December 31, 2012.
19		Broad Spectrum and scope of standardization in nanomaterials: Synthesis, Characterization and nanoindustry	1st national seminar on standardization for Nano science and nanotechnology held at NPL New Delhi during February 25-26, 2013.
20	Dr Santa Chawla	Photoluminescence, Advanced Luminescent Materials & their Applications	Workshop on Nano and Advanced materials (WONAMA-2012), under UGC Networking, Banaras Hindu University, April 10 -16, 2012.
21		Photoluminescence and Applications of Luminescent nanoparticles	Anna University, Chennai, August 30, 2012.

S No	Speaker's Name	Topic	Event and Venue
22	Dr Santa Chawla	Solar spectrum conversion by fluorescent nanoparticles for improved energy harvesting by solar Cells	National Seminar on Materials and Energy Security (NSME-2012) held at BHU, December 31, 2012.
23		Solar spectrum conversion by fluorescent nanoparticles for improved energy harvesting by solar Cells	National Conference on Luminescence and its Applications (NCLA 2013), held at Bangalore, India, January 8-10, 2013.
24	Dr A K Upadhayaya	Indian Regional Warning Centre	ISES Meeting, Mysore July 13-14, 2012
25	डॉ. क्षेमेन्द्र शर्मा	ग्रीन हाउस गैसों के उत्सर्जन का आंकलन तथा इसका भविष्य के जलवायु परिवर्तन के प्रक्षेप पर प्रभाव	"रेडियो एवं वायुमण्डलीय विज्ञान के विभिन्न आयामों पर परिचर्चा, राष्ट्रीय संगोष्ठी, 2012" राष्ट्रीय भौतिक प्रयोगशाला, नई दिल्ली–110012
26	Dr A Sen Gupta	Recent Advances in Standards of Time and Frequency	AdMet 2012, ARAI Pune, February 2012
27		Time generation and dissemination using ensemble of atomic clocks at NPL, India.	AdMet 2013, NPL Delhi, February 2013
28		Status Report of Time and Frequency activities at NPL India	APMP-TCTF 2012, Wellington, November 2012
29		What is an atomic clock and how accurate it can be	IIT Kanpur, February 8, 2013
30	Dr Ashish Agarwal	Precision Measurements of Time and Frequency at NPL India	Visitors Program 2013 Delhi University March 2, 2013
31		Development of a laser cooled Cesium Fountain frequency Standard at NPL, India	CDAMOP Delhi University
32		Quantum Metrology and Precision Measurements of Time and Frequency	Winter School on Ultra cold atoms for fundamental science and enabling technologies, Goa, December 17 - 21, 2012
33	Dr Subhadeep De	"Experiments with Mixtures of Bose Condensate Rubidium and Degenerate Fermionic Lithium	Raman Research Institute, Bangalore, India, March 26, 2013
34		Ultra-cold Degenerate Bosons and Fermions	Raman Research Institute, Bangalore, India, March 26, 2013
35		Domain Coarsening and Coalescence in Quenched Binary BEC	Domain Coarsening and Coalescence in Quenched Binary BECs", AMOP 12: IISER Kolkata, India, December 14 - 17, 2012
36	Dr Poonam Arora	Timekeeping and Atomic Clocks	Physics Society Lecture 2012, Shivaji College, DU, New Delhi.
37		Development of Cs Fountain Frequency Standard at CSIR-NPL, India	National Laser Symposium 2013, BARC, Mumbai.

S No	Speaker's Name	Topic	Event and Venue
38	Dr Poonam Arora	Development of Cs fountain at NPL, India	LNE-SYRTE, Paris, France, July 12, 2012.
39	Mr Anil Kumar	Preparation for calibration and Performance verification test for minor analytical Instruments	Workshop on calibration of Chromatographic Technique On Forensic Science. Loknayak Jayaprakash Narayan Institute of Criminology and Forensic Science, New Delhi
40	Mr Goutam Mandal	Metrology and its Relevance to our Society	Invited talk at Invertis University, Bareilly
41	Dr K P Chaudhary	Dimensional Metrology, Principles of Metrology & Industrial Metrology	44th International Training Programme on Standardization and Quality Assurance for Developing Countries Venue: National Institute of Training for Standardization, Noida, May 01, 2012
42		Calibration & Measurement: Criticality in R&D	Orientation Training Programme for Technical Group III Personnel Venue: CSIR-HRDC, Ghaziabad, June 28, 2012
43		PT Programme	Quality System – Laboratory Management, Need for Calibration / Accreditation as per IS/ISO/IEC – 17025:2005 Venue: NPL Conference Room, New Delhi August 23, 2012
44		Application of LASER in Bio-Medical Instrumentation	19th Management Development Programme on Operation Maintenance & Repair of Bio-Medical Equipments Venue: CSIO, New Delhi, October 6, 2012
45		LASER and its use in Opthalmology	Management Development Programme on Operation Maintenance & Repair of Optical / Ophthalmic Equipments Venue: CSIO, New Delhi, December 26, 2012
46		Dimensional Metrology, Principles of Metrology & Industrial Metrology	International Training on Laboratory Quality System, Management and Internal Audit Venue: National Institute of Training for Standardization, Noida, February 25, 2013
47	Dr Nita Dilawar Sharma	Pneumatic Pressures : Methods, facilities and calibration- A Simplified overview	Training on Pneumatic and Hydraulic Pressure Measuring Instruments and Their calibrations at NPL, New Delhi, January 17-18, 2013

S No	Speaker's Name	Topic	Event and Venue
48	Dr Nita Dilawar Sharma	Case studies for uncertainties in measurement	Training on Pneumatic and Hydraulic Pressure Measuring Instruments and Their calibrations at NPL, New Delhi, January 17-18, 2013
49	Sh Jasveer Singh	Proficiency Testing- An Inter-Laboratory Comparison	Training on Pneumatic and Hydraulic Pressure Measuring Instruments and Their calibrations at NPL, New Delhi, January 17-18, 2013
50	Dr Sanjay Yadav	Principle of Pressure Measurement and Pressure Standards	Legal Metrology Officers Visit on July 13, 2012
51		Hydraulic pressure : Concept, Theory, Standards and calibration – A case study on calibration of dead weight tester	Training on Pneumatic and Hydraulic Pressure Measuring Instruments and Their calibrations at NPL, New Delhi, January 17-18, 2013
52	Dr Ashok Kumar	Investigations on Ferroelectric and Dielectric Properties of Nanostructured $BaTiO_3/Ba_{(1-x)}Sr_xTiO_3$ Superlattices	NSFD XVII, 2012, ITER Bhubneshwar, December 17, 2012
53		Micro and Nano Scale studies on Novel Room Temperature Magnetoelectric	Physics and Technology of Novel Materials (PTNM II-2012), Odisha, Sambalpur University, March 2012
54	Dr Yudhisther Kumar	Ultrasonic attenuation measurement and characterization of materials	National Seminar on Material Characterization by Ultrasonics, Amity School of Engineering & Technology, Bijwasan, New Delhi, April 3-4, 2012
55	Dr Mahavir Singh	Development of Lightweight Sandwich Material as Acoustic Partitions for Building Applications	National Seminar on Material Characterization by Ultrasonics, Amity School of Engineering & Technology, Bijwasan, New Delhi, April 3-4, 2012
56		Development of Noise Control	H. N. B. Garhwal University Srinagar (Garhwal), May 18, 2012.
57		National Standards and R&D Activities of AUV-NPLI	8th Meeting of CCAUV at BIPM, France, June 13-14, 2012
58		Meeting the Market's Growing Need for High-STC Walls: Innovative Solutions for a High-Density India	SRM University, Kattankulathur (Chennai), June 29, 2012
59		Importance of Sound Transmission Class in the Indian Building Industry	DAV (PG) College, Bulandshar (UP), November 26, 2012
60		Evaluating Accurate Value of the Reverberation Chamber Sound Absorption Coefficient	National Symposium on Acoustics (NSA-2012), Tirunchegode, December 5-7, 2012
61		Acoustic Properties of New Rice Husk Sound Absorptive Material	International Conference on Advances in Building Sciences, IIT Chennai, Feburary 13-16, 2013

