



CSIR-NPL

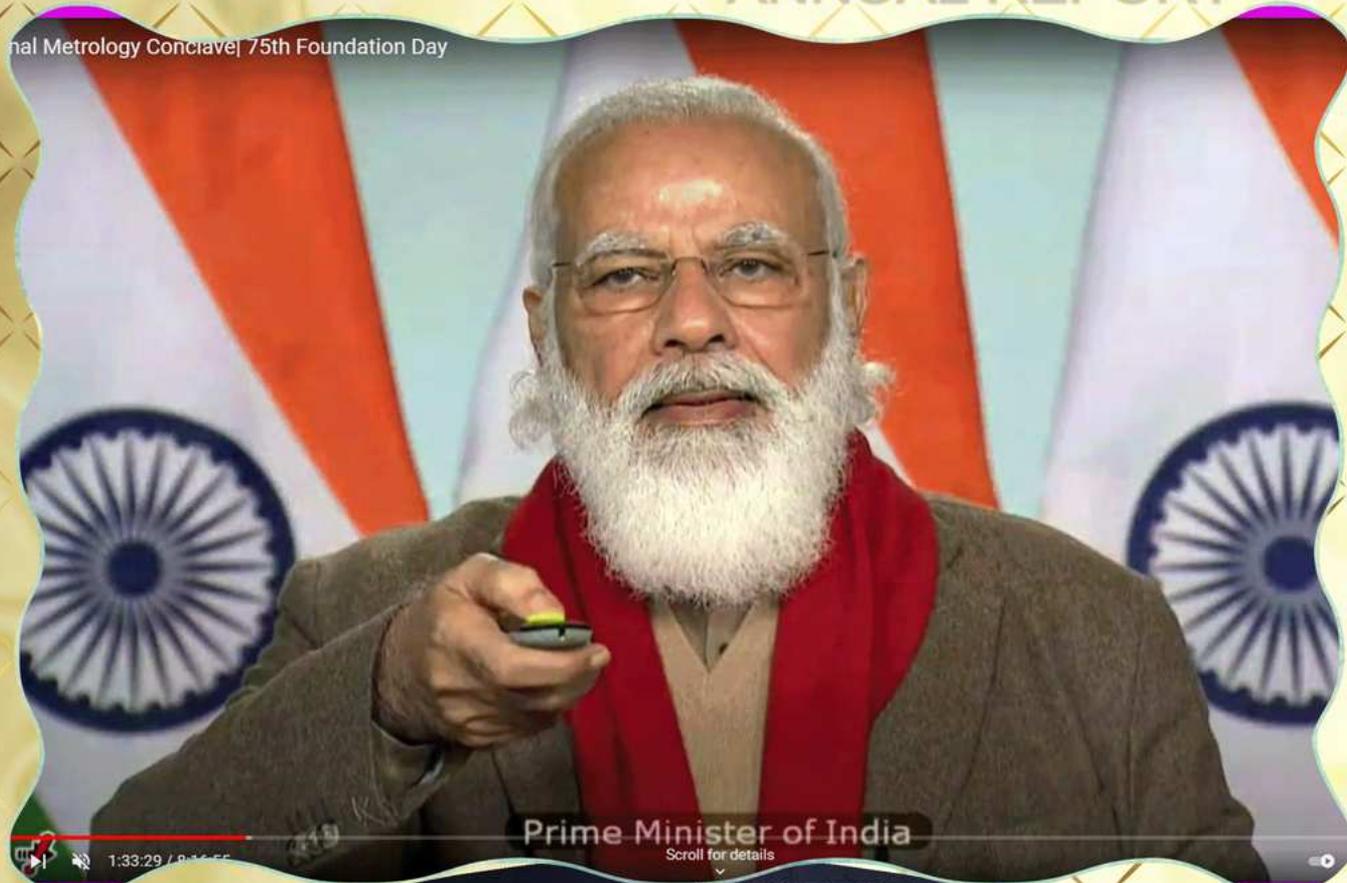


वाषिक प्रतिवेदन

2020-21

ANNUAL REPORT

International Metrology Conclave | 75th Foundation Day



2021



ANNUAL REPORT 2020 - 2021



सीएसआईआर- एनपीएल

CSIR- National Physical Laboratory

(राष्ट्रीय मापिकी संस्थान)

(National Metrology Institute)

नई दिल्ली/ New Delhi



सी एस आई आर-राष्ट्रीय भौतिक प्रयोगशाला
(भारत का राष्ट्रीय मापिकी संस्थान)
CSIR-NATIONAL PHYSICAL LABORATORY
(National Metrology Institute of India)



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गुणवत्ता नीति • Quality Policy

अंतरराष्ट्रीय मानकों के अनुरूप सतत् अनुसंधान और विकास के माध्यम से राष्ट्रीय मापन मानकों का प्रापण, स्थापना, रखरखाव व उन्नयन करना और भारतीय निर्देशक द्रव्य (बी एन डी[®]) का विकास/उत्पादन करना।

आई एस/आई एस ओ/आई ई सी 17025 : 2017 की आवश्यकताओं के अनुरूप ग्राहकों को मापन की अनुमार्गणीयता बनाए रखने के लिए शीर्षस्तरीय अंशांकन/परीक्षण सेवाओं तथा मानकों का प्रसार निष्पक्ष और प्रभावी ढंग से प्रदान करना।

आई एस/आई एस ओ 17034 : 2016 की आवश्यकताओं के अनुरूप प्रयोक्ताओं हेतु अनुमार्गणीयता के प्रसार के लिए बी एन डी का विकास/उत्पादन करना और निर्देशक द्रव्य उत्पादकों (आर एम पी) को बी एन डी के विकास/उत्पादन में तकनीकी सहायता प्रदान करना।

To realize, establish, maintain and upgrade the national standards of measurement compatible to international standards and to develop/produce Bharatiya Nirdeshak Dravya (BND[®]), through continuous research and development.

To provide apex level calibration/testing services and dissemination of standards for maintaining the traceability of measurements to the customers fulfilling the requirements of IS/ISO/IEC 17025 : 2017, impartially and effectively.

To develop/produce BNDs for disseminating traceability to the users and to provide technical support to the Reference Material Producers (RMPs) in the development/production of BNDs, conforming to the requirements of IS/ISO 17034 : 2016.

उद्देश्य • Objectives

ग्राहकों/प्रयोक्ताओं की संतुष्टि के लिए निर्दिष्ट समय-सीमा में निष्पक्षता व सक्षमता से अंशांकन/परीक्षण सेवाएं और बी एन डी प्रदान करना।

अंशांकन, परीक्षण व बी एन डी विकास/उत्पादन से संबंधित सभी कर्मियों को गुणवत्ता प्रणाली प्रलेखन तथा नीतियों और प्रक्रियाओं के कार्यान्वयन से परिचित कराना।

To provide calibration/testing services and BND within the specified time, impartially, competently and to the satisfaction of the customers/users.

To familiarize all personnel concerned with calibration, testing and BND development/production with the quality system documentation and implementation of policies and procedures.

प्रो. वेणु गोपाल आचन्टा
निदेशक

Prof. Venu Gopal Achanta
Director

CSIR-NPL: Vision and Mandate



Shri Narendra Modi
Prime Minister
President, CSIR

Vision and Mission

“Accurate and precise measurement are essential to drive the growth engines of Indian Science & Industry as it removes chaos and prompts innovations, which in turn, would save precious lives, resources and time....



Dr. Jitendra Singh
Hon'ble Union Minister of State
(Independent Charge) Science &
Technology, Minister of State
(Independent Charge) Earth Sciences
Vice President CSIR

- a) *Developing India's measurement standards that are internationally accepted and disseminating the measurement capabilities to industry, government, strategic and academia that underpin the India's prosperity and quality of life.*
- b) *Conducting multidisciplinary R&D with a mission to establish the futuristic quantum standards and upcoming technologies so that India remains on par with international measurement laboratories.*
- c) *Developing sophisticated analytical equipments (i.e. import substitutes) under “Make in India” programme to cater the ever increasing demands of emerging India.*
- d) *Training of young scientists and industry personnel in the area of measurements under “Skill India” programme.*



Dr. Shekhar C. Mande
Director General,
CSIR and Secretary DSIR

Mandate

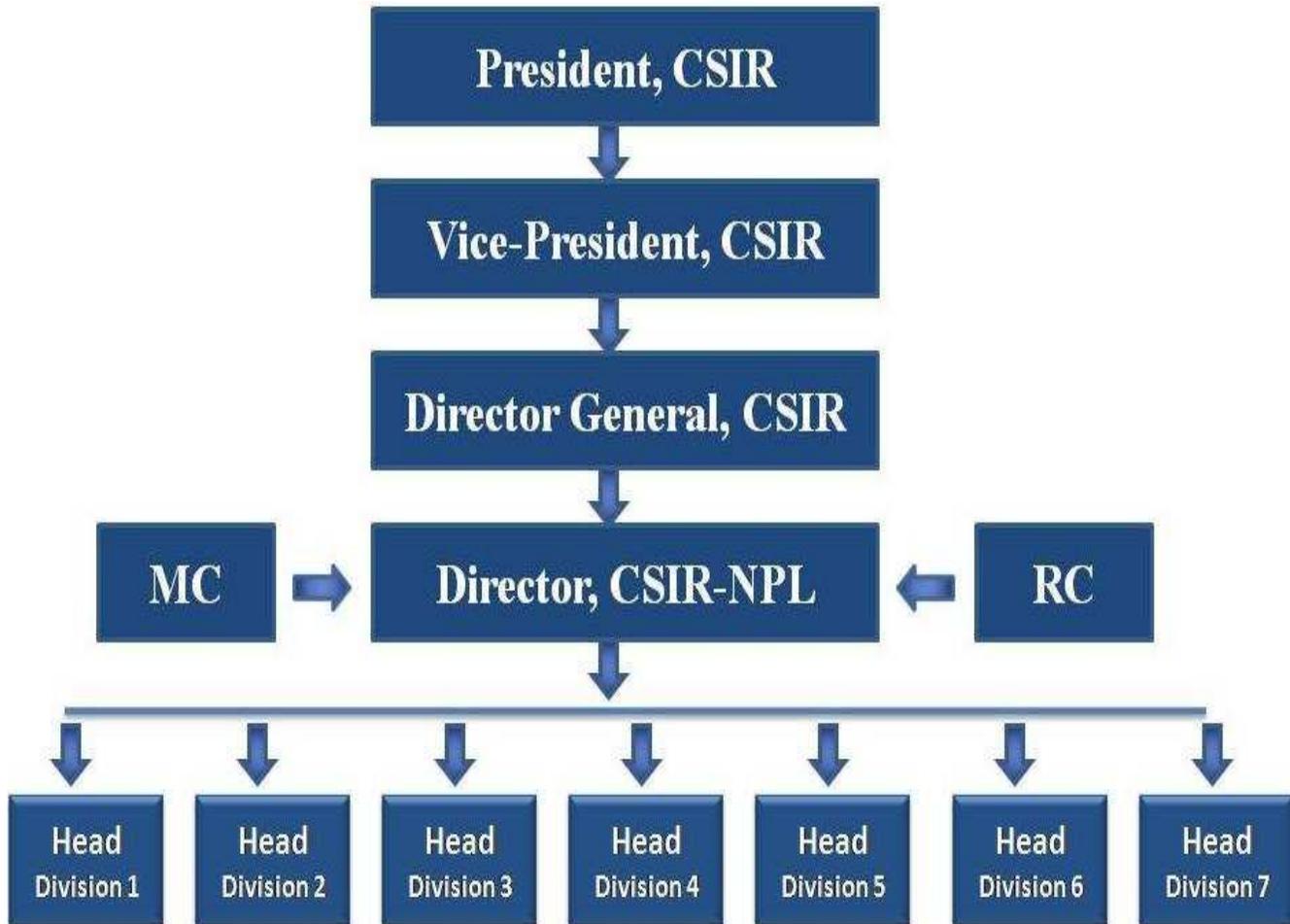
CSIR-National Physical Laboratory (NPL-India) is mandated to be India's “National Metrology Institute” (NMI) by the act of Parliament and is the custodian of “National Standards” with a responsibility of the dissemination of measurements to the needs of the Country.



Prof. VenuGopal Achanta
Director CSIR-NPL

Organizational Structure

CSIR-NPL: Assuring Quality of Life

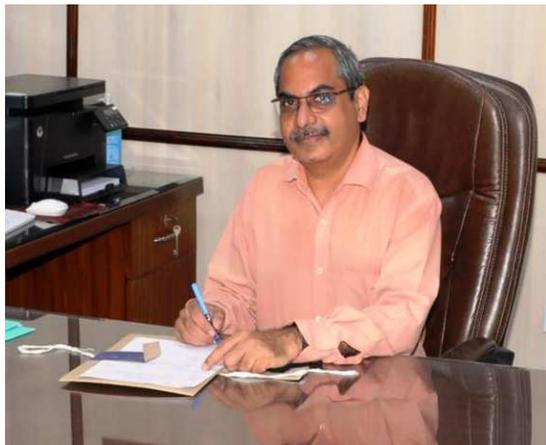


- Division 1:** Physico-Mechanical Metrology
- Division 2:** Electrical & Electronics Metrology
- Division 3:** Environmental Sciences and Biomedical Metrology
- Division 4:** Advanced Materials and Device Metrology
- Division 5:** Bhartiya Nirdeshak Dravya (BND®): Indian Reference Materials
- Division 6:** Indian Standard Time Metrology
- Division 7:** Directorate

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Preface



I am indeed privileged to present the **Annual Report** of CSIR-National Physical Laboratory (CSIR-NPL) for the year **2020-21**. This year coincides with the **75th foundation day of CSIR-NPL**. To commemorate this special day, CSIR-NPL organized a National Metrology Conclave (NMC) on January 04, 2021. On this auspicious occasion, the **Honourable Prime Minister of India, Sh. Narendra Modi** dedicated the **National Atomic Timescale** and **Bhartiya Nirdeshak Dravya (BND®)** – CRMs to the nation. He also laid the foundation stone of the **National Environmental**

Standard Laboratory. Honourable Prime Minister inspired, motivated, and appreciated the strides made by Indian Scientists for nation-building, especially the role of CSIR-NPL and the impact of metrology on self-reliant India.

Being the "**National Measurement Institute**" (NMI) of India, CSIR-NPL is the custodian of "**National Standards**". The primary responsibility of the laboratory is to maintain the National Standards through continuous research and disseminate the apex level SI traceability for accurate and precise measurements to drive the growth engines of Indian Science & Industry. Apart from being a premier research laboratory for the fundamental and thrust area of **Physical Sciences**, CSIR-NPL with several externally funded and in-house projects addressed several national problems, thereby contributing to making the nation self-reliant. Since its creation, CSIR-NPL continued its commendable efforts to achieve the mandated objectives and played a key role in the country's initiatives in cutting-edge research and manpower training in the emerging areas of Physical Sciences, Metrology, and other allied subject streams. Amid the global pandemic crisis throughout the year due to **COVID-19**, the lab had faced unprecedented challenges. In spite of several bottlenecks, there have been several significant outcomes during the year 2020-21. In brief, several new standard facilities for testing and calibration have been established to address the issues related to health, wealth, energy, and the environment. In addition, significant efforts were made to further strengthen the existing precision measurement facilities like - established stylus based surface texture parameter measuring machine, establishment of UV measurement traceability for Ultraviolet Germicidal Irradiation (UVGI) application, testing facility for IR clinical thermometers, ultrasonic pulse velocity tester device with threshold error correction, calibration/testing system for non-invasive blood pressure monitoring system, development of Coriolis mass flow meter as artefact device and participated for its APMP supplementary comparison (APMP.M.FF-S3.2020), monitoring of trace gas concentrations in western Himalayan region, variability in PM 2.5 mass concentration during crop residue burning (CRB) period in 2018, a case study of unique interaction between night-time MSTID and Mid-latitude field-aligned plasma depletion structures observed over low-mid latitude, creation of a new facility for the testing of clean air delivery rate of air purifiers/cleaner, strengthening the calibration capabilities in

biomedical field, testing facility for personal protective equipment (PPE), gas sensor testing facility, amicrobial UVC disinfection casket, clean water and sanitation, certified reference material development, efforts for establishment of one nation – one time mission, up-gradation of internet time dissemination service (NTP Service), best performance on time keeping well below ± 2 ns achieved, time transfer through white rabbit network based optical fibre Link, and accessing topological surface states and negative magnetoresistance in FIB sculpted nanowires at ultra-low temperature. Further, CSIR-NPL has designed a new technologically advanced luminescent security ink for bank cheques. For this, a new strategy is adopted for the anti-counterfeiting ink and made it to be both luminescent and magnetic. The developed pigment emits different colours when exposed to different wavelengths and also has storage capability. Also, CSIR-NPL has established: i) a centre for ballistic material testing and WCNTs based armoured materials, ii) Development of high density isotropic nuclear grade graphite demonstration and validation of a 5 KW HT-PEMFC based on combined cooling and power system, iii) Carbon fiber composite limbs for recurve archery bow, iv) Conversion of crop stubble and municipal solid waste (MSW) into bio-coal by Torrefaction as useful raw material for co-firing in thermal power plants, v) Development of Lithium titanate-graphene based battery chemistry for EVs anode for LiB, vi) Creation of National Center for Battery Evaluation & Safety Test, vii) Direct synthesis of carbon nanotube yarn by chemical vapor deposition, viii) Development of efficient and economically viable carbon nanomaterials for water purification, ix) Development of BND of graphitized petroleum coke and calcined petroleum coke, x) Development of fiberboards and panels from agricultural waste and polymers.

Besides these notable contributions, CSIR-NPL has focused on industry, environment, and academia, which are some of the significant aspects that are considered the backbone of any developing economy. With a view to empower them, CSIR-NPL is striving to build on its expertise in precision measurements to address distinct gaps that exist in the field of science and technology. Thus, to fulfill its objectives, the entire CSIR-NPL is committed to:

- Be the national hub for measurement standards and calibration of equipment to meet the evolving needs of Indian industry and academia in emerging areas.
- Be the apex laboratory for testing environmental pollutants with Indian standard reference materials (BNDs) which would also be useful in calibrating equipment.
- Develop sophisticated equipment to reduce import dependence.
- Be the Centre of Excellence in skill development in the area of precision measurements.
- Setup a research outreach program that offers state-of-the-art facilities for industrial and academic research.

All of these roles have enabled CSIR-NPL to support measurement-related S&T and academics in the country. Also, it has been a great opportunity for all of us to be associated with the institute's objectives and we will strive to build our dimensions further so that we will contribute to solving the societal problems.

Further, the SCI publications of the institute (359 in number); 12 patents (02 - patents applications filed in India, 06 - patents granted in India, 04- patents granted abroad), distinct R&D projects (Consultancy projects, Collaborative projects, Technical Services projects, Sponsored projects etc.) signify a few of the achievements of the institute during

the period. Apart from being a key research and development institute, CSIR-NPL plays a vibrant role in Human Resource Development in the areas of Metrology. In addition to the other skill development programs, a good placement ratio was achieved for the candidates registered for the Precision Measurement and Quality Control Certification Course (PMQC) of the CSIR-NPL. The course has been further recognized by AcSIR and this year the first batch of PG Diploma was started. CSIR-NPL also provides facilities to students from universities and other educational institutes like IITs, IISc-Bangalore, etc., for project work and training. During the period from 1st April 2020 to 31st March 2021, 48 research fellows (JRFs/SRFs) joined CSIR-NPL and AcSIR Ph.D. The total strength of Research Fellows (JRFs+SRFs) in CSIR-NPL is 300 as of 31.03.2021. Also, for widening and deepening its scientific and social responsibilities, CSIR-NPL has conducted numerous lectures and three Jigyasha Programme with around 390 students and 40 teachers during 2020-2021.

All these achievements in the R&D and academic fronts have been successful only because of the significant support, cooperation, and motivation that CSIR Headquarters, Research Council, and Management Council have provided from time to time. I would like to acknowledge the sincere efforts of CSIR-NPL staff for their all-sphere involvement in the continuous growth of the institute. I wish for more productive years ahead and hope that the institute will live up to the expectations and benefit society to a greater extent.

(Prof. Venu Gopal Achanta)

Director CSIR-NPL

CSIR-NPL: Enabling Quality Infrastructure

List of selected organizations to whom support, advices and apex calibration services are being provided

Government/Semi-government Organizations

Air Force; Air India; Bharat Electronics; BHEL; Bhilai Steel Plant; Bureau of Indian Standards; Central Pollution Control Board; Central Power Research Institute; Central Public Works Department; Railway Information System; Central Institute of Mining and Fuel Research; Defense Electronics Applications Laboratory; Delhi Jal Board; Directorate of Border Security Force; Hindustan Aeronautic Limited; Indian Oil; ISRO Inertial Systems Unit; Maharashtra State Electricity Board; Micro, Small and Medium Enterprise Testing Center; NTPC; Nuclear Fuel Complex (DAE); Ordnance Factory; Rail Coach Factory; FCRI, DRDO, etc.

Industries

ABB India; ACC; AIMIL Ltd.; Alstom India; Ambuja Cement; Binani Cement; Birla Tyres; Blue Star; Bureau Veritas; Casio India; Crompton Greaves Limited; Diesel Locomotive Works; Essar Oil Ltd.; Godrej & Boyce Mfg. Co. Ltd; Havells India; Honda Cars; International Zinc Association; J.K. White Cement; JK Lakshmi Cement; Kirloskar Brothers; Larsen & Toubro; Maruti Suzuki; Mysore Paints & Varnish; Philips India; Piramal Healthcare; Ranbaxy; Rapid Metro Rail Gurgaon; Samsung India; Endress + Hauser India Pvt. Ltd.; Capital Power, Itron, Padmini VNA Mechatronics etc.

SAARC Nations

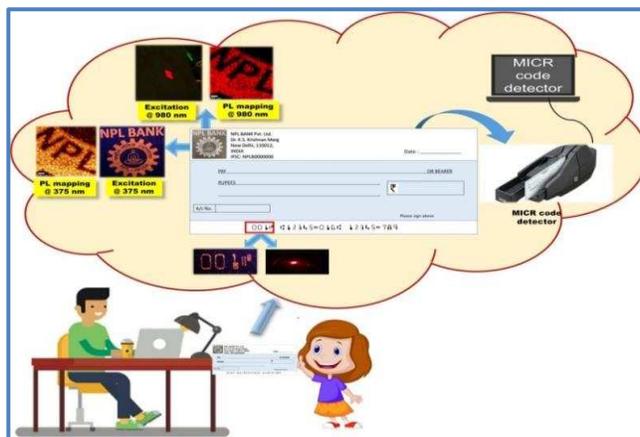
Nepal Bureau of Standards & Metrology (MBSM), Nepal; Bangladesh Standards and Testing Institution (BSTI), Bangladesh; Measurement Units, Standards and Services Department (MUSSD), Sri Lanka; National Physical and Standards Laboratory (NPSL), Pakistan; Bhutan Standards Bureau (BSB), Bhutan; Afghanistan National Standards Authority (ANSA), Afghanistan; Maldives Standards and Metrology Unit (MSMU), Maldives.

2020-21

Significant Contributions

An Advanced Security Ink with Manifold Protection to Curb the Counterfeiting of Bank Cheques

Advanced anti-counterfeiting technologies have protected banknotes with multiple security features so far. On the other hand, forging a bank cheque isn't that difficult due to fewer security features. To provide a solution to this problem, researchers of CSIR-NPL have developed a new technologically advanced security ink for bank cheques which is hard to duplicate. Numerous security pigments have been developed for the banknotes in past decades and upgraded with time to enhance the protection against counterfeiting. Some of them include single/dual/ multi-stage excitable or afterglow security pigments that appear white in normal light, and show different emissions when excited with different wavelengths (Near UV, UV, or NIR). These pigments have fluorescence, phosphorescence, or both i.e., shining in a colour under a light as well as radiating light in a particular colour after removal from a light source. The security feature based on the luminescence of pigments is used for banknotes but not for bank cheques.



A new strategy for formulating a high-security anti-counterfeiting ink by synthesizing a pigment having both luminescent and magnetic features is demonstrated

- Currently, the security features present in bank cheques include, luminescent ink for the bank logo and a special magnetic ink for MICR (Magnetic Ink Character Recognition) code, which makes the cheques machine-readable. But these features are used separately and can be easily detected using advanced instrumental analysis. We developed a new strategy for a more secure anti-counterfeiting ink by synthesizing a pigment having both luminescent and magnetic features. The as-synthesized pigment emits intense orange (580 nm wavelength) and red (660 nm wavelength) color upon excitation with 351 and 980 nm wavelengths, respectively. Furthermore, the room temperature M-H curve of as-synthesized pigment shows

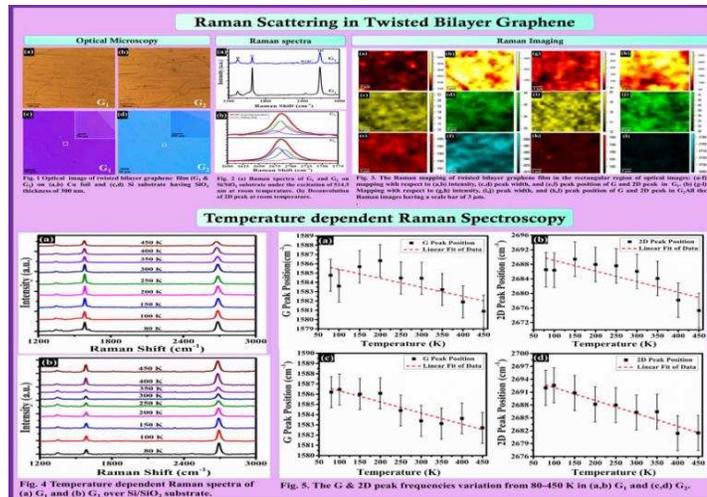
ferromagnetic behaviour that clearly makes it machine-readable similar to a magnetic ink used for bank cheques. The new advanced security ink developed at CSIR-NPL has next-level security as it has a pattern made of multi-stage excitable luminescent pigment-based security ink that emits two different encrypted wavelengths when excited with two distinct wavelengths. The inks currently used even in currency notes shine only in one colour under, say, UV light. However, the new ink shines in two colours when excited with two different wavelengths of light. This technology also has storage capability which is not easy to duplicate. Thus, with this pigment ink, the cheques will become even more difficult to counterfeit.

- Research work on the development of “A novel approach to design luminomagnetic pigment formulated security ink for manifold protection to bank cheques against counterfeiting” is published in *Advanced Materials Technologies*, 6, 2021, 2000973 (I.F.: 5.96). It is recognized on December 2020 as the HOT TOPIC ARTICLE of Magnetic materials in Wiley publication and Highlights of this research work are published in Science Wire; VigyanPrasar Science Portal, 29th January, 2021; EET (Electronics Engineering community for news) India portal on 2nd February, 2021; CSIR News in Media, 1-5th 2021, page number : 14, VigyanPragati; CSIR-News Bulletin, page number: 50, February, 2021; Science Reporter; page number : 52-53, March, 2021 in CSIR Technology Showcase.

Temperature Dependent Raman Studies in LPCVD Grown Twisted Bilayer Graphene Film

Twisted bilayer graphene exhibits interesting phenomena such as unconventional superconductivity, anomalous Hall effect, correlated insulating phases, band topology and many more. Raman spectroscopy at different temperature in graphene plays a crucial role to understand the thermal properties and become useful to set up the metrology at the nano scale. The study of graphene stability with temperature variation is a prerequisite for graphene-based device fabrication. Researchers at CSIR-NPL have synthesized the twisted bilayer graphene film using indigenously developed low-pressure chemical vapor deposition

(LPCVD) setup. The twisting properties of synthesized film have been analyzed on the basis of different peaks namely R, G, and 2D peaks in Raman spectra. This study becomes useful to know the effect of temperature on the twisting behaviour of bilayer graphene film and its an harmonic properties in different applications such as quantum devices, tunable superconductivity, quantum cryptography, and many more.



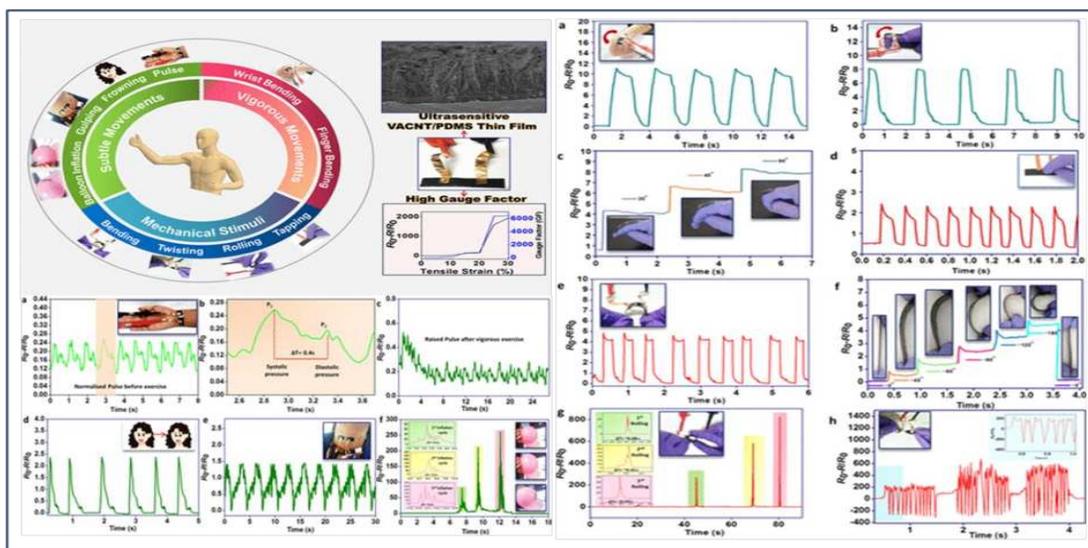
Twisted bilayer graphene is synthesized by indigenously developed low-pressure chemical LPCVD setup at CSIR-NPL: A study on temperature dependent Raman spectroscopy

Ultrasensitive Wearable VACNT/PDMS Derived Strain Sensors for Human Motion Monitoring

CSIR-NPL has developed a simplistic, amenable, cost-effective vertically aligned carbon nanotube (VACNT)/poly (dimethylsiloxane) (PDMS) thin-film flexible structure for robust stretchable sensors with a full range of human motion and multimode mechanical stimuli detection functionalities. Conventional metal-based and semiconductor-based sensors have restricted applications due to their poor sensing sensitivity (~2 GF) and limited monitoring ranges (typically ~5%) reducing their wide-range healthcare monitoring capabilities, which include extremely intricate deformations (such as pulse modulation, breathing, gulping) and fundamental movements (such as finger and wrist bending). Therefore, wearable sensors with excellent sensitivity in compliance with comprehensive sensing range, good stretchability, fast response/recovery time and reproducibility are vitally desirable to emulate the multimodal sensing attributes of human skin with a complete range of healthcare monitoring.

In search of a better ultrasensitive sensor, scientists from the CSIR-NPL designed a light weight ultrasensitive wearable VACNT/PDMS - derived Strain Sensors. This sensor exhibits

the best reported response of carbon nanotube (CNT)-based sensors with extensive multiscale healthcare monitoring of subtle and vigorous ambulations ranging from 0.004 up to 30% strain deformations, coupled with an exceptionally high gauge factor of 6436.8 (at 30% strain), the super-fast response time of 12 ms, recovery time of 19 ms, ultrasensitive loading sensing, and an excellent reproducibility over 10000 cycles. The sensor evinces distinctive electromechanical performances and reliability in real time for motions like wrist pulsing, frowning, gulping, balloon inflation, finger bending, wrist bending, bending, twisting, gentle tapping, and rolling. Thus, high sensitivity, mechanical robustness, and real-time monitoring of wide-range of motions endow the potential multifunctional application of this sensor to meet the highly diversified demands in electronic skins, wearable electronics and flexible touch sensors



The ultrasensitive VACNT/PDMS thin film sensor has been demonstrated and this sensor effectively detects and discerns elaborate range of subtle-vigorous human motions and several mechanical stimuli ranging from 0.004% up to 30% strain deformations and yields ultimately high GF of 6436.8 at 30% and exceptionally fast response/recovery time of 12ms/19ms

Research work on development of “Ultrasensitive wearable strain sensors based on a VACNT/PDMS thin film for a wide range of human motion monitoring” is published in ACS Applied Materials & Interfaces, 13, 2021, 8871-8879 (I.F.:8.76) and the highlights of this research work is published at Nature India Platform as “Wearable sensors for monitoring heart beats, blood pressure”, 22 March 2021, doi:10.1038/nindia.2021.43.

Polystyrene BND

We developed a technology for polystyrene films and delivered the know-how to M/s Sirim Scientific Solutions, Hyderabad-500013, Telangana



Technology on '**Development of Polystyrene Films**' was Transferred to **M/s Sirim Scientific Solutions**, Hyderabad, Telangana on 6th October, 2020 in presence of Director at CSIR-National Physical Laboratory, New Delhi.

Established Stylus Based Surface Texture Parameter Measuring Machine

Surface texture is one of the important factors that control friction. Manufacturing processes such as machining processes that produces surface texture are usually optimized to ensure that the resulting surface texture or surface finish is usable. One of the important parameter of surface texture, surface roughness is a measure of total spaced surface irregularities. The surface finish



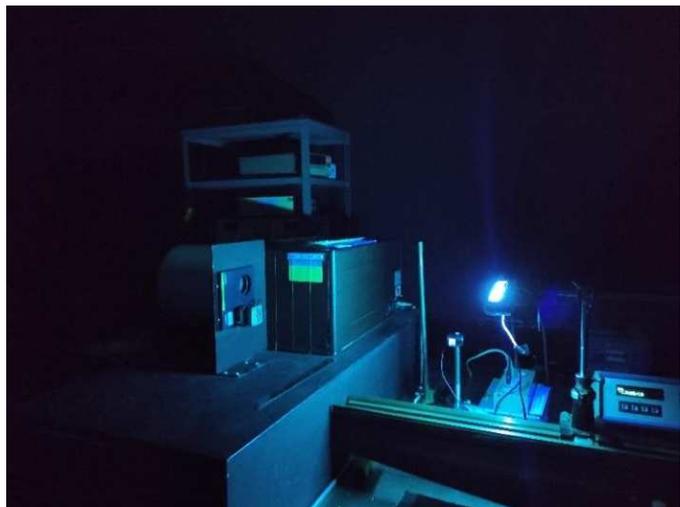
Photograph of stylus based surface texture parameter measuring machine established at CSIR- NPL

may be measured in two ways: contact and non-contact methods. At CSIR- National Physical Laboratory, we have recently established a contact type measurement instrument (Stylus based surface texture parameter measuring machine) for measurement of surface texture parameters such as Ra, Rq, Rz, Rp, Rpmax, Rvmax, Rt, Sm, Sk, Ku, material ratio parameters along with contour measurements for assessing angles, radii, and distances across a workpiece, and determining deviations from the component's nominal parameters. With this new facility, we can provide calibration services for texture parameters such as Ra, Rz (mostly sought after parameters in manufacturing processes) and depth standards with $\pm 6\%$ uncertainty of measurement with a coverage factor of $k=2$ at a confidence interval of 95%.

With our newly established facility, CSIR-NPL is now capable of catering to the needs of manufacturing sector, government sector and NABL accredited laboratories, etc. for surface texture parameters measurements as well as contour measurements.

Establishment of UV Measurement Traceability for Ultraviolet Germicidal Irradiation (UVGI) Application

Globally the human population is reeling under the COVID-19 pandemic situation. Being a viral infection, the human-to-human spread has not only occurred through direct or close contacts but also through indirect interactions like contaminated objects and surfaces. For non-wet and non-chemical sanitization of the surfaces and ambient air, Ultraviolet-C (UVC, spectral range 200 nm to 280 nm)



UVC measurement setup at CSIR-NPL

radiation based sanitization has gained enormous importance all over the world in the pandemic situation due to outbreak of SARS-Cov-2 virus. The effectiveness of UV-C based sanitization has to be quantified which is derived from a radiometric parameter,

‘irradiance’. Hence, the metrological traceability of irradiance measurement is essentially required for achieving requisite accuracy of measurements and hence ensuring germicidal efficacy. The metrological traceability for UVC irradiance has been established with the standard spectral irradiance sources and is being further disseminated for measurement of UVGI devices.