S No	Speaker's Name	Topic	Event and Venue
62	Dr Ranjana Mehrotra	Principle, instrumentation and application of IR Spectroscopy in Forensic Science	Workshop on Instrumentation Techniques in Forensic Science, October 17-19, 2012.
63		Exposure to analytical instruments (FTIR/UV-Visible)	Workshop on Instrumentation Techniques in Forensic Science, October 17-19, 2012.
64		IR Spectroscopy & Applications	Biomedical Instrumentation Programme, CSIO, New Delhi, March 25, 2012.
65	Dr V N Ojha	Evaluation of Uncertainty in Measurement	Training program for legal metrology officers of various states, UTS, ILM and RRSL on blood pressure, Force measuring instruments and Clinical thermometers, August 27-29, 2012, NPL- New Delhi.
66		Fabrication of superconducting films, tunnel junctions arrays and their Applications-An Overview.	University of Delhi, Inauguration of Electronics Society of Ramjas College, October 13, 2012.
67		Advances in Quantum Voltage Metrology	8th International conference on Advances in Metrology (AdMet-2013), NPL-New Delhi, February 21-23, 2013.
68	Dr V K Jaiswal	Phase correlation study of polarized phase singular optical beam	DAE-BRNS Symposium on Atomic, Molecular and Optical Physics 2012 (AMOP-2012), Indian Institute of Science Education and Research Kolkata (IISER-K), Kolkata, December 14-17, 2012.
69	Dr H C Kandpal	Surface plasmon for high frequency generation and combining photovoltaic with plasmonics	Indo-Finnish Workshop on "Plasmonics for photovoltaics", VIT Research Centre, Finland, December 4-5, 2012
70		Effect of polarization on propagation of radiation	XXXVII OSI Symposium on 'Frontiers in Optics and Photonics', Pondicherry, January 23-25, 2013
71		Classical vs. Quantum Candela: Prospects and Challenges	AdMet-13, NPL, New Delhi, February 21-23, 2013
72	Dr Vijay Toutam	Conducting AFM based patterning and characterization of nanomaterials	Workshop on Advanced materials and characterization techniques organized by SASD 7 division, CSIR-NPL
73		Measurements using AFM	Workshop on 'AFM Measurements, for Nanometrology and Evaluation of Uncertainty, NPL, New Delhi, September 27-28, 2012
74	Dr Rina Sharma	Concepts and terminology of nanometrology	Workshop on 'AFM Measurements, for Nanometrology and Evaluation of Uncertainty, NPL, New Delhi, September 27-28, 2012
75		Characterization of AFM	Workshop on 'AFM Measurements, for Nanometrology and Evaluation of Uncertainty, NPL, New Delhi, September 27-28, 2012

S No	Speaker's Name	Topic	Event and Venue
76	Dr Rina Sharma	Evaluation and expression of uncertainty in AFM measurements	Workshop on 'AFM Measurements, for Nanometrology and Evaluation of Uncertainty, NPL, New Delhi, September 27-28, 2012
77	Dr G Bhagavannarayana	Advanced X-ray Crystallography-1	National Workshop on "Advanced Analytical Techniques in Research & Development" held at Amity Institute of Applied Sciences, Amity University (AATRD) during December 20 - 21, 2012.
78		An overview on advanced X-ray characterization techniques for composition/purity, structure and crystalline perfection	XVII National Seminar on Crystal Growth organized by Department of Physics, Anna University, Chennai during January 9-11, 2013.
79		An overview on advanced X-ray characterization techniques	Physics Department, Queen Mary's College, Chennai-600 004, January 10, 2013.
80		Advanced X-ray characterization techniques for purity, composition, structure and perfection	Physics Department, Andhra University, January 21, 2013.
81		An overview on renewable energy harvesting and energy conservation	Physics Department, VSM College, Ramachandrapuram, East Godavary (Dt.), Andhara Pradesh, March 13, 2013.
82		Energy harvesting by Renewable energy sources in Indian Context and Conservation of energy	Department of Physics, Commerce & Home Science, Ch.S.D.ST.Teresa's Autonomous College for Women, Eluru, Andhra Pradesh, February 15-16, 2013
83		Advanced X-ray characterization Techniques	Department of Physics, Commerce & Home Science, Ch.S.D.ST.Teresa's Autonomous College for Women, Eluru, Andhra Pradesh held during February 15-16, 2013.
84		Role of characterization techniques for the development of novel materials	School of Physics, Alagappa University, Karaikudi, March 20-22, 2013.
85		Characterization of Advanced Materials by various X-ray Techniques for purity, composition, structure and perfection	School of Physics, Alagappa University, Karaikudi, March 20-22, 2013.
86	Dr Rashmi	X-ray Fluorescence Spectrometry for Characterization of Materials	Workshop on Advanced Material Characterisation Techniques, CSIR-NPL, New Delhi, July 10-13, 2012

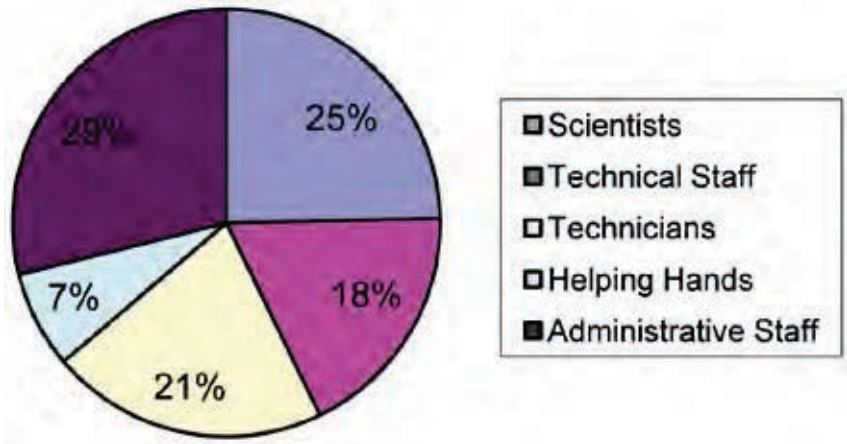
S No	Speaker's Name	Topic	Event and Venue
87	Dr K K Maurya	Growth of Technologically Important Single Crystals and their Characterization by High Resolution X-ray Diffractometry	National Physical Laboratory, New Delhi, July 10 -13, 2012.
88		X-ray scattering: an unique method to characterize materials with structures at the nanoscale	Department of Physics, Shaheed Bhagat Singh Sate Technical Campus, Ferozpur on 18 December 2012. Continuing Education Centre, IIT Roorkee, February 21, 2013
89	Dr N Vijayan	Growth of some organic and semiorganic based single crystals and their structural and optical analyses for Nonlinear Optical (NLO) applications	National Seminar on New Materials research and Nanotechnology held at Department of Physics, Ooty, Tamil Nadu, September 12-14, 2012.
90		Synthesis and Growth of Organic and Semiorganic Single crystals for Optoelectronic and data storage applications	Department of Physics, Mannar Thirumalai Naicker College, Madurai, September 13, 2012.
91		Introduction to Single Crystal Growth and Its Technological Applications	Department of Physics, Syed Ammal Arts and Science College, Ramanathapuram, September 12. 2012.
92		Growth of Topological and some scintillation single crystals by Vertical Bridgman Technique (VBT) and its characterization analyses	Department of Physics, PSN College of Engineering, Tirunelveli, January 23-25, 2013
93		Growth of Single crystals and its technological applications	Department of Physics, SRM University, Ramapuram Campus, January 24-25, 2013.
94	Dr Manas K Dalai	Surface and Interface Analysis of Materials using Time of Flight Secondary Ion Mass Spectrometry (TOF-SIMS)	12th ISMAS-Triennial International Conference on Mass Spectrometry, Goa, March 3-8, 2013
95	Dr A K Srivastava	Complex growth morphologies, microstructures and properties of novel nanostructures	National Institute of Technology, Kurukshetra, March 29, 2013
96		High resolution electron microscopy for characterization of nano-materials	Seminar on nano-pico pharmaceuticals & invivgensome, Amity Institute of Nanotechnology, December 27, 2012
97		High resolution transmission electron microscopy and associated nano-probe techniques	Workshop on advanced materials characterization techniques, New Delhi, July 13, 2012
98		Electron microscopy of oxide nanostructures: importance and implications related to energy applications	The XXXIII Annual Meeting of the Electron Microscopy Society of India, Indian Institute of Science, Bangalore, July 2 – 4, 2012

S No	Speaker's Name	Topic	Event and Venue
99	Dr A K Srivastava	Materials characterization at nano-scale: importance and implications related to energy applications	Department of Energy, NEMAS - Center for Nano Engineered Materials and Surfaces, Milano, Italy, June 18, 2012
100	Dr Sukhvir Singh	Chracterization of materials using TEM, Workshop on Advanced Material Characterization Techniques	CSIR-NPL New Delhi, India, July 10-12, 2012
101		Chracterization of materials using SEM, Workshop on Advanced Material Characterization Techniques	CSIR-NPL New Delhi, India, July 10-12, 2012
102		2nd International Symposium on Semiconductor Materials and Devices (ISSMD-2) held at Department of Physics and Electronics	Jammu University, Jammu and Kashmir, India January 31 to February 2, 2013
103		Basic principles involved in the characterization of materials by using TEM Nanotechnolgy	Department of Amity University, NOIDA-UP, -2012
104		National Seminar on Experimental and Computational Techniques in Material Science (ECTMS-2012)	Department of Physics, Himachal Pradesh University, Shimla –HP, March 31- April 2, 2012
105	Dr R P Pant	Ferrofluids and MR fluids	National Symposium on Physics and Engineering Materials, DCRUST, Murthal, HR, March 15 - 17, 2013
106	Dr Prabhat K Gupta	MiC and CRMs: Emerging opportunities	CII/ NABL 1st national conclave for laboratories, IHC, New Delhi, 5 April, 2012
107		Traceability in chemical testing & calibration for reliability of measurements	Inaugural address in Workshop on Calibration of Chromatographic Technique in Forensic Science, Natl. Inst. of Criminololy & FS, Rohini, Delhi, August 6, 2012
108		Traceability in chemical testing & calibration for reliability of measurements	Inaugural address in Workshop on Instrumentation Technique in Forensic Science", LNJPN Natl. Inst. of Criminololy & FS, Rohini, Delhi, October 17-19, 2012
109	Dr S G Aggarwal	The Measurement Science (Metrology): Unrealized science but most practiced one in our daily life"	in INSPIRE Internship Camp (DST-New Delhi initiative), Pt. Ravishankar Shukla University, Raipur, May 29-June 2, 2012.
110		"MiC at NPL India: Recent progress and action plan for 2013"	in APMP- TCQM meeting-2012, Wellington, New Zealand, November 26-28, 2012
111		"A Simplified Approach to Calibrate Condensation Particle Counter for Aerosol Number Concentration Measurement"	in 8th International Conference on Advances in Metrology (AdMet-2013) and Pre-AdMet Workshop, New Delhi, February 20-23, 2013.

APPENDIX - 15

HUMAN RESOURCE
As on March 31, 2013

GROUP IV		**GROUP II**	**Sub-Total :**	**154**
Director	1			
Outstanding Scientist	1			
Chief Scientist	31	**GROUP I**	**Sub-Total :**	**54**
Sr. Principal Scientist	19			
Principal Scientist	32	ADMN-A		10
Sr. Scientist	27	ADMN-B		65
Scientist	62	ADMN-C		32
Jr. Scientist	8	ADMN-C (Cafeteria Staff)		8
Sub-Total :	**181**	ADMN-D		90
		ADMN-D (Cafeteria Staff)		*7*
GROUP III			**Sub-Total :**	**212**
Principal Technical Officer	8		**GRAND TOTAL :**	**734**
Supt. Engg. & Asst. Engg.	4			
Sr. Technical Officer (3)	31			
Sr. Technical Officer (2)	12			
Sr. Technical Officer (1)	11			
Technical Officer	11			
Tech Asstt Gr III(2)	*5*			
Tech Asstt Gr III(1)	51			
Sub-Total :	**133**			