CSIR-NPL Developed Testing Facility for IR Clinical Thermometers

The measurement of body temperature is a basic parameter and vital sign of human body health. During contagious disease situations like Covid-19, SARS, Ebola, etc the non-contact type IR Clinical thermometers are used for the effective thermal screening. As per the Legal Metrology requirement, all the IR Clinical thermometers, imported or developed in India, need to be tested for their model approval. With in-house R&D efforts, in the initial phase of Covid-19, we have successfully developed the IR Forehead Thermometer Testing facility as per IS/ISO 80601-2-56:2017 and served our Legal Metrology Department for the Model Approval Testing.



Testing facility for IR clinical thermometers

We have also established a metrological correlation between forehead and wrist site measurements. We are now establishing IR Clinical Thermal Imager/Thermal Scanner Testing Facility at NPLI.

Ultrasonic Pulse Velocity Tester Device with Threshold Error Correction

Ultrasonic pulse velocity (UPV) is an extremely useful parameter to investigate the mechanical properties of bulk materials such as metals, composites, and concrete structures. By measuring the ultrasonic transit time through the material other related properties can be evaluated. Recently CSIR-NPL has developed a



Ultrasonic pulse velocity tester developed at CSIR-NPL

unique UPV tester with automatic threshold error correction facility for more accurate transit time measurement. The device is battery-operated and is suitable for site operations. Any generalized commercially available transducers of suitable frequency can be used. The developed device has the best transit time measurement resolution of 50 ns. It has various applications such as Ultrasonic transit time measurement (in metallic, non-metallic, concrete), Ultrasonic velocity measurement, Estimation of concrete strength, Homogeneity and quality estimation of concrete materials and estimation of dynamic modulus of elasticity in concretes.

Calibration/Testing System for Non-invasive Blood Pressure Monitoring System

In 2019, the Government of India amended the medical device rule of 2017 and added a list of 36 medical devices for which the type approval and related certification became mandatory. In this list, blood pressure (BP) monitoring devices (including digital type) is also present. At that time, the lack of proper infrastructure



Calibration/testing system for the non-invasive blood pressure monitoring system CSIR-NPL

for the testing facility of BP monitoring devices in India created an obstruction to the implementation of the amendment.

So CSIR-NPL developed the calibration/testing system for non-invasive BP monitoring system. This system can operate in fully automatic as well as manual mode. It is capable of simultaneous calibration/testing of 20 BP monitoring devices altogether.

CSIR-NPL Participated in International Inter-comparison of Water Flowmeters to Support CMC Claims

The Fluid Flow Metrology Section participated in **APMP Supplementary Comparison (APMP.M.FF-S3.2020) of water flow using a Coriolis mass flowmeter of DN20 size, make Emerson as artifact.**

Total 7 NMIs, namely, NIMT, Thailand; NMIA, Australia; NMIJ, Japan; NMC A*Star, Singapore; CSIR-NPL (NPLI),



[New 5 SS pipe lines along with associated instrumentations and controls of primary WFCF](#)

India; ITDI, Philippines and EMI, United Arab Emirates (UAE) are participating in this intercomparison and NIMT, Thailand is Pilot Laboratory. The measurement was done during **March-April 2021**. Before measurement, we prepared for a system performance check by calibrating various standards such as a 300 kg weighing scale, frequency counters, digital multimeter, offline digital density meter, and digital thermometer. The artifact was installed in the DN50 line after fabrication of a special adaptor for this purpose. Although the mass flowmeter does not have upstream and downstream straight pipe length requirement, in the set-up, approx. **10D upstream** and **10D downstream straight length** were provided to the artifact for improved flow profile. This comparison will support our water flowmeter calibration measurement capability (CMC).



Installed artifact Coriolis mass flowmeter



Display of Coriolis mass flowmeter in primary WFCF

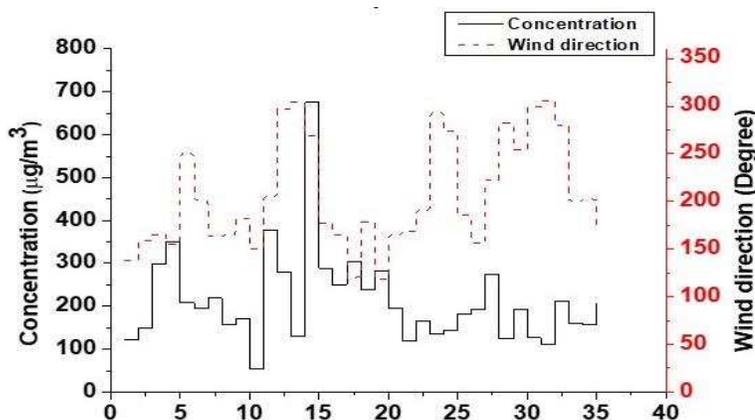
NPL's Remote Atmospheric Monitoring Station: Monitoring of Trace Gas Concentrations in Western Himalayan Region

The air quality not only influences the health of the people living in a particular region or area but also influences the economy of a nation. The deterioration of the air quality is not limited to urban regions but the most fragile ecosystems of the world are also impacted by it. The Himalayas are one of the youngest mountains in the world, and support a wide variety of flora and fauna providing immense ecosystem services. A high altitude site can also provide the values of pollutant species which can be used to assess the baseline scenario that would help in understanding the atmospheric chemistry & physics besides providing valuable inputs to decision-making bodies to improve the air quality. The CSIR-National Physical Laboratory has established a remote atmospheric monitoring station on the campus of CSIR -Institute of Himalayan Bio-resource Technology (IHBT), Palampur, Himachal Pradesh (32.12°N, 76.56°E) at 1347 m above mean sea level (AMSL). Palampur is a hill station, located in the district Kangra of Himachal Pradesh (HP), and surrounded by the Dhauladhar ranges of the Himalayas. The station is equipped with analyzers that can measure the trace gases such as Ozone (O₃), Nitrous Oxide (NO), Nitrogen Dioxide (NO₂), Sulphur dioxide (SO₂), Carbon Monoxide (CO), and Ammonia (NH₃). The four-year continuous measurement data for the period 2016 to 2019 monitored at this high altitude site was used to understand the variability of these trace gases over the Indian western Himalayan region. Significant variability in the mixing ratios of the trace gases has been

observed. All the trace species showed maximum variability during the pre-monsoon season except CO which showed the highest variability in the mixing ratio during the monsoon season. The influence of the factors like forest fires, stubble burning, agricultural activity, and industries has been attributed to be the main reason for the observed variabilities in trace gas concentrations at the site. The pollutant sources from the Indo-Gangetic Plains (IGP) region were also found to influence the trace gas concentrations at the site. The mixing ratio of SO₂ at the site indicated the influence of point sources such as industries and thermal power plants as indicated by the air mass back trajectory analysis. The meteorology and the Himalayan orography have also been found to significantly influence the mixing ratios of the trace gases as the site received valley winds.

Variability in PM_{2.5} Mass Concentration during Crop Residue Burning (CRB) Period in 2018

The average PM_{2.5} mass concentration was found to be 200.1±12.1 µg/m³ varying from 53.5 to 674.8 µg/m³ during CRB period, 2018. The study period comprised two distinct events Crop Residue Burning (CRB) and Diwali. Therefore, the average mass concentration is exclusive



Variations in PM_{2.5} concentrations and wind direction during CRB 2018 period

of the PM_{2.5} mass concentration observed on the Diwali day, i.e. 674.8 µg/m³. The mass abundance of PM_{2.5} during late October (25th - 31st October 2018) ranged from 121.7 to 350.9 µg/m³ (Average: 220.7±13.1 µg/m³, n=7). The maxima of PM_{2.5} mass concentration was observed on 28th October 2018. The CRB that occurs on a large scale in the neighboring states of Punjab and Haryana, could be the reason for the high mass abundance of PM_{2.5} during the study period at Delhi. Besides, vehicular and industrial emissions, construction activities are also the major contributors to aggravated fine particulate matter levels.

The PM_{2.5} levels during November (01st - 30th Nov 2018), varied in the range 53.5-377.4 $\mu\text{g}/\text{m}^3$ (Average: $195.1 \pm 13.1 \mu\text{g}/\text{m}^3$, $n=30$) (exclusive of episodic Diwali day PM_{2.5} mass concentration 674.8 $\mu\text{g}/\text{m}^3$). During such conditions, the hygroscopic components of PM_{2.5} uptake the atmospheric moisture and get enhanced in size, thus resulting in the haze and smog formation and subsequently, affecting the visibility. Additionally, the prominent NW wind during the CRB period was responsible for bringing the winds laden with high particulate matter concentration. The higher level of PM_{2.5} can be attributed to the long-range transport of emissions of CRB, along with local sources of emissions in the region.

A Case Study of Unique Interaction between Nighttime MSTID and Mid-latitude Field-aligned Plasma Depletion Structures Observed over Low-mid Latitude

A study using an airglow imager operating at 630.0 nm from Hanle, Leh Ladakh (32.7°N, 78.9°E; Mlat. ~24.1°N), and Digisonde operating at New Delhi India, captured a unique event involving interaction of two F region plasma structures on a geomagnetically quiet night (06 May 2019, $A_p = 4$). One of these structures is a nighttime Medium Scale Traveling Ionospheric Disturbance (MSTID) and the other is a geomagnetically north-south oriented Mid-latitude Field-aligned Plasma Depletion (MFPD). A sequence of processes constituted this unique interaction between the MSTID and MFPD, which were spatially separated initially and merged into a single structure later on. The processes observed include bending of the MFPD, establishment of a plasma channel between the MSTID and MFPD, and merging of the MSTID and MFPD leading to the intensification of the merged region and further propagation as a single MSTID structure. Contrary to the previous reports in the past, wherein the post-interaction MSTID was unperturbed and the plasma depletion decayed, the present case study reveals an interesting class wherein the MSTID and MFPD were independent structures initially, but got merged subsequently and formed a conspicuously stronger MSTID structure due to their mutual interaction. It is proposed that vertical shear in zonal plasma drift brought the MFPD structure towards the MSTID structure facilitating the interaction. These are the first observations of such interactions from a geomagnetic low-mid latitude transition region and are important for understanding the plasma irregularity processes prevalent therein.

Creation of a New Facility for the Testing of Clean Air Delivery Rate of Air Purifiers/Cleaner

Clean Air Delivery Rate (CADR, $\text{m}^3 \text{h}^{-1}$), is the measure of the delivery rate of purified air by an air purifier or cleaner. These devices are used in the home, office car, etc. The CADR is calculated by subtracting the natural decay rate constant from the total decay rate constant (of a pollutant) and multiplying the difference by the volume of test chamber (m^3). CADR

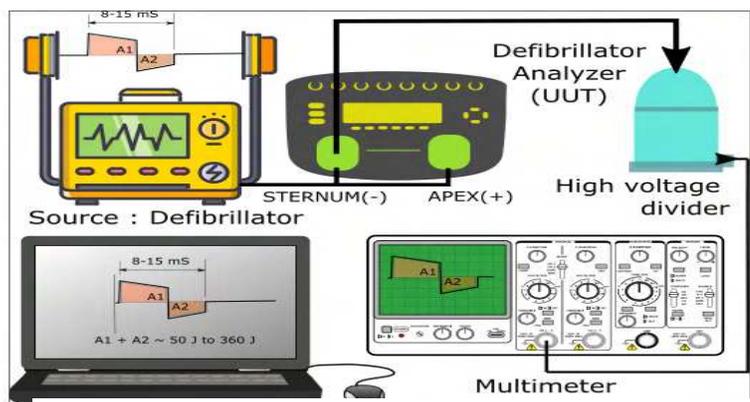


Clean air delivery rate (CADR) testing facility for air purifier

calculation is independent of the technology used in an air purifier for contaminant removal. The facility needed for the testing of CADR includes a glass chamber with an air handling unit, particle injection, and control unit, and measurement system of several pollutants as spike and by-product. This facility is designed as per Indian Standard (IS 17531: 2021), fabricated, and successfully tested. Now the facility is open for Indian industries and manufacturers.

Strengthening the Calibration Capabilities in Biomedical Field

The biomedical section has enhanced its current calibration capabilities for defibrillator and defibrillator analyzer in uncertainty measurement at the estimated value of following parameters viz. Energy (J), Discharge time positive pulse width Discharge time (s) negative pulse width, Load resistance, Energy (J), Discharge time (s) positive pulse width, Discharge time (s) negative pulse width,



Calibration capability of measurements for defibrillator analyser

Pacer load resistance. Calibration certificates have been issued for defibrillator analyzer to biomedical testing laboratories viz. Kirloskar Technologies, New Delhi, GODREJ & BOYCE MFG. CO. LTD. Lawkim Motors Group, Mumbai, Maharashtra, Apex Quality Certification Services Pvt. Ltd., Jaipur.

Testing Facility for Personal Protective Equipment (PPE)

Personal protective equipment (PPE) is the protective gear to safeguard the exposure to the harmful ambiance. The potency of PPE depends upon stringent testing as per the standard protocols. These tests assure that such PPE would safeguard the health workers or patients and restrict bacterial/viral transmission flow. The resistance offered by PPE fabric to synthetic blood is considered an acid test for their utility in pandemic situations like the worldwide spread of COVID19, which is airborne viral transmission. The prime requirement of blood penetration tests for PPE fabric is synthetic blood with physical properties similar to human blood. NPL-CSIR has taken the lead in developing the standard for synthetic blood, particularly for testing of PPE fabric.

Gas Sensor Testing Facility

Sensor Devices & Metrology group has established a gas sensor characterization system to test the performance parameters of developed gas sensors such as sensitivity, selectivity, stability and response/recovery time. The system consists of a vacuum chamber, sensor holder, sensor heater, mass flow controllers, gas manifold, gas mixture chambers,



Gas sensor testing facility at sensor devices and metrology group

source meter, data acquisition unit, and electrical communication cables. Sensor performance can be tested at different temperatures ranging from room temperature to 400 °C. Various concentrations of target gases are achieved by dilution of respective higher

concentration gases with synthetic air. The gas response and recovery characteristics of sensors are measured by alternating the flow of target gas and synthetic air, respectively. Control of gas mass flow and collection of measurement data are performed with help of computer automation. A Keithley electrical source meter is employed for biasing gas sensors with desired voltage and measuring the amount of current flow across the sensor. The gas response is determined from the change in sensor resistance under the flow of synthetic air and target gas.

Certified Reference Material Development

Reference Material (BND) is being utilized for the calibration of measuring equipments and also traceability of the measurement. To fulfill the demand of industries, R&D institutions, and laboratories, CSIR-NPL has taken initiative for the development of Reference Material in-house and in collaboration with reference material producers accredited by NABL as per ISO 17034 requirements. CSIR-NPL has done agreement with several RMPs like HPCL, BPCL, NCCBM, Aashvi LLP, Jalan, CSIR-IITR etc. for the development of reference materials related to petroleum products, cement, water, precious metals etc. CSIR-NPL has taken initiatives for the development of reference materials related to water, cement, petroleum products etc. in-house as well as in collaboration with RMPs. CSIR-NPL is also exploring new areas like polymers, pesticides, metals and alloys to cater to the Indian laboratories, R&D institutions, industries etc. Reference Materials (BNDs) are available for customers related to petroleum products, cement, water, precious metals etc.

One Nation – One Time Mission

CSIR-NPL has started a mission, One Nation – One Time, to synchronize all the clocks in India to ISTTM. CSIR-NPL has been tirelessly working to strengthen the IST dissemination network across the nation. BIPM in Paris, which manages the Global timekeeping, has been collecting data of 500 clocks from more than 70 NMIs, and CSIR-NPL is one of them. CSIR-NPL realizes IST with a state-of-the-art "National Atomic Timescale" consisting of atomic clocks and sophisticated measurement systems. A replica of the same has also been created for backup. IST is kept traceable to UTC (international reference time) with an uncertainty of ± 2.8 ns, one of the best in the world. IST traceability is given successfully currently to

ISRO timing centers located at Bengaluru and Lucknow for IRNSS or NavIC, India's GPS-like system. All seven NavIC satellites are now synchronized to IST within a few nanosecond accuracies. Through NTP service, IST dissemination with millisecond accuracy is available over the internet. More than 1 lakh users are benefitted from this free service, and about two crores of NTP requests are handled each month. A web clock showing IST is also available on the NPL website. Under this auspice, significant developments happened in the National Mission to establish the timing laboratories of Legal Metrology Department (LM) in five RRSLs namely, Guwahati, Bangalore, Faridabad, Ahmedabad, and Bhubaneswar, and one Disaster Recovery Center (DRC) in Bangalore. Also, in this context, the Disaster Recovery Center (DRC) in Bangalore will be a permanent laboratory and property of CSIR-NPL. CSIR-NPL's efforts to disseminate, legalize, and implement IST as a national mission, One Nation - One Time, will boost the country's economic growth and become the key enabler for Aatmanirbhar and Safe Digital India.

Up-gradation of Internet Time Dissemination Service (NTP Service)

CSIR-NPL has been providing Internet Time Dissemination Service via NTP for more than a decade under the 'Stratum 1 service'. This service has been updated by adding the backup of 19 high-end NTP servers with enhanced capabilities to cater to the needs of the entire nation. Some of the servers are in reserve while few servers are available for general use of public. The NTP Time Dissemination service has been upgraded and configured fully with 10 additional NTP servers with the new domain name as "time.nplindia.in" while the earlier NTP service via "time.nplindia.org" remains unaltered. This service is ready for public use.

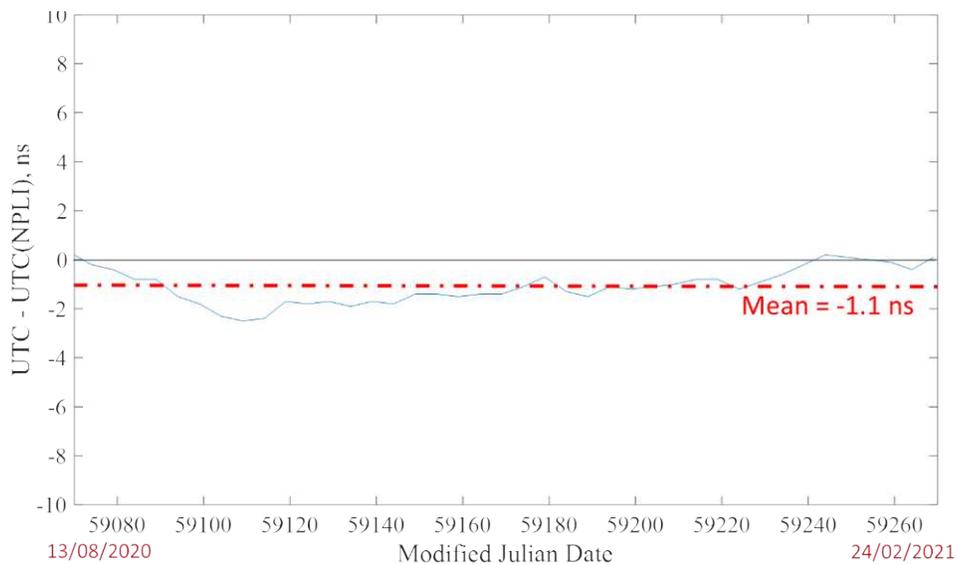
Best Performance on Time Keeping

The Primary Time Scale generating Indian Standard Time (IST) became the best in the history of CSIR-NPL. With the additional of new clocks and measurement systems, a new architecture was implemented in the Primary Time Scale. The improved Time Scale with the new Passive Hydrogen Maser is shown in the figure



Primary time scale with new passive hydrogen maser

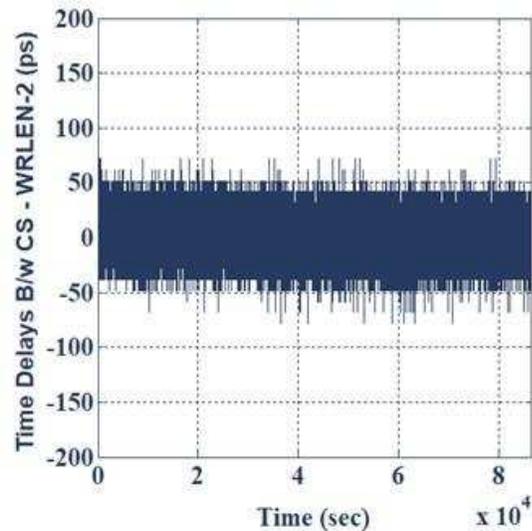
Best performance in the history on time keeping in India was achieved with long-term accuracy, UTC - UTC (NPLI) keeping well below ± 2 ns as shown in the figure.



Best performance of primary time scale was achieved during 2020-21

Time Transfer through White Rabbit Network Based Optical Fibre Link

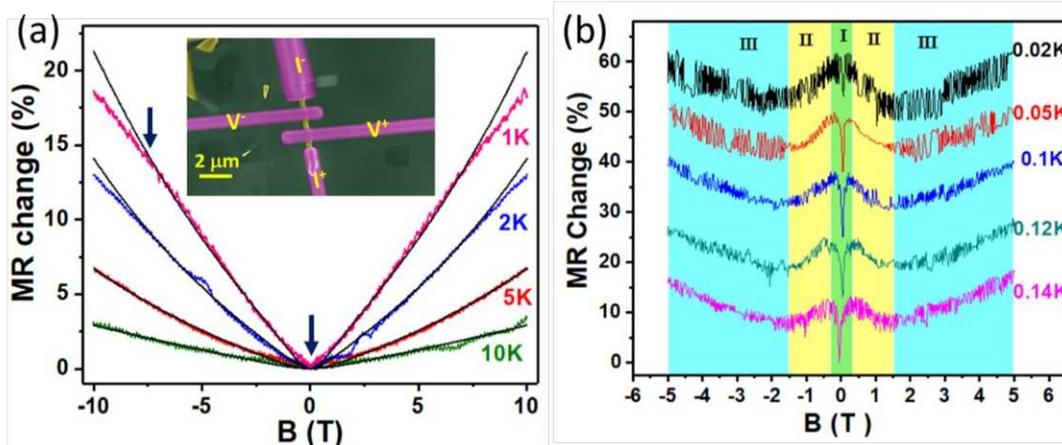
Precise transfer of time and frequency signals and clock comparison are inseparable portions of the Time & Frequency metrology section. It plays a crucial role in many technological applications as well as for advanced scientific research. These reinforce a wide range of applications such as navigation, power grid management, mobile communication, etc. The evolution of timekeeping through the development of the advanced and more accurate atomic clock has made it indispensable to improve the accuracy of time transfer methods. To synchronize or compare performances of two highly stable and precise atomic clocks, it is always desirable that the link between them, i.e., the transmission link, should have a higher level of stability than those clocks. At CSIR-NPL, we have established an ultra-stable optical fiber link employing a White Rabbit (WR) network for accurate and precise transfer of time and frequency signals and comparing the performance of atomic clocks. Utilizing this optical fibre link, time signals were transmitted within an uncertainty of ~ 100 ps at an ambient condition, and the instability of this link in terms of modified Allan-deviation reaches $\sim 10^{-16}$ within one day of integration time.



In house experimental setup of the White Rabbit network based optical fibre link and time delay variation between the two ends of the optical fibre link

Accessing Topological Surface States and Negative Magnetoresistance in FIB Sculpted Nanowires at Ultra-low Temperature

FIB milling of 2D flakes is a simple method to fabricate nanomaterial of any desired shape and size. Inherently milling process can introduce the impurity or disorder which might show exotic quantum transport phenomenon when studied at a low temperature. FIB lab reported the temperature-dependent weak antilocalization (WAL) effects in the sculpted nanowires of topological insulators in the presence of a perpendicular magnetic field. Results indicate that transport through topological surface states (TSS) in sculpted nanowires of Bi₂Te₃ can be achieved at mK range and linear magnetoresistance observed at ~2 K could be the coexistence of electron transport through TSS and contribution from the bulk band. These experimental findings show a significant advancement in the FIB lab's device fabrication capability, and successful coupling of these devices at ultra-low temp where survival of electrical pads /contacts is a challenging task.



FIB fabrication of Bi₂Te₃ nanowire and MR study. a) MR measurements performed for temp 1K and inset represents the device image. b) MR measurements performed at ultra low temp 0.14 K

(Ref. Yadav, R., et al., 2020. Accessing topological surface states and negative MR in sculpted nanowires of Bi₂Te₃ at ultra-low temperature. *Journal of Physics: Condensed Matter*, 33(8), p.085301.)

Additionally at room temperature, we have fabricated the high performing flexible photodetectors made from the topological material operating efficiently under the NIR

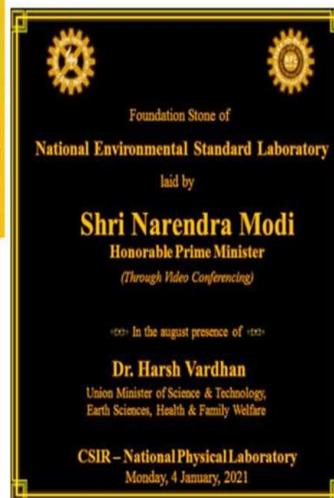
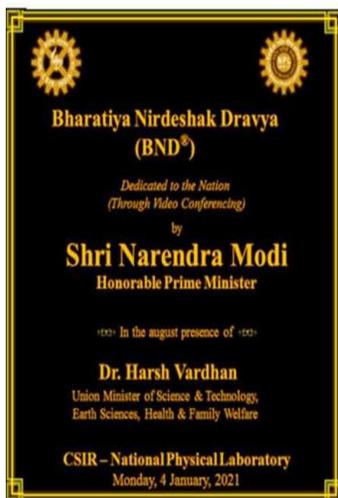
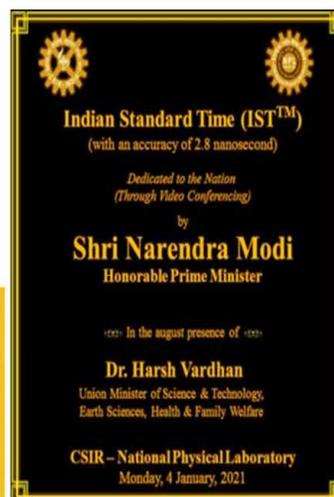
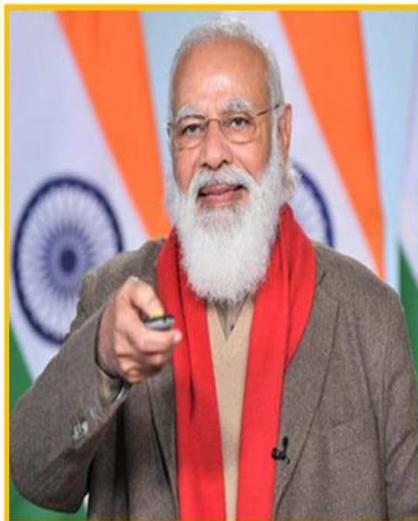
as well as visible wavelengths. A high responsivity was observed for telecom wavelength which is very competitive compared to the available thin film based flexible photodetectors. Our results indicate that TI films deposited on flexible PET substrates can be used for broad spectral photodetection with high responsivity for the telecom wavelength and may be considered a suitable material for fabricating the wearable optoelectronic devices. *(Ref. Pandey, A., et al., 2021. High performing flexible optoelectronic devices using thin films of topological insulator. Scientific Reports, 11(1), pp.1-8.)*

2020-21

Glimpses of Events

National Metrology Conclave (NMC) (January 04, 2021)

To commemorate its 75th Foundation Day, the CSIR-NPL organized a National Metrology Conclave (NMC) on January 04, 2021. On this auspicious occasion, the Honourable Prime Minister of India, Sh. Narendra Modi dedicated the **National Atomic Timescale** and **Bhartiya Nirdeshak Dravya (BND®)** – CRMs to the nation. He also laid the foundation stone of **National Environmental Standard Laboratory**. He addressed the august gathering in the gracious presence of Honourable Union Minister of Science and Technology, Dr. Harsh Vardhan. Honourable Prime Minister inspired, motivated and appreciated the strides made by Indian Scientists for nation building, especially the role of CSIR-NPL and impact of metrology for self-reliant India.



Former Union Minister of S&T and Vice President, CSIR, Dr. Harsh Vardhan on this auspicious occasion inaugurated the Poster Gallery, released the book titled, “**Metrology for Inclusive Growth of India**”, and dedicated the online ‘**Thesaurus of Metrology**’. A book entitled “Metrology for Inclusive Growth of India” was published by Springer Singapore (2020).

Several of the world metrology leaders also presented their visions, in the NMC, on the role of metrology in societal and industrial growth through online virtual platform. The main emphasis was placed on the importance and impact of the metrology in the success of several initiatives of Government of India namely, ‘AtmaNirbhar Bharat’ (Self-Reliant India), ‘Make in India’, ‘Digital India’, ‘Skill India’, ‘Vocal for Local’, etc.



Release of Brochure on “Indian Standard Time (ISTTM): One Nation – One Time” (January 04, 2021)



On-site International Peer Review of Quality System (November 17-19, 2020)

Successful undergone on-site international Peer review of Quality System based on IS/ISO/IEC 17025: 2017 through Asia Pacific Metrology Program (APMP) to complete the transition of the standard from 2005 to 2017 during 17-19.11.2020. No NC was raised during peer review.



Glimpses of peer review of quality system of mass metrology section

CSIR-NPL (NPLI) has successfully undergone international Peer Review of Quality System based on ISO/IEC 17025: 2017 and ISO 17034: 2016 of 23 Sub-Divisions through Asia Pacific Metrology Program (APMP) for fulfilling the requirements of International Committee for Weights and Measures Mutual Recognition Arrangement (CIPM MRA).

APMP has accepted Quality System of NPLI based on both the standards.



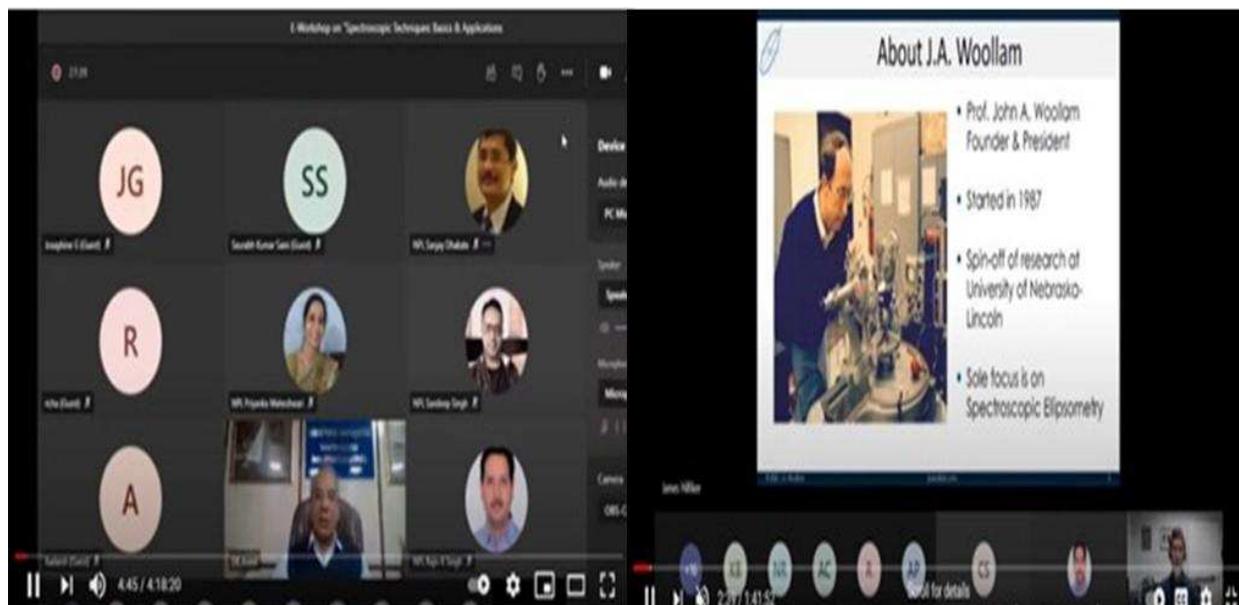
Group photograph with Quality Expert of APMP

(L-R : Dr. Anuradha Sengar, Mr. Goutam Mandal, Dr. S. R. Dhakate, Dr. S. S. K. Titus, Mr. M. A. Ansari, Dr. D. K. Aswal, Mr. S. C. Huria, Mr. J. C. Biswas, Dr. Nita Dilawar Sharma, Dr. Anurag Gupta, Dr. C. Sharma, Dr. Nahar Singh)

2-Day E-Workshop on "Spectroscopic Techniques: Basics & Applications" (December 3 - 4, 2020)

Photonics Materials and Metrology Section has conducted a 2-Day E- workshop on "Advanced Spectroscopy for Emerging Materials" during December 22nd - 23rd, 2021, at the CSIR-NPL campus. The workshop offered a platform for a broad audience interested in gaining in-depth knowledge of the aspects and developments in emerging materials and related scalable technologies Viz. Ultrafast, Photoluminescence, RAMAN Spectroscopy, 2D IR spectroscopy, Plasmonic Materials, etc. The workshop's primary focus was on how spectroscopic methods may assist in understanding material behavior, connecting structure-property links, and finally explaining the structure of existing and newly

developed materials. Nine speakers were invited from various sectors as well as from different prestigious institute, and 914 individuals registered for the session from India and abroad. More than 250 participants were actively present throughout the course in online mode via CSIR MS Team subscription.



2020-21

Divisional Activities

Physico-Mechanical Metrology:

Division 1

The Physico-Mechanical Metrology (PMM) division has the mandate to establish, maintain, disseminate and continuously upgrade the Physico-mechanical standards such as Mass, Density and Viscosity; Length, Dimensions and Nanometrology; Temperature, Humidity and Moisture; Optical Radiation; Force and Hardness; Pressure, Vacuum & Ultrasonic; Acoustic and Vibration, and Fluid Flow Metrology. Along with apex level calibration and testing services being provided to several customers, we also strive to provide the Technical and Consultancy services to various customers, such as DRDO, Department of Legal Metrology, and Industry. Similarly few of the R&D projects have been approved by CSIR in this year on Testing Facility for PPEs, NCP Project for Boltzmann Constant, FBR project for quantum pascal, Facility creation in Physico-mechanical metrology, etc.

All our Sub-divisions are part of one-year Post Graduate Diploma (PGD) course on Precision Measurement and Quality Control (PMQC) under AcSIR on Mass and related parameters.

During the year 2020-21, the division has published over 70 SCI papers, about 60 conference presentations, Few Book Chapter, Invited Talks and about 6 students got Ph.D. in PMM Metrology area.

A glimpse of activities of each subdivision is described below.

Mass Metrology

Prepared Document Manual of the section as per guidelines of new Quality Manual based on IS/ISO/IEC 17025: 2017 for the implementation of new standard. Undergone internal audit of Mass, Volume, Density and Viscosity prior to undergo Peer Review of quality system.

Successful undergone on-site international Peer review of Quality System based on IS/ISO/IEC 17025: 2017 through Asia Pacific Metrology Program (APMP) to complete the

transition of the standard from 2005 to 2017 during 17-19.11.2020. No NC was raised during peer review.

According to some studies, at the beginning of the pandemic situation due to Covid-19, in absence of suitable medicine and vaccine, Hydroxychloroquine (HCQ) had shown strong antiviral effects on the corona virus infection and sudden demand for increased production of HCQ came up. Further there was increased demand of paracetamol also. Various countries were also seeking India's help in procuring the medicines. Mass Metrology Section has provided traceability of weights of E1 and E2 accuracy classes to various pharmaceutical industries such as Zydus, IPCA Laboratory Ltd., Ajanta Pharma, Stride Pharma Science Ltd., Nektar Therapeutics India Pvt. Ltd., Vivimed Life Sciences Pvt. Ltd., Eisai Pharmaceuticals India Pvt. Ltd., etc. those who manufacturer various lifesaving drugs and medicines including HEQ, paracetamol, etc.