SCIENTISTS AND OFFICERS AS ON 31.03.2013

DIRECTOR
Prof R C Budhani

PHYSICS OF ENERGY HARVESTING Head : Dr Suresh Chand	
Name	**Designation**
Dr S T Lakshmikumar	Chief Scientist
Dr Suresh Chand	Chief Scientist
Dr Parakram Kumar Singh	Chief Scientist
Dr Omvir Singh Panwar	Chief Scientist
Dr Abdul Mobin	Sr Principal Scientist
Dr S M Shivaprasad	Sr Principal Scientist
Dr (Ms) Kiran Jain	Sr Principal Scientist
Sh C M S Rauthan	Sr Principal Scientist
Dr K M K Srivatsa	Sr Principal Scientist
Dr T D Senguttuvan	Principal Scientist
Dr Sushil Kumar	Principal Scientist
Dr Amish G Joshi	Principal Scientist
Dr Jeya Kumar Ramanujam	Principal Scientist
Dr Shailesh Narayan Sharma	Principal Scientist
Dr Suraj Prakash Khanna	Principal Scientist
Sh Chockalingam Sreekumar	Sr Scientist
Dr Govind	Sr Scientist
Dr (Ms) Ritu Srivastava	Sr Scientist
Dr Asit Patra	Sr Scientist
Sh Kamlesh Patel	Scientist
Dr Vinay Gupta	Scientist
Dr (Ms) Vandana	Scientist
Dr Muthusamy Senthil Kumar	Scientist
Dr Mahesh Kumar	Scientist
Sh Sanjay Kumar Srivastava	Scientist
Dr Rajiv Kr. Singh	Scientist
Dr Praveen Kumar Siwach	Scientist
Dr Prabir Pal	Scientist
Dr Preetam Singh	Scientist
Dr Sunil Singh Kushvaha	Scientist
Dr Ajay Kumar Shukla	Scientist
Dr Chandra Kant Suman	Scientist
Dr P Prathap	Scientist
Dr S Sudhakar	Scientist
Dr (Ms) Rachna Kumar	Scientist
Dr Mukesh Javeria	Scientist
Dr Srinivas Rao Ragam	Scientist

Name	Designation
Dr Jai Prakash Tiwari	Jr Scientist
Sh Mukul Sharma	Sr. Technical Officer (3)
Sh Gauri Datt Sharma	Sr. Technical Officer (3)
Dr V K Hans	Sr. Technical Officer (3)
Sh Bhikham Singh	Sr. Technical Officer (3)
Sh Jagdish Chand	Sr. Technical Officer (2)
Sh Manikandan R M	Technical Officer

MATERIAL PHYSICS AND ENGINEERING

Head : Dr A M Biradar

Name	Designation
Dr Rakesh Behari Mathur	Chief Scientist
Dr Virendra Shanker	Chief Scientist
Dr Ashok Manikrao Biradar	Chief Scientist
Sh Subodh Kumar Singhal	Chief Scientist
Dr R K Kotnala	Chief Scientist
Dr Sunil Kumar Singhal	Chief Scientist
Dr Sher Singh Rajput	Sr Principal Scientist
Dr S K Dhawan	Sr Principal Scientist
Dr (Ms) Santa Chawla	Sr Principal Scientist
Dr Ajay Dhar	Sr Principal Scientist
Sh Sanjay Rangnate Dhakate	Principal Scientist
Dr Rajesh	Sr Scientist
Dr Divi Haranath	Sr Scientist
Sh Vipin Jain	Sr Scientist
Dr (Ms) G Sumana Gajala	Sr Scientist
Dr Nirmalya Karar	Sr Scientist
Dr Dinesh Kumar Misra	Sr Scientist
Sh Bhanu Pratap Singh	Scientist
Sh Parveen Saini	Scientist
Dr (Ms) Nidhi Singh	Scientist
Dr Ved Varun Agrawal	Scientist
Sh Pankaj Kumar	Scientist
Sh Bathula Sivaiah	Scientist
Sh M Saravanan	Scientist
Dr Bipin Kumar Gupta	Scientist
Dr (Ms) Priyanka Heda Maheshwari	Scientist
Dr Bhasker Gahtori	Scientist
Dr Kiran Mahadevgan	Scientist
Dr (Ms) Saroj Kumari	Jr Scientist
Sh Rajiv Sikand	Principal Technical Officer
Dr (Ms) Manju Arora	Sr Technical Officer (3)
Sh Pinaki Ranjan Sengupta	Sr Technical Officer (3)
Sh Rajesh Kumar Seth	Sr Technical Officer (2)

Name	Designation
Sh Vinod Kumar Tanwar	Technical Officer
Sh Manoj Kumar Pandey	Technical Officer

RADIO AND ATMOSPHERIC SCIENCES

Head : Dr M V S N Prasad

Name	Designation
Dr Bhuwan Chandra Arya	Chief Scientist
Dr M V S N Prasad	Chief Scientist
Sh Pattamatta Subrahmanyam	Sr Principal Scientist
Dr (Ms) Meena Jain	Sr Principal Scientist
Dr Chhemendra Sharma	Principal Scientist
Dr Tuhin Mandal	Principal Scientist
Dr Sachidanand Singh	Principal Scientist
Dr (Ms) Monika J. Kulshrestha	Sr Scientist
Sh Ashish Ranjan	Sr Scientist
Dr Arun Kumar Upadhayaya	Scientist
Sh Rupesh M Das	Scientist
Sh Sumit Kumar Mishra	Scientist
Dr (Ms) Kirti Soni	Scientist
Dr Sudhir Kumar Sharma	Scientist
Dr Rajesh Agnihotri	Scientist
Dr Radhakrishnan Soman Radha	Scientist
Sh Arun Kumar Ghoghar	Sr Technical Officer (3)
Sh Shambhu Nath	Sr Technical Officer (3)
Ms Shiv Kumari Bhatia	Sr Technical Officer (3)
Ms Beena Gupta	Sr Technical Officer (3)
Sh Vinod Kumar Sharma	Sr Technical Officer (3)
Sh Man Mohan Gupta	Sr Technical Officer (3)
Sh Alok Mukherjee	Technical Officer

TIME AND FREQUENCY STANDARDS

Head : Dr A Sengupta

Name	Designation
Dr Amitava Sengupta	Outstanding Scientist
Ms Arundhati Chatterjee	Principal Scientist
Dr Ashish Agarwal	Sr Scientist
Dr Subhasis Panja	Sr Scientist
Dr (Ms) Poonam Arora	Scientist
Ms Pranalee Premdas Thorat	Scientist
Dr Subhadeep De	Scientist
Sh Anil Kumar Suri	Principal Technical Officer

APEX LEVEL STANDARDS AND INDUSTRIAL METROLOGY

Head : Dr A K Bandhyopadhyay

Name	Designation
Dr Ashis Kumar Bandyopadhyay	Chief Scientist
Dr Ashok Kumar	Chief Scientist
Dr Sushil Kumar Jain	Chief Scientist
Sh Mukesh Kumar Mittal	Chief Scientist
Dr K P Chaudhary	Chief Scientist
Dr Yesh Pal Singh	Chief Scientist
Sh Anil Kishore Saxena	Chief Scientist
Sh Anil Kumar	Chief Scientist
Sh Thomas John	Sr Principal Scientist
Sh Pramendra Singh Negi	Sr Principal Scientist
Sh Joges Chandra Biswas	Principal Scientist
Dr Mahavir Singh	Principal Scientist
Sh D Arun Vijayakumar	Principal Scientist
Sh Ajeet Singh	Principal Scientist
Dr Sanjay Yadav	Principal Scientist
Dr (Ms) Nita Dilawar	Principal Scientist
Dr S Seela Kumar Titus	Principal Scientist
Sh Rajesh Kumar	Principal Scientist
Sh Rajbir Singh	Principal Scientist
Sh M A Ansari	Principal Scientist
Sh Shiv Kumar Jaiswal	Sr Scientist
Sh Saood Ahmed	Sr Scientist
Sh Goutam Mandal	Sr Scientist
Dr Ashok Kumar	Sr Scientist
Dr Premshankar Kedarnath Dubey	Sr Scientist
Sh Naveen Garg	Scientist
Sh Dilip Dhondiram Shivagan	Scientist
Sh Harish Kumar	Scientist
Dr Satya Kesh Dubey	Scientist
Sh Satish	Jr Scientist
Sh K P S Yadav	Sr Supt Engineer (Elect)
Sh Virendra Babu	Principal Technical Officer
Sh Ravi Khanna	Principal Technical Officer
Sh Gurbir Singh	Principal Technical Officer
Ms Reeta Gupta	Principal Technical Officer
Dr Yudhisther Kumar Yadav	Sr Technical Officer (3)
Sh Kul Bhushan Ravat	Sr Technical Officer (3)
Sh Gurcharanjit Singh	Sr Technical Officer (3)
Sh Mohammad Saleem	Sr Technical Officer (3)
Sh Ishwar Singh Taak	Sr Technical Officer (3)
Sh Avdhesh Kumar Goel	Sr Technical Officer (3)

Name	Designation
Sh Rakesh Khanna	Sr Technical Officer (3)
Sh Mukesh Kumar	Sr Technical Officer (2)
Sh Om Prakash	Sr Technical Officer (2)
Sh K N Basavaraju	Sr Technical Officer (2)
Sh Bijendra Pal	Sr Technical Officer (2)
Sh Sudama	Sr Technical Officer (2)
Sh Mahargha Baran Das	Sr Technical Officer (2)
Ms Usha kiran	Sr Technical Officer (1)
Dr Bharat Kumar Yadav	Sr Technical Officer (1)
Sh Harish Kumar	Sr Technical Officer (1)
Sh Sridhar Lingam	Sr Technical Officer (1)
Sh Manoj Kumar	Sr Technical Officer (1)
Sh Rasik Behari Sibal	Technical Officer
Sh Anoop Singh Yadav	Technical Officer
Sh Vikram	Technical Officer
Sh Abhishek Singh	Technical Officer

QUANTUM PHENOMENA AND APPLICATIONS

Head : Dr H C Kandpal

Name	Designation
Dr Hem Chandra Kandpal	Chief Scientist
Dr Vijay Narain Ojha	Chief Scientist
Dr (Ms) Ranjana Mehrotra	Chief Scientist
Dr Tushya Kumar Saxena	Chief Scientist
Dr (Ms) P L Upadhyay	Sr Principal Scientist
Dr (Ms) Rina Sharma	Principal Scientist
Dr Veerpal Singh Awana	Principal Scientist
Dr Anurag Gupta	Principal Scientist
Dr Hari Krishna Singh	Principal Scientist
Ms Manju Singh	Sr Scientist
Dr (Ms) Sangeeta Sahoo	Sr Scientist
Sh Virendra Kumar Jaiswal	Scientist
Dr (Ms) Anjana Dogra	Scientist
Ms Priyanka Jain	Scientist
Dr Parag Sharma	Scientist
Dr Sudhir Husale	Scientist
Dr Rajib Kr. Rakshit	Scientist
Dr Vijay Kr. Toutam	Scientist
Dr Ajeet Kumar	Scientist
Dr Ashok Kumar	Jr Scientist
Ms Girja Moona	Jr Scientist
Ms Santhya Malikar Patel	Jr Scientist
Ms Poonam Sethi Bist	Sr Technical Officer (1)

ADMINISTRATION

Head : Mr T V Joshua

Name	Designation
Sh T V Joshua	COA
Ms Veena Jain	Admn Officer
Sh M C Meena	Admn Officer
Ms Manju	Hindi Officer
Sh Jay Narayan Upadhyay	Hindi Officer
Sh Jagan Nath Prasad	Sr Technical Officer (3)
Sh Jokhan Ram	Sr Technical Officer (2)
Sh Vikram Singh	S O(G)
Ms Bhawna Guglani	S O(G)
Sh Anil Kumar	S O(G)
Sh S K Yadav	S O(G)
Sh Hari Narain Meena	SO(G)
Sh A K Handa	SO(G)
Sh Mange Ram	PS
Ms Paramjit Kaur	PS
Sh Amar Singh	PS
Sh Ram Gopal Meena	PS
Ms Saroj Gandhi	PS
Sh R Subramanian	PS

FINANCE AND ACCOUNTS

Head : Mr S K Mehta

Name	Designation
Sh S K Mehta	CO (F & A)
Sh M K Jain	CO (F & A)
Sh S N Gulia	F&AO
Sh Ajay Kumar	S O (F&A)
Sh S K Thakur	S O (F&A)
Sh R P Meena	S O (F&A)
Ms Sumit Kumari Panwar	S O (F&A)

STORES AND PURCHASE

Head : Sh Tariq Badar

Name	Designation
Sh Tariq Badar	CO (Str & Pur)
Sh Kuldeep Kaushik	SPO
Sh Vinay Sharma	S O (Str & Pur)
Sh Jai Singh	S O (Str & Pur)

WORKS AND SERVICES

Head : Dr J C Sharma

Name	Designation
Dr Jugdish Chandra Sharma	Chief Scientist
Dr Sanjeev Sinha	Principal Scientist
Sh S K Kushwaha	Sr Supt Engineer (Civil)
Sh Deepak Bansal	Sr Technical Officer (3)
Sh Mohan Chandra Singh	Sr Technical Officer (3)
Sh Gurdeep Singh Lamba	Sr Technical Officer (3)
Sh Anand Kumar Mishra	Asstt Exe Engineer (Civil)
Dr Harish Chandra	Sr Technical Officer (1)
Sh Rambir Singh	Asstt Engineer