NPLI is one of the few NMIs in APMP region those who are part of both intra-RMO and inter-RMO of APMP as well as Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB) CMC review team for volume and viscosity parameters. On behalf of NPLI, Scientist of the section reviewed CMCs of four NMIs i.e. Institute of Metrology of Bosnia and Herzegovina (IMBIH), Bosnia and Herzegovina; Bulgarian Institute of Metrology (BIM), Bulgaria; National Institute of Metrology (NIM), China; and General Directorate of Metrology (DPM), Albania.

A collaborative project with Physikalisch-Technische Bundesanstalt (PTB), Germany (GAP 181232) is going on in the field of metrology to promote quality infrastructure in SAARC region. Accordingly, organization of an Inter-Laboratory Comparisons (ILC) piloted by NPLI on Volume (micropipette - 5 μ l, 100 μ l and 1000 μ l) among SAARC NMIs is under process.

Provided Technical services (TSP 190132) titled "Technical Services for Evaluation of Metrological Characteristics of 32 t (32,000 kg) Weighing Scale" to Micro Precision Products Pvt. Ltd., Palwal, Haryana, as PI/Coordinator. Provided technical services (TSP 200132) titled "Technical services for the preparation of specifications, budget estimate and vetting of specifications of various calibration systems required by DRDO-SASE to be

established at Manali Centre”. Involved in one of the nine activities under this project, i.e. “Snow Precipitation Gauge Calibration System”.

Length, Dimension and Nano-metrology

Dimensional measurements have evolved as indispensable part of numerous industries. This subdivision maintains primary standard of length i.e., iodine stabilized He-Ne laser (wavelength ≈ 633 nm) for realization of SI unit “meter” and maintains the traceability chain for various dimensional parameters across the country and to SAARC NMIs. Through state-of-the-art facilities such as linear displacement measuring laser



Primary standard of length at CSIR-NPL

interferometer, coordinate measuring machine, roundness measuring machine, flatness measuring laser interferometer and gauge block interferometer etc., we provide apex level calibration services in dimensional metrology to cater the growing needs of leading automobile industries, manufacturing industries, academic institutions, defense sectors, various CSIR laboratories, calibration industries, and SAARC NMIs contributing significantly towards socio-economic growth of the nation. Recently we have established a new stylus-based surface texture parameters measuring instrument for surface roughness and contour measurements. This instrument is capable of characterizing the surface of a workpiece for various surface texture parameters such as Ra, Rq, Rz, Rp, Rpmax, Rvmax, Rt, Sm, Sk etc. and contour features with resolution <1 nanometer, benefiting various manufacturing and automobile industries and helping us to increase the total number of our CMCs.

In addition to this, we conduct technical workshops, training programs and provide consultancy services to various industrial segments. We are involved in numerous relevant research and development activities to augment our capabilities in dimensional metrology. Investigations have been conducted towards the application of Monte Carlo simulation

approach for measurement uncertainty evaluation as per JCGM 101:2008 for calibration of portable CMM, He-Ne laser heads, gauge blocks and optical flats etc. Various research articles have been communicated / published based on this work.

We continuously pilot and participate in different international intercomparison in order to establish our equivalence in international system of measurements. Recently we participated in international intercomparison EURAMET.L-K5 for step gauge. We have submitted the final report of APMP.L-S7: the intercomparison we piloted, to TCL chair and WG-MRA for review. We prepared the new document manual of the Sub. Div. as per IS/ISO/IEC 17025: 2017 guidelines, undergone internal audit of Length, dimension and nanometrology, followed by international peer-review for quality system through APMP.

Temperature and Humidity Metrology

The Temperature and Humidity Metrology subdivision provides the Apex level calibrations and traceability to SPRTs, RTDs and various resistance sensors, LIGTs, Thermocouples, pyrometers, blackbodies, thermo-hygrometers, 30 °C to 50 °C dew/frost measurements, moisture measurements and mercury-free (electrical and IR based) clinical thermometers to NABL accredited Labs, SAARC NMIs and the government sectors from -200 °C to 3000 °C and 10 % RH to 95 % RH. In the early phase of Covid-19 pandemic, we have successfully developed the blackbody cavity based IR Forehead Thermometer Testing facility as per IS/ISO 80601-2-56:2017 and rigorously tested to fulfill the requirements of the requirement of this standard for the laboratory accuracy level of ± 0.3 °C. With this facility we have served our Legal Metrology Department for the Model Approval Testing of about 70 IR Clinical thermometer Models imported or developed in India. We have supported about 6 MSMEs, those who started making IR Forehead Clinical thermometers in India, by calibrating their blackbodies used for the development work.

We have also established metrological correlation between Forehead and Wrist site measurements. We are now establishing IR Clinical Thermal Imager/Thermal Scanner Testing Facility at NPLI.



Standardization of several IR blackbody sources used for development of IR clinical thermometers

We are in the process to establish the Acoustic Gas Thermometry facility for realization of Boltzmann Constant based new kelvin. We have standardized the ensemble of 3 TPW cells and 4 cSPRTs, pressure-flow monitoring. On metal-Carbon Eutectic Fixed Point Development for Radiation Thermometry, so far, we have successfully developed Fe-C [1153 °C], Co-C [1324 °C] and Ni-C [1329 °C] eutectic fixed points for Thermocouple thermometry and blackbodies for Radiation Thermometry Applications. We have now successfully established in-house traceability for radiance temperature scale upto 3000 °C. We have initiated few new services on, Humidity Source Mapping, Infant/Baby Incubators, Digital Moisture Meters, Moisture Content Testing in 2020-21.

Optical Radiation Metrology

Candela, which is one of the seven base SI units, for luminous intensity, is the only base SI unit giving a physical base to a physiological phenomenon. This aspect leads to quantification of human perception of light known as Photometry. With the advancement of human race and their scientific knowledge, artificial lighting has become an integral part of our life. With the advancement of the electric lighting technology the interest in the measurement of illumination has increased manifold. Further, with the advent of

directional sources, like LED based lighting, the Photometric measurement has a new dimension.

The section maintains two primary standards, blackbody and cryogenic radiometer, for disseminating optical standards to the nation. The section provides apex measurement traceability for various photometric, radiometric, colorimetric and spectroscopic parameters including, Luminous Intensity, Luminous Flux, Illuminance, Luminance, CCT, Chromaticity Coordinates, Spectral Irradiance, Transmittance, Reflectance, Wavelength etc. Currently, the section is dedicatedly working towards the establishment of a state of the art calibration and testing facility dedicated to LED based lamps and luminaires as per national/ international standards which not only will serve the industrial requirements, support the energy saving initiative of Government of India but also pave the way for apex LED metrology at CSIR-NPL.

Force and Hardness Metrology

The role of Force, Torque and Hardness Metrology is very important to achieve the quality assurance in various engineering sectors of the country such as Infrastructure, Space, Automotive and Aviation, Defense, Energy, Mining, Metallurgy, etc.

Among these, infrastructure sector is very fundamental for production of building materials like cement, steel, aluminum, etc. which are the essential things required by every construction sector for building and developing the desired industrial infrastructure in the country. The Indian cement industry is one of the booming sectors of the Indian economy and the cement industry is the most important primary and basic industry for the economic development of the country, next comes the iron and steel industry. Due to a large demand of cement, many cement manufacturers have come in the country to meet the demand under various names and brands as per the requirement of relevant IS standards. The compressive strength of cement used in buildings are carried out on a 50 mm (2-inch) cement mortar test specimen after 3, 7, 14 and 28 days of casting. Concrete cubes are casted and kept for water curing and then they are subjected to a compressive load (usually from a compression testing machine) until failure in the civil engineering laboratory. These compression testing machines are first verified for their generated forces

against a master (force proving instrument) either duly calibrated by CSIR-NPL or some NABL accredited laboratories to maintain an unbroken chain of measurement traceability across the country for the quality assurance related to the cement produced in the country.

Steel is the next most important material in the world for engineering applications and construction of systems. It has large variety depending on the compositions and alloying elements to fulfil the desired applications. Unlike cement, steels are tested for their tensile strength on a tensile testing machine/universal testing machine which are further traceable to a master load cell (force proving instrument) calibrated as per IS:4169:2014 either by CSIR-NPL or NABL accredited lab. The desired mechanical properties like strength (tensile and compressive) and hardness parameters are controlled by heat treatments. A desired hardness value is also important to resist the wear and tear of the machined components in an assembly during the operational conditions to achieve the optimal life as per the design criteria. We have established, developed and maintaining the force Primary standard of force in the range from 1N to 3000KN to cater to the needs of these industries. We are also maintaining the hardness standards as per different IS/ISO standards in Rockwell, Vickers and Brinell hardness for the Indian industries and disseminating to Indian industries in the form reference hardness blocks to verify the hardness testers which are further testing different engineering products. In the last year we also renovated our laboratory which was long due for a better performance and house keeping.

We at CSIR-NPL have a combined base of around 450 to 500 customers from various sectors including cement and steel sector using our measurement traceability which helps in achieving quality infrastructure in the country to help in the following:

- Meeting requirements of regulatory agencies
- Selecting appropriate materials and treatments for an application
- Evaluating product design or improvement specifications
- Verifying a production process
- To achieve goals of standardization

In the processing of providing traceability to the industries in these sectors, we have not only enabled them to harmonize and maintain their standards.

Pressure, Vacuum & Ultrasonic Metrology

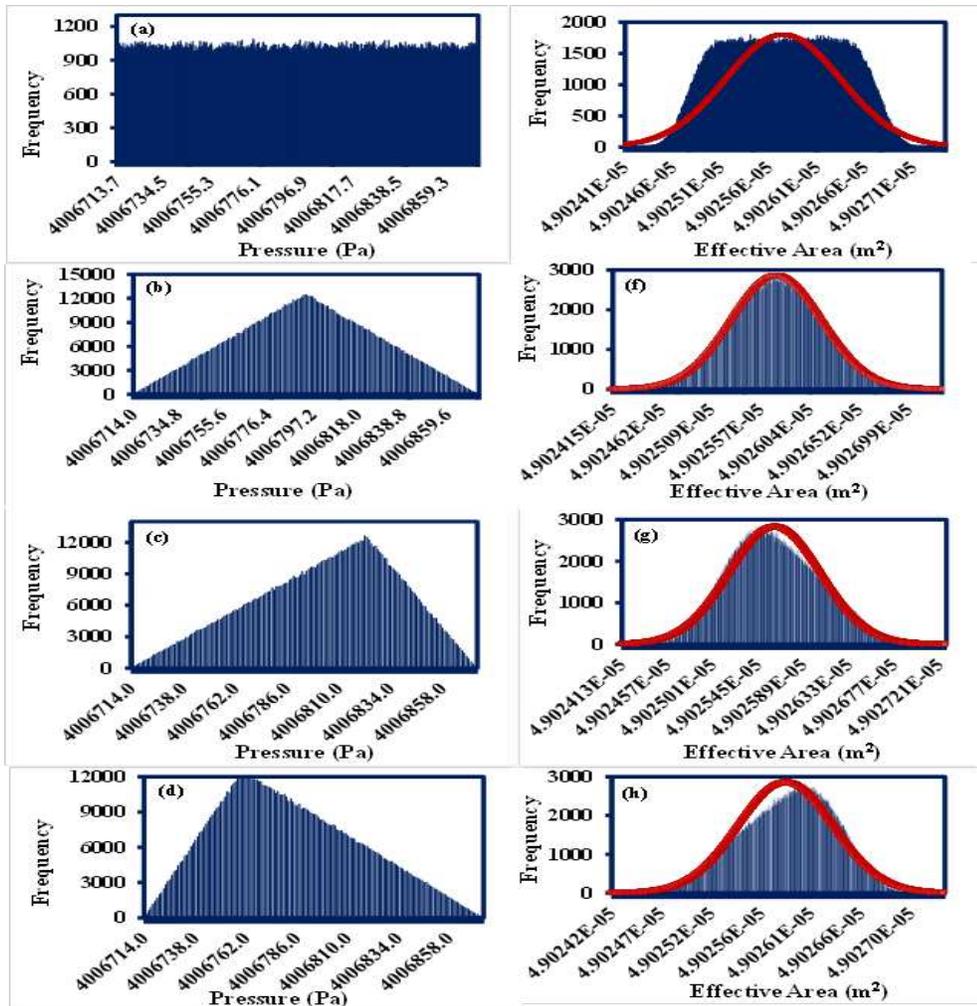
National metrological traceability of parameter 'pressure' is maintained and disseminated by using national primary and secondary pressure standards by the means of calibrations and technical services for the government and private sectors

Two projects are currently under process. Details are given below;

- (i) Fabrication and establishment of pressure calibration system in the range upto 140 MPa. Participating agency is M/s National Council for Cement and Building Materials, Ballabgarh.
- (ii) Design, development, fabrication and establishment of customized indigenous working standards for verification of blood pressure measuring instruments (2 systems). Participating agency is Legal Metrology Department, Department of Consumer Affairs, New Delhi.

- **A Monte Carlo Simulation (MCS) Study on the Effect of the Probability Distribution of Input Quantities on the Effective Area of a Pressure Balance:**

In MCS, the assignment of probability density functions (PDF) of the input quantities is the most significant factor which directly influences the PDF of the output quantities. The assignment of these PDFs needs to be made judiciously depending upon several factors. The effect of variation in PDF of all the input quantities on the PDF of the output effective area was investigated by considering PDFs differing from their assigned PDFs and it was found that the PDF of pressure has the most significant effect on the PDF of the effective area. A change in the output PDF also significantly affects the estimation of uncertainty using MCS as well as the coverage interval obtained. All other input quantities have little or no effect on the PDF of effective area owing to their smaller contribution to the uncertainty of the effective area.



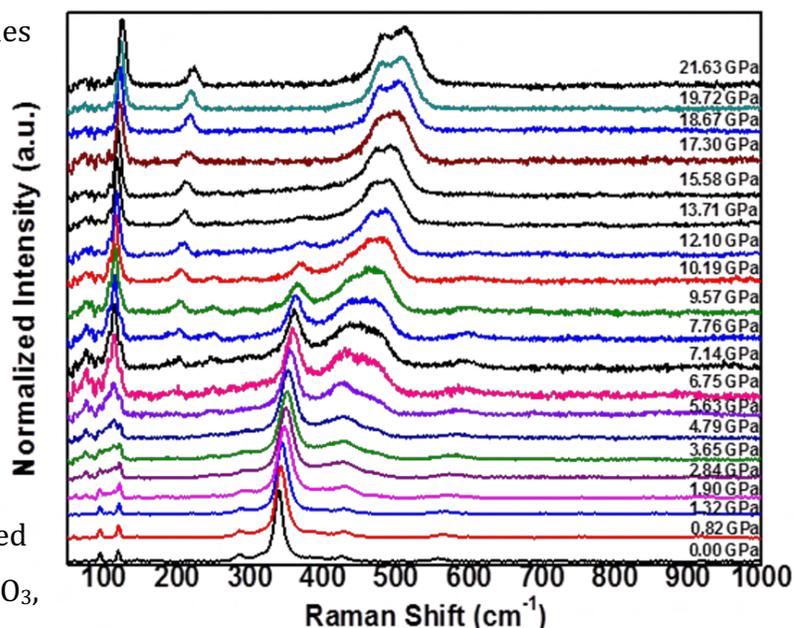
(a-d) Histogram for input pressure using assumed rectangular distribution, symmetric triangular, left and right skewed triangular distribution respectively (e-h) Histogram for output effective area obtained using assumed rectangular distribution, symmetric triangular, left and right skewed triangular distribution of pressure respectively

- **Participation in the APMP TCM Meeting 2020**

Scientists from the Mass, Pressure, Vacuum and Force divisions took active part in the online APMP-Technical committee for mass and related quantities meeting in Nov. 2020 and presented the current status of these activities at CSIR-NPL. Dr. S.S.K. Titus, Head, Force Metrology section was unanimously elected as the next Chairman of the TCM.

- **High Pressure Raman Studies on Eu₂O₃ up to 21.6 GPa:**

Pressure-dependent Raman studies using the Diamond Anvil cell were carried out wherein pressure was increased gradually and was monitored using ruby fluorescence technique which reveal structural phase transitions in strategic materials. Figure shows one such study with the stacked Raman spectra of cubic Eu₂O₃,



depicting the dependence of various phonon modes or

Pressure dependent Raman spectra of the Eu₂O₃ showing cubic to hexagonal phase transition

characteristic peaks on the externally applied pressure. As can be seen from the graph, with an increase in the applied pressure, the predominant cubic phase peaks start broadening and shift to the higher wavenumbers along with a loss in the intensity. Simultaneously, it can be seen that at around 3.65-4.79 GPa of pressure, a hump starts appearing in the spectra around 430 cm⁻¹ almost overlapping the mode at 425 cm⁻¹. At 5.63 GPa, the cubic mode is seemingly replaced by this wide band. Another broad band is seen developing around 470 cm⁻¹ at 4.79 GPa. Both newly developed features further grow in intensity with pressure. Concurrently, the intensity of the peaks corresponding to the cubic phase also decreases. At the highest studied pressure where transitions get completed, we observed four clearly distinguishable peaks. These peaks belong to the Hexagonal phase of the material. In addition, temperature dependent studies on the evolution of these phonon modes were also investigated in the temperature range 80-440K.

Acoustic and Vibration Metrology

The Acoustics and Vibration parameter of CSIR-NPL, since its inception, has played a key role in the industrial growth. In accordance with the well-laid out objectives of CSIR-NPL to strengthen and to carry out advanced physics-oriented research, the acoustic and vibration parameter has immensely contributed to reducing the air and noise pollution in the country. The major activities involved are calibration of acoustical instruments, evaluation of industrial products, acoustical materials, performance characteristics of audio equipment, auditorium acoustics and noise and vibration measurements, and control. The calibration and other facilities available in CSIR-NPL in the area of Acoustics and Vibration are comparable with facilities in other countries. It is equipped with advanced instrumentation for measurement of sound and vibration and calibration of electro-acoustic equipment such as Sound Level Analyzer, Vibration Analyzer, Sound Intensity Probe and Impedance Tube system, specialized Reverberation and Anechoic Chambers for carrying out sound insulation and absorption studies of materials and diagnosing machinery noise. CSIR-NPL had been able to provide apex level calibration and testing services and technical advisory consultancy in architectural acoustics to the industries and institutions of the country. The major areas of focus had been:

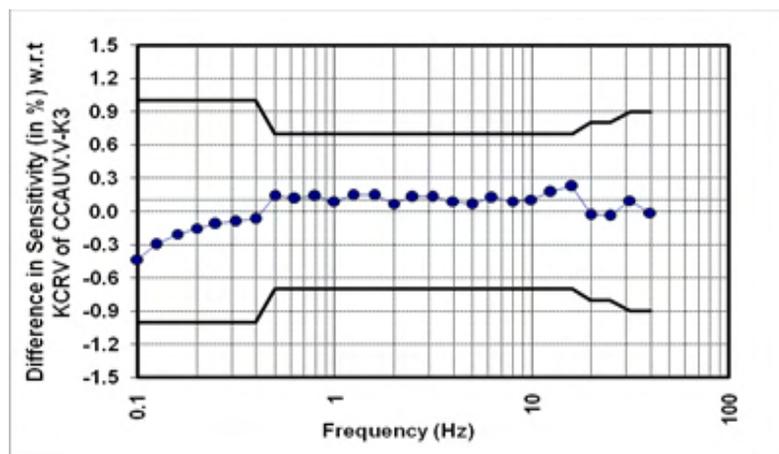
- a) Maintenance of primary standards of sound pressure and vibration amplitude,
- b) Calibration and testing of electro-acoustical equipment,
- c) Noise and vibration measurements and control,
- d) Acoustics materials characteristics measurement for building industries,
- e) Technical advisory consultancy in building acoustics,
- f) Noise barrier design and development for highway, railway, metro, etc.,
- g) Environmental noise measurement and control,
- h) Formulation of Standards for noise and vibration control.

The section has been involved in reducing the measurement uncertainty in primary sound standard and the dimensional characterization of the front cavity volume and precise

determination of other microphone parameters of the reference standard microphones. Efforts have been targeted for the up-gradation of the primary sound standard in frequency range of 1 Hz to 25 kHz with a measurement uncertainty ranging from ± 0.05 to 0.15 dB. The section was also involved in up-gradation of primary vibration calibration standard in frequency range from 0.1 Hz to 20 kHz using a long-stroke shaker and low frequency shaker. The multi-point laser positioning approach is followed for the precise determination of the sensitivity of the transducer in the frequency range of 5 Hz to 20 kHz. The Document Manual of the section as per guidelines of new Quality Manual based on IS/ISO/IEC 17025: 2017 was prepared. The section participated in International Key Comparison for Sound Level Meter (APMP MEDEA Project with NMI Japan as pilot laboratory and six participating laboratories) in March, 2021. The section has also focused on reducing the measurement uncertainty in sound transmission loss and sound absorption testing and provided consultancy to some private building manufacturers for developing better acoustical products. The section has also worked in collaboration with M/s West Bengal Electronics Corporation Ltd., Kolkata for the development and validation of indigenous Noise Monitoring Terminals (NMT). The scientific staff working in the acoustics and vibration standards has been involved in various committees set up by Central Pollution Control Board, Delhi Pollution Control Committee etc. for noise pollution monitoring and control in metropolitan city.

- **Successfully Participated in APMP.AUV.V-K3.1 Key Comparison in Frequency Range of 0.1 Hz to 40 Hz:**

The final report of International Key Comparison Exercise, APMP.AUV.V-K3.1 with Center for Measurement Standards, ITRI, Taiwan as pilot Laboratory in March, 2021 has validated CSIR-NPL CMCs in range 0.1 Hz to 40 Hz. Final report published in June, 2020 shows the linkage of



Difference in CSIR-NPL results (in % for sensitivity measurements) w.r.t Key Comparison Reference value (KCRV) of CCAUV.V-K3 comparison

KCRV with CCAUV.V-K3 Key comparison results. The final report shows that CSIR-NPL successfully qualified the Key Comparison. The successful participation has resulted in increase of 2 CMCs in Key Comparison Data Base (Collaborative work).

Fluid Flow Metrology

The Fluid Flow Metrology section has mandate to establish, maintain and upgrade standards of Fluid Flow measurements and provide apex level testing and calibration services of various types of water and gas flowmeters to various users across the country. The section operates and maintains 3 standards namely, Primary Water Flow Calibration Facility upto 650 m³/h, Gas Flow Calibration Facility upto 1200 L/min, and Primary Water Meter Testing Facility upto 38 m³/h. The primary Water Flow Calibration Facility is used to provide calibration of various types of water flowmeters such as Coriolis mass, magnetic, turbine, ultrasonic, differential pressure, vortex, bulk water meter, infusion pumps, dialysis meters, infusion device analyzers, etc. upto DN250 size. The Primary Water Meter Testing Facility is used to test domestic water meters upto DN50 sizes and calibrate rotameters upto DN50 size. The water meters (bulk type) above DN50 size is performed in Primary Water Flow Calibration Facility. The Gas Flow Calibration Facility is used to calibrate various types of gas flowmeters such as mass flow controllers, mass flow meters, laminar flow meters, sonic nozzles, volume samplers, orifice flowmeters, piston flow calibrators, air flow calibrators, dry gas meters, root meters, ventilator testers, gas flow analyzers, etc. The various users of our testing and calibration facilities are Oil Companies, State Water Boards, Central Pollution Control Boards, Biomedical Laboratories, Domestic Gas Meter Manufacturers, NABL accredited laboratories, R&D laboratories, pollution monitoring instrument manufacturers, Sugar industries, etc. The section has also participated in APMP Supplementary Comparison (APMP.M.FF-S3.2020) of water flow using Coriolis mass flowmeter of DN20 size, make Emerson as artifact during March-April 2021 to establish the degree of equivalence of our primary water flow calibration facility and to support the CMC claims of water flow. Total 7 NMIs, namely, NIMT, Thailand; NMIA, Australia; NMII, Japan; NMC A*Star, Singapore; CSIR-NPL (NPLI), India; ITDI, Philippines and EMI, United Arab Emirates (UAE) are participating in this intercomparison and NIMT, Thailand is Pilot Laboratory. The measurement results have been sent to pilot laboratory.

Electrical and Electronics Metrology:

Division 2

The mandate of Electrical and Electronics Metrology Division is to establish, maintain, disseminate and continuously upgrade the National standards of electrical and electronic parameters. These include DC parameters such as voltage, current and resistance; low frequency and high frequency impedance related quantities such as capacitance, inductance and AC resistance; DC high voltage; and AC high voltage & current; AC power & energy; and quantum which includes quantum hall resistance (QHR), quantum current (QC) and quantum nanophotonics (QN). The major activities are based on the research and indigenous development of quantum standards of electrical and electronic parameters such as QHR, QC and QN. The traceability of above said parameters are based on Josephson Voltage Standard (JVS), QHR standard and frequency (time). The measurements are disseminated through an unbroken chain of calibrations at par with other leading NMI's to the industries, strategic sectors, regional calibration and testing laboratories and support the robust quality infrastructure required for various ongoing government vision/missions such as AtmaNirbhar Bharat, Make-in-India and Vocal-for-local. The division is continuously putting major efforts to upgrade existing facilities to cater the demand and needs of the country. This division also participate in to established international degree of equivalence in measurement through international inter comparisons. Along with these, research efforts on the development of quantum standards like single photon detection, quantum current standard, graphene and topological insulators-based quantum Hall resistance are a constant endeavour and continue to be at the forefront. Glimpses of activities of each subdivision have been described below.

LF, HF Impedance and DC Metrology

As per the new definition of the SI units, the ampere, the base unit of electrical metrology has to be defined in terms of the electron charge 'e'. Broadly, there are two methods by which counting of electrons can be accomplished and thereby define a quantum current

standard (QCS). Single electron tunneling (SET) deals with direct pumping of electrons in quantum dot (QD) structures with respect to a reference frequency ($I=ef$). Quantum phase slip (QPS) process, relates to the continuous quantum phase fluctuation in 1D superconducting nanowire structures. A QPS junction (dual to the Josephson junction), in presence of a reference frequency produces constant current plateaus ($I=2ef$), which can be considered as the measurement of current. With this mandate we pursue fundamental research on quantum transport and quantum phase slip (QPS) in low dimensional superconductors in order to establish QCS at CSIR-NPL. Inclined to this objective, we have developed protocols to fabricate superconducting materials and composites suitable for QPS study. The main achievements are (i) introduction of magnetic doping to superconducting films for the initiation of phase slips and the material in this case is NbGd, (ii) fabrication of low dimensional structures like nanowires, meander lines etc. for the exploration of QPS, (iii) establishment of a new substrate mediated nitridation technique by using nitride-based substrate to produce superconducting transition metal nitrides such as ultrathin films of TiN, Nb₂N, NbTiN etc. (iv) demonstration of superconductivity in ultrathin films of Nb₂N which shows promises in the phase slip study, (iv) growth of disordered ultrathin (~ 5 nm) TiN films with reasonably high critical transition temperature (T_C).

- **Maintenance, Upgradation and Dissemination of DC Electric Quantities and Impedance Parameters**

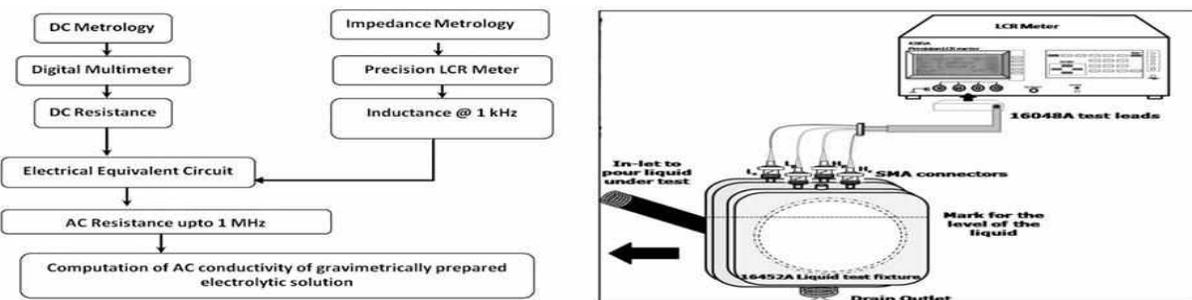
The mandate of the division also includes activities related to the maintenance, constant upgradation and dissemination of dc electric quantities such as voltage (10 μ V-1000 V), current (1 μ A -20 A) and resistance (0.1 $\mu\Omega$ to 1 G Ω), and impedance related parameters such as capacitance (10 pF -1 mF @ 1 kHz), inductance (10 μ H to 10 H@1 kHz) and AC resistance (1 Ω to 1 M Ω @ 1 kHz). The division also maintains DC high voltage standards upto 100 kV, which caters for power grid, power transmission and allied industries. The above-mentioned parameters are recognised internationally through 37 CMCs listed on BIPM web site.

We have developed recently a new process protocol for the fabrication of transition metal nitride based superconducting materials those are suitable for the study of QPS and other

interesting quantum physics related phenomena. Here, it should be noted that one of the most important and crucial requirements for QPS study is to have truly one-dimensional superconducting nanowire and for that the initial superconducting film, from which the nanowires are going to be fabricated, should be of thickness of the order or less than the coherence length (ξ). Further, for QPS study, disordered superconductors are must and in our new nitridation technique, the superconducting nitride film is inherently disordered by the presence of other non-superconducting by-product material. In summary, we have developed a new substrate mediated nitridation technique by using nitride-based substrate to produce superconducting transition metal nitrides such as ultrathin films of TiN, Nb₂N, NbTiN etc. We have demonstrated superconductivity for the first time in ultrathin films of Nb₂N which shows promises in the phase slip study. We have been able to fabricate disordered ultrathin (~ 5 nm) superconducting TiN films with reasonably high critical transition temperature (T_C) as the future phase slip material.

- **Establishment of Metrological Traceability of Electrolytic Conductivity of KCl Solutions with 0.01 Molality.**

The metrological traceability for electrolytic conductivity of reference liquid solutions is established through ac method. A precision LCR meter is used to measure the AC resistance of electrolytic solution (gravimetrically prepared) using a two-electrode system. The measurement of ac resistance is performed at frequencies above 10 kHz to minimize the impact of electrode polarization. Thereafter, electrolytic conductivity of the liquid samples is computed using cell constant and AC resistance. Metrological traceability chart and measurement setup for the ac conductivity of electrolytic solution as shown in Fig. (a) and Fig. (b) respectively.



(a) Metrological traceability chart (b) Measurement setup for electrolytic conductivity

The measurement results of KCl electrolytic solution of 0.01 M are shown in Table 1. The measurement results are shown for the frequency 100 kHz. While the ac conductivity of electrolytic solution of KCl is shown in Table 2. Computed results are in close agreement with reference values.

Table 1: Measured AC resistance of electrolytic sample solutions at 100 kHz

Sample No.	Measurement of AC Resistance, Ω at 100 kHz					Average (Ω)	Standard Deviation (Ω)
1	12.38	12.84	12.43	12.67	12.61	12.59	0.08
2	13.16	12.41	12.55	12.63	12.66	12.68	0.13
3	12.85	12.39	12.42	12.67	12.61	12.59	0.09

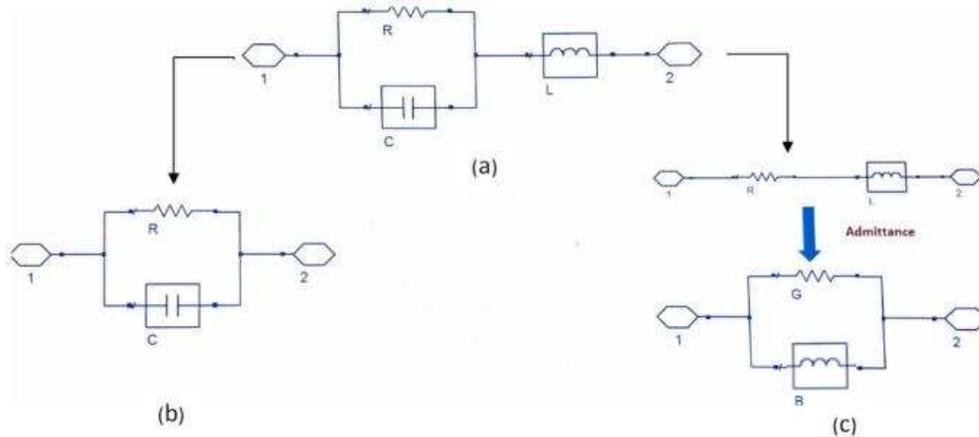
Table 2: Computed conductivity of electrolytic solutions at 100 kHz

Sl. No. of Sample	Conductivity, $\mu\text{S}/\text{cm}$	u_e , $\mu\text{S}/\text{cm}$
1	1401.13	10.00
2	1390.55	15.00
3	1400.97	10.00

This will help the reference material laboratories to produce the reference electrolytic materials of KCl solutions of different molality in India under the CIPM-MRA agreement which will open the international market for the Indian Reference Materials Producers.

- **Establishment of Calibration Facility for AC Resistance Standards upto 1 MHz**

The metrological traceability of AC resistance is established from audio frequencies to MHz band using electrical equivalent circuit. Electrical equivalent circuit consists of resistance and its parasitic components in the form of either capacitance or inductance or both depending upon the construction of the resistance standard. The uncertainty in measurement of AC resistance is also computed using uncertainty propagation method. After assigning the value of ac resistance upto 1 MHz, a precision LCR meter will be calibrated for ac resistance which will be used to calibrate the entire range of ac resistance.

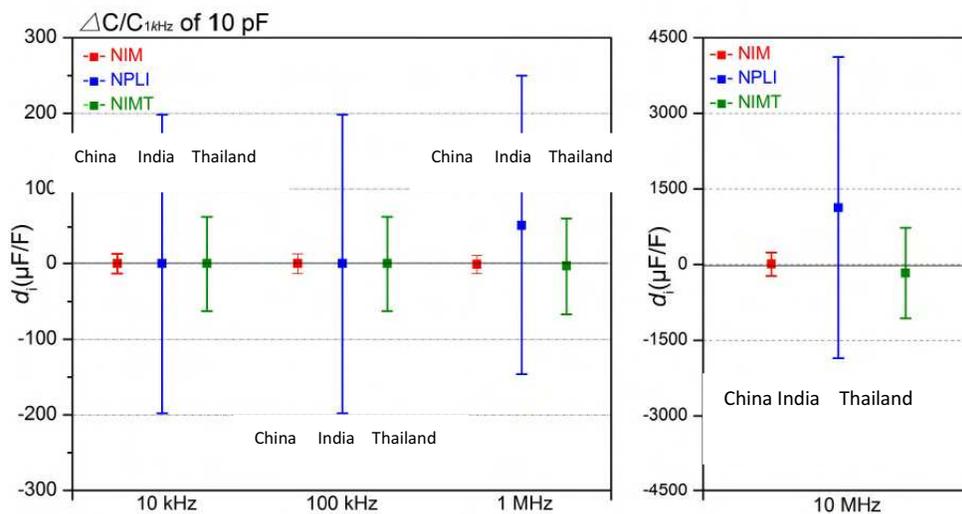


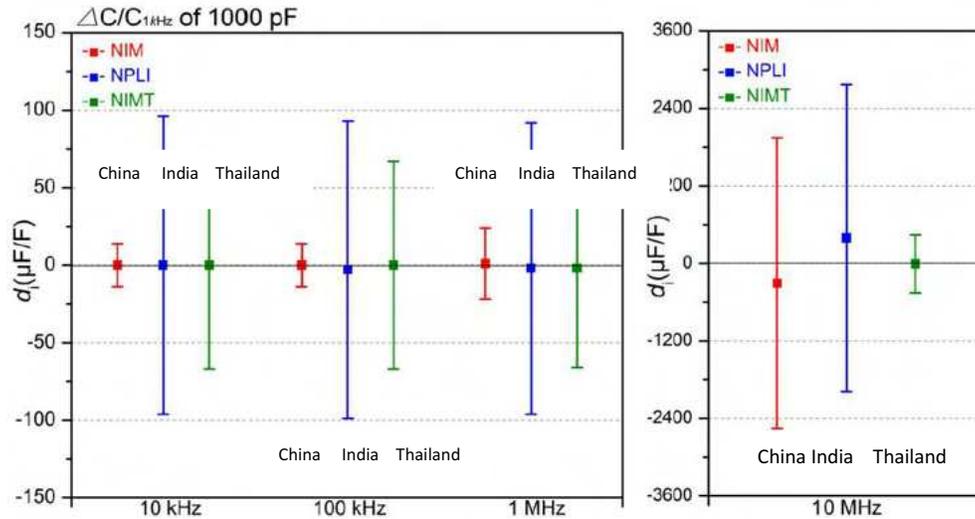
(a). Electrical equivalent circuit for AC resistance where 1 and 2 are the termination ports. (b) Circuit for high value resistance standard reduces to parallel combination of resistance and parasitic capacitance. (c) Circuit for low value of resistance standard reduces into the parallel combination of conductance and susceptance

- International Inter-comparison (APMP.EM-S15)**

International inter-comparison (APMP.EM-S15) is successfully completed and calibration and measurement capability (CMC) will be added in the coming peer review of the LF, HF Impedance and DC Metrology.