WORKSHOP

Head : Sh T Raghavendra

Name	Designation
Sh Rajendra Singh Meena	Scientist
Sh Murari Lal Sharma	Sr Technical Officer (3)
Sh Jai Pal Singh	Sr Technical Officer (2)
Sh Amar Singh	Sr Technical Officer (1)
Sh Rajeev Sharma	Sr Technical Officer (1)
Sh Virendra Kumar Gupta	Technical Officer

COMPUTATION AND NETWORK FACILITY

Head : Dr Ravi Mehrotra

Name	Designation
Dr Ravi Mehrotra	Chief Scientist
Ms Deepti Chaddha	Sr Scientist
Sh Nitin Sharma	Scientist
Ms Anjali Sharma	Scientist
Sh Trilok Bhardwaj	Scientist
Sh Vijay Sharma	Sr Technical Officer (3)
Sh Kanwaljit Singh	Sr Technical Officer (2)

DIRECTORATE

Head : Prof R C Budhani

Name	Designation
Prof R C Budhani	Director

Name	Designation
Dr Godavarthi Bhagavannarayana	Chief Scientist
Sh Prabhat Kumar Gupta	Chief Scientist
Dr (Ms) Rashmi	Chief Scientist

Name	Designation
Sh T Raghavendra	Chief Scientist
Dr Rajendra Prasad Pant	Sr Principal Scientist
Dr Sukhvir Singh	Principal Scientist
Dr (Ms) Renu Pasricha	Principal Scientist
Dr Avanish K Srivastava	Principal Scientist
Dr Kamlesh Kumar Maurya	Principal Scientist
Dr Jiji Thomas Joseph Pulikkotil	Principal Scientist
Ms Santosh Singh Golia	Sr Scientist
Dr Nahar Singh	Sr Scientist
Dr (Ms) Prabha Johri	Sr Scientist
Dr Shankar Gopal Aggarwal	Sr Scientist
Dr Surendra Pal Singh	Scientist
Dr Narayanaswamy Vijayan	Scientist
Dr Sushree Swarupa Tripathy	Scientist
Dr (Ms) Daya Soni	Scientist
Dr Vidya Nand Singh	Scientist
Dr Gounda Abdul Basheed	Scientist
Dr Manas kumar Dalai	Jr Scientist
Sh Niranjan Singh	Principal Technical Officer
Sh V D Arora	Principal Technical Officer
Sh Kedar Nath Sood	Sr Technical Officer (3)
Sh Rajiv Kumar Saxena	Sr Technical Officer (3)
Sh Ashok Kumar	Sr Technical Officer (3)
Sh Dinesh Singh	Sr Technical Officer (1)
Ms Anita Sharma	Technical Officer
Dr Khem Singh	Technical Officer

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Head : Dr K P Chaudhary

Name	Designation
Dr Krishan Kumar Saini	Chief Scientist
Dr Rajeev Chopra	Sr Principal Scientist
Dr (Ms) Jyoti Lata Pandey	Sr Principal Scientist
Dr D P Bhatt	Sr Principal Scientist
Dr Vijay Kumar Gumber	Sr Principal Scientist
Sh N K Wadhwa	Principal Scientist
Ms Anuradha Sengar	Sr Scientist
Dr R G Mathur	Scientist
Sh Abhishek Sharma	Jr Scientist
Sh Jagdish Prasad	Sr Technical Officer (3)
Sh Ashwani Kumar Suri	Sr Technical Officer (3)
Sh Chander Kant	Sr Technical Officer (3)
Sh Rajpal Zamaji Walke	Sr Technical Officer (2)
Ms Neetu Chandra	Sr Technical Officer (1)

Retired Persons

Sh Tarun Kumar Chakraborty, Principal Tech Officer
Sh Prag Das, Lab Assistant
Ms Harpal Kaur, Asstt (F&A) Grade-1
Sh V K Joshi, Asstt (G) Grade-1 (ACP3)
Ms Gian Wati, REcord Keeper (ACP2)
Ms S K Jaitley, Asstt (G) Grade-1 (ACP3)
Sh Ravinder Kumar Raheja, Asstt (G) Grade-1 (ACP3)
Sh Kartar Singh, Lab Assistant
Sh Satya Pal, Asstt (G) Grade-1 (ACP1)
Dr Devinder Gupta, Sr Principal Scientist
Sh H K Maini, Sr Principal Scientist
Sh Chaman Lal, Lab Assistant
Sh Kavindra Pant, Sr Principal Scientist
Ms Gurinder Pal, Sr Stenographer (ACP3)
Dr Narinder Kumar Arora, Principal Scientist
Ms Savita Chawla, Asstt (G) Grade-1 (ACP3)
Sh H R Singh, Sr Principal Scientist
Sh Ved Parkash Singh, Sr Technician (1)
Ms Abha Bhatnagar, Sr Technical Officer (2)
Dr Pardeep Mohan, Chief Scientist
Sh Dharam Singh (Yadav), Sr Technician
Ms Rita Kulshreshtha, Asstt (G) Grade-2 (ACP-2)
Sh V K Ojha, Sr Technical Officer (3)
Sh Vikram Prasad Semwal, Asstt (F&A) Grade-1 (ACP3)
Sh Suresh Chander, Sr Technician (2)
Sh Hanuman Prasad Sharma, Lab Assistant
Sh Ram Kanwar, Sr Technician (2)
Sh Hanuman Singh Sharma, Sr Technician (2)
Sh Anil Kumar Govil, Chief Scientist
Ms Shashi Lekha Bhatnagar, Sr Technical officer (2)
Sh Amar Singh Vats, Sr Technical (2)
Sh Randhir Singh Tanwar, Principal Scientist
Sh Sudhanshu Dwivedi, Principal Scientist
Sh Prem Singh, Asstt (G) Grade II
Sh Ganga Prasad, Sr Principal Scientist
Ms Indra Tiwari, Sr Principal Scientist
Dr Rakesh Kumar Garg, Chief Scientist
Sh J P Bhatt, Sr Technician (2)
Ms Satnam Kaur, Sr Technician (2)
Sh Pooran Lal, Lab Assistant
Sh Yash Pal, Technical Assistant
Dr (Ms) Gurusharan Kaur Padam, Principal Scientist
Sh Ved Singh, Lab Assistant
Sh Jagdish Kumar Gupta, Principal Technical Officer
Sh Ramesh Kumar Sethi, Sr Technician (2)
Sh Naresh Kumar Sharma, Sr Technician (2)

Obituaries

Sh Ram Janam Ram, Sr Technician (2)
Sh Subhash Chander, Karya Sahayak (ACP3)
Sh Kailash Chand, Sr Technician (2)
Sh S Suresh Babu, Technical Assistant
Sh Ambika Prasad, Lab Assistant