Participating NMIs: CSIR-NPL (NPLI), NIM China (NIM) and NIM Thailand (NIMT)





Degree of equivalence for high frequency capacitance standards 10 pF and 1000 pF from 10 kHz to 10 MHz

- **vdP Standard for Sheet Resistance and Sheet Charge Carrier Concentration**

The metrological traceability of the vdP standard is established from the magnetic metrology and in-house DC metrology standards. The facility can be used for testing the semiconductor thin films to estimate bulk/sheet carrier concentration, carrier mobility and resistivity at room temperature. The uncertainty in the measurement mainly arises due to the uncertainty in the permanent magnet's field, the uncertainty in the applied DC current and the user error. For the preliminary study, commercially procured ITO thin film (on glass substrate) has been used as the test sample. The sheet resistance and sheet carrier density were found to be $1.7010 \times 10^1 \pm 0.0002 \text{ } \Omega/\text{sq}$ ($k=1$) and $8.30 \times 10^{15} \pm 2.17 \times 10^{13}$ ($k=1$) cm^{-2} , respectively. In future, test samples based on III-V semiconductors will be used to map the bulk charge concentration from 5×10^{14} to $5 \times 10^{19} \text{ cm}^{-3}$ and this could be used as reference material in the semiconductor industry and related research.

AC High Voltage and Current Metrology

This subdivision is maintaining the National Standards of AC High Voltage Ratio upto 100kV, High Voltage Capacitance & Tan δ facility upto 200 kV and AC High Current Ratio upto 5 kA. It is providing Apex Level Calibration Services for Current Transformers, Current Transformer Test Sets, AC High Current Sources, Clamp Meters, Current Probes, CT Burdens, Voltage Transformers, Voltage Transformers Test Sets, HV Probes, HV Break Down Test Sets,



Calibration set-up for 200kV divider

Voltage Transformer Burdens, AC High Voltage Sources, HV Dividers, kV Meters, Capacitance & Tan δ Bridges, etc. to Power Utilities, Electrical Equipment Manufacturers and Electrical Testing and Calibration Laboratories.

The subdivision is planning to enhance calibration facility of AC HV ratio upto $220\text{kV}/\sqrt{3}$ and for HV Capacitors, kV meters upto 300 kV to meet the requirements from power utilities, electrical equipment manufacturers, testing & calibration laboratories. This section also working on insulating materials using Nanofluids/Nanomaterials for HV applications. Condition assessment of transformer insulation plays a major role to keep the electrical system healthy and reliable. In recent years, the nanosolid and nanofluid, the mixture of nanomaterial with solid insulation and nanomaterial with liquid insulating oil respectively, used as an alternative insulation with enhanced dielectric strength and permittivity with reduced loss characteristics. Hence, based on the above need for the development of dielectrics and electrical insulation, an R & D activity has been initiated which involves the investigation of electrical properties like AC BDV test, loss tangent, dielectric permittivity tests, etc. to be conducted with high dielectric Nanofluids/

Nanomaterials for the condition assessment studies for HV application, according to IEC, ASTM, IEEE & BIS standards.

AC Power & Energy Metrology

The group is engaged in the maintenance and upgradation of primary standards and to disseminate apex level of measurement traceability for power and energy parameter to those who needs the best accurate and reliable measurement as per world leading NMIs. The primary and reference power/energy standards with measurement uncertainty from 10 ppm to 150 ppm are being used to maintain traceability chain throughout the nation.



Testing of smart energy meter

As it is primary concern to fulfill industrial requirements, the laboratory provide testing services on all types of energy meters as per international/ national standards such as IEC: 62053-21, IEC: 62053-22, IS: 13779, IS 16444(2015), IS-14697, IS: 13010 and CBIP-88.

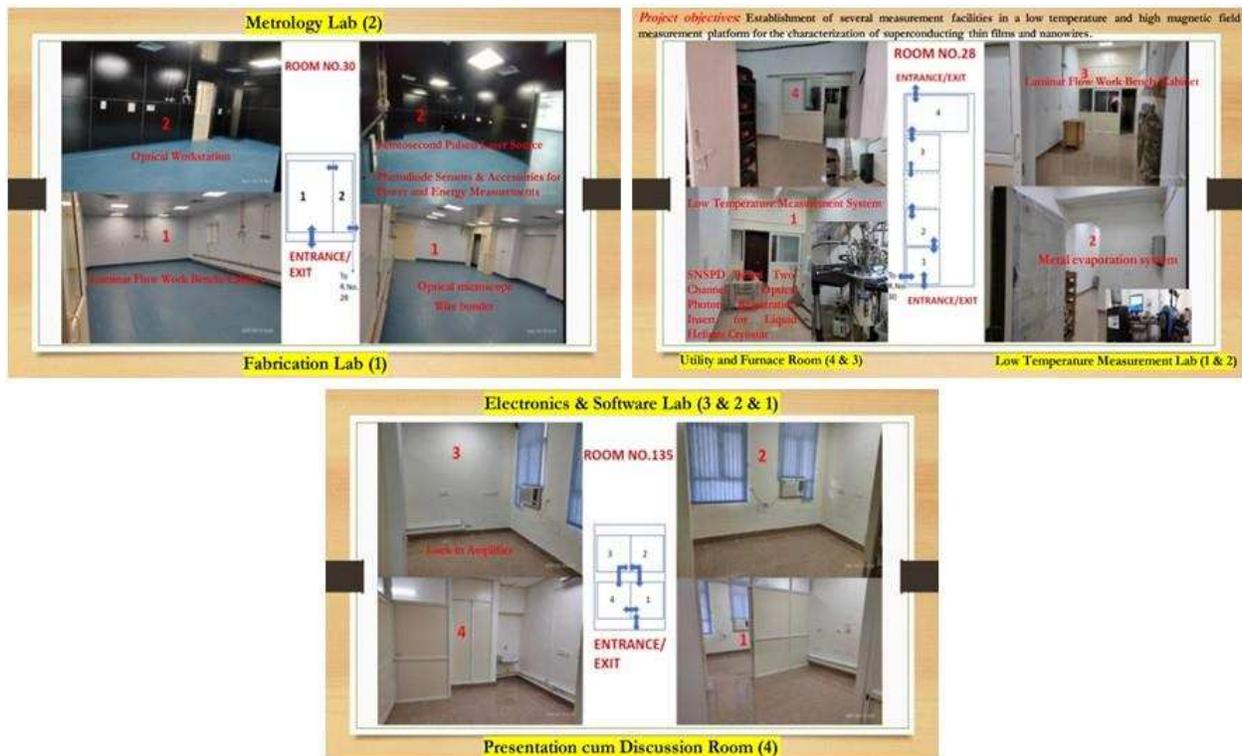


Advanced grid infrastructure for energy solution

This group also initiated the process of establishing apex level for measurement facilities for Smart Metering as per IEC/IS/CBIP specifications for the growing demands of Smart Grid.

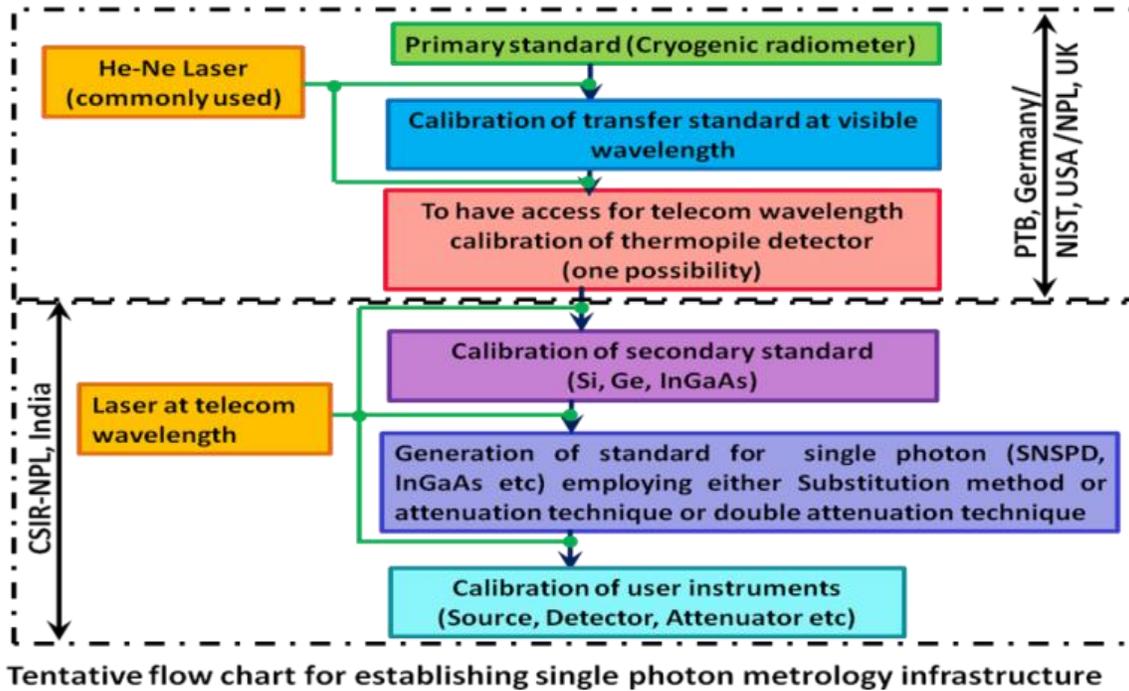
Quantum Nanophotonics Metrology

Quantum Nanophotonics Metrology section is working on following two ongoing projects with an initiative to undertake research activity in the area of single photon detection using quantum optical techniques, which has enormous scope for realizing quantum information processing systems. The outcome of the activity would provide the ground to (1) manufacture single photon detectors indigenously and (2) establish the standards for single photon detection, which would provide the calibration facility for quantum optical applications. The following labs (Fig.) were established with the partial or full facilities for divisional activities of Fabrication, Measurements, System Integration and Metrology infrastructure.



Facility creation and lab renovation to establish (a) Quantum Metrology infrastructure and fabrication lab (b) Low temperature measurement lab (c) Electronics and software lab.

Deposition and measurements on ultra-thin superconducting films such as NbN, NbTiN, VN & YBCO was initiated in order to find its suitability for its use as SNSPD devices. Also, tentative plan for establishing Metrology Infrastructure (Fig.) was worked out along with detailed study of the status of calibration services at international level.



Tentative flow chart for establishing metrology infrastructure

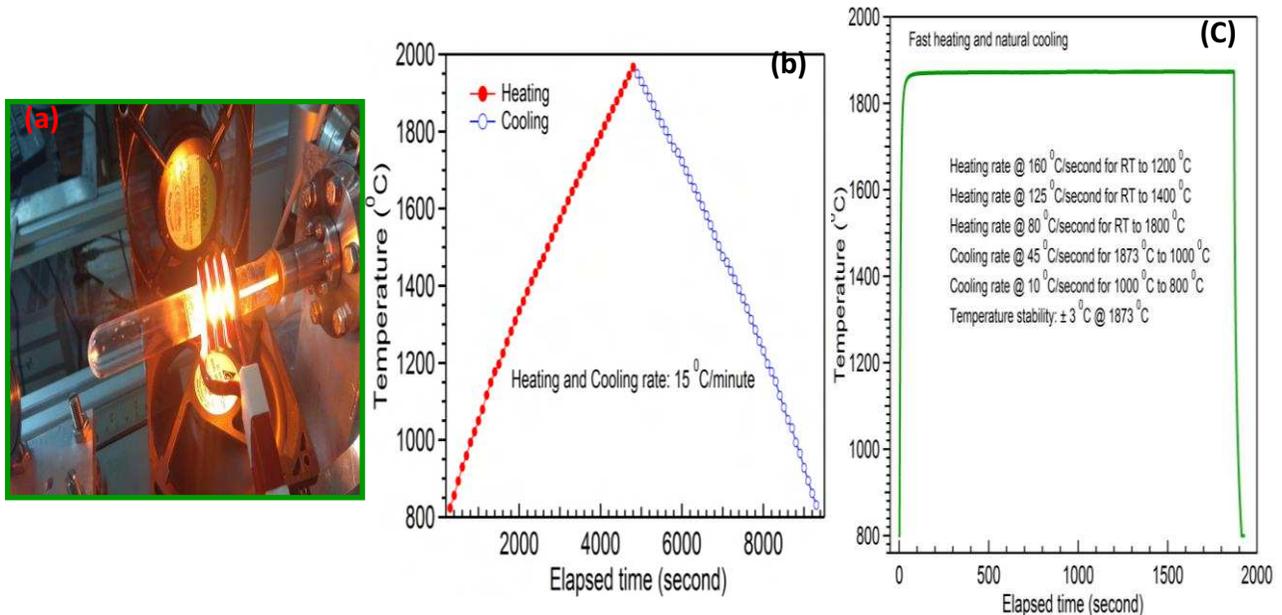
Research (initiated in 2015) carried out on Studies of interface for ferrromagnet/organic semiconductor heterostructures. The research was planned to focus on the investigation of the proximity effect between 3D metals and various molecular layers.

Quantum Hall Resistance Metrology

Quantum Hall Resistance metrology sub-division at CSIR-NPL maintains the national standards for the resistance measurements and calibration. The theory is based on the well established phenomena of quantized two-dimensional electron gas observed at the GaAs/AlGaAs hetero-interface at low temperatures and in the intermediate to high magnetic field regime. The group also carries out R&D activities looking for alternatives to the GaAs/AlGaAs which includes Graphene, magnetic doped topological insulators and oxide heterostructures. These experiments are well supported by computational studies

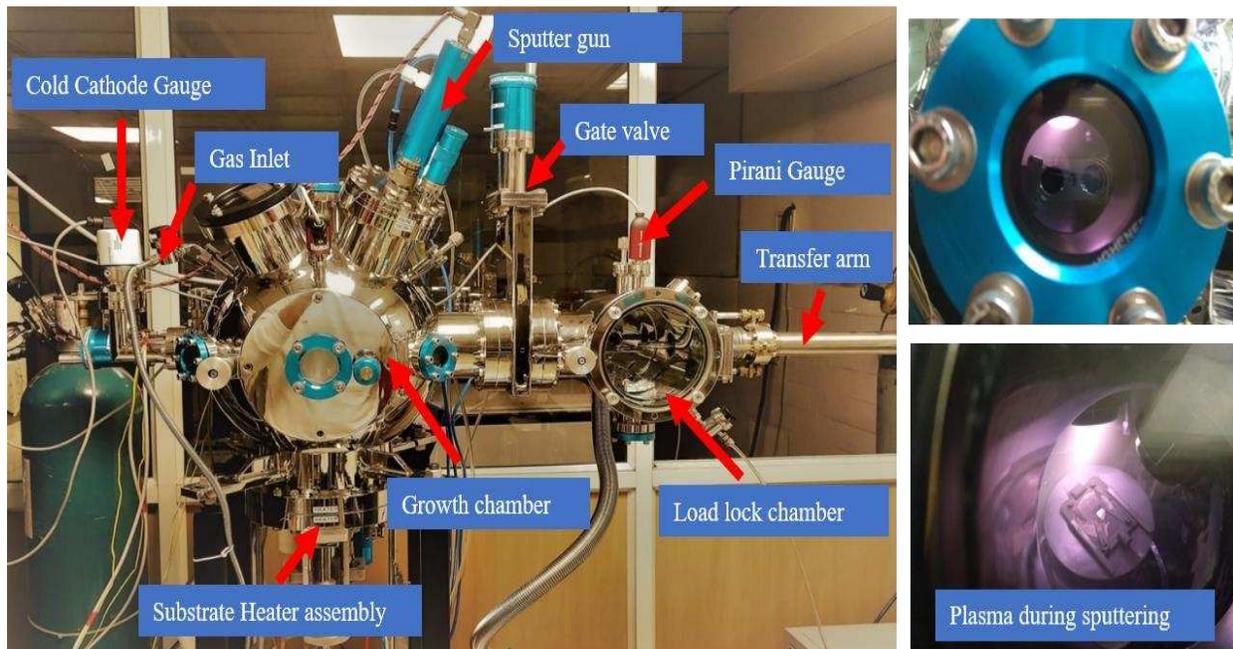
using the density functional theory. The aforementioned systems such as epitaxial graphene and oxide heterostructures are well known for the realization of Quantum Hall Effect. R&D activities also include realization of quantum anomalous Hall effect (QAHE) in magnetic doped topological insulators thin films and other hetero-structures, using state-of-art growth and characterization techniques.

Growth temperature close to 2000 0C has been achieved in the indigenously designed and developed Graphene Epitaxy (GrapE) system meant for the growth of epitaxial graphene on SiC for Quantum Metrology applications. Achieving such high growth temperature in various operating environments (high vacuum to atmospheric pressure) became possible only after several novel design modifications of original GrapE system. Beside epitaxial grphahene growth, GrapE has potential to be used as a low/high pressure chemical vapor deposition system, high temperature high vacuum induction furnace and rapid thermal annealing system.



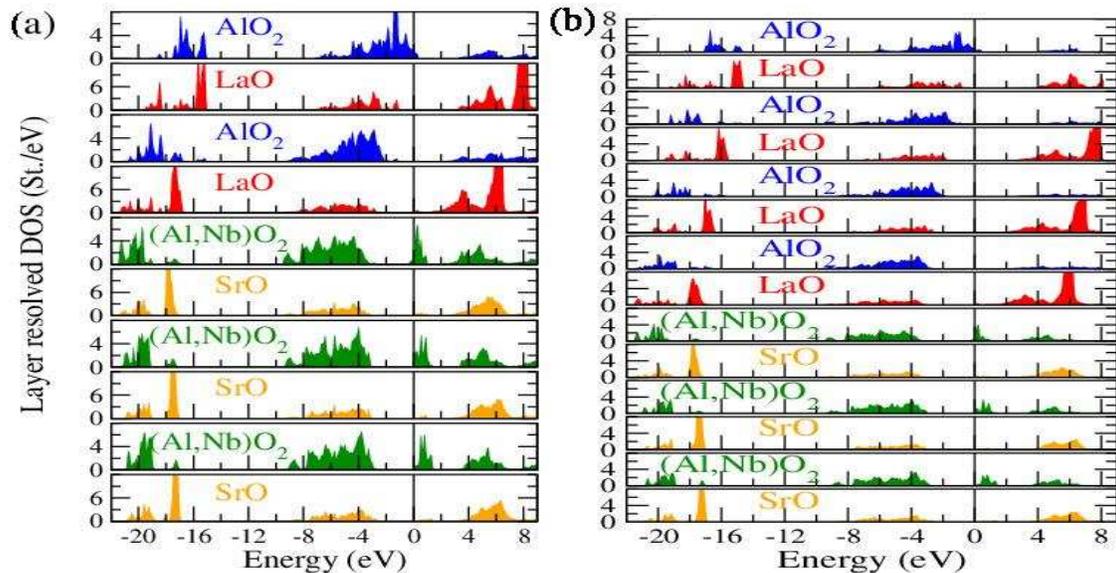
(a) GrapE system operating at ~2000 0C. (b) Heating and cooling rates calibration of GrapE exhibiting identical heating and cooling rates due to excellent temperature control in the system. (c) Fast heating and natural cooling of GrapE exhibiting range of heating and cooling rates at various temperature regimes and demonstrating its potential to be used as a rapid thermal annealing system on par with commercial systems

Mostly magnetic doped topological insulator thin films and hetero-structures have been grown using molecular beam epitaxy and thereby limiting their use at device integration level. For QHRS based on magnetic topological insulator, the multi-source magnetron sputtering facility has been created as shown in figure below. This system consists a high vacuum chamber (base pressure: $\leq 2 \times 10^{-7}$ mbar) along with load lock chamber, configured in sputter down confocal configuration. The magnetron sputtering system is equipped with several components such as in-situ thickness monitor, sputtering guns, substrate heater (RT-900 °C) and mass flow controller. This system is compatible for reactive and sequential co-sputtering deposition on various substrates with film thickness uniformity of $\pm 5\%$ from edge to edge. The deposited Bi₂Se₃ films revealed the c-axis oriented film on sapphire (0001) and Si (100) substrates after post-selenization process of sputtered films. This confirmed the capability of magnetron sputtering system to deposit high-quality stoichiometric Bi₂Se₃ thin films for further magneto-transport studies and their applications towards QAHE devices.



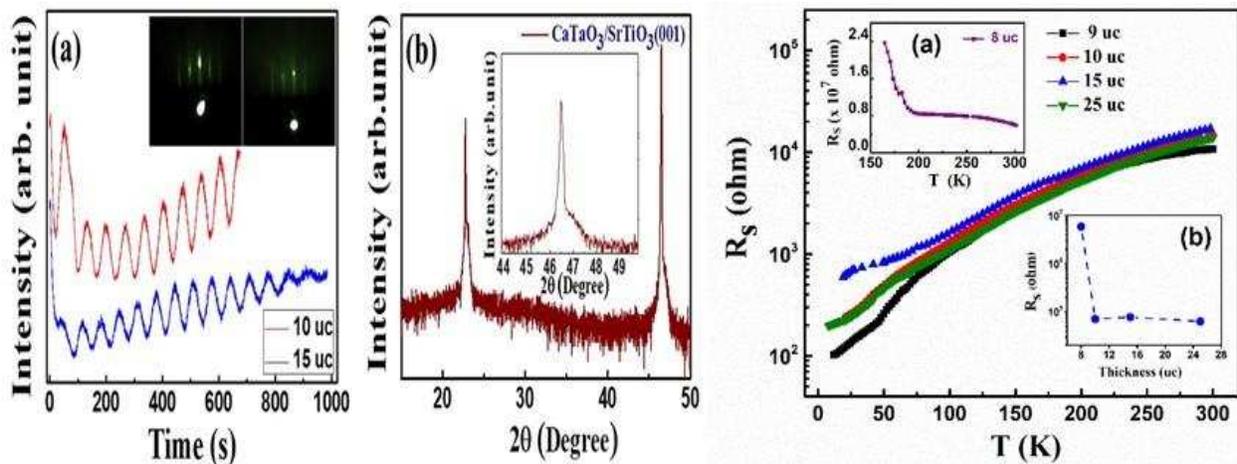
Magnetron sputtering system for topological insulator thin films

In the theoretical and computational frontier of materials research in CSIR-NPL, density functional theory-based methods are used to study the structural, electronic, transport and magnetic properties of bulk and low dimensional systems. While open source softwares are encouraged and used extensively (such as quantum espresso, SPRKKR, LMTO47, etc), CSIR-NPL also have license to use proprietary electronic structure codes such as WIEN2K and VASP. Most of the theoretical/ computational works are done in collaboration with experiments. In this field, two novel oxide heterostructure systems that can exhibit quasi 2D electron gas (q-2DEG) at the interface has been identified from all-electron full potential electronic structure calculations. They are $\text{Sr}_2\text{AlNbO}_6$ and CaTa_2O_6 films on (001) TiO_2 terminated SrTiO_3 substrates. The hetero-interface conductivity of the latter system, i.e., $\text{CaTa}_2\text{O}_6 / \text{SrTiO}_3$ has been recently confirmed from the experiments. However, a constraint to the desired carrier concentration and mobility is largely restricted due to the less dispersive Ti 3d orbitals of the SrTiO_3 substrate. To overcome this limitation, an alternative substrate, namely the double perovskite (001) $\text{Sr}_2\text{AlNbO}_6$ was modelled. Following first principles calculations a quasi-2D electron gas is evidence at the interface of $\text{LaAlO}_3/\text{Sr}_2\text{AlNbO}_6$ heterostructures. The carriers are primarily Nb 4dxy in nature and that the width of the q-2DEG being confined within three LaAlO_3 unit-cell thickness. The dispersion of the Nb 4dxy conduction band, evidences to a high carrier mobility interface and hence significant to electronics applications based on q-2DEG.



The layer projected partial density of states of (a) 2 monolayer (ML) LaAlO_3 and (b) 4 ML LaAlO_3 on $\text{Sr}_2\text{AlNbO}_6$ substrates

Quasi-2D oxide system represents several additional phenomena associated with strong electron correlations, spin-orbit coupling, magnetism and 2D superconductivity thereby being applicable as multi-functional devices. In order to have a better insight to the underlying mechanism of q-2DEG, there is a need to explore newer oxide heterostructures. We explore the propensity of conducting hetero-interface between $\text{Ca}_{0.5}\text{TaO}_3$ at TiO_2 terminated SrTiO_3 . The epitaxial thin films of non-stoichiometric $\text{Ca}_x\text{Ta}_y\text{O}_{3+\delta}$ in cubic phase are successfully deposited on TiO_2 terminated SrTiO_3 through PLD technique. The electric transport measurements at heterointerface with thin films of thickness ≥ 9 uc reveal the q-2DEG type charge transport with carrier concentration $\approx 10^{13} \text{ cm}^{-2}$ and the carrier mobility (μH) from $\approx 4\text{-}7 \text{ cm}^2/\text{Vs}$ at room temperature to $\approx 102 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$ at 50K, in similar range reported for polar perovskite-based q-2DEG systems. The non-stoichiometry of $\text{Ca}_x\text{Ta}_y\text{O}_{3+\delta}$ epitaxial thin films, obtained from Rutherford backscattering measurements, makes the origin mechanism quite complex with active role of lattice structure and disorder. Notably, a nearly thickness independent transport characteristic pushes it towards an ideal q-2DEG behaviour for practical utilization in oxide electronics applications.



(Left) (a) RHEED intensity oscillation during growth with streaky RHEED pattern of bare substrate (left) and thin film (right) in the inset. (b) XRD θ - 2θ scan for 30 uc epitaxial thin films. (Right) Sheet resistance (R_s) for $\text{Ca}_{0.9}\text{Ta}_{1.1}\text{O}_{3+\delta}/\text{SrTiO}_3(001)$ heterostructure for 9-25 uc thick films. The insets show the sheet resistance as a function of temperature, $R_s(T)$ for 8 uc thick film (a) and as a function of film thickness at room temperature (b)

Environmental Sciences and Biomedical Metrology: *Division 3*

The Environment Sciences & Biomedical Metrology Division (ESBMD) of CSIR-NPL has been fostering quality measurements in the domain of atmospheric pollution, biomedical metrology and sensor devices metrology under its mission project through working with different stakeholders. The division has four specialized subdivisions namely the Atmospheric Sciences and Metrology, Gas Metrology, Biomedical Metrology, and Sensor Devices & Metrology. Each of these subdivisions is working on the issues of national importance related to the field of environment, gas standards and sensor development and biomedical. A brief detail of the activities of each subdivision is described below.

Atmospheric Sciences and Metrology

In the field of environmental monitoring, data quality has posed a major challenge as the reliability of such measurements needs to be ascertained. The role of instruments and calibration are the major issues that need to be addressed. While most of the instruments which are used are usually imported, comes with certifications from agencies like USEPA, TUV, and MCERT etc. These certificates are issued based on the environmental conditions of the certificate issuing country, which are very different from the environmental conditions prevalent in India. This affects the quality of measurements by the instrument operation in the long run in Indian conditions. Therefore, the certification process needs to be updated at regular intervals. However, at present no certification system is available in India for environmental monitoring equipment. The traceability of measurement is also an integral part of the generation of reliable data. In December 2018, the Ministry of Environment, Forest & Climate Change (MOEF&CC) had designated the CSIR-NPL as the “Certification Agency” for Air Pollution Monitoring Equipments. In view of this, the subdivision has been actively working to establish a testing and calibration facility for various automated Air Monitoring Systems (AMS) especially for Continuous Emission Monitoring Systems (CEMS) and Continuous Ambient Air Quality Monitoring Systems (CAAQMS). This would be a new national facility to provide Certification in the coming

time. It will buttress the process of removing the major barriers in ensuring the quality of environmental monitoring data from various sources. This subdivision also measures various atmospheric species including greenhouse gases and particulate matter to study their chemical and physical properties and identifying their roles in influencing the atmosphere and climate through state-of-the-art instruments and models. The Environmental Sciences & Biomedical Metrology Division is currently working on developing best practices for accurate measurement of atmospheric trace species for adoption by different agencies and institutions in India engaged in atmospheric monitoring. The work in this field is of great importance as air quality and climate change has a direct impact on human health and the ecosystem. The improvement in measurement quality will have societal benefits as it will foster better policy formulations for the amelioration of air quality and mitigation of climate change. This subdivision is also engaged in developing low-cost indigenous monitoring equipment for air pollution measurement. Further, it is also involved in the characterization of the ionized and non-ionized atmospheric media over Indian latitudes, Polar Regions and terrestrial environments. The scientific activity involves study for radio propagation for the betterment of radio communication & navigation, atmospheric coupling processes (in lower and upper atmospheres), ionospheric earthquake precursor studies and other societal/strategic applications. This subdivision also provides ionospheric forecasting to users worldwide through the space weather Regional Warning Centre (RWC, NPL-India).

Gas Metrology

Reliable measurements of national ambient air quality parameters, greenhouse gases (GHGs), emission gases and particulate matter (PM) play important role in strategic sectors and policy decisions. The mandate of Gas metrology activity is to realize mole (SI unit of amount of substance) in gas measurements and to disseminate traceability in ambient air quality measurements, GHGs and emission measurement in India through Primary Reference Gas Mixtures (Gas-BNDs), calibration and testing services for gas and particulate matter (PM) measurements. The SI unit 'mole' (symbol "mol") is the amount of substance which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12. At gas metrology activity, mol is realized through development of Primary Reference

Gas Mixtures (PRGMs) standards in the area of Gas measurements. Use of PRGMs for gas measurements provides traceability to SI unit mol. Consultancy services and technical services are also provided in gas and aerosol metrology area to solve the pollution related problems eg. Mask testing, control efficiency testing of sensors and analyzers etc. This group is also doing research in development of testing facility for mask for the particle filtration efficiency as per IS 9473:2002. During the year 2020-21, the section has continued its efforts for development of new facility for testing and providing testing, calibration and traceability. Some of the significant work for 2020-21 are; a) Technical services for the preparation of specifications, budget estimates and vetting of specifications for wind tunnel required by DRDO-SASE; b) Testing and calibration services to various stakeholders through filter efficiency test and Cut off size of PM_{2.5} sampler impactor; c) During the COVID-19 pandemic, Gas Metrology section has provided testing of particle efficiency of masks to DRDO and testing of oxygen enrichment by oxygen concentrator for NPL R & D work; d) Testing of CO₂ concentration in mass metrology lab of vacuum balance system and 1kg mass balance; e) Impurity testing in helium and some other gases to meet national testing needs for VVIP Security.

The gas metrology activity has successfully completed the quality management audit as per ISO17025:2017 and ISO 17034:2016. We continuously work to pilot/ participate in different international intercomparison in order to establish our equivalence in international system of measurements.

Biomedical Metrology

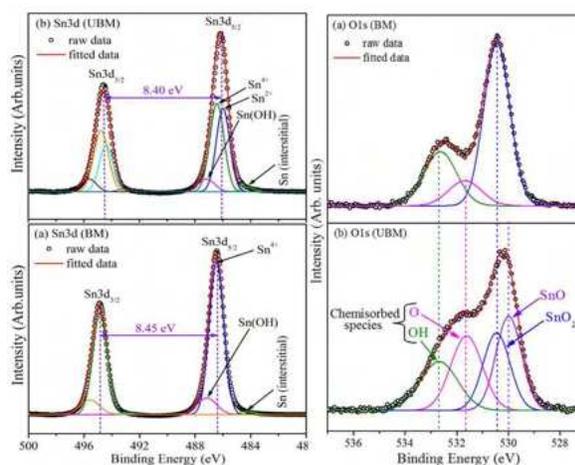
The sub-division has established an apex level calibration facility for defibrillator analyzer by installing a set-up of a primary standard of defibrillator with its physical parameters traceable to national standards in recent past. This facility is the “first-of-its kind” in India to cater the needs of quality assurance in the area of healthcare. The sub=division caters to the leading healthcare calibration centers, manufacturing industries, hospitals, CSIR laboratories etc. and contributing significantly towards socio-economic growth of the nation. It also conducts technical workshops, training programs besides providing consultancy services to various industrial segments. The group is also involved in research

and development activities in biomaterials, electro active materials and biomedical applications etc. to enhance the capabilities in the biomedical metrology.

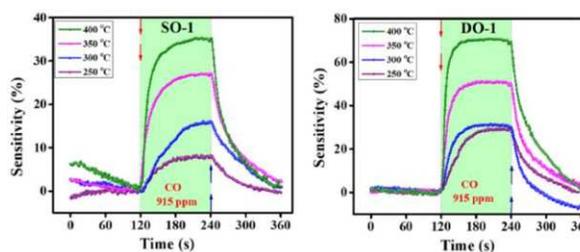
Sensor Devices & Metrology

- **Development of Metal Oxide Based Gas Sensors for Air Pollutants by PVD Process:**

Sensor Devices & Metrology group is engaged in developing gas and optical sensors based on semiconducting materials. SnO₂ and ZnO thin films are developed by sputtering and vacuum evaporation processes. In sputtering process, it is found that SnO₂ film deposited under unbalanced magnetron (UBM) configuration consist of Sn⁴⁺ oxidation state, while those deposited under UBM configuration have Sn⁴⁺ and Sn²⁺ oxygen states. SnO₂ based CO gas sensors have been developed by post oxidation of vacuum evaporated Sn films. The post-oxidation was performed by two different methods such as step-oxidation (SO-1) and direct-oxidation (DO-1) at a maximum temperature of 850°C. The SnO₂ films produced by both oxidation methods possess a rutile crystal structure and porous, granular surface morphology with an optical bandgap of 3.36–3.59 eV. But, the sensitivity towards 915 ppm of CO gas is significantly higher with 71 % for the direct-oxidized 100 nm thick SnO₂ with a fast response time of 21 s and a limit-of-detection of 10 ppm.



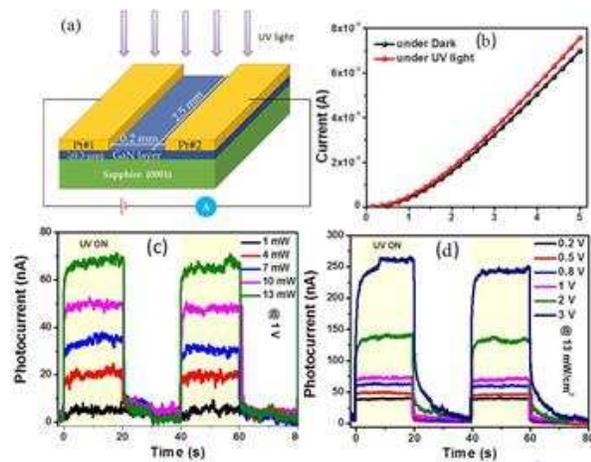
Sn3d and O1s XPS signals of sputtered SnO₂ thin films under UBM and BM configurations



CO gas sensing characteristics of vacuum evaporated SnO₂ films

- Fabrication and Characterization of GaN UV Detectors Developed by Laser MBE:**

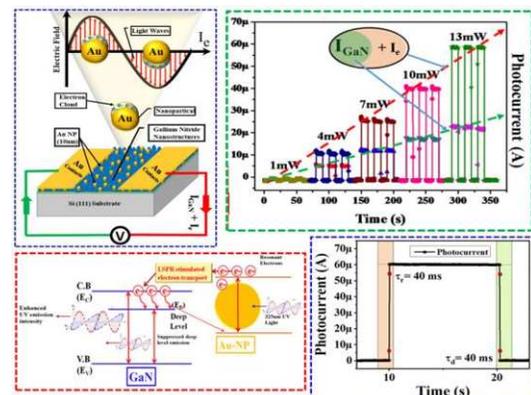
Metal - semiconductor - metal (MSM) Ultraviolet (UV) photo-detectors have been fabricated on GaN epitaxial layers grown on sapphire (0001) by laser molecular beam epitaxy using laser ablation of polycrystalline GaN in the ambient of nitrogen plasma. The influence of threading dislocation density on UV photo response properties of GaN layers have been studied. It is found that the Pt/GaN/Pt MSM structure with lesser screw dislocation densities exhibits a higher responsivity of 4.3 mA/W with fast response and recovery time of 100~130 ms.



(a) Pt/GaN/Pt sensor, (b) I-V curves, (c) power and (d) voltage dependent photo-response of GaN UV photo-detector

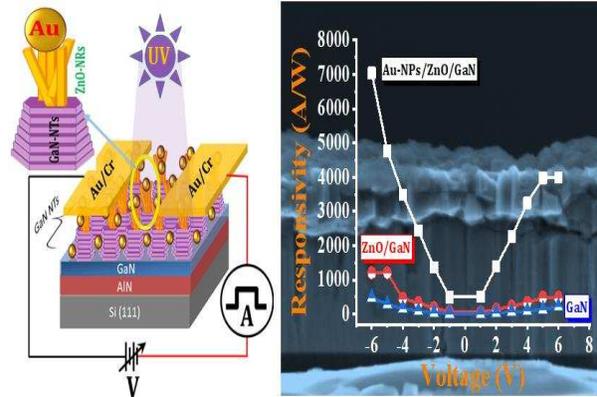
- Au-Nanoplasmonics Mediated Surface Plasmon Enhanced GaN Nanostructured UV Photodetectors:**

The impact of nanoplasmonics through chemically synthesized Au-nanoparticles (~10nm) on the performance of GaN nanostructured based Ultraviolet (UV) photodetectors is analyzed. The report illustrates the mechanism where light interacting with the metal nanoparticles guided by the surface plasmon to effectively enhance the device performance. The study comprehensively analyzes the device design, laser power and bias dependent enhanced responsivity (~380mA/W), detectivity (~ 10^{10}), EQE (~145%), reduced noise equivalent power ~ $5.5 \times 10^{-13} \text{ WHz}^{-1/2}$, and fast response/recovery time (~40ms).



- GaN Nanotowers Grown on Si (111) and Functionalized with Au Nanoparticles and ZnO Nanorods for Highly Responsive UV Photodetectors:**

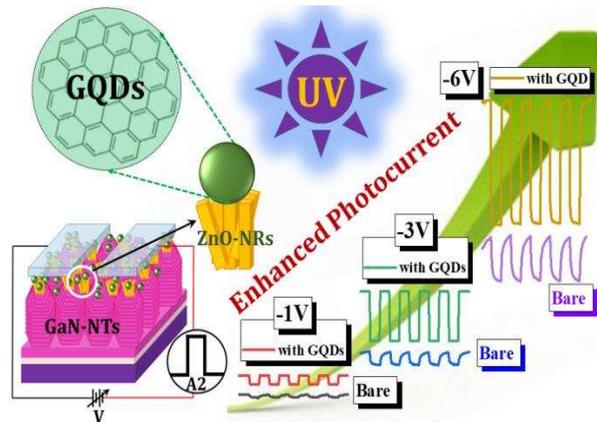
Vertically aligned GaN Nanotowers (NTs) were grown on Si (111) substrate by plasma-assisted molecular beam epitaxy to design a highly responsive ultraviolet photodetector. The GaN-NT based detector further functionalized with Au Nanoparticles and ZnO Nanorods. This hybridization significantly accelerate the performance of



the device where a prominent three order reduction in dark current is observed along with gigantic enhancement in R ($484.77 \text{ A/W} \rightarrow 7042 \text{ A/W}$), reduction in NEP ($1.76 \times 10^{-13} \text{ W.Hz}^{-1/2} \rightarrow 1.84 \times 10^{-14} \text{ W.Hz}^{-1/2}$) and extremely enhanced EQE ($1.85 \times 10^5\% \rightarrow 2.7 \times 10^6\%$) has been observed.

- Graphene Quantum Dots Sensitized ZnO-Nanorods/GaN-Nanotowers Heterostructure Based High Performance UV Photodetector:**

The fabrication of superior performance UV photodetector utilizing graphene quantum dots (GQDs) as sensitization agent on ZnO NR/GaN-NT heterostructure has been realized. GQD sensitization displays substantial impact on the electrical as well as the optical performance of heterojunction UV photodetector. The GQDs sensitization stimulates charge carriers in both ZnO & GaN and allows energy band alignment which is realised by spontaneous time-correlated transient response. The fabricated device demonstrates an excellent enhancement ($\sim 265\%$) of R ($3.2 \times 10^3 \text{ A/W}$) at -6V as compare to its bare counterpart. In addition, photodetector also exhibits very high EQE of $1.2 \times 10^6\%$, better switching speed and signal detection capability as low as $\sim 50\text{fW}$.



Advanced Materials and Device Metrology: *Division 4*

The division of Advanced Materials and Device Metrology aims towards synergizing the research, development and their metrology for state-of-the-art bulk and nano-scale (0-D, 1-D, 2-D and 3-D) materials, process technologies and devices for industrial, strategic, health, energy and societal applications. The central aim is to design and develop the materials with metrological grade to convert into all laboratory research invention to innovation, which will directly help all industrial sectors to promote their quality products with world class infrastructure. The thrust is on the development of indigenous, economically viable and efficient organic and inorganic photovoltaic and thermoelectric devices, luminescent materials, advanced carbon based materials, composites and products. During the year 2020-21, the division has continued its efforts to undertake distinct mandated research and development through several International and National projects, including Consultancy, Collaborative, Grant-in-aid and Sponsored projects. A glimpse of activities of each subdivision is described below:

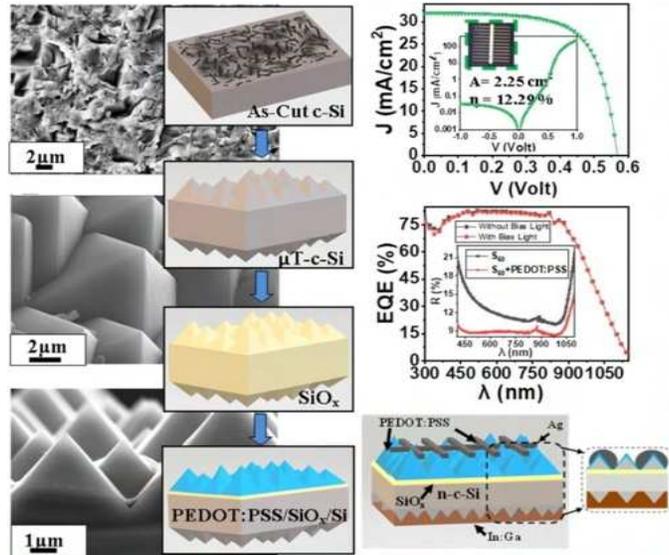
Photovoltaic Metrology

Photovoltaic Metrology section deals with advanced research and developments in Si photovoltaics and emerging futuristic photovoltaic technologies based on organic and perovskite semiconductors and accurate measurements in their fabrication and testing. Some of the glimpses of the work carried out in this direction in this section are given below:

- **Silicon Photovoltaics**

Organic carrier selective layer, poly (3,4- ethylenedioxythiophene):poly(styrene sulfonate) (PEDOT:PSS) coated on Si wafers, has attracted a lot of attention towards the development of low-cost and efficient hybrid solar cells (HSCs). We have demonstrated highly efficient PEDOT:PSS/Si HSCs via an effective surface micro-engineering of the as-cut, low-cost solar-

grade thin Si wafers. The influence of surface micro-structuring on their light harvesting properties has also been studied. The simple one-step process under the optimized processing condition reduces the weighted surface reflectivity from >35% to <9% in broad spectral range in addition to removing the surface saw-damages of the wafers completely. The combined effect in turn improves the PEDOT: PSS/Si interface property leading to a highly efficient PEDOT: PSS/Si HSCs even in its simplest possible device structure. Moreover, the anti-reflective and surface passivation properties of the PEDOT: PSS layer for the micro-structured Si surfaces are also demonstrated. Further, the role of ethylene glycol as conductivity enhancement in PEDOT:PSS, and other processing parameters such as spin coating speed, pre-heat and post heat treatment of the PEDOT:PSS/Si samples, etc. on the performance parameters of the solar cells have been investigated. KOH texturing for an optimized time duration works in 2 folds: (i) increasing the light absorption as a result of multiple interactions/reflections of the incident light on the texture surfaces, (ii) reducing the surface damages significantly (improving the PEDOT:PSS/Si interface and hence the junction property). The optimized micro-surface, interface engineering via optimization of parameters and cell processing conditions resulted in the HSCs with photo-conversion efficiency >12.25% (on large area, >2.25 cm²) which is absolute ~9.70% (~5 folds) higher when compared to that on starting non-structured Si wafers. The study establishes that micro-engineering of the commercial as-cut Si wafers removes the surface-damages on both sides which if not addressed properly, cause very high surface recombination losses and has detrimental effect on the polymer/Si junction and hence the PV performances. The study paves the way to develop



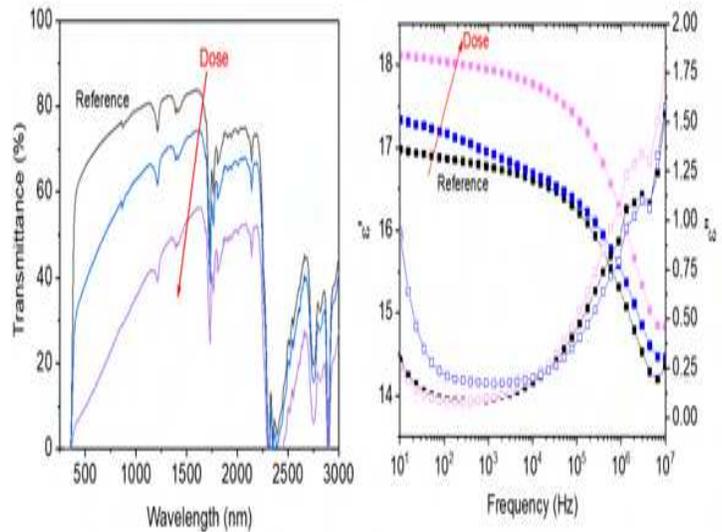
Highlights of the 'one step surface micro engineering of as-cut solar grade silicon wafers' for highly efficient PEDOT: PSS/Si hybrid solar cells demonstrated

simple yet efficient HSCs on such economic solar-grade Si wafers commonly used for the conventional Si solar cells. The highlights of this process are presented in figure.

The solar cells in the module are encapsulated by a set of materials that should ensure reliable performance for >25 years. Degradation in encapsulant materials themselves can have a significant impact on the performance of the cells (in terms of faster power degradation or even catastrophic failures), as well as safety of the module. Several failure issues have been noticed

in India as a result of degradation in encapsulant materials. To avoid these failures appropriate testing methods

should be developed to ensure reliable performance of the module. We have initiated to establish test facilities to ensure high reliability in module materials and long-term performance of solar modules. We are engineering the module components such as glass, EVA other components using fillers to reinforce its structure and hence to improve their thermal, mechanical, optical and electrical characteristics. These materials are being tested for their efficiency against the PID effects in solar cells. Dielectric strength improved by a factor of 1.1 with respect to the reference, but the optical quality of the composite degraded with the dose of filler materials. Figure shows the optical and electrical characteristics of EVA composites with respect to filler dose.

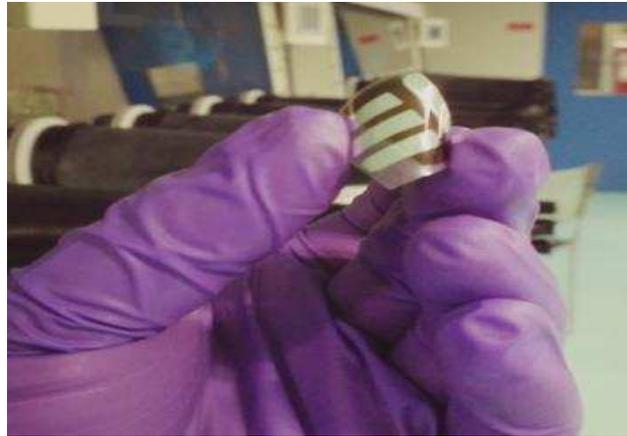


Optical and electrical characteristics of EVA composites with respect to filler dose hybrid solar cells demonstrated

- **Organic and Perovskite Photovoltaics**

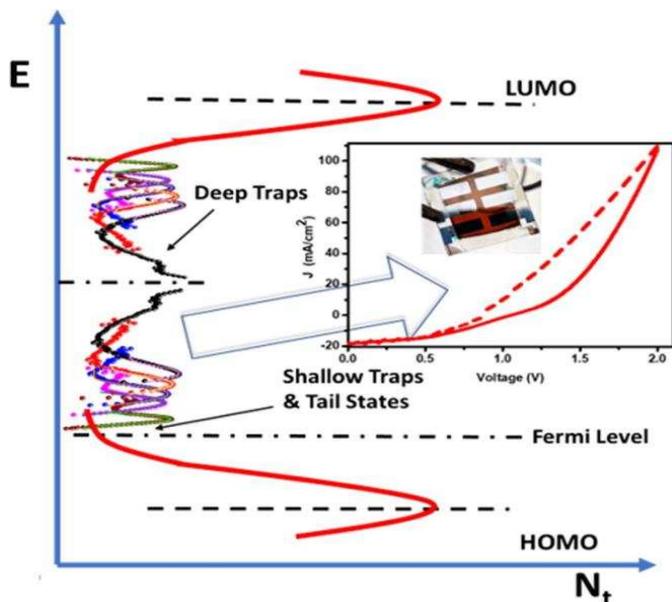
We are engaged in the development of flexible perovskite solar cells (FPSCs) and we have been fabricating them so far on flexible PET substrates via spin coating technique, which has some inherent limitations and is not suitable for scale up of this technology, therefore we now aim to develop this technology via conventional printing techniques. The spin

coated FPSCs prepared at CSIR-NPL have shown over 13% PCE and figure shows the photograph of one of these solar cells. For small scale printing of FPSCs, we are fabricating a small printing machine at CSIR-NPL and once the machine works well and we successfully print these solar cells on small scale we will set up a facility for their roll to roll printing. Roll to roll printing of FPSCs will take us more to closer to their commercialization.



Photograph of one of the FPSCs prepared at CSIR-NPL

Along with device development, we are trying to understand the fundamental physics behind several anomalous features observed in organic and perovskite solar cells (PSCs). Hysteresis is quite a unique behavior observed in PSCs. We performed low-temperature capacitance spectroscopy and current-voltage analysis and found that the open-circuit voltage and hysteresis tend to decrease as the temperature falls below ~ 200 K. For temperature range of ~ 300 K to ~ 180 K, the hysteresis index



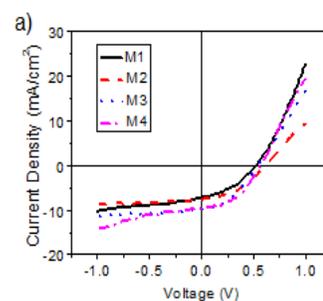
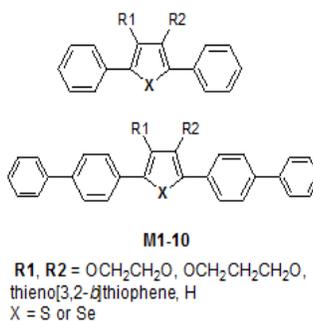
Photograph of one of the FPSCs prepared at CSIR-NPL

under dark condition remains almost unaltered whereas, under illuminated condition, the hysteresis index increases with a decrease in temperature. The average hysteresis index under the dark and illuminated conditions is $\sim 71\%$ and $\sim 18\%$ in the tetragonal phase, whereas it becomes $\sim 4\%$ and $\sim 24\%$ in the orthorhombic phase, respectively. Further, below ~ 180 K, both hysteresis index decreases mutually with the identical rate with a decrease in temperature. Two inflection points have been observed in forward and reverse

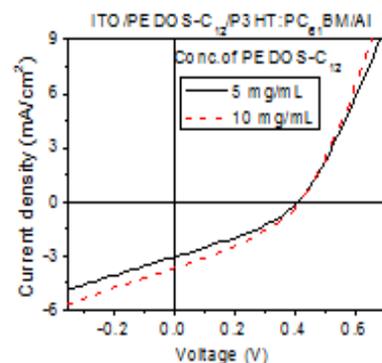
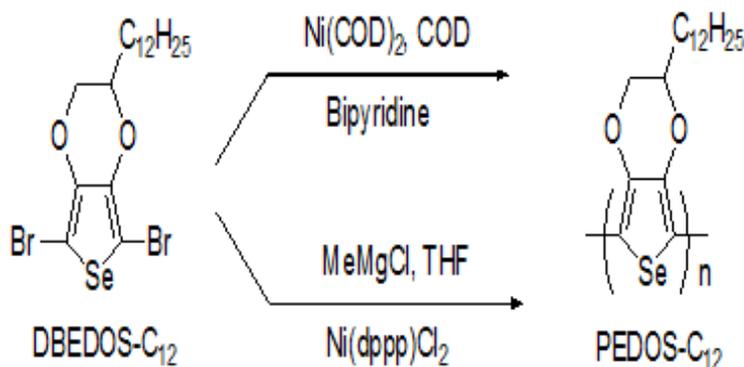
current cross over-voltage points, indicating rearrangement of internal built-in field distribution and defects at different temperatures. In the tetragonal phase, the Gaussian profile of defect density extends towards lower energy as temperature decreases that refer to a shift in quasi-Fermi level which changed the open-circuit voltage. The increased distribution defect leads to unfavorable accumulation of mobile ions at the electrode and grain boundaries interfaces lead to hysteresis effect in the device. Figure shows direct relation between defect density and hysteresis in PSCs.

• Indigenously Materials Development for Solar Cells

We have synthesized a series of π conjugated small molecules through direct C-H arylation for hole transport material (HTM) in organic solar cells (OSCs). Ten phenyl(s)-flanked conjugated small molecules were prepared using the optimized reaction conditions. Electrical and optical properties were measured by cyclic voltammetry and UV-vis absorption spectroscopy. The OSCs, prepared by using these HTMs in ITO/HTM/PCDTBT: PC70BM/Al structure, exhibited around 2.4% PCE. The figure shows the chemical structures of synthesized HTMs and J-V characteristics of the OSCs incorporating them.



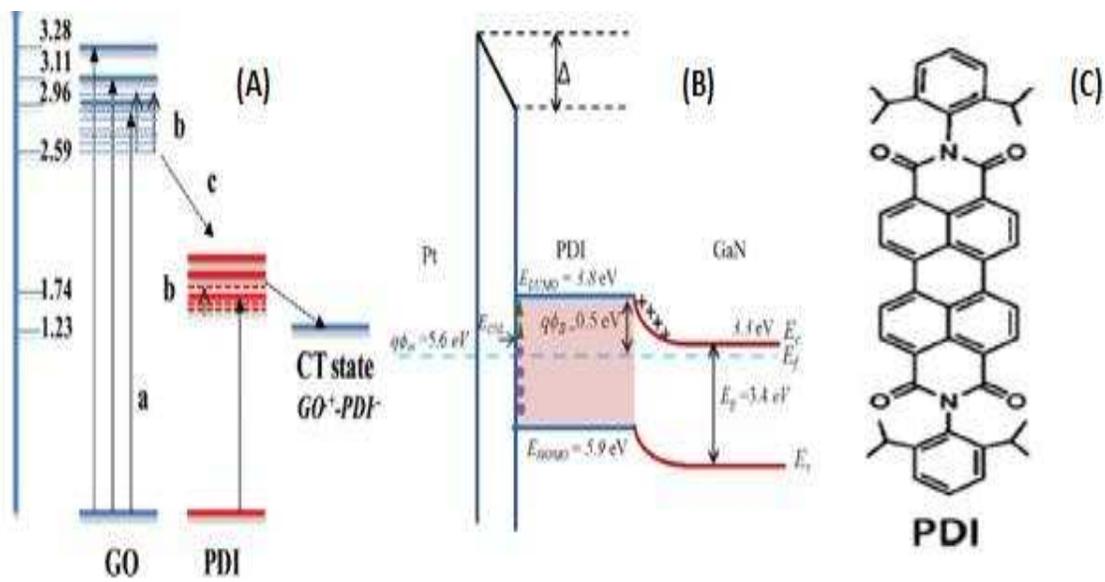
Chemical structures of M1-10 and J-V characteristics of PCDTBT: PC70BM OSCs based on M1-4 HTMs



Synthesis scheme of PEDOS-C12 and J-V characteristic of P3HT:PC61BM OSCs based on PEDOS-C12 as a HTM on M1-4 HTMs

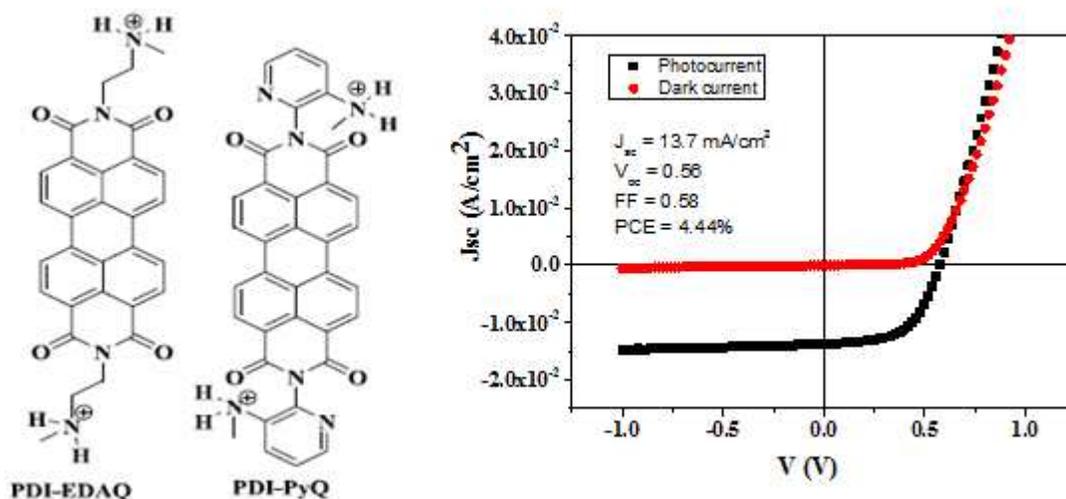
We also synthesized dodecyl-substituted poly(3,4-ethylenedioxysephenone) (PEDOS-C12) by two different chemical polymerization methods- transition metal-mediated and Grignard metathesis (GRIM). The obtained neutral polymer PEDOS-C12 (hydrazine-dedoped) prepared by GRIM was used for spray process able electro chromic property and OSCs. PEDOS-C12 was used as HTM for OSCs prepared in ITO/PEDOS-C12(HTL)/P3HT:PC61BM/Al structure. The following figure shows the scheme of synthesis of PEDOS-C12 and J-V characteristics of the OSCs based on PEDOS-C12 HTM

We also performed studies on the interaction of n-type organic semiconductor materials, i.e. perylenediimide (PDI) with organic and inorganic electron donating materials in solution and as interface in devices. Graphene oxide (GO) prepared with the controlled band gap showed strong interactions with PDI molecules by forming a charge transfer complex in solution as confirmed by ground state absorption and transient absorption spectroscopy study (figure A). Similarly, PDI the charge transfer interaction was studied at the gallium nitride/ PDI interface (figure B). Proper interface formation resulted in band gap tuning as well as facilitated electron transport as evident in I–V characteristics. Growth of PDI/GaN hybrid system with band gap tuning from ultra-violet to visible region and excellent electrical properties open up new paradigm for fabrication of efficient optoelectronics devices on flexible substrates.



(A) Transitions between GO and PDI on excitation and formation of CT state, (B) Schottky junction at the GaN/PDI interface, (C) Structure of PDI molecule

Naphthalene diimide (NDI) derivatives have been developed for their applications in organic photovoltaics. These NDI derivatives have been analysed for their aggregation behaviour and aggregation-induced emission (AIE) by absorption and emission spectroscopy. All the materials showed excellent electron mobility of the order of 10^{-4} to 10^{-3} $\text{cm}^2 \text{V}^{-1} \text{s}^{-1}$ measured following the standard protocol of SCLC model. New PDI materials have been synthesized and used as electron transport material in organic solar cells delivering efficiency $\sim 4.5\%$.

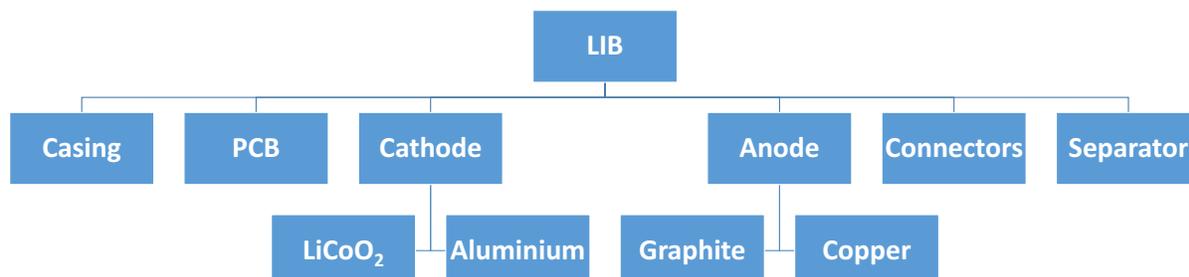


Structure of perylenediimide derivatives and device performance (ITO/PDI-Q/PTB7:PC71BM/MoO₃/Ag)

- **E-waste Recycling Process**

Globally as well as in India huge volumes of E-waste is generated via both regular as well as early loss scenario, due to end of life (EOL) equipment damage, malfunctioning, obsolescence, and technological advancements. Therefore, CSIR-NPL has taken initiatives for development of indigenous technologies for management of E-waste e.g. solar photovoltaic (SPV) systems which consists of Si-Solar panels, general electrical/electronic components, PCS and sometimes batteries. CSIR-NPL has successfully demonstrated chemical route for recovery of metals (e.g. Silver and Aluminium) from Si-solar cells, and other facilities for bulk processing via size reduction; physical separation; chemical & thermal treatment are in establishment stage. As PCB is considered as heart of electronic

systems and related WEEEs and strategies for the recycling of PCB have been established also. Efforts have also been made for recycling of energy storage devices and demonstrated EOL Li-ion batteries (LIBs) recovered from used mobile phones.



Primary and secondary treatment steps in the recycling of EOL Li-ion batteries, for recovery of various components and compounds

Photonic Materials Metrology

This group at CSIR-NPL is actively engaged in the areas of nanophotonics, organic photonics, optoelectronics, ultrafast optoelectronics & terahertz photonics, 2d materials and advanced luminescent materials for security ink. The Photonic materials metrology at CSIR-NPL has worked on various consultancy and sponsored projects and transferred technology to industries. This group is presently working on the "Development of color shift intaglio ink (CSII)", which is the top security feature of Indian Banknotes and "Development of PCR free, facile luminescence based kit for ultra-sensitive detection of covid-19".

- **Shape Evolution and Spectroscopic Studies of APCVD Grown MoS₂ Monolayer**

MoS₂ is the representative of two dimensional transition metal dichalcogenides having remarkable properties such as a direct bandgap at monolayer thickness, excellent carrier mobility, spin-valley physics, tunable excitonic effects, and many more. CSIR-NPL have been synthesized monolayer MoS₂ flakes using a home-built CVD setup at atmospheric pressure, and a wide range of shapes from triangle to many point star has been achieved. The quality of as-grown MoS₂ flakes is analyzed by optical microscopy, Raman spectroscopy, and photoluminescence (PL) successively. The shape evolution has been

interpreted via the growing rate of Mo and S zigzag edges. This study becomes important to synthesize the high-quality MoS₂ monolayer with a wide range of shapes and useful in photo detector applications.

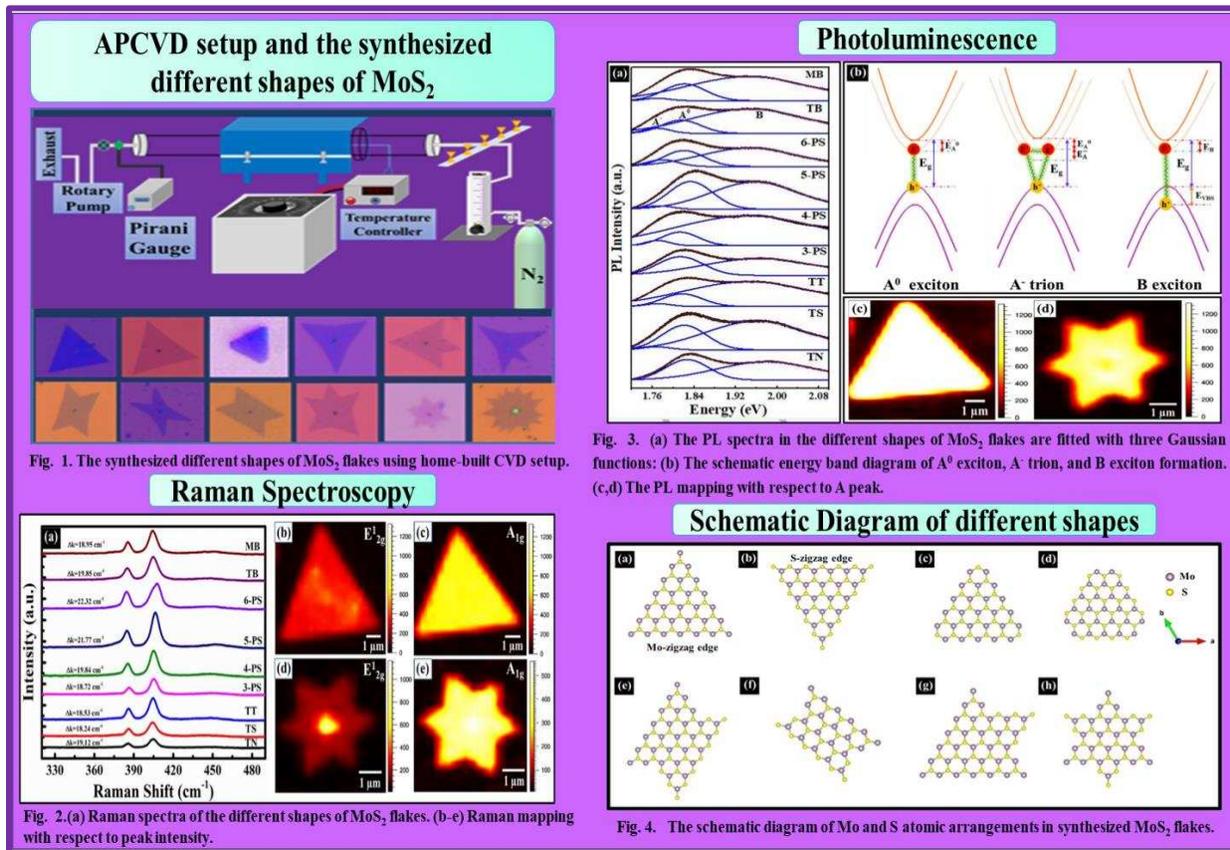


Fig. 1. The synthesized different shapes of MoS₂ flakes using home-built CVD setup.

Fig. 3. (a) The PL spectra in the different shapes of MoS₂ flakes are fitted with three Gaussian functions: (b) The schematic energy band diagram of A⁰ exciton, A⁻ trion, and B exciton formation. (c,d) The PL mapping with respect to A peak.

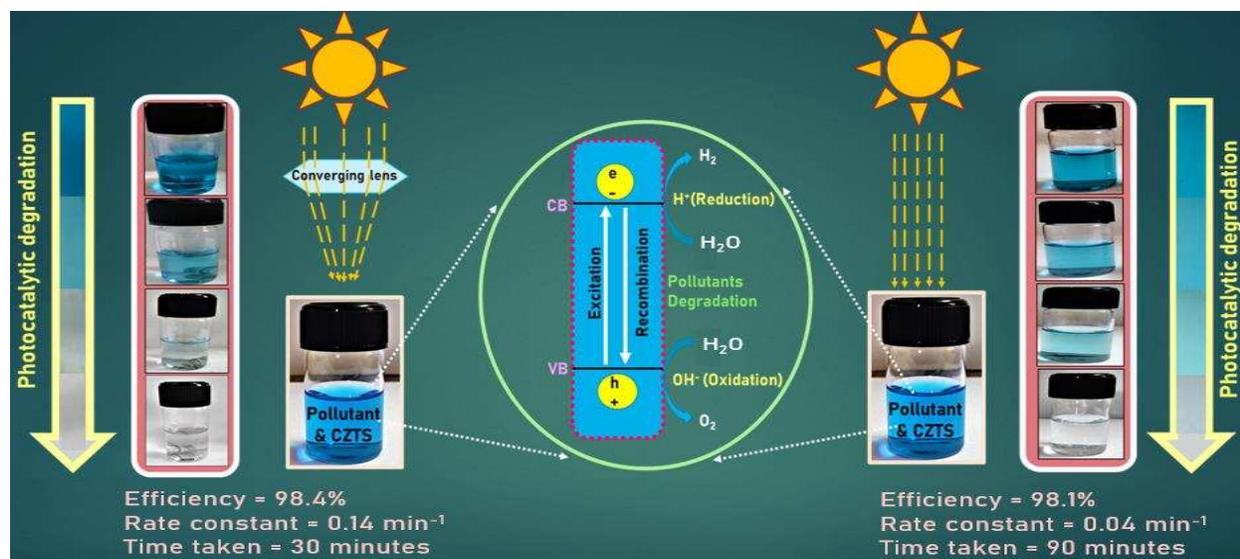
Fig. 2. (a) Raman spectra of the different shapes of MoS₂ flakes. (b-e) Raman mapping with respect to peak intensity.

Fig. 4. The schematic diagram of Mo and S atomic arrangements in synthesized MoS₂ flakes.

Monolayer MoS₂ flakes is synthesized by indigenously developed CVD setup at atmospheric pressure at CSIR-NPL: Shape evolution study on MoS₂ flakes using optical microscopy, Raman spectroscopy, and photoluminescence spectroscopic techniques

- **A Novel Method of Water Remediation of Organic Pollutants and Industrial Wastes by Solution- Route Processed CZTS Nanocrystals**

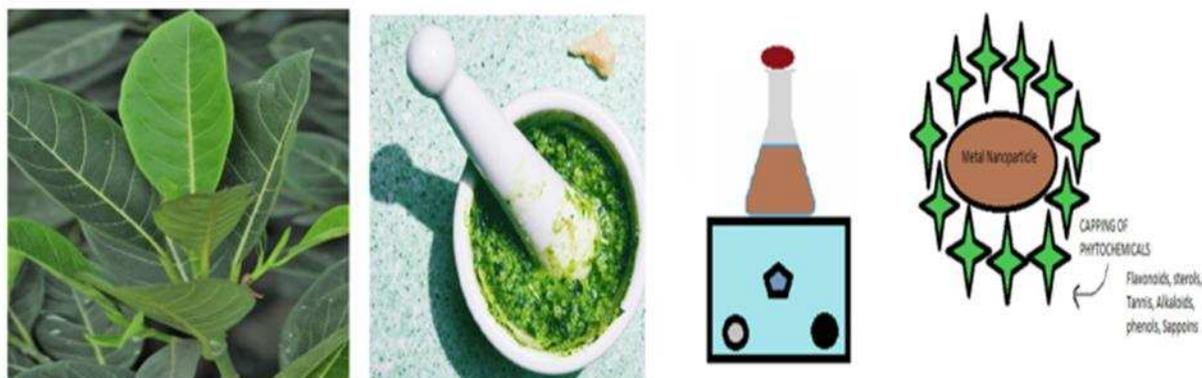
CZTS (Cu₂ZnSnS₄), a P-type semiconductor with a direct bandgap (1.2-1.7eV), earth-abundant, non-toxic, and has a large absorption coefficient makes it extremely useful in optoelectronics and light-harvesting applications. CZTS is prepared by an ingenious, cost-effective colloidal route using the 'hot-injection' method with the usage of different ligands. The best photocatalytic efficiency under sunlight was 98.4% for organic pollutants and 75% for industrial waste via converging lens while the corresponding efficiencies with bare sunlight were 98.1% and 73% respectively.