Scientists Fellow & Emeritus Scientists

Dr C P Sharma, Emeritus Scientist
Dr S K Aggarwal, Emeritus Scientist
Dr Ramadhar Singh, Emeritus Scientist
Dr S K Haldar, Emeritus Scientist
Dr B R Chakraborty, Emeritus Scientist
Dr S K Sarkar, Emeritus Scientist
Dr V Mohanan, Emeritus Scientist
Dr Hari Kishan, Emeritus Scientist
Dr K K Mahajan, INSA Honorary Scientist
Dr Krishan Lal, INSA Sr Scientist
Dr Preeti Bijlani, Part time Medical Officer
Dr M L Moga, Part time Medical Officer
Dr Sudhesh K Chug, Part time Medical Officer
Dr S K Joshi, Platinum Jubilee Emeritus Scientist
Dr Anuj Kumar, Post Doctoral Fellow
Dr Gopal Bhatia, Project Adviser
Sh R C Anandani, Project Adviser
Sh Kavindra Pant, Project Adviser
Sh H R Singh, Project Adviser
Dr O P Bahl, Project Adviser / Co-ordinator
Dr Vikram Soni, Research Scientist C
Dr (Ms) Shubhra Kala, Scientist Fellow
Dr Koushik Samanta, Scientist Fellow
Dr Prasun Ganguly, Scientist Fellow - CSIR Nehru Science PDR Fellowship
Dr Avneesh Anshul, Scientist Fellow - CSIR Nehru Science PDR Fellowship
Dr Deepak Garg, Ad-hoc Scientist

Research Fellows / Associates / Interns

Ms Mansi Sharma, JRF (NPL)
Ms Deepika Chaudhary, JRF (NPL)
Ms Minakshi, JRF (NPL)
Sh Gajendra Singh, JRF (NPL)

Sh Rahul Singh Bhauryal, JRF (NPL)
Ms Sonia, JRF (NPL)
Sh Komal Jain, JRF (NPL)
Ms Anupam Shakya, JRF (NPL)
Ms Renchu Scaria, JRF (UGC)
Sh Avirup Sen, JRF- SPMF (S P Mukherjee Fellowship)
Ms Pratibha Goel, JRF(CSIR)
Ms Stuti Joshi, JRF(CSIR)
Sh Shijin Babu P., JRF(CSIR)
Sh Suraj Singh Saini, JRF(CSIR)
Sh Prakash Ranjan Singh, JRF(CSIR)
Ms Shweta Agarwal, JRF(CSIR)
Sh Shahjad, JRF(CSIR)
Sh Shashank Tripathi, JRF(CSIR)
Sh Raman M, JRF(CSIR)
Ms Swati, JRF(CSIR)
Ms Shobhita Singal, JRF(CSIR)
Ms Chanchal Gupta, JRF(CSIR)
Ms Kumari Vijeta, JRF(CSIR)
Sh Sudhanshu Kumar, JRF(UGC)
Ms Rekha Gupta, JRF(UGC)
Ms Neha Gupta, JRF(UGC)
Sh Vishal Bharti, JRF(UGC)
Aman Bhardwaj, JRF(UGC)
Sh Ompal Singh, JRF(UGC)
Sh Akash Yadav, JRF(UGC)
Ms Kanika Thukral, JRF(UGC)
Sh Hitesh Gautam Borkar, JRF(UGC)
Sh Aniket Rana, JRF(UGC)
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Sh Ashutosh Sharan Sinha, JRF-GATE
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Ms Aarti Mehta, JRF-MNRE
Dr Pratima R Solanki, P.I.
Dr Farman Ali, P.I. (INSPIRE Faculty)
Dr Jai Prakash, P.I. (INSPIRE Faculty)
Dr Priti Singh, P.I. (INSPIRE Faculty)
Dr K K Jain, P.I. (user scheme)
Dr R P singhal, P.I. (user scheme)
Dr (Ms) Punita Singh, P.I.(WOS-A)
Ms Sonal, P.I.(WOS-A)
Ms Munu Borah, P.I.(WOS-A)
Ms Deepika Yadav, Quick Hire Scientist (Trainee)
Sh D K Kaushik, Quick Hire Scientist (Trainee)
Sh Aswin V., Quick Hire Scientist (Trainee)
Sh Vattikonda Bharath, Quick Hire Scientist (Trainee)
Sh Anuj Krishna, Quick Hire Scientist (Trainee)
Sh Ratneshwar Thakur, Quick Hire Scientist (Trainee)
Sh Achu Chandran, Quick Hire Scientist (Trainee)
Sh Dibyajyoti Mohanty, Quick Hire Scientist (Trainee)
Ms Indu Elizabeth, Quick Hire Scientist (Trainee)
Ms Naseema Begum, RA
Ms Indrani Coondoo, RA
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Ms Nirmal Prabhakar, RA
Dr Jitender Gaur, RA
Dr Gajala Ruhi, RA
Dr Sandhya Dwevedi, RA
Dr (Ms) Maumita Das, RA
Sh Ankur Anand, RA
Ms Anubha Sharma, Res. Intern
Ms Gunjan Mittal, Res. Intern
Sh Pradeep kumar Pandey, Res. Intern
Ms Shilpa Jain, Res. Intern
Ms Kanika Anand, Res. Intern
Sh Virendra Singh Manral, Res. Intern
Ms Pooja Singh, Res. Intern
Ms Ankita Rajput, Res. Intern
Sh Venkata Swamy Gollapothu, Res. Intern
Sh Mohammad Israfil, Res. Intern
Ms Ambika Bawa, Res. Intern
Ms Poonam Gupta, Res. Intern
Sh Abhinav Agnihotri, Res. Intern
Ms Sathi Chakraborty, Res. Intern
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Sh Sourav Das, Res. Intern
Ms Shiva Maheshwari, Res. Intern
Sh Vigil Varghese, Res. Intern
Ms Kritika Anand, Res. Intern
Ms Geetanjali Sharma, Res. Intern
Ms Poonam Rani, Res. Intern
Ms Naina Narang, Res. Intern
Ms Chandni Puri, Res. Intern
Ms Sheetal Rajput, Res. Intern