Graphical abstract showing photocatalysis procedure

- Silver Oxide Nanoparticles Synthesized by Green Method from Artocarpus Hetrophyllus for Antibacterial and Antimicrobial Applications**

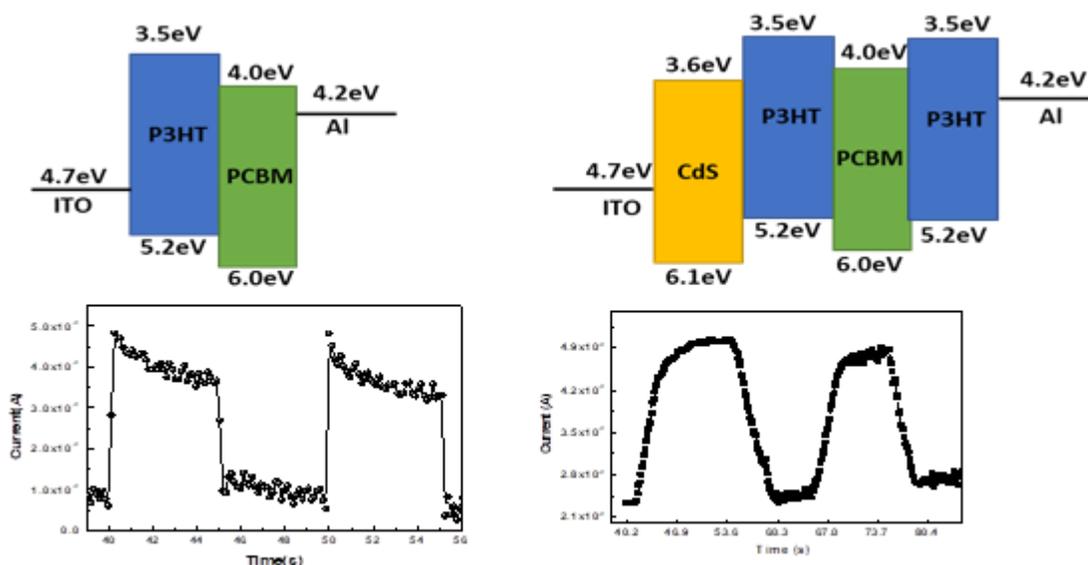
Silver oxide nanoparticles (Ag_2O NPs) used widely in fuel cells, sensor, antimicrobial activity, analgesics, catalysis, optics, cosmetic and drug delivery. Nanoparticles are synthesized by chemical, physical and green route. The (Ag_2O NPs) synthesized by green route as it is environment friendly, less hazardous, inexpensive and also plants have phytochemicals used as capping agent, stabilizing agent and reducing agent. Artocarpus Hetrophyllus plant (as shown in Fig.) extract is used for the synthesis of Ag_2O NPs by natural chemicals. Artocarpus Hetrophyllus tree leaves are hazardous-free from chemicals, eco-friendly for the optoelectronic, antibacterial, antimicrobial activity, drug delivery and coupling reaction for application in pharmaceuticals medicines.



Synthesis and purification of Artocarpus Hetrophyllus tree leaves of Ag_2O NPs

- **CBD Grown Thin Film of CdS for Optoelectronic Devices**

The cadmium sulphide (CdS) was synthesized by chemical bath deposition (CBD) in two different conditions of stirring and temperature or other physical conditions. These thin films were inserted in the different device to improve the performance parameters. The photodiode developed with these nano materials thin films shows the control on their rise and fall time of the device. The following figure shows the schematic device energy diagram. The response time of these devices are also shown in the following figure. The specific detectivity were control by the use of these synthesized nanomaterials thin films and their device which is of industrial applications.

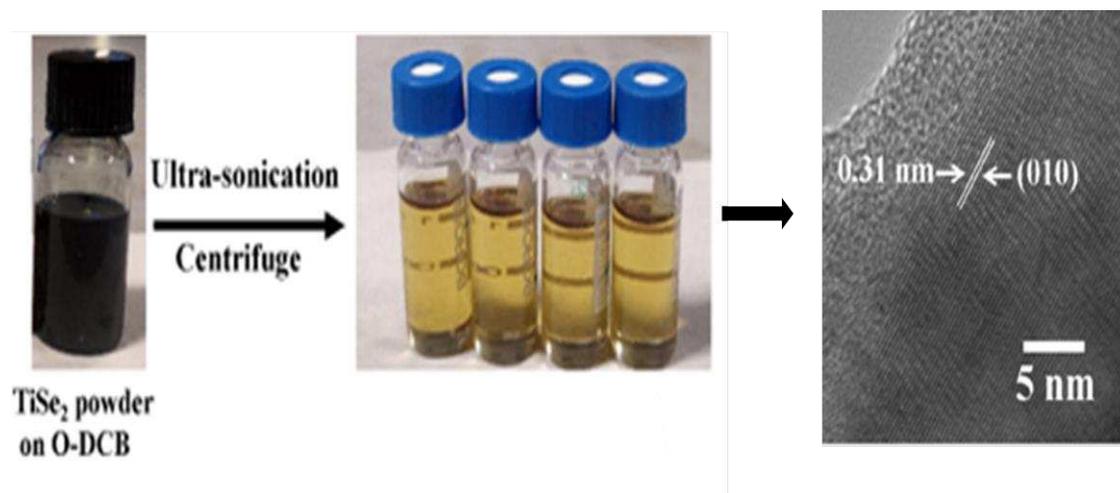


(a). XRD pattern, UV-VIS spectra & TEM images of Ag₂O nanoparticles (size ~ 14 nm)

- **Chemical Exfoliation of Two-dimensional Layered Titanium Diselenide to Study their Structural and Optical Properties**

TiSe₂ has an electronic structure near the Fermi energy level, and the layered structure of the TiSe₂ shows the semiconducting and charge density wave (CDW) properties. Therefore, TiSe₂ has been used extensively for electrodes in batteries and has excellent potential for broad application in sodium storage, charge density wave, and photonic devices. CSIR-NPL, for the first time, has investigated the liquid phase exfoliation of chemical vapor transport (CVT) synthesized 2D-TiSe₂ platelets in the presence of an organic ligand OLA using non-

polar organic solvent ortho-dichlorobenzene (O-DCB). OLA ligands are instantly absorbed onto selenide vacancy defect sites on the surface during sonication. The stable dispersions of the exfoliated TiSe_2 nanosheets have been enabled using hydrophobic non-polar long alkyl chains. The presence of OLA increased the stability by preventing aggregation of the exfoliation of TiSe_2 nanosheets for several potential applications in optoelectronic devices.

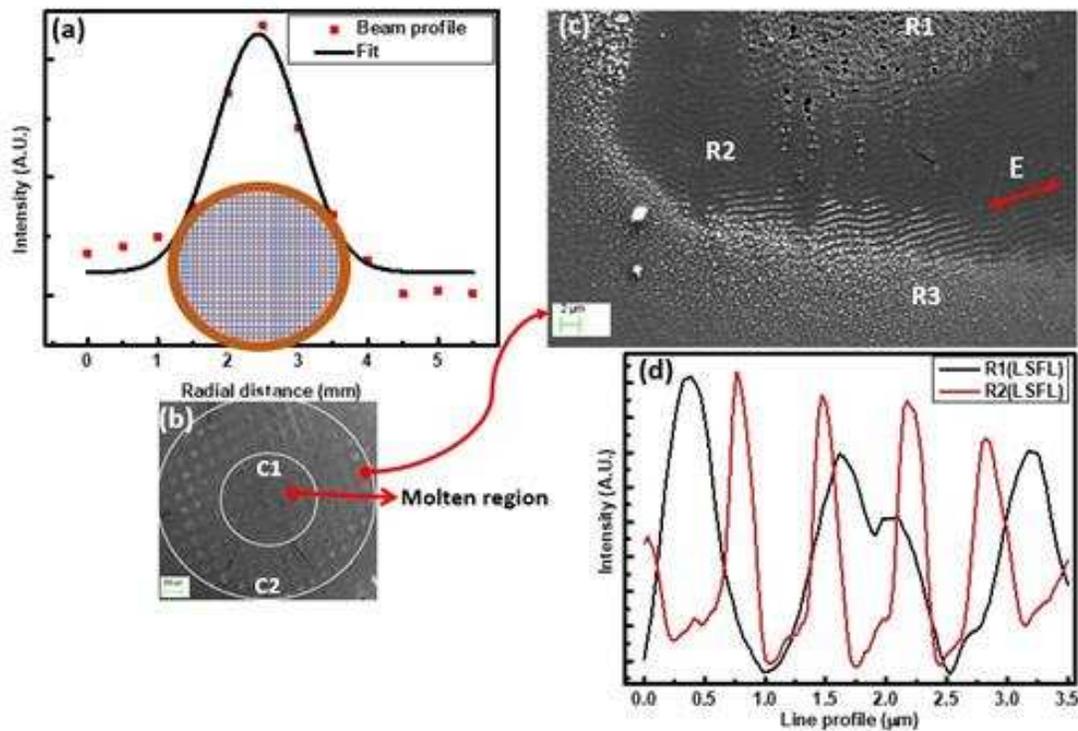


Liquid phase exfoliation of 2D- TiSe_2 platelets

- **The Study of the Modification of Surface Plasmon Resonance (SPR) and the Relaxation Dynamics of Hot Carriers in the Laser-induced Periodic Surface Structure (LIPSS)**

Surface plasmons are the collective oscillations of electrons arising due to light-matter interaction at a metal-dielectric interface. The choice of materials, the dielectric constant of the surrounding medium, particle/grain size and shape can tune the characteristics of the SPR band. The structures that can generate surface plasmons, in general, are characterized as a) metallic thin film generating surface plasmonpolariton (SPP) waves, b) nanoparticles of dimensions less than 100nm generating the localized surface plasmon resonance (LSPR), and c) plasmonic sub-micron clusters (periodic, quasi-periodic, or random) of nanoparticles. The present study reveals the modification of surface plasmon resonance (SPR) and the relaxation dynamics of hot carriers in the laser-induced periodic surface structure (LIPSS) of silver formed by varying the incident laser fluence. The studies are performed using a femtosecond laser ($\lambda_0=800\text{nm}$) based ultrafast transient absorption spectroscopy (UFTS) setup. An array (of $\sim 2\text{mm}$ size) of laser-induced periodic surface

structures were obtained in a single-step fabrication process in open air without translating the sample using a femtosecond laser ($\lambda_0 = 800$ nm). Each unit cell of the array consists of low spatial frequency laser-induced periodic surface structures near the center and nanoparticles/clusters around the edges. The nanoparticles/clusters show a random distribution that falls in 50nm -300 nm range. An effect of laser fluence on SPR behaviour is also analyzed and it is observed that there is a non-linear redshift (~ 16 nm) in the SPR peak wavelength while there is a large enhancement in the relaxation times of the hot carriers. Therefore, by varying the laser fluence a wide spectral and carrier relaxation lifetime tunability is achieved. The study highlights the suitability of LIPSS in applications requiring efficient energy transfer, enhanced photocatalyticaction, and tunable sensors.



Comparison between the laser beam profile used for LIPSS and TEM grid used for masking the sample. b) A rectangular array of Ag obtained because of masking. C1 and C2 are regions formed due to the Gaussian shape of the laser beam profile. c) Zooming into the individual rectangular spot from C2 revealed three regions: R1, R2, and R3. The red arrow indicates the polarization of the laser. R1 shows blurred structures, while R3 shows nanoparticles. Well-defined Ripples are obtained in the R2 region. d) line profile of R1 and R2 regions indicating the periodicity of LIPSS formed

Advanced Carbon Products and Metrology

The subdivision is engaged in the development of advanced carbon materials, magnetic materials and thermoelectric materials catering to the need of the country in the Industrial, Health, Energy as well as Strategic sectors like Defense, Aerospace and Nuclear power. The major focus area of projects activities are as listed below:

- Establishing centre for ballistic material testing and MWCNTs based armour materials
- Development of high density isotropic nuclear grade graphite Demonstration and validation of a 5 KW HT-PEMFC based on combined cooling and power system
- Characterization of coal tar, their conversion into coal tar pitch and zero Q.I. pitch, and characterization
- Carbon fiber composite limbs for recurve archery bow
- Conversion of crop stubble and municipal solid waste (MSW) in to bio coal by Torrefaction as useful raw material for co-firing in thermal power plants
- Development of Lithium titanate-graphene based battery chemistry for EVs anode for LiB
- Creation of National Center for Battery Evaluation & Safety Test
- Direct Synthesis of Carbon Nanotube Yarn by Chemical Vapor Deposition
- Development of Efficient and Economically viable Carbon Nano Materials for Water Purification
- Development of BND of Graphitized petroleum Coke and Calcined Petroleum Coke
- Development of fiberboards and panel from agricultural waste and polymers

The highlights of the achievements of the subdivision during the period are as follows:

- **Setting up Testing Facility at CSIR-NPL, New Delhi of Mechanical Properties Measurement for PPEs as per National /International Standards**

In order to support the healthcare industry, there is need to establish the testing facility for accurate and precise measurement of the properties of PPE as per relevant standards. This will also help government to set essential policies for these important PPE testing. The testing facility for four following properties have been established under ISO17025:2017

- Tensile strength (dry and wet),
- Bursting strength (dry and wet)
- Seam strength (dry and wet),
- Tear Strength

The ball burst test set-up for the measurement of bursting strength of textile fabrics has been indigenously designed, developed and established in the laboratory

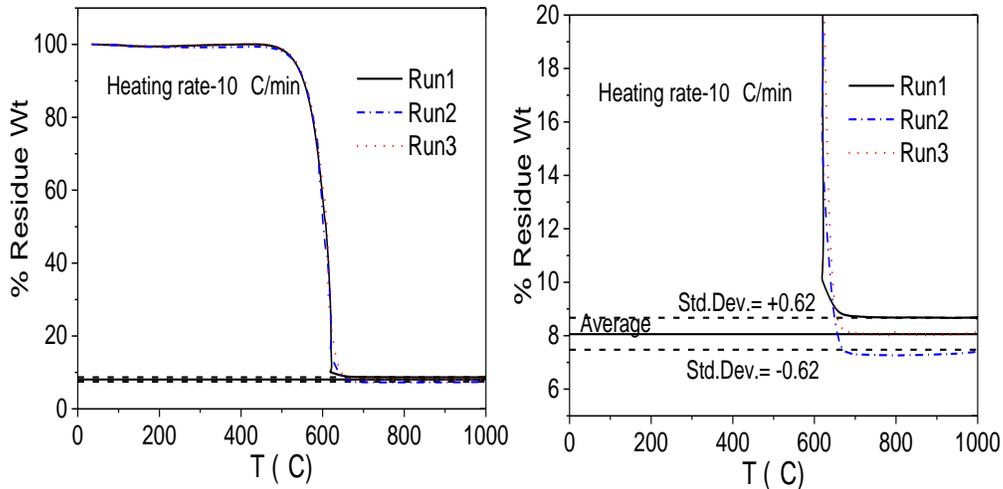


(a) Components of ball burst test set-up (b) Indigenously developed Ball burst test set-up for bursting strength measurement of surgical gowns platelets

- **Development of Indian Standard on Characterization of Carbon Nanotubes (CNTs) by Thermo Gravimetric Analysis to Insure the Quality of CNTs**

Carbon nanotube is a very important material in the field of nanotechnology and it has wide range of applications. Purity of CNTs is one of the key aspects in its applicability and there is no Indian standard to ascertain the same. Hence, a standard is prepared which will provide guidelines for the characterization of CNT-containing samples by the use of TGA technique. Guidance will be provided on purity assessment of CNT samples through a quantitative measure of the non-carbon impurity (i.e. metal catalyst) level within the material. Further, this technique can provide a qualitative assessment of the thermal stability and homogeneity of the CNT-containing sample. The following figure shows a TGA plot of as produced CVD-MWCNT and showing the weight loss with temperature along with its standard deviation in weight residue.

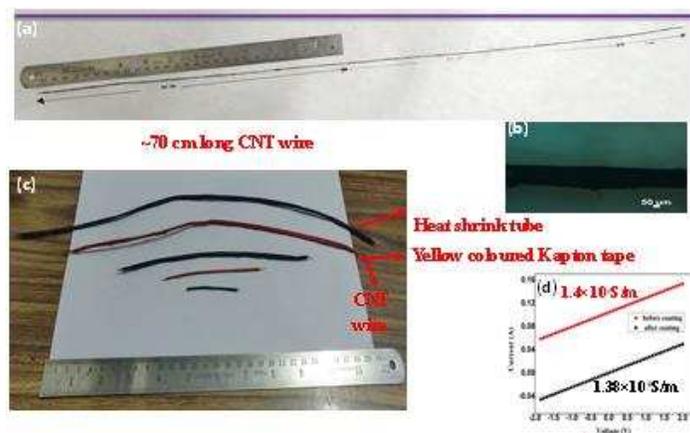
A large number of experiments of TGA of as produced multiwall carbon nanotubes at CSIR-NPL have been performed and based on these results a draft has been prepared and submitted to BIS.



a) Actual TGA Curve b) W_{res} average and standard deviation
 TGA plot of as produced CVD-MWCNT and showing the weight loss with temperature along with its standard deviation in weight residue

- **Development of Carbon Nanotube Yarn as Conducting Wire**

Carbon nanotubes yarn is an important material as it can outperform copper (Cu) because CNTs have astonishing electrical properties with low density. A CNT yarn based conducting wire is developed in the laboratory in different length and coated with Kapton tape and heat shrink tube (Figure a-c). The electrical conductivity of the wire without Kapton coating (140 S/cm) and with Kapton coating (138 S/cm) is not having any significant difference ((Figure d). This kind of light weight conducting material is very useful in spacecraft where weight reduction is the major concern.



(a) 70 cm long CNT yarn based wire, (b) Optical micrograph image of CNT yarn, (c) CNT wire coated with Kapton tape and Heat shrink tape of 5 cm, 10 cm, 20 cm, 30 cm and 40 cm length, (d) Electrical conductivity of CNT wire without coating and with coating

- **VAMAS TWA 41**

CSIR-NPL has participated under VAMAS TWA 41 in Project 1: Structural characterization of CVD-grown graphene, coverage on substrate, number of layers, and level of disorder. The laboratory participated in the inter laboratory comparison (ILC) having 17 participants including many NMIs. The performed measurements and results were sent to NPL, UK. The outcome of the present project 1 under TWA 41 help the standardization specially through ISO TC229 'Nanotechnologies', jointly with IEC, including ISO/PWI 21356 'Structural characterization of graphene', which focuses on determining the physical properties of graphene flakes and CVD-grown graphene, this TWA 41 has very much important role to play.

- **Development of Particle Board Material from Agricultural Waste (Rice Straw)**

Under this program particle board material has been prepared from waste rice straw using a novel adhesive. The tiles made of size 20 cm x 32 cm have been characterized for the different properties as per IS. The particle board so developed fulfills the requirements for furnishing application as per IS: 3087-2005, Particle Boards of Wood and Other Lignocellulosic Materials (Medium Density) for General Purposes — Specification (*Second Revision*).



Particle board from rice developed at CSIR-NPL

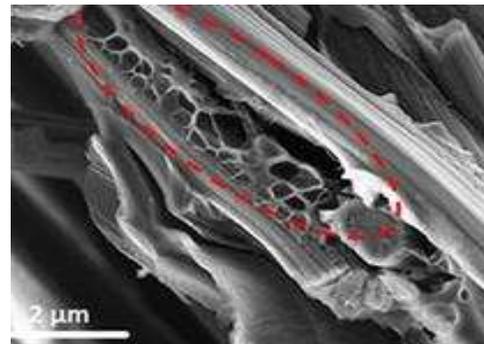
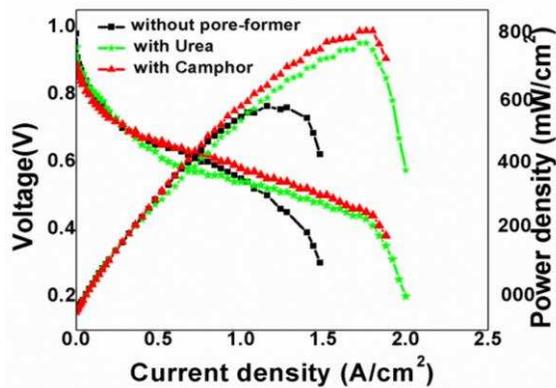
Sunmica glued to the particle board for general purpose furniture

- **Development of Porous Conducting Carbon Paper as Fuel Cell Electrode**

Pore formers have been effective in creating connected porosity and a uniform pore size distribution in the carbon paper. Porosity gives a cushioning effect & saves the sample

against flexural damage. Urea and Camphor as pore formers showed overall balanced properties in carbon paper.

The polarization curve of the unit PEM Fuel cell (with an effective electrode area 25 cm²) shows a peak output power density of 797.2 mW/cm² and 756.8 mW/cm² with camphor and urea as pore formers, as compared to 576.2 mW/cm² obtained using the paper prepared without pore former, which is a hike of more than 30%.

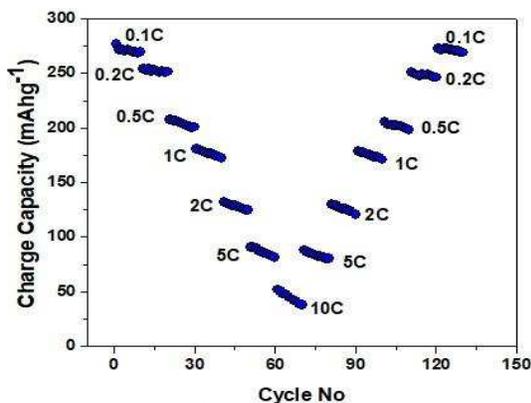


Comparative I-V performance of unit PEM Fuel Cell using carbon paper samples with and without pore-former

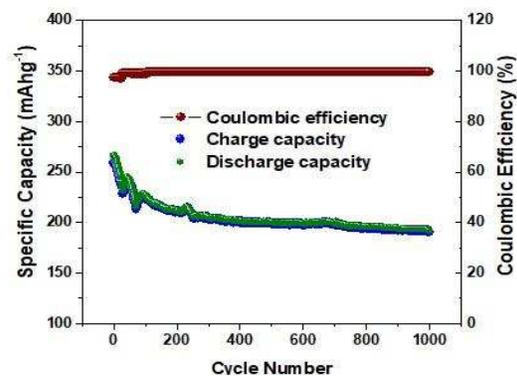
SEM of carbon paper showing pores created by pore former

- **Development of Carbon Fiber Composite Paper as an Anode of Sodium-ion Battery**

Carbon Papers were heat treated to 800^o C, 1100^o C, 1400^o C, 1800^o C and 2350^o C and tested as anode for SIB, wherein the sample heated to 800^o C showed a discharge capacity of more than 200 mAh/g for more than 1000 cycles



Charge-Discharge cycles of Na-ion battery for 1000 cycles

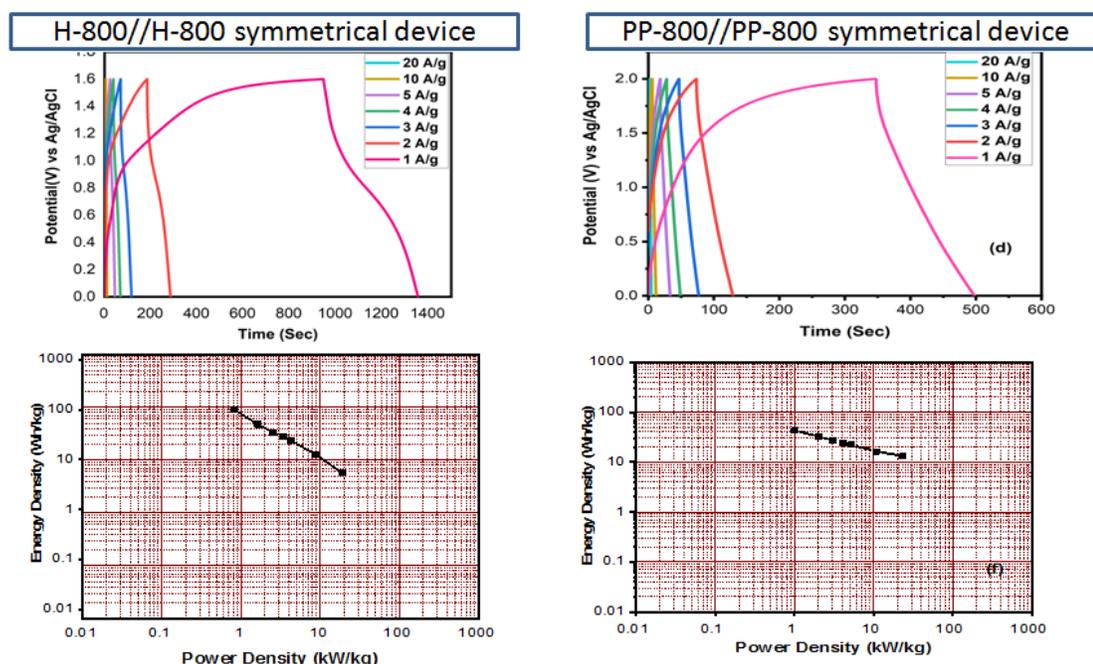


Cyclic performance of carbon anode at different current densities

- **Development of Biomass Derived Activated Carbon and their Composite as Electrode Material for Symmetric and Electric Double Layer Supercapacitor Devices**

Human hair (H) and pineapple peel (PP) were activated with KOH at 800 °C to synthesize activated carbon. H-800 and PP-800 displayed superior performance in terms of surface area and specific capacitance. (787 m²/g, 1643 m²/g).

Further the electrodes were used to assemble a symmetric supercapacitor device which gives appreciable power density and energy density as shown in the figures below.

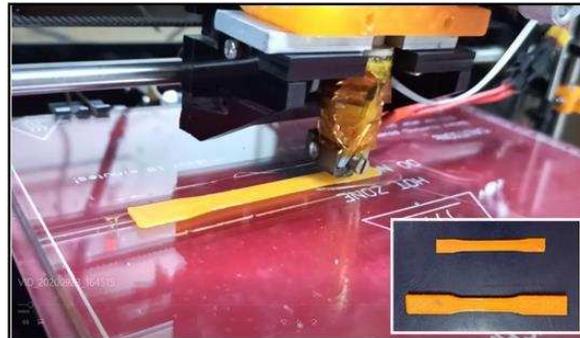


Galvanostatic charge-discharge curves; and Ragone plots for the symmetric super-capacitor device

- **Modified FDM 3D Printer for Polymer Carbon Composite Deposition**

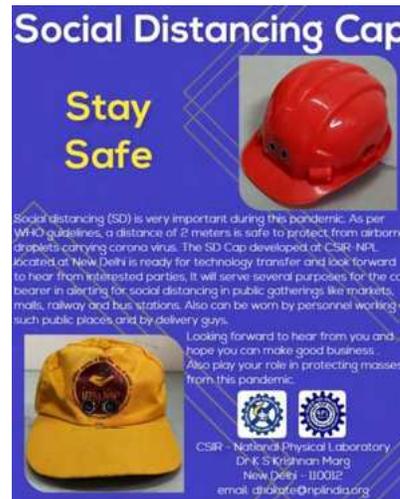
Fused Deposition Modeling (FDM) is an additive manufacturing technique which constructs superior rapid prototypes from 3D CAD data where in a thermo plastic material is extruded in the form of filament. As 3D printing is in its infancy and not acclaimed industrially there is a dire need for standardization of both deposition conditions and the technique for which ASTM D638 tensile sample is deposited for testing strength of plastics and other resin materials. To study the effect of compositional variation on mechanical

properties of FDM printed PLA Carbon composite structures, the extruder of 3D printer is modified for direct feed of carbon precursor.



ASTM D638 tensile test sample under printing using PLA

- **Social Distancing Cap**



Social Distancing helmet and cap

As the need of hour during pandemic, a module has been developed which can be fit onto a cap. It is named as Social distancing cap. This is very helpful for anyone to maintain a distance of 2 meters while getting into public for their day to day requirements. The technology is ready for takeover.

- **Thermoelectric Activity**

Basic research on the development of Half Heusler, Skutterudites and Magnesium Silicides, based p-type and n-type Thermoelectric (TE) material. These materials were synthesized employing a combination of arc melting and spark plasma sintering.

Bhartiya Nirdeshak Dravya (BND): Indian Reference Material: *Division 5*

The main objective of In-House BND group is the preparation and dissemination of In-House BNDs along with the collaboration of various Reference Material Producers.

Accuracy and precision are two main key factors for taking data and to perform scientific measurement. Accuracy signifies how close a measurement is to its actual value. This is essential because bad instrument, poor data processing or human mistake can lead to incorrect results that are not very nearby to the accurate one. Precision is how close a series of measurements of the same thing are to each other. Measurements that are imprecise do not properly identify random errors and can produce a widespread result. In research, new innovations are possible only by doing the accurate and precise measurements. Otherwise the whole research will not be used or considered for the corresponding work. To get accurate and precise results, the instrument to be calibrated by comparing with the reference material, which is often a Reference Material like a BND.

Quality Control Documentation as per ISO 17034:2016 and ISO 17025:2017 prepared for Outreach RMP Group. ISO 17034 covers BND development program and ISO 17025 covers HRXRD activity under the Outreach RMP Group. Peer review by external expert conducted on 18/11/2020. The auditors approved the documents prepared for the Outreach RMP Group.

The following R&D work has been carried out during the period:

- **Synthesis and Characterization of Silver Nanoparticles for TEM BND:**

Silver nanoparticles (AgNPs) were prepared by sol-gel route and characterized by XRD to confirm the formation. The particle size variation with time and stability are checked by HRTEM. To assign life of as prepared Ag NPs BND. It is necessary to record TEM images at regular interval of time. This work was partly hampered due to non-functioning of HRTEM and COVID related lockdowns.

In this context, uniform size (5 nm, 10 nm and 15 nm) Ag NPs with very narrow size distribution (± 2 nm) were synthesized.

- **Development of BNDs of Aqueous Elemental Standard Solution and Building Materials**

Chemical & Food BND Group plays a very important role in the development and certification of several Certified Reference Materials (CRM)/ Bharatiya Nirदेशक Dravyas (BNDs) by In-house and through Reference Material Producers (RMP). Under our Metrology in Chemistry activity, various BNDs have been developed in various matrices supporting to the RMPs. There are sixteen nos. of BNDs developed during this period through RMP Aashvi Technology LLP which are mostly used as calibration standards and for the method validation purposes and being disseminated to the water testing laboratories, Academy Institute, Research Institute of India. Apart from aqueous elemental solution, several Cement and Building Materials BNDs have been produced supporting NCCBM, Faridabad and are used as the primary standard for the cement and building materials calibration and method development. The use of these BNDs will certainly ensure the quality of the end product and lay down quality infrastructure in India.

- **Sponsored/Other Projects**

Our group was involved in the development of Microbial UVC Disinfection Casketin collaboration with M/s Motras Scientific Instrument Pvt Ltd as a member of project CNP 200132 for disinfecting mobile phones, Remotes, keys, and other gadgets which cannot be sanitized using normal procedure. It can be used for protection against viruses and other microbes. An Indian patent has been filed for the same (Patent Application no: 202011021206)

- 1) Process for the joint development of functionized and intrinsic silver/non silver based sanitiser to sanitise various surfaces for microbe inhibition.
- 2) Consultancy on design, development and validation of conveyor based UVC sanitization system.

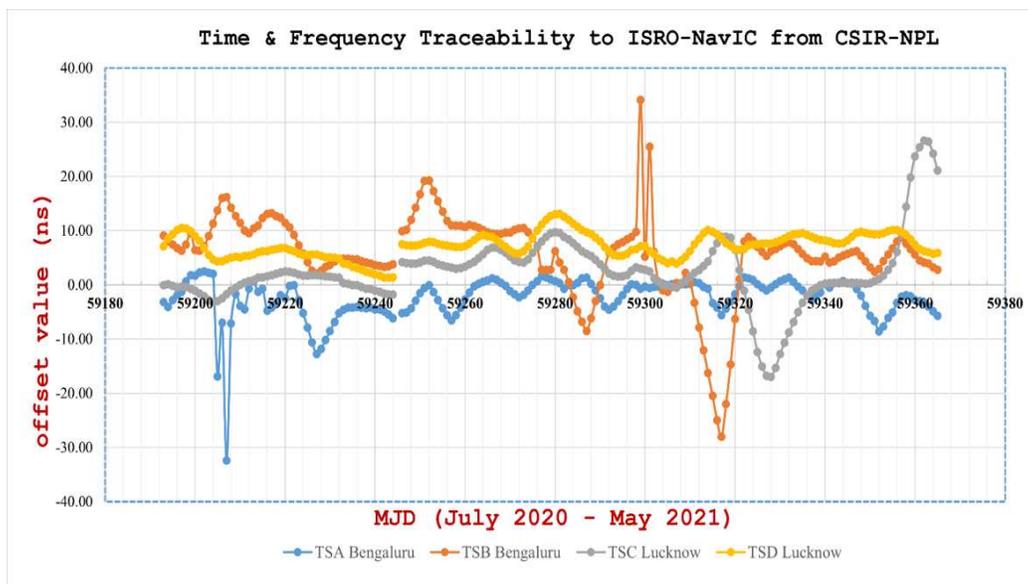
Indian Standard Time Metrology:

Division 6

The Division of Indian Standard Time intends to strengthen and enable the overall development in science and technology towards the service of the country. The prime responsibilities include the realization, establishment and maintenance, custody, dissemination, and up-gradation of the national standards for Time & Frequency, LF & HF Voltage, Current, Microwave, and Magnetic parameters. The Time & Frequency Metrology Section is responsible for the highest level of time and frequency measurements in India using ultraprecise satellite links. The NavIC satellites are likewise synchronized to the time provided by the CSIR-NPL. It maintains a bank of Caesium atomic clocks and a Hydrogen maser. These precise clocks would lose or gain one second in the span of approximately three lakh years. The traceability of this time scale with BIPM is at the level of a few nanoseconds (ns). This Division also provides apex level calibration services in LF & HF Voltage, LF Current, Microwave power and PMU parameters as per ISO/IEC 17025 standards to the industry, strategic sectors, STQC labs & private organizations of the country by maintaining their respective primary standard and also includes an essential metrological activity “Josephson Voltage Standard,” which is one of the Quantum standards at CSIR-NPL. Under this Division, the Microwave metrology includes parameters such as attenuation, impedance, insertion loss followed by free space microwave measurements such as Electric Field, SAR, shielding effectiveness, dielectric measurements, and advanced Quantum E-Field measurements traceable to Planck Constant. The Division also has additional capabilities like cryostat system, E-field, RF I-V impedance analyzer, Phasor Measurement Unit (PMU), nanofabrication facility with the help of Focused Ion Beam (FIB) system. The Division is continuously providing various apex level calibration services in the above parameters to the industry & user organizations of the country. It provides educational training on industrial metrology to support economic growth. It is also involved in developing several indigenous technologies for the societal and industrial benefit to make India self-reliant. A glimpse of activities of each subdivision is described below:

Time and Frequency Metrology

Indian Standard Time (IST) is generated by the Primary Time Scale Ensemble at CSIR-NPL. As the time keeper of the nation, the realization, maintenance and dissemination of Indian Standard Time (IST), is the key responsibility of CSIR-NPL. During the year, CSIR-NPL undertook regular maintenance and upgradation of Time Scale systems, and its environmental conditions for realization of the National Time. The dissemination of IST was provided through Two-way Time and Frequency Transfer (TWSTFT) System and Global Navigation Satellite system (GNSS) to ISRO; and through NTP service to all types of e-services in the country. For the contribution of CSIR-NPL's atomic clocks in the development of international time scale - TAI, and for providing the global visibility to the CSIR-NPL's efforts in time and frequency metrology at the international platform.

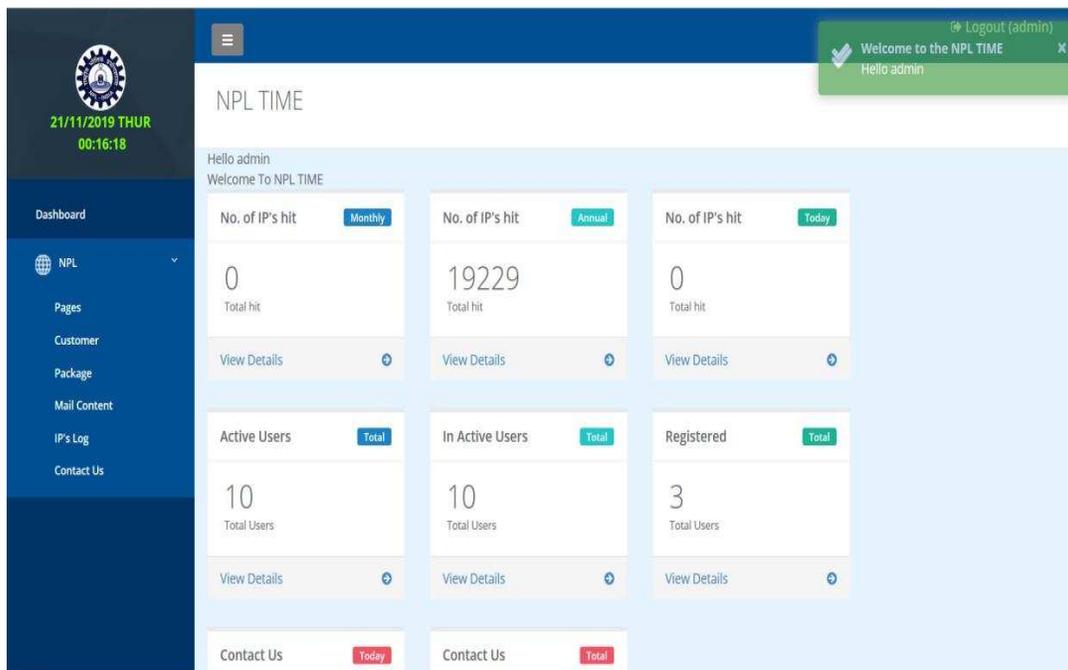


TWSTFT traceability from July 2020 to May 2021 to IRNWT centres located in Bengaluru and Lucknow which maintains the NavIC system time

- **Development of “Samay” Portal**

Time dissemination via internet called Network Time Protocol (NTP) Service is very popular and the only active Time Dissemination available at CSIR-NPL. A guaranteed authenticated service for genuine and critical service users was lacking. To bridge this gap, a Front Desk Portal has been designed and developed. This portal is named as “SAMAY”. This portal is ready to be launched once rigorous testing of the same is completed. Beta

version is expected to be launched in few months. It is planned to be a paid service once independent secured network gets ready. This shall guarantee secure time synchronization to the registered customers. Moreover, this portal will facilitate to know the where-about and credential of the clients.



Admin portal of “Samay” app

- **Cesium Fountain Primary Frequency Standards**

A Cesium atomic fountain frequency standard realizes SI definition of a second with highest accuracy and serves as a primary frequency standard. Worldwide, there are only about 14 Cesium fountains which are operational and contribute to the steering of International Atomic Time (TAI). NPLI successfully completed the development of its first Cesium fountain primary frequency standard known as NPLI-CsF1 a couple of years ago. NPLI-CsF1 has been approved as a primary frequency standard (PFS) in the 20th session of CCTF held in 2015. Along with NPLI-CsF1, a second generation Cesium fountain, NPLI-CsF2 is being developed at NPLI.

NPLI-CsF1 has been evaluated several times for the statistical and systematic biases. More than eight evaluations of NPLI-CsF1 have been submitted to the International Bureau of

Weights and Measures (BIPM) and these have appeared in Circular-T. NPLI-CsF1 also successfully participated in the international comparison campaign between Cesium fountains from PTB Germany, SU Russia, NIM China, and NPLI India. Optical set-up of NPLI-CsF1 is currently being upgraded in order to have it operational continuously without major interruptions.



NPLI-CsF₂ is being built with some new design features which will enhance the accuracy of frequency measurement. So far, most of the electronic subsystems and vacuum sub-assemblies have been tested. The c-filed solenoid has been designed and tested. The magnetic field along the flight path has been mapped and homogenized using compensation coils. At present, optical system of the fountain is being developed. The lasers have been installed, optics is being laid out and beam expanders have been assembled and characterized. The assembly and characterization of the microwave cavity is one of the major challenges ahead in the development of the second fountain.

- **Time Dissemination over Telephone and Internet**

FonOclock is a time dissemination system which has a unique technique to transfer and synchronize FonOclock receiver via Public Switched Telephone Network (PSTN). Its design is indigenous which was developed at NPLI for easier time synchronization over telephone network with commendable synchronization accuracy at low cost. It has mainly three

components, namely, the transmitter (time server), a transmission channel (PSTN), and a receiver. It basically has two phases of development. First phase of the development is for the public use where high precision is not much of concern but the device and service have to be economical. It consists of transmitter and receiver which are embedded with a low-cost soft modem and a micro-controller. The microcontroller, which is configured with 16MHz crystal oscillator, operates the complete time dissemination and synchronization mechanism. Synchronization accuracy up to ± 10 ms is achieved routinely with the system. Several LED Fonoclock IST time displays have been put up around the CSIR-NPL campus and they are always synchronized to IST via telephone line. A calibration technique has also been developed to reduce the drift of the crystal oscillator on the receiver board. In the second phase of development, work is being done to improve the precision and accuracy (up to ± 1 ms) which is required in many sectors where time stamping is of utmost important and cost is not much of concern. Upon evaluation of the system thoroughly, it was found that uncertainty is solely dependent on the instrumentation, majorly on the modem, rather than PSTN channel. Some new good quality hard modems are being tested to improve the accuracy.

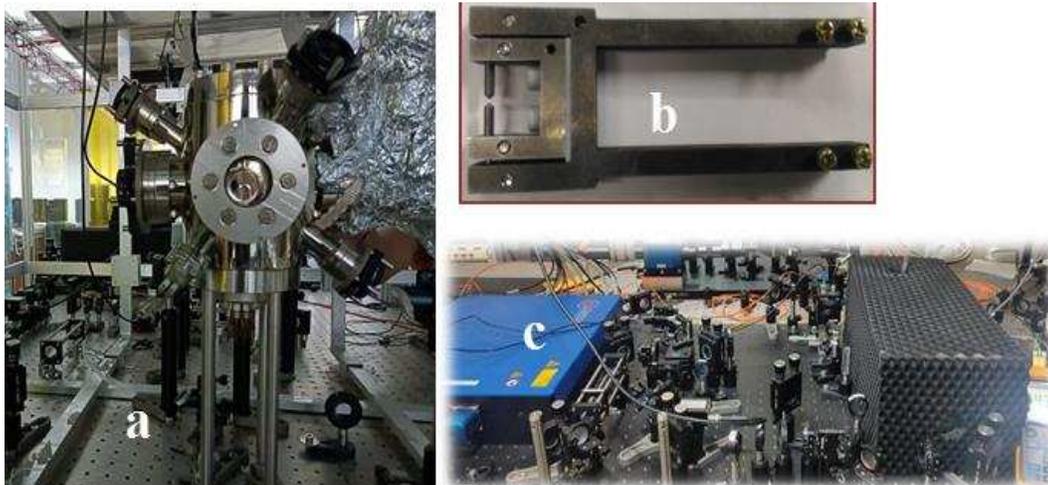


Network Time Display (NTD) devices synchronizes itself to UTC(NPLI) from NTP server ('time.nplindia.org'). Two compact and affordable Network Time Display (NTD) devices have been developed to display IST and their performance is being optimized. In the first device, Raspberry Pi had been used to access time information from NPLI NTP server, and time is displayed on an LCD. In the second device, a Wi-Fi module has been programmed to operate and synchronize the device to IST via NTP server. Once completely tested, these devices will be up for technology transfer and commercialization.

Additionally, with most of the services available in mobile software application, an android application for a user/client to directly access IST has been developed. The mobile application displays accurate IST obtained from CSIR-NPL's NTP servers. The mobile application is being tested thoroughly. Moreover, an IOS based version of the application is being prepared. Once launched for public, this application developed by CSIR-NPL, the NMI of India, will become IST dissemination service having wider reach than any other time dissemination service of CSIR-NPL.

- **Development of an Optical Frequency Standard**

CSIR-NPL carrying activities on “quantum metrology in time and frequency” towards developing an optical atomic clock based on the highly forbidden $4f^{14}6s\ ^2S_{1/2} - 4f^{14}5d\ ^2D_{3/2}$ quadrupole transition of Ytterbium-ion ($^{171}\text{Yb}^+$). This work involves several stages- the theoretical computation associated with the design of single-ion trap potential, the design and construction of the ion trap module based on the calculations, the main trap vacuum chamber, a custom designed helical resonator for delivering impedance matched high voltage RF to the trap electrodes for creating a precise ion trap potential, the oven for generating the neutral Yb atomic beam. The Yb^+ ions will be created by photo-ionizing the neutral Yb atoms. Initial tests for production of ions in a separate vacuum chamber has been carried out and confirmed by spectroscopic techniques. Currently work is under progress to realize the cooling lasers and their locking to pre-defined atomic cooling transitions, and the development of associated electronics & instrumentation.



** (a) Main vacuum chamber (b) end cap type ion trap and (c) Laser system

LF & HF Voltage, Current and Microwave Metrology

LF & HF Voltage, Current and Microwave Metrology section, is working with an objective to develop, maintain and upgrade national standards of LF & HF Voltage, Current, PMU-CAL (Phasor Measurement Unit Calibration) System and Microwave Metrology as per international level and disseminate traceability of measurement through apex level calibration to the industries-power sectors, STQC Labs, calibration laboratories & allied industries in India and to SAARC countries as per quality system ISO/IEC-17025:2017, so that India remains at par with international measurement laboratories.



CSIR-NPL PMU CAL system

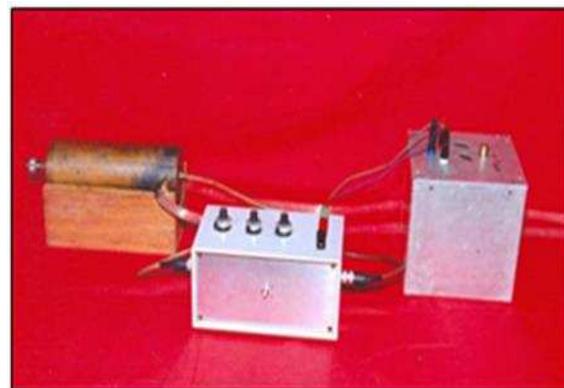
PMU (Phasor Measurement Unit) is basically a monitoring device that captures data at a very high speed and each measurement is time stamped to a common time reference. PMU Calibration System is used to test/calibrate PMUs and report the errors, as the difference between the systems reported 'True' values and the measured output. Errors are reported in the form of Total Vector Error (TVE), Frequency Error (FE) and Rate of Change of Frequency Error (RFE) as per IEEE C.37.118.1a-2014 standard. CSIR-NPL PMU CAL System traceability has been established against the primary standards of CSIR-NPL that are at par to international level. PMU-CAL system metrological characterization using PMU reference standard has been carried out which will lead to good efficiency and reliability. Our potential users are CPRI Bangalore, IDEMI Mumbai, PGCIL Haryana for calibration of PMU CAL system and SEBIs, SEL PMU, Valliant PMU, power regulators (POSCO) for calibration and testing of PMUs.

We are defending 26 existing CMCs and have proposed 09 new CMCs to be validated and approved in the forthcoming Peer review. Microwave Power section provides apex level

calibration services and dissemination of standards for maintaining the traceability in microwave power measurements up to 10 mW in the frequency range of 1 MHz to 50 GHz with an uncertainty of $\pm 1.9\%$ at 50 GHz. The National standards (2.4mm/7mm Coaxial Microcalorimeter System) of microwave power have been re-established up to 50 GHz which is showing reproducible results. Reference standards of Microwave power has been used for calibrating power standards of ETDC Bangalore and BEL Ghaziabad. LF Voltage & Current activity has the responsibility for the establishment, maintenance, updating the Primary Standards and calibration facilities for the LF voltage and current. Traceability of the Low Frequency Voltage at 2V, 10 Hz to 1 MHz and Current standard at 5 mA, 40 Hz to 10 kHz is accomplished with Primary Standard (MJTC). The established standards have the uncertainty from $\pm 5\text{ppm}$ to $\pm 20\text{ppm}$ and will be used to calibrate the transfer standards of Notional and user organizations. The traceability of thermal transfer Standard covering voltage range 250 mV to 1000 V and the traceability of Low Voltage Thermal Converter, standards of low voltage measurements, covering voltage range 1mV to 200 mV in the frequency range 10 Hz to 1 MHz is to the primary standard of LF voltage with an uncertainty of $\pm 7\text{ppm}$ to $\pm 1000\text{ppm}$. The traceability of thermal current converters covering the current range from 1 mA to 20 A is to the primary standard of LF current in the frequency range 10 Hz to 10 kHz with an uncertainty of $\pm 10\text{ppm}$ to $\pm 92\text{ppm}$. We have also initiated the processes of establishing in-house traceability of RF Voltage Primary Standard from DC Resistance, RF Impedance and Microwave Power and will be validating the measurement results through a bilateral comparison with PTB Germany.



2.4mm Coaxial microcalorimeter

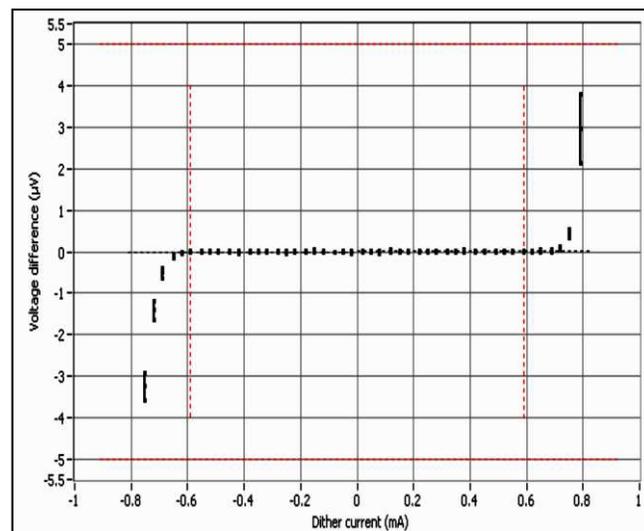


HF voltage primary standard

- **Programmable Josephson Voltage Standard (PJVS)**

Quantum effects play a fundamental role in modern metrology for the realization of the SI electrical units because of their exquisite precision. This metrology group at CSIR-NPL maintains one such quantum effect-based standard, namely Programmable Josephson voltage standard (PJVS) system, for disseminating the unit 'volt'. This group is involved in the precision measurements of voltage levels that are intrinsically accurate and repeatable for the realization of voltage and assign the measurement values and uncertainties based on fundamental constants.

The Programmable Josephson Voltage Standard, established at CSIR-NPL is characterized for its optimal functioning to disseminate 'Unit' Volt at par to international level. This optimization in the characterization of the system has ensured us to operate the system consistently and with better stability and reproducibility. The center position of output voltage states was analyzed and optimized to get symmetric DC flat spot measurements. When a PJVS circuit is operated, the arrays of junctions are biased at a fixed microwave frequency, and the microwave power is chosen to simultaneously produce three constant voltage steps ($n = -1, 0, \text{ and } +1$), each of which has a current range of at least 1 mA.



DC flatspot test at 18.645 GHz and -0.0 dBm

This group provides calibration services to disseminate the primary voltage standard. The 10 V PJVS system is capable of providing traceability at 1.018 V and 10 V levels. This system is

primarily used for the calibration of dc reference standards which serves as secondary standard of voltage for further dissemination to industries.

Electromagnetic Metrology

Electromagnetic (EM) Metrology at CSIR-NPL comprises of various measurement facilities in frequency range from 1 Hz to 110 GHz of electromagnetic spectrum for devices from household electronic appliances to advanced strategic communication and instrumentation. CSIR-NPL (NMI of the country) provides measurements for microwave frequencies from 9 kHz to 110 GHz frequency range that is precise, accurate, reliable, internationally recognized and traceable to the SI units through Microwave Metrology and Magnetic Metrology. The Microwave and Magnetic based National Standards and measurement capabilities are realized, established, maintained, and upgraded at CSIR-NPL. These standards are disseminated to reference laboratories across India to provide traceability to various sectors: strategic, defence, manufacturers, testing industries, government regulators and research institutions. Electromagnetic metrology at CSIR-NPL has a unique combination of comprehensive capabilities of various parameters of Electromagnetics such as attenuation, microwave power, E-Field and specific absorption rate (SAR), Magnetic flux Density, Magnetic flux, turn area of search coil, power loss measurement of electrical steel, along with various free space measurements parameters. Upcoming 5G technology is not just a routine technological change but a platform to enable several smart technologies such as smart banking, smart city, smart village, smart healthcare smart automobile and many more. This shows the overall impact of Electromagnetic metrology on country's upcoming technological needs.

Microwave metrology includes parameters such as attenuation, impedance, insertion loss followed by free space microwave measurements such as Electric Filed, SAR, Shielding effectiveness, dielectric measurements along with advanced Quantum E-Field measurements traceable to Plank Constant. Each parameter have their associated primary standards, their calibration and measurement capabilities (CMCs) and their degree of equivalence with the leading NMIs of the world, and associated on-going research for advanced measurements including quantum standards.

Magnetic metrology deals with maintaining and upgrading National Standard related to magnetic parameter like Magnetic flux Density, Magnetic flux, turn area of search coil, power loss measurement of electrical steel, through continuous development. Calibration and testing facility are provided for these parameters to industries and institutions as per ISO/IEC: 17025 guidelines which are traceable internationally. Traceability is maintained and disseminated by means of Calibration of permanent Magnet, Calibration of AC/DC Gaussmeter, Calibration of Magnetic field indicator, Calibration of low field magnetometer, Calibration of Helmholtz Coil, Calibration of Flux meter, Calibration of Turn area of search coil, Testing of AC/DC electromagnet, Power loss measurement of Electrical Steel, Magnetic Radiation Measurement, etc.

In addition to calibration and testing services, training, human resource development and technical consultancy are also being provided.

Microwave Metrology

Microwave Metrology at CSIR-NPL exhibits an international degree of equivalence for various measurement parameters such as Microwave Power, Attenuation, Impedance, E-Field, Shielding Effectiveness, Radiated power density, Specific Absorption Rate in the frequency range from 9 kHz to 50 GHz with fifteen registered CMC's and seven international inter-comparisons. Microwave Metrology also engages in Dielectric Material characterization (ϵ and σ) for Lossy Liquids and biological materials by using commercial open ended Dielectric probe, along with VNA (ZNB 8), for frequencies up to 6 GHz as recommended in IEEE-1528 2013 standard. However, the IEEE-1528:2013 standard, is now superseded by the new IEEE/IEC-62209 1528: 2020 standard, which has made few advancements to measurement methods and standards used. The traceability is being established by using multiple reference liquids measured at standard temperatures and inter-comparison. Also, upgradation for this measurement facility for higher frequencies up to 10 GHz to incorporate upcoming 5G frequencies in underway as well.

Electromagnetic metrology section has already completed a technology transfer for “process-know how for Tissue Equivalent liquids as per IEEE-1528 standard” on Sept 24, 2020. We are working to extend the scope of this by preparation or standard TELs for

upcoming 5G frequencies. These TELs are being prepared as per by the new IEEE/IEC-62209 1528: 2020 standard, which require different chemicals from the ones used for previous studies. Also, for BND purpose, the properties of TELs are being measured and recorded at various temperatures in range 10°C to 50°C along with shelf-life study, stability and temperature tolerance studies to be carried out.

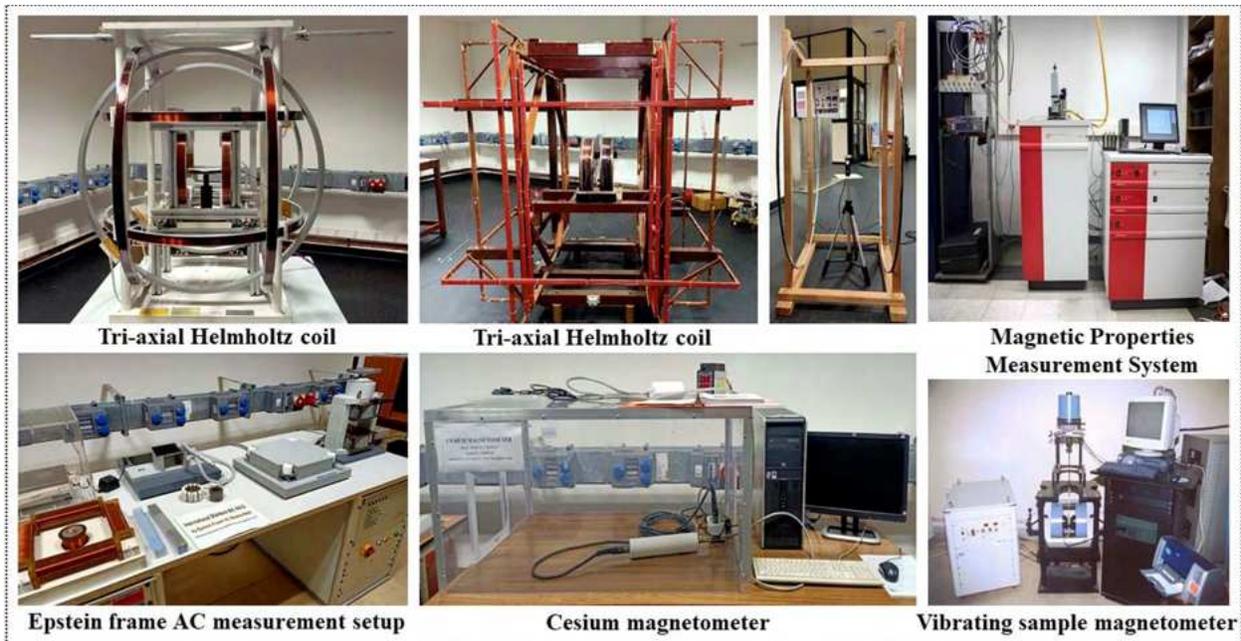
Vector SAR measurement system, CSIR-NPL has partnered with EURAMET consortium for development of calibration methods for probe calibration of time domain probes and arrays for vector SAR measurement systems. These probe measure simultaneous amplitude and phase at much faster rate than the existing SAR measurement systems/probes. In this work, CSIR-NPL plans to establish its own vector SAR assessment facility and provide traceability to vector SAR measurement in the country by allowing technology transfer to different organizations. A Specific Absorption Rate (SAR) evaluation system is indigenously developed by CSIR-NPL. In this setup E-Field Sensor, Tissue equivalent liquid, Robotic automation (Robotic arm procured from epson) and a controlled GUI are being indigenously developed. The system is capable to evaluate SAR upto 3W/kg with an expanded uncertainty of $\pm 0.15\text{W/kg}$ per 1.6W/kg.



SAR measurement setup at CSIR-National Physical Laboratory

Magnetic Metrology

This section is responsible for maintaining and upgrading National Standard related to the magnetic parameter like Magnetic flux Density, Magnetic flux, turn area of search coil, power loss measurement of electrical steel, through continuous development and providing calibration/test services (as per ISO/IEC: 17025 guidelines) to more than 100 customers (MSME sectors, Large scale industries, Govt. organizations and R&D institutes like Indian Air Force, Air India, Power Grid, CPRI, IDEMI, ERTL, ETDC, ABB, Siemens, Samsung, GE Healthcare, L&T, Adani power, Genus Power, Secure Meters etc.) to improve the quality infrastructure of India.



Available facilities:

- Low magnetic field measurement facility (AC/DC): 1 to 2000 μT (expanded uncertainty 1.6-0.5 %).
- AC magnetic field measurement setup: range 10 mG to 20 G (50 Hz).
- Magnetic flux measurement of range 0.0001-10 weber with uncertainty of ± 0.005 to 0.15 %.
- Cesium magnetometer: measuring magnetic field of Nano tesla range i.e., 10000-1 nT.

Directorate

This division comprises of Planning, Monitoring Evaluation and Outreach; Industrial Liaison Group; Centre for Calibration & Testing; Workshop; International Science and Technology Affairs Group; Human Resource Development Group; Administration; Quality Management System; Rajbhasha Unit; Knowledge Resource Centre; Finance &Accounts Store & Purchase Section; Works & Services.

Planning, Monitoring Evaluation and Outreach

CSIR-NPL undertakes projects sponsored by various external agencies such as Ministry of Science & Technology, MNRE, DST, etc. The department is involved in the planning, monitoring and evaluation of the various type of GAP, TLP, FTT, SSP, CLP & Mission Mode projects. The details of External Cash Flow i.e., money received from these agencies to carry out specified project is regularly recorded and monitored by PME against the target established by the Institute. Registration of all projects and allotment of specific identity in terms of a Project No. is made at PME, soon after the money for the project is received along with In-Principle approval. Projects are registered in different modes viz FTT, mission mode, Sponsored research, Grant-in-Aid, Collaborative and CNP. The total number of projects registered in different modes during **2020-21 is 18**. In the year 2020-21, **three** new GAP projects have started worth **Rs. 1.31 Crores**, while five New MLP/HCP CSIR Funded projects have taken off, costing **Rs. 16.85 Crores**. A grant of **Rs. 26.09 Crores** in the twenty-one continuing GAP projects was received.

Apart from this, PME also attends to technical queries, Parliament Questions and technical audit as well as assist Director in liaisoning with CSIR-HQ, Management Council (MC) and Research Council (RC) on project related matters. In 2020-21, **PME has successfully conducted 03 Research Council and 06 Institutional Scientific Review Meetings**. PME has processed **1627 indents** worth **Rs. 90.01 Crores**.

Business Development Group (BDG)

The Business Development Group (BDG) earlier Industrial Liaison Group (ILG) serves as an interface between CSIR-NPL and Government/Public/Private Organizations, Industries, Universities etc. BDG plays an active role for show-casing technologies and know-hows developed by CSIR-NPL to the stakeholders at various platforms including CSIR-NPL website. BDG further facilitates utilization of CSIR-NPL knowledgebase by licensing the technologies/knowhow to the Industries and other stakeholders. BDG also offers consultancy and technical services to the clients in time bound project mode for utilization of expertise available within CSIR-NPL regarding development of new products/processes and for improvement of Quality System in the country. Contract Research Projects (sponsored/collaborative etc) are also undertaken to cater to the specific requirements of the Industry. BDG receives a number of queries on daily basis through telephone, emails and personal visits. Further to serve the country, during Covid-19, BDG had collaborated with many Industries to provide pandemic oriented solutions in various project modes. To establish long term association with the clients, BDG also handles signing of MoUs, Agreements and NDAs with the Indian Industries, Institutes, Research Organizations etc along with registration of new Bharatiya Nirdeshak Dravya (BNDs). In addition to this, BDG is proactively involved in management of S&T outputs including generation of various reports to be sent to CSIR-Head Quarters.

The details of the technology/know-how licensed, MoUs signed, dissemination of traceability through BNDs and consultancy/sponsored/technical services projects undertaken during this period has been given below:

- **Consultancy Projects**

Sl No	Project Title	Client	Project cost including GST
1	Feasibility studies on the Design and Development of UV sanitization chamber based on UVC characterization	Motras Scientific Co. Ltd, Sector 7, IMT Manesar, Gurugram, Haryana	Rs. 2,36,000
2	Process for the joint development of functionalized & intrinsic silver/non-silver based sanitizer	Speciality Organics Pvt. Ltd, Industrial Area, Mandideep, Distt; Raisen 462046	Rs. 2,95,000

	to sanitize various surfaces for microbe inhibition		
3	To Conduct Proficiency Testing (PT) program on heavy metals in rice flour for the Rice Testing Laboratories	LT Foods Limited, G T Road, Bahalgarh, Sonipat, Haryana-131021	Rs. 3,49,870
4	Consultancy on design, development and validation of Conveyor based UVC Sanitization System	DR Optical Disc India Pvt Ltd, Phase-II, Mayapuri Indl. Area, New Delhi-110064	Rs. 3,54,000
5	Consultancy for the Development of Ultrasonic Standard Time Delay Blocks for 40 kHz to 50 kHz Applications	M/s Ojasv Scientific, Giri Nagar, Kalkaji New Delhi- 110019	Rs. 2,36,000
6	Consultancy on design and development of UVC based air microbial disinfection unit in an enclosed environment	M/s Life Force, Hasanpur, I.P. Extn, New Delhi-110092	Rs. 2,36,000
7	Consultancy for the development and validation of Noise Monitoring Terminal	West Bengal Electronics Industry Development Corporation Ltd., (WEBEL), Taratala Road, Kolkata-700088, West Bengal	Rs. 5,90,000

- Collaborative Projects**

Sl No	Project Title	Client	Project cost including GST
1	Design and Development of ventilator system through Rapidly Prototyped Polymeric Components	M/s 3D Paradise, Lajpat Nagar 1, New Delhi-110024	Rs. 2,36,000

- Technical Services Projects**

Sl No	Project Title	Client	Project cost (including GST)	Money Received (Rs)
1	Development of timing laboratories of Legal Metrology Department (LM) traceable to National Time Scale generating IST at five locations and creation of one disaster recovery center (old running project)	M/s Legal Metrology Department, Department of Consumer Affair, New Delhi, Govt of India	Rs. 87,39,00,000	Rs. 24,10,15,000
2	Technical services for the preparation of specifications, budget estimate and vetting of specifications of various calibration systems required by DRDO-SASE to be established at Manali Center"	Director, Snow & Avalanche Study Estt. (DRDO-SASE), Research & Development Center, Him Parisar Chandigarh 160 036	Rs. 35,40,000	Rs. 32,40,000

- Registration of Bharatiya Nirdeshak Dravya (BND), Indian Reference Material with Reference Material Producers (RMPs)**

Sl No	Project title	Funding agency	No of BNDs	Money received (Rs.) including GST
1	Dissemination of Metrological Traceability through Chemical BNDs	Bharat petroleum corporation Ltd (BPCL), Ballard Estate, Mumbai City, Maharashtra-400038	3	Rs. 35,400
2	Dissemination of	Aashvi Technology LLP,	6	Rs. 70,800

	Metrological Traceability through Chemical (water) BNDs	Shahibaug, Ahmedabad, Gujarat-380004		
3	Dissemination of Metrological Traceability through BNDs	SUMS Techno Labs Private Ltd, Sankalapura Industrial area, Ballari Main Road, Hospet, Ballari (Bellary), Karnataka-583201	4	Rs. 47,200

- Licensing of Technology/Know-How**

Sl. No.	Name of the technology/Know-how	Name of the client	Date of licensing
1	A Microbial UVC Disinfection Casket; Project cost : Rs. 2.36 Lakh including GST; Non exclusive	Motras Scientific Co. Ltd, IMT Manesar, Gurugram, Haryana	20-May-2020
2	Tissue Equivalent Liquids as per IEEE-1528 for SAR compliance Testing; Lumpsum : Rs. 5,60,000 including GST; Non exclusive	FARE Labs Private Limited; IFFCO Chowk, M.G. Road, Gurgaon-122002, Haryana	24-Sep-2020
3	Process for development of polystyrene films; Lumpsum: Rs. 5,60,000 including GST; Non exclusive	M/s Sirim Scientific Solutions, Srinivasapuram, Ramanthapur, Hyderabad, Pin-500013, Telangana	06-Oct-2020

- Agreements/MoUs/NDA etc signed by CSIR-NPL**

Sl. No.	Name of the company/Industry/Organization	Signing date
1	Agreement with FARE Labs Private Limited, Gurugram, Haryana for "Production of Bhartiya Nirdeshak Dravyas (BND)"	20-May-2020
2	Agreement with M/s Jalan and company, New Delhi for "Production of Bhartiya Nirdeshak Dravyas (BND)".	20-May-2020
3	License Agreement with Motras Scientific Instruments Private Limited, Gurugram, Haryana for the "Joint development of Microbial UVC Disinfection Casket".	20-May-2020

4	License Agreement with FARE Labs Private Limited; Gurugram, Haryana for transfer of know-how for the process “Tissue Equivalent Liquids as per IEEE-1528 for SAR compliance Testing”.	24-Sep-2020
5	License Agreement with M/s Sirim Scientific Solutions, Hyderabad, Telangana for licensing of know-how “Process for development of polystyrene films”.	06-Oct-2020
6	License Agreement with Bhabha Atomic Research Centre (BARC) (Designated Institute for Ionizing Radiation) Mumbai-400085, Maharashtra “to assess the Quality System of Radiation Standard Section (RSS) of BARC”.	22-Oct-2020

Centre for Calibration and Testing Centre

Centre for Calibration and Testing has been setup to promote calibration, testing and BND services of CSIR-NPL. It acts as an interface between clients and all the calibration, testing and BND groups at CSIR-NPL. CFCT is responsible for accepting the applications, generating case files and sending calibration certificates and testing reports to the clients. It maintains a client database of more than 4205 clients from industries, national laboratories, and government organizations from all over the country and abroad, including SAARC nations. About 81% of them are private industries, 13% government organizations and rest are PSU’s & SAARC clients.

During the year 2020-21 the revenue generated from calibration and testing is Rs. 10.22 crore. This centre follows/maintains the Laboratory Quality System ISO 17025 and ISO 17034:2016

- ECF (non-notional) 10.22 crores
- Reports(non-notional) 1943
- Reports(notional) 688

Total No of clients registered with CSIR-NPL is 4205. It would be difficult to give list of all 4205 clients, but some of the important ones are given below:

Government/Semi-government organizations: Air Force; Air India; Bharat Electronics; BHEL; Bhilai Steel Plant; Bureau of Indian Standards; Central Pollution Control Board; Central Power Research Institute; Central Public Works Department; Railway Information System; Central Institute of Mining and Fuel Research; Defense Electronics Applications Laboratory; Delhi Jal Board; Directorate of Border Security Force; Hindustan Aeronautic Limited; Indian Oil; ISRO Inertial Systems Unit; Maharashtra State Electricity Board; Micro,

Small and Medium Enterprise Testing Center; NTPC; Nuclear Fuel Complex (DAE); Ordnance Factory; Rail Coach Factory; FCRI, DRDO, etc.

Industries: ABB India; ACC; AIMIL Ltd.; Alstom India; Ambuja Cement; Binani Cement; Birla Tyres; Blue Star; Bureau Veritas; Casio India; Crompton Greaves Limited; Diesel Locomotive Works; Essar Oil Ltd.; Godrej & Boyce Mfg. Co. Ltd; Havells India; Honda Cars; International Zinc Association; J.K. White Cement; JK Lakshmi Cement; Kirloskar Brothers; Larsen & Toubro; Maruti Suzuki; Mysore Paints & Varnish; Philips India; Piramal Healthcare; Ranbaxy; Rapid Metro Rail Gurgaon; Samsung India; Endress + Hauser India Pvt. Ltd.; Capital Power, Itron, Padmini VNA Mechatronics etc.

SAARC Nations: Nepal Bureau of Standards & Metrology (MBSM), Nepal; Bangladesh Standards and Testing Institution (BSTI), Bangladesh; Measurement Units, Standards and Services Department (MUSSD), Sri Lanka; National Physical and Standards Laboratory (NPSL), Pakistan; Bhutan Standards Bureau (BSB), Bhutan; Afghanistan National Standards Authority (ANSA), Afghanistan; Maldives Standards and Metrology Unit (MSMU), Maldives.