Ms Jasmeet Kaur, Res. Intern
Sh Anshul Jain, Res. Intern
Ms Vanita Devi, Res. Intern
Sh Sanjeev Kumar, Research Assistant
Dr (Ms) Suman, Sr. Res. Assoc.
Dr Ashok Kumar, Sr. Res. Assoc.
Dr Manoj Kumar Srivastava, Sr. Res. Assoc.
Dr (Ms) Amita Verma, Sr. Res. Assoc.
Sh Prabal Pratap Singh Bhadauria, SRF (CSIR)
Sh Ranjit Kumar, SRF (CSIR)
Ms K Jayanti, SRF (CSIR)
Sh Monojit Chakraborty, SRF (CSIR)
Sh Vinod Kumar Chahar, SRF (CSIR)
Ms Hema Bhandari, SRF (CSIR-UGC)
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Ms Deepa Joshi, SRF(CSIR)
Sh Neeraj Dwivedi, SRF(CSIR)
Ms Rajni, SRF(CSIR)
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Ms Rachna Sharma, SRF(UGC)
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Sh Rajveer Jha, SRF-CSIR, NPL
Ms Vasundha Agarwal, SRF-CSIR, NPL
Ms Neha Batra, SRF-CSIR, NPL
Ms Daisy Verma, SRF-CSIR, NPL
Ms Ruchi Singh, SRF-CSIR, NPL(Project)
Ms Sonika, SRF-DBT
Ms Gunjan Tyagi, SRF-ICMR, NPL
Sh Anil Kumar, SRF-MNRE
Ms Monika Mishra, SRF-MNRE
Ms Tanvi Upreti, SRF-NPL (Project)
Sh Gyanendra Singh, SRF-NPL (Project)
Sh Dharam Pal Singh, SRF-RGN
Ms Arti Rani, SRF-RGN
Sh Dharmendra Kumar Singh, Trainee Scientist
Ms Jaya Dwivedi, Trainee Scientist
Mohammad Yameen, Trainee Scientist
Sh Shravan Kumar Verma, Trainee Scientist
Sh Shri Harsh Pandey, Trainee Scientist
Sh Piyoosh Tripathi, Trainee Scientist

APPENDIX-16

Members of the Research Council of CSIR-NPL
(01.04.2010 - 31.03.2013)

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Chairman
Division of Physical and Mathematical Sciences
Dept of Physics
Indian Institute of Science
BANGALORE - 560 012

02 **Prof Shyam Lal** ... . Member
Head, Space and Atmospheric Science Division (External)
Physical Research Laboratory (PRL)
Navarangpura
AHMEDABAD – 380 009

03 **Prof Ashutosh Sharma** .. .. Member
Dept. of Chemical Engineering
Indian Institute of Technology
(IIT) Kanpur
KANPUR – 208 016

04 **Dr M J Zarabi** .... Member
C – 28
Pamposh Enclave
NEW DELHI - 110 048

05 **Dr C S Sundar** .... Member
Director
Materials Science Group
Indira Gandhi Centre for Atomic Research (IGCAR)
KALPAKKAM - 603 102

06 **Prof E V Sampath Kumaran** .... Member
Dept. of Condensed Matter Physics & Materials Sciences
Tata Institute of Fundamental Research (TIFR)
Homi Bhabha Road
MUMBAI - 400 005

07 **Dr Praveer Asthana** .... Member
Mission Director (Nano Mission) (Agency Representative)
Department of Science and Technology (DST)
Technology Bhawan
New Mehrauli Road
NEW DELHI - 110 016

08 **Dr Pawan Kapur** .... Member
Director (DG's Nominee)
Central Scientific Instruments Organisation (CSIO)
Sector – 30
CHANDIGARH - 160 030

09 **Prof Indranil Manna** .... Member
Director (Sister Laboratory)
Central Glass & Ceramic Research Institute (CGCRI)
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KOLKATA - 700 032

10 **Dr Chandra Shekhar** .... Member
Director (Cluster Director)
Central Electronics Engineering Research Institute (CEERI)
PILANI – 333 031

11 **Dr Sudeep Kumar** .... Member
Head, Planning & Performance Division (Permanent Invitee)
Council of Scientific & Industrial Research
Anusandhan Bhawan
2 Rafi Marg
NEW DELHI - 110 001

12 **Prof R C Budhani** .... Member
Director
National Physical Laboratory
Dr K S Krishnan Marg
NEW DELHI - 110 012

13 **Sh T Raghavendra** .. ..Non-Member
Head, Planning Monitoring & Evaluation Group Secretary
National Physical Laboratory
Dr K S Krishnan Marg
NEW DELHI - 110 012

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01.	Prof R C Budhani, Director	...	...	...	Chairman
02.	Dr A Sengupta, Outstanding Scientist	...	...	...	Special Invitee
03.	Dr A M Biradar, Chief Scientist	...	...	...	Member
04.	Dr (Ms) Renu Pascricha, Prin. Scientist	...	...	...	Member
05.	Dr S G Aggarwal, Sr. Scientist	...	...	...	Member
06.	Dr (Ms) Nidhi Singh, Scientist	...	...	...	Member
07.	Sh Virender Babu, Prin. Tech. Officer	...	...	...	Member
08.	Dr S Gangopadhyay, Director, CRRI	...	...	...	Member
09.	Sh T Raghavendra, Head, PME	...	...	...	Member
10.	Sh S K Mehta, CFA	...	...	...	Member
11.	Sh T V Joshua, COA	...	...	...	Member Secretary

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RESEARCH AREAS

- Physics of Energy Harvesting
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NEWS AND EVENTS

- List of candidates called for written examination for the post of Technical Assistant; Group-III(1), post code 8.2.6 against advt. no. 5/2012
- The schedule for written examination for the posts of Technical Assistant; Group-III(1), post codes 8.2.5 & 8.2.6 against advt. no. 5/2012

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Outstanding Achievement Award

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January 16, 2012 at 02.30 PM. (IST) onwards
January 17, 2012 up to 05.00 PM. (IST)
Limited+website Tender
Section Officer S&P

निकटवर्ती प्रमुख लैंडमार्क
IMPORTANT NEARBY LANDMARK

पूसा कैम्पस (आईसीएआर)
PUSA CAMPUS (ICAR)
राजेन्द्र प्लेस मेट्रो स्टेशन
RAJENDRA PLACE METRO STN.

- राजेन्द्र प्लेस मेट्रो स्टेशन : **01** किमी
  Rajendra Place Metro Station : 01 km
- कनॉट प्लेस (राजीव चौक) : **05** किमी
  Connaught Place (Rajiv Chowk) : 05 km
- नई दिल्ली रेलवे स्टेशन : **06** किमी
  New Delhi Railway Station : 06 km
- अंतरराज्यीय बस-अड्डा : **08** किमी
  I.S.B.T. : 08 km
- पुरानी दिल्ली रेलवे स्टेशन : **09** किमी
  Old Delhi Railway Station : 09 km
- इन्दिरा गांधी अंतर्राष्ट्रीय हवाई-अड्डा
  Indira Gandhi International Airport
  - घरेलू (टर्मिनल) : **11** किमी
    Domestic (Terminal) : 11 km
  - अंतर्राष्ट्रीय (टर्मिनल) : **19** किमी
    International (Terminal) : 19 km

निदेशक :
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Working Days :
सोमवार से शुक्रवार
Monday to Friday

कार्य समय
Working Hours
प्रातः **9:00** बजे से सांय **5:30** बजे तक
9:00 am to 5:30 pm

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