The centre has also generated data for State-wise distribution of metrological services of CSIR-NPL across the country. The data shows that majority of the clients utilising the services at CSIR-NPL are from four states, namely- New Delhi, Maharashtra, Haryana and Uttar Pradesh. Rest of the states form less than 50% of the entire clientele. The data also shows that the north eastern states of India and the union territories (except Delhi) aren't using the technical services provided by CSIR-NPL. CSIR-NPL is reaching out to all the states and UTs in the country and also to spread the awareness about accurate measurements.

Also, data for Sector-wise distribution of Industries & various Organizations in a State of India that use metrological services of CSIR-NPL was generated. This was done for all the states in the country. The data gives the dominant industry in a particular state and could be used for future planning by the Government as well as CSIR-NPL. Also, it is knowledge generation.

A 25% waiver scheme for the micro MSME enterprises was initiated and processed by CFCT this year. In this scheme, the micro MSME enterprises would get a 25% waiver in the actual calibration, testing and in-house BND charges. The micro MSME have been classified as the enterprises with turnover that does not exceed five crore rupees. It was also decided that the micro MSME would have to produce a certificate from the MSME ministry to avail this waiver.

Central Workshop

Central Workshop of the CSIR-National Physical Laboratory provides technical services related to design, drawing and development of new experimental set up/instruments, fabrication of high precision components, repair and maintenance of existing instruments/setup required by the various section of the laboratory. In addition to that this facility also provides inside campus mechanical maintenance and other related work etc.

The central workshop equipped with the state-of-the-art facilities:

- 4-Axis Deckle Make CNC Milling Machine with FANUC Controller
- Precision Lathe Machines
- Micro Milling Machines
- Tool and Cutter Grinder
- Precision Surface Grinder
- Sheet Metal and Fitting Shop
- Welding and Glass Technology Workshop

During the period under report, 359 jobs in workshop and 88 jobs in GTU were done. Some of the Instruments/components were fabricated in the workshop. During Covid-19 pandemic condition, the Central Workshop supported the Testing Facility Project for PPE Kits, Ventilators and IR Thermal Body Scanner by fabricating a number of components/parts in shortest possible time. Some of the items/parts fabricated are Hydrostatic Resistance Test set-up as per ASTM D-751, Spray Head of Impact Penetration Set-up, Particles on Mask Sampling (PMS) probe as per IS/ASTM standard, Set-up for Water Wave Transmission Rate (WVTR) Testing. Also some of the fabrications and fitting works were

carried out for Mechanical Blood Pressure Measuring System for Legal Metrology Department, Govt. of India. Fig. 1 shows photographs of some of the set-ups where Central Workshop supported in fabrication and fitting work.

Beside this, the central workshop helps in the maintenance of Apex level standards and establishment of new facility/Instrument, fabrication of the accessories and components used for calibration and testing in the different standards lab.



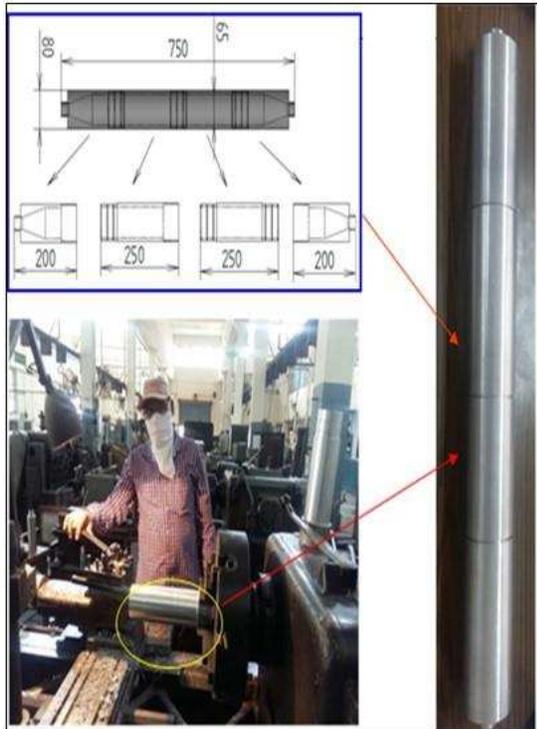
Hydrostatic resistance test set-up as per ASTM D-751



Set-up for water wave transmission rate (WVTR) testing



Fabrication of Spray Head of Impact Penetration Set-up



Fabrication of Particles on Mask Sampling (PMS) probe as per IS/ASTM standard



A Mechanical Blood Pressure Measuring System for Legal Metrology Department, Govt. of India
(Some of the fabrication and fitting works were carried out at Central Workshop)

Contribution of central workshop to support different R&D activities

International Science and Technology Affairs Group

International Scientific Collaborations are assisting the scientists to share their ideas & papers for developing new technologies & bridging the gap between them for the service of mankind. ISTAG group facilitates the overseas visits of scientific and technical personnel of the laboratory to get acquaintance & learn new techniques. It advises the scientists to participate in International Conferences, Seminars and Summer Schools. It helps the scientists to get prestigious international fellowships. This group also advises the scientists to avail bilateral exchange programme. The total numbers of visits conducted by the CSIR-NPL scientists/technologists were nil during 2020-21 due to corona pandemic. The group also encourages and facilitates the visits of young students to abroad. This year nil students visited abroad for attending International conferences/seminars/ workshops and others for research oriented programmes. It also organizes the visit of foreign delegations at CSIR-NPL. International experts are also invited to deliver talks and lectures at CSIR-NPL.

The total numbers of foreign delegations visited CSIR-NPL were nil during 2020-21 due to covid condition in India. The scientific staff is motivated to avail sabbatical leave/study leave. Arranging training programmes for international candidates is also the job of this group. International collaborative projects, bilateral exchange programme and MOU are also handled by this group.

Human Resource Development Group

During the period major activities of the group are as follows:

1. Ph.D. Registration and other Support to Research Fellows

One of the most prominent activities of the CSIR-NPL is to provide help and support to Research Fellows (JRFs / SRFs), starting from the time they join the institute till the time they leave the CSIR-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 /up-gradation, deputation to attend conferences, etc.

During the period from 1st April, 2020 to 31st March, 2021, 48 research fellows (JRFs/SRFs) joined CSIR-NPL and AcSIR Ph.D. Programme, resulting in a total strength of Research Fellows (JRFs+SRFs) in CSIR-NPL is 300 as on 31.03.2021.

2. Organization of Student's Training at CSIR-NPL

CSIR-NPL provides training 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 CSIR-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, 2020 to 31st March, 2021 total 53 students were provided training oriented towards the fulfillment of their academic degree requirements in different areas of research under the guidance of senior scientists.

ECF Generated : 4,21,260/-

3. Deputation of CSIR-NPL Staff Members to Attend Conferences / Similar Events

CSIR-NPL encourages and supports its staff members, including the floating members 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 CSIR-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, 2020 to 31st March, 2021 , total 86 cases of CSIR-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.

4. Skill Development Programme in CSIR-NPL

Precision Measurement and Quality Control Certification Course (PMQC) batch Placement interview were organized by inviting interested organization. A good placement ratio was achieved. The course has been further recognized by AcSIR and this year first batch of PG Diploma was started.

5. Jigyasha Programme with Kendriya Vidhyalaya Sangathan

Total Programme: 3; Student: 390 + 40 Teachers during 2020-2021

Quality Management System

CSIR-NPL is mandated to be India's "National Metrology Institute" (NMI) by the Act of Parliament since 1956. CSIR-NPL is the custodian of "National Standards" with a responsibility of realization, establishment, up-gradation, maintenance and dissemination of standards at par to international level. Being NMI, NPLI is the apex laboratory for calibration/testing/BND activities in the country. NPLI has already in place a recognized

Quality Management System (QMS) based ISO/IEC 17 025 and is able to demonstrate technical competence at the international level and 236 Calibration and Measurement Capabilities (CMCs) are registered in KCDB at BIPM website. Bharatiya Nirdeshak Dravya (BND) – Indian Reference Material is the registered trademark of CSIR-NPL. In view of the above, CSIR-NPL has recently implemented QMS based on ISO/IEC 17025 : 2017 and/or ISO 17034 : 2016 in various Metrological Activities. Preparation of new Quality Manual: NPLI has been following Quality System based on IS/ISO/IEC 17025 for last two decades. Time to time, revision of Quality Manual is also mandatory for NPLI as per current edition of respective standard. Accordingly, two committees for “Implementation of IS/ISO/IEC 17025 : 2017 and IS/ISO 17034 : 2016” were constituted by the Director for transition from IS/ISO/IEC 17025 : 2005 to IS/ISO/IEC 17025 : 2017 for calibration & testing activities and adoption of IS/ISO 17034 : 2016 for BND (CRM/RM). Both the committees, discussed and deliberated among committee members regarding all the aspects of standards, existing Govt. and CSIR rules for the preparation of integrated “Quality Manual” based on IS/ISO/IEC 17025 : 2017 and IS/ISO 17034 : 2016. Quality Manual consists of policies, objectives, procedures and guidelines for preparation of Document Manual in various Sub-Divisions covered under QMS. New Quality Manual was issued in May 2020. Implementation of new Quality Manual : The Sub-Divisions prepared Document Manuals as per new Quality Manual fulfilling the requirements of IS/ISO/IEC 17025 : 2017 and/or IS/ISO 17034 : 2016, as applicable to respective Sub-Division. Internal audits of various SubDivisions were scheduled and conducted. Thereafter, QMS convened the Steering Committee Meeting that was chaired by the Director. International Peer Review of Quality System: As per the provisions in Asia Pacific Metrology Program (APMP) Guidelines for on-site Peer Reviews/Assessments under Unexpected Circumstance due to Covid-19 issued in May, 2020, separate peer review of Quality System of NPLI was planned. Necessary approval for the schedule and Quality Expert was obtained from APMP Technical Committee on Quality System (TCQS) Chair. Peer Review of Quality System of 23



Opening Meeting of Peer Review on Quality System (17.11.2020)

activities of NPLI was conducted as per ISO/IEC 17025 : 2017 and ISO 17034 : 2016 during November 17-19, 2020. These includes Quality Management System (QMS), Centre for Calibration and Testing (CFCT) - Customer Interface, Mass, Volume, Density and Viscosity; Length and Dimension; Temperature and Humidity; Optical Radiation; Force and Hardness; Pressure, Vacuum and Ultrasonic; Acoustic and Vibration; Fluid Flow; LF, HF Impedance and DC; AC High Voltage & Current; AC Power & Energy; Quantum Hall Resistance; Time and Frequency; LF, HF Voltage, Current and Microwave; Electromagnetic; Ozone; Gas; Chemical and Food for Aqueous Elemental Solution; BND Management; Outreach RMP and In-House BND. There was no non-conformity during on-site assessment and peer reviewer was impressed with Quality System documentation, particularly the uniformity maintained in all the sub divisions.

Knowledge Resource Centre

In CSIR-NPL, the umbrella term 'Knowledge Resource Centre (KRC)' comprised of Library and IT related activities under its domain.

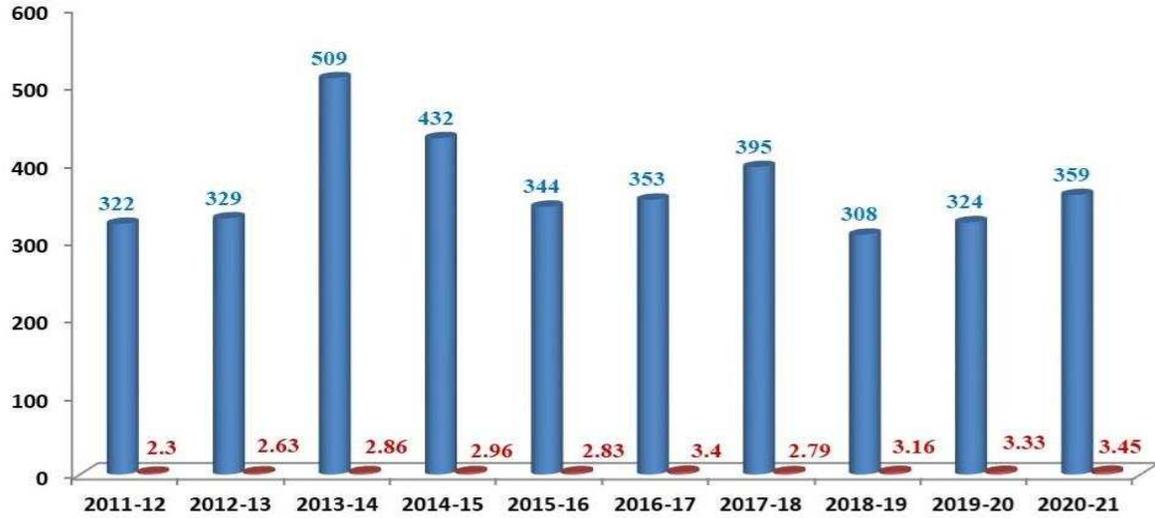
As far as library and information support is concerned, KRC over the years has developed a rich collection of scholarly books and journals, especially in the field of physics and related sciences. During the current year, KRC subscribed to numerous scholarly journals and added a variety of books both in English and Hindi languages to enrich its textual collection. Regarding the services offered, KRC serves the CSIR-NPL community with services like Electronic Document Delivery service, Inter Library Loan service, Reference service, Literature Search service etc. Further, towards improving the quality of science produced by the lab in terms of research publications, NPL-KRC offers content similarity check with the help of the recommended software 'iThenticate'. In addition to the printed content, the centre also offers online access to more than 6000+ full text journals under the e-consortium project of NKRC (CSIR+DST). The project facilitates access to the electronic content from various publishers such as, ACS (American Chemical Society), AGU (American Geophysical Union), AIP (American Institute of Physics), APS (American Physical Society), IOP (Institute of Physics), OSA (Optical Society of America), Oxford

University Press, RSC (Royal Society of Chemistry), Springer, Wiley etc. KRC also provides access to the Indian Standards.

The shift in technology achieved with the automation of KRC activities and installation of improved routers helped in attracting the R & D personnel in large number to optimize the use of the available resources. Further, to promote free worldwide access to the intellectual outputs of CSIR-NPL in form of journals articles, research papers, conference papers, technical reports, preprints, and other scholarly communication, NPL-KRC has established the Institutional Repository (IR@NPL) <http://npl.csircentral.net/> and till date, around 3700 records have been added. Further, to facilitate the understanding of Metrology concepts in a semantic manner, mMap, which is a Metrology Thesaurus in electronic form, was developed by the KRC. The mMap was release by Hon'ble Minister Dr. Harsh Vardhan as NPL Thesaurus on 75th Foundation Day of CSIR-NPL i.e. on 04th January 2021.

Apart from the library related activities, NPL-KRC also contributes towards maintaining the CSIR-NPL website (<http://www.nplindia.in>) on the Internet. This is to inform others about the activities of the institute, such as its role towards the society, thrust area of research, facilities, services and achievements. KRC also provides IT facilities to cater to the computing and communication needs of the laboratory. Data Center services are running 24x7 with in-house set up of various Linux based servers. Internet connectivity has been implemented using 100Mbps through National Knowledge Network (NKN). A gigabit fiber optics backbone network solution is running at various locations across the CSIR-NPL campus and providing CAT6 based ethernet LAN to connect approximately one thousand network based devices i.e. computers, servers, laptops, IP cameras, attendance machines. The gateway security solution has been setup, which includes a Unified Threat Management (UTM) system for multi-level firewall, anti-virus etc. A Radio Link is established between NPL-Campus and NPL-Colony for JRF Hostel Network. JRF hostel is equipped with complete wireless technology solution and devices such as Omni Directional/Directional antennas and various Wi-Fi devices in different modes and configuration. Email services of the laboratory are facilitated using NIC mail services at email.gov.in.

Papers Published by the CSIR-NPL in SCI Journals



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 उपबंधों 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।

- हिन्दी दिवस/हिन्दी मास तथा प्रत्येक तिमाही में हिन्दी कार्यशालाओं/व्याख्यानो 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 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 छःमाही में हिन्दी समीक्षा पत्रिका का प्रकाशन ।
- प्रयोगशाला की वार्षिक रिपोर्ट तथा अन्य महत्वपूर्ण प्रकाशनों में हिन्दी अंश का संपादन ।

3. अनुवाद :

- प्रयोगशाला में प्रयुक्त सभी प्रपत्रों (फार्मों), मानक मसौदों का द्विभाषीकरण ।
- हिन्दी अनुवाद कार्य ।
- राष्ट्रीय भौतिक प्रयोगशाला के वार्षिक प्रतिवेदन के महत्वपूर्ण 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)

प्रयोगशाला द्वारा राजभाषा की प्रगति के लिए उठाए गए कदम एवं प्रयास

- प्रत्येक तिमाही में निदेशक, एन पी एल की अध्यक्षता में राजभाषा कार्यान्वयन समिति की बैठक में वार्षिक कार्यक्रम में निर्धारित लक्ष्यों को प्राप्त करने हेतु चर्चा एवं उनकी समीक्षा की जाती है तथा बैठक में लिए गए निर्णयों पर अनुवर्ती कार्रवाई की जाती है।
- संघ सरकार की राजभाषा नीति, राजभाषा अधिनियम के उपबन्धों तथा आदेशों से प्रयोगशाला के वैज्ञानिकों/अधिकारियों/कर्मचारियों को अवगत कराया जाता है, अनुपालन कराया जाता है एवं अनुपालन हेतु सहायता प्रदान की जाती है।
- हिन्दी दिवस/हिन्दी सप्ताह/हिन्दी पखवाड़ा/हिन्दी मास मनाया जाता है। इस दौरान विभिन्न प्रतियोगिताओं का आयोजन किया जाता है, जिसमें प्रयोगशाला के सभी अधिकारी/कर्मचारी भाग लेते हैं और उन्हें नकद पुरस्कार द्वारा प्रोत्साहित किया जाता है।
- प्रत्येक तिमाही में प्रयोगशाला के अधिकारियों/कर्मचारियों हेतु हिन्दी कार्यशालाओं/व्याख्यानों का आयोजन किया जाता है। इन कार्यशालाओं के माध्यम से स्टाफ सदस्यों को हिन्दी में अधिक से अधिक कार्य करने हेतु प्रेरित एवं प्रोत्साहित किया जाता है। टेबल-वर्कशाप के माध्यम से व्यक्तिगत रूप से चर्चा की जाती है एवं कठिनाइयों का समाधान किया जाता है।
- प्रत्येक वर्ष विज्ञान विषयों पर हिन्दी में दो दिवसीय राष्ट्रीय संगोष्ठी का आयोजन किया जाता है। वैज्ञानिकों द्वारा शोध पत्र हिन्दी में प्रस्तुत किए जाते हैं। राष्ट्रीय संगोष्ठी की सारांश पुस्तिका हिन्दी में प्रकाशित की जाती है, जिससे विज्ञान शोध सम्बन्धित जानकारी हिन्दी में आम जन तक पहुंचती है।
- प्रयोगशाला के अधिकारियों/कर्मचारियों को केन्द्रीय हिन्दी प्रशिक्षण संस्थान से हिन्दी प्रशिक्षण (प्रबोध, प्रवीण एवं प्राज्ञ पाठ्यक्रम) दिलाया जाता है। कम्प्यूटर पर हिन्दी में कार्य करने का प्रशिक्षण दिलाने हेतु कार्यक्रम आयोजित किए जाते हैं।

हिन्दी पखवाड़ा, 2020

राष्ट्रीय भौतिक प्रयोगशाला में कोविड-19 महामारी के परिप्रेक्ष्य में केन्द्र सरकार व राजभाषा विभाग, गृह मंत्रालय द्वारा जारी दिशा-निर्देशों, मानक प्रचालन प्रक्रिया (S.O.P) को ध्यान में रखते हुए राजभाषा यूनिट द्वारा हिन्दी पखवाड़ा-2020 (दिनांक 01 सितंबर से 14 सितम्बर, 2020 तक) का आयोजन यथासंभव ऑनलाइन माध्यम से किया गया। 14 सितम्बर, 2020 को हिन्दी दिवस तथा हिन्दी पखवाड़ा समापन समारोह का ऑनलाइन आयोजन किया गया। प्रयोगशाला में स्टाफ सदस्यों को हिन्दी में

अधिक से अधिक कार्य करने के लिए प्रोत्साहित एवं प्रेरित करने के उद्देश्य से हिन्दी पखवाड़ा के दौरान विभिन्न प्रतियोगिताओं का ऑनलाइन आयोजन किया गया। प्रत्येक वर्ष की भाँति इस वर्ष भी जो प्रतियोगिताएं आयोजित की गयी वे इस प्रकार से हैं :-

क्रम सं.	प्रतियोगिताएं	दिनांक
1	वाद-विवाद प्रतियोगिता	01 सितम्बर, 2020
2	चित्राधारित कथा लेखन प्रतियोगिता	03 सितम्बर, 2020
3	लोकोक्ति पल्लवन प्रतियोगिता	04 सितम्बर, 2020
4	श्रुतलेख (श्रव्य माध्यम आधारित) प्रतियोगिता	07 सितम्बर, 2020
5	गीत एवं काव्य पाठ प्रतियोगिता	08 सितम्बर, 2020

इन सभी प्रतियोगिताओं में प्रयोगशाला के स्टाफ सदस्यों ने अत्यधिक रूचि प्रदर्शित करते हुए उत्साहपूर्वक भाग लिया। दिनांक 14.09.2020 को हिन्दी दिवस तथा हिन्दी पखवाड़ा समापन समारोह का ऑनलाइन आयोजन किया गया। निदेशक महोदय ने कार्यक्रम का शुभारंभ **राष्ट्रकवि रामधारी सिंह 'दिनकर'** की कविता '**कोई अर्थ नहीं**' के सुमधुर वाचन से किया। इस पावन अवसर पर मुख्य व्याख्यान प्रयोगशाला के निदेशक महोदय ने दिया। निदेशक महोदय ने हिन्दी दिवस के अवसर पर ऑनलाइन आयोजन में उपस्थित स्टाफ सदस्यों को दैनिक सरकारी कामकाज में हिन्दी का प्रयोग करने के लिए प्रेरित एवं प्रोत्साहित करते हुए ज्ञान सृजन हेतु '**असवाल मॉडल**' विषय पर अत्यन्त सारगर्भित एवं विवेचनात्मक व्याख्यान प्रस्तुत किया। समारोह के अंत में हिन्दी पखवाड़ा के दौरान आयोजित की गयी प्रतियोगिताओं में भाग लेने वाले 25 विजेता प्रतिभागियों को हार्दिक बधाई दी गयी तथा पुरस्कार राशि व ई-प्रमाण पत्र ऑनलाइन माध्यम से प्रदान किए जाने की घोषणा की गयी।

' आत्मनिर्भर भारत में भारतीय निर्देशक द्रव्य (बीएनडी) का योगदान' विषय पर प्रयोगशाला के अधिकारियों/ कर्मचारियों के लिए संगोष्ठी

राजभाषा विभाग, गृह मंत्रालय, भारत सरकार के दिशा निर्देशों का अनुपालन सुनिश्चित करते हुए हिन्दी के प्रगामी प्रयोग में उत्तरोत्तर वृद्धि हेतु प्रयोगशाला के वैज्ञानिकों/तकनीकी अधिकारियों/स्टाफ सदस्यों के लिए प्रत्येक तिमाही में हिन्दी कार्यशाला आयोजित की जाती है।

उपर्युक्त के संदर्भ में प्रयोगशाला के सभी वैज्ञानिक/तकनीकी अधिकारियों/स्टाफ सदस्यों के लिए तृतीय तिमाही (अक्टूबर- दिसम्बर, 2020) में हिन्दी कार्यशाला/संगोष्ठी के अंतर्गत बी एन डी प्रभाग एवं राजभाषा यूनिट के संयुक्त तत्वाधान में ' आत्मनिर्भर भारत में भारतीय निर्देशक द्रव्य (बीएनडी) का योगदान' विषय पर एक लघु तकनीकी बेबिनार संगोष्ठी का ऑनलाइन आयोजन दिनांक 28 अक्टूबर, 2020 को प्रातः 10 बजे से एम एस टीम के माध्यम से सफलतापूर्वक सम्पन्न हुई।

संगोष्ठी का उद्घाटन डा.डी के असवाल, निदेशक, सीएसआईआर-एनपीएल ने किया। माननीय निदेशक ने अपने सारगर्भित संबोधन में इस बात पर बल दिया कि भारत सरकार के 'आत्मनिर्भर भारत' कार्यक्रम में मेट्रोलॉजी/बी एन डी की विशिष्ट भूमिका है। भारत को 'आत्मनिर्भर' बनाने के लिए यह लगभग सभी सामाजिक-आर्थिक क्षेत्रों में गुणवत्ता आश्वासन को सुनिश्चित करेगा।

तत्पश्चात् पाँच अतिथि वक्ताओं एवं प्रमुख, बी एन डी प्रभाग ने व्याख्यान दिया।

- प्रथम अतिथि वक्ता डा.विवेकानंद महापात्रा, डीजी, एनसीसीबीएम ने 'निर्माण सामग्री बीएनडी का आत्मनिर्भर भारत में महत्व' विषय पर व्याख्यान दिया।
- द्वितीय अतिथि वक्ता डा.आर एन ठाकुर, गुणवत्ता प्रबंधक, एच पी सी एल ने 'पेट्रोलियम उत्पाद बीएनडी का आत्मनिर्भर भारत में सहयोग' विषय पर सरस, रोचक व ज्ञानवर्धक व्याख्यान दिया।
- तृतीय अतिथि वक्ता डा. नीरजकांत पाण्डेय, निदेशक, आश्वी टेक्नालॉजी ने 'कैमिकल बीएनडी का आत्मनिर्भर भारत में' विषय पर महत्वपूर्ण व्याख्यान दिया।
- चतुर्थ अतिथि वक्ता डा. एन वेंकटेश्वरन वेंकट, सीईओ, एनएबीएल, ने 'बीएनडी सवर्धन में एनएबीएल की भागीदारी' विषय पर व्याख्यान दिया।
- पंचम अतिथि वक्ता श्री आर सुब्रमणियन, जी एम, बीपीसीएल ने 'पेट्रोलियम उत्पाद बीएनडी की उपयोगिताएं' विषय पर श्रोताओं के साथ अपने अनुभवों को साझा किया।

संगोष्ठी के अंतिम वक्ता डा.आर पी पंत, प्रमुख, बीएनडी, सीएसआईआर एनपीएल 'आत्मनिर्भर भारत में बीएनडी कार्यक्रम : एक सफल प्रयास' विषय पर तथ्यपरक व ज्ञानवर्धक व्याख्यान दिया।

इस संगोष्ठी में लगभग 65 वैज्ञानिकों/तकनीकी अधिकारियों सहित अन्य संस्थानों के लगभग 15 अधिकारियों ने सक्रिय भागीदारी की।

संगोष्ठी के अंत में औपचारिक धन्यवाद प्रस्ताव डा.के के मौर्य, वरिष्ठ प्रधान वैज्ञानिक, बीएनडी एवं श्री जय नारायण उपाध्याय, हिन्दी अधिकारी ने संयुक्त रूप से ज्ञापित किया । 'आत्मनिर्भर भारत' कार्यक्रम के अंतर्गत यह संगोष्ठी भारत के समग्र आर्थिक विकास में बी एन डी की महत्ता, उपयोगिता व योगदान की अपरिहार्यता को सफलतापूर्वक सिद्ध करने में सहायक हुआ ।

प्रयोगशाला के वैज्ञानिकों/तकनीकी अधिकारियों/अधिकारियों/कर्मचारियों के लिए कार्यशाला

राजभाषा विभाग, गृह मंत्रालय, भारत सरकार के दिशा - निर्देशों का अनुपालन सुनिश्चित करते हुए हिन्दी के प्रगामी प्रयोग में उत्तरोत्तर वृद्धि हेतु प्रयोगशाला के स्टाफ सदस्यों के लिए हिन्दी कार्यशाला आयोजित की गयी । श्री केशव देव , उपनिदेशक (राजभाषा), भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली ने “राजभाषा नियमों के अनुपालन में तिमाही प्रगति रिपोर्ट की महत्ता ” विषय पर व्याख्यान दिया। प्रयोगशाला के लगभग 40 वैज्ञानिकों/अधिकारियों/कर्मचारियों ने भाग लिया । यह कार्यशाला अपने उद्देश्य में पूर्णतः सफल रही।

2020-21

Annexures

Annexure I

Major R & D projects during 2020-21

The major projects of value >50 Lakhs are listed below

Sl. No	Project Title	Funding Agency	Contract Value (in lakhs)	Amount Received during 2020-21
1	A system to generate a common synchronised clocks using CVGNSS with an uncertainty of few ns at geographically disturbed sensor nodes	Defence Electronics Research Laboratory (DERL) Ministry of Defence	95	NIL
2	Implementation of IST service using NPL controlled remote oscillator system for national knowledge Network at National Informatics	National Informatics Centre Services Inc. (NICSI)	94.34	NIL
3	Carbonaceous Aerosols Emissions, Source Apportionment and climate effects	Ministry of Environment & Forest (MoEF)	274.67	9.46
4	National Primary Standard facility for cell calibration	Ministry of New and Renewable Energy (MNRE)	1788.50	NIL
5	Development of new Interfacial layers for efficient and stable excitonic solar cells	Department of Science & Technology (DST)	92.80	NIL
6	Growth and study of highly conducting delafossite single crystal: Device application in metrology	Department of Science & Technology (DST)	89.00	7.25

7	Megacity Delhi atmospheric emission quantification assessment and impacts (Delhi Flux)	Ministry of Earth Sciences (MoES)	198.28	NIL
8	Buried contacts high efficiency crystalline radial p-n junction Si Nanocord Solar Cell	Department of Science & Technology (DST)	89.00	NIL
9	Chemical Composition and source apportionment of Aerosols using Receptor Models at urban sites of the Himalayan Region of India	Department of Science & Technology (DST)	71.72	NIL
10	Creation of Testing and Calibration Facility for LED and LED based Lighting at NPL India as per National/International Standards	BEE (Bureau of Energy Efficiency)	2025.00	NIL
11	Production of Certified Reference Materials-Bharatiya Nirdeshak Dravya® (BND)	Ministry of Commerce & Industry, Department of Commerce	1627.00	NIL
12	Delineation of Airshed for Air Quality Management in Delhi-NCR	CPCB (CSIR-NEERI)	193.80	NIL
13	Establishment of type testing calibration and certification facility for online continuous Emission Monitoring System (OCEMS) and Continuous Ambient Air Quality Monitoring System (CAAQMS)	Ministry of Environment, Forest & Climate Change (MoEF)	5660.00	361.82
14	Advanced Single Photon Detector & Establishment of Single Photon Defection Based Quantum Standard for QuEST	DST	578.14	28.59
15	Bulk preparation of p-type and n-type materials for excitonic solar cells	DST	58.24	28.59

Awards & Achievements

Distinguished National/ International Award

- Dr Sanjay Yadav awarded APMP Award for Developing Economies for the year 2020 by APMP Secretariat, Japan (04th January, 2021)



- Dr. S.K. Dubey: Young scientist award for the work '**E-field strength measurement using Rydberg** atom-based sensor for Microwave metrology' at XXXIII URSI General Assembly and Scientific Symposium, Rome, Italy (August 29- Sept. 05, 2020).

Best Paper Award

- Best Paper Award to the following in AdMet 2021 held at Maharaja Surajmal Institute of Technology (MSIT), C4 Janakpuri, New Delhi [5th - 6th March, 2021]:
 - Bushra Ehtesham, Thomas John, and Nidhi Singh; Limitation of artifact based definition of kilogram, its redefinition and realization using Kibble balance.

- Priyanka Jain, Sachin Kumar, Satish, Jyotsana Mandal, Nidhi Singh, J.C.Biswas and A.K.Saxena; Determination of inductance through capacitance using commercial LCR meters.
- Subhash Nimanpure, Guruvander Singh, Girija Moona, Rina Sharma and Mukesh Jewariya; Investigation of dynamic study of cobalt ferrite for magneto-optic sensor applications in terahertz frequency region.
- Afaqul Zafer, Shibu Saha, Sanjay Yadav, Shiv Kumar Jaiswal and Dinesh Kumar Aswal; Feasible methods for precise g-measurement.
- Neha Bura, Ankit, Deepa Yadav, Jasveer Singh and Nita Dilawar ; Structural studies on dysprosium scandate under the stimulus of pressure and temperature.
- Renu Masiwal; Indoor air pollution in Indian rural kitchen- A case study.
- N. Vijayan, R.P. Pant, Ravinder Kumar, Nagma Khan; α -Quartz(SiO₂) (Tectosilicate) as a Reference Materials for Quantitative Analysis for Powder X-Ray Diffraction.
- Divya Singh Yadav; Indian Standard Time synchronization via NTP server over different networks.
- Award during 2-days E-Workshop on ‘Spectroscopic Techniques: Basics & Applications’ held at CSIR-NPL, New Delhi [3rd-4th, December 2020]:
 - Kanika received First Prize (oral presentation); Design and development of luminomagnetic pigments assisted security ink for manifold protection to curb the counterfeiting of bank cheques.
 - Girija Shankar Papanai received Third Prize (oral presentation); Number of layers identification of MoS₂ nanosheets via spectroscopic tools for metrological aspects.

Editorial Board of Reputed Journals

- Dr Monika J. Kulshrestha was elected as member of Editorial Advisory Committee in Journal of Indian Geophysical Union since March, 2021.
- Dr Monika J. Kulshrestha served as Guest Editor for the special issue on ‘Reactive Nitrogen’ for the International Research Journal Current World Environment since April, 2020.

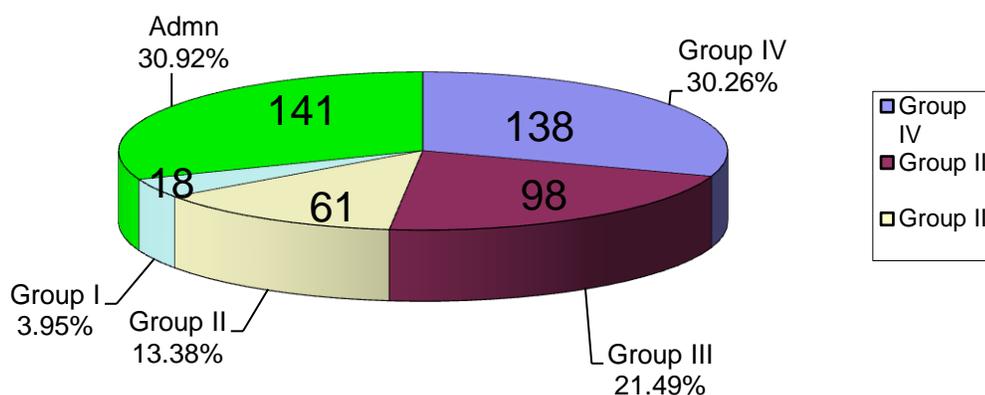
- Dr. Bipin Kumar Gupta is appointed as Associate Editor on February 2021 in Frontiers in Materials (Thin Solid Films), Publisher: Frontiers, Switzerland.
- Dr. Bipin Kumar Gupta is appointed as Editorial Board Member on June 2020 in Journal of Physics and Applications, Publisher: Helics Group, USA.
- Dr. Bipin Kumar Gupta is appointed as Associate Editor on June 2020 in Journal of Functional Materials and Chemical Engineering (JFMCE), Frontier Scientific and Academic Publishing (FSAPub).
- Dr. Bipin Kumar Gupta is appointed as Editorial Board Member on July 2020 in Journal of Nanotechnology in Diagnosis and Treatment, Savvy Science Publisher: Bulgaria.
- Dr. Sunil Singh Kushvaha is appointed as Review Editor on April 2020 in Frontier of Materials.

Annexure III

Staff, Patents, Reports & Financial Outflow

- Regular Staff in Position as on 31.03.2021

TOTAL NUMBER =



- New Recruitments (2020-21)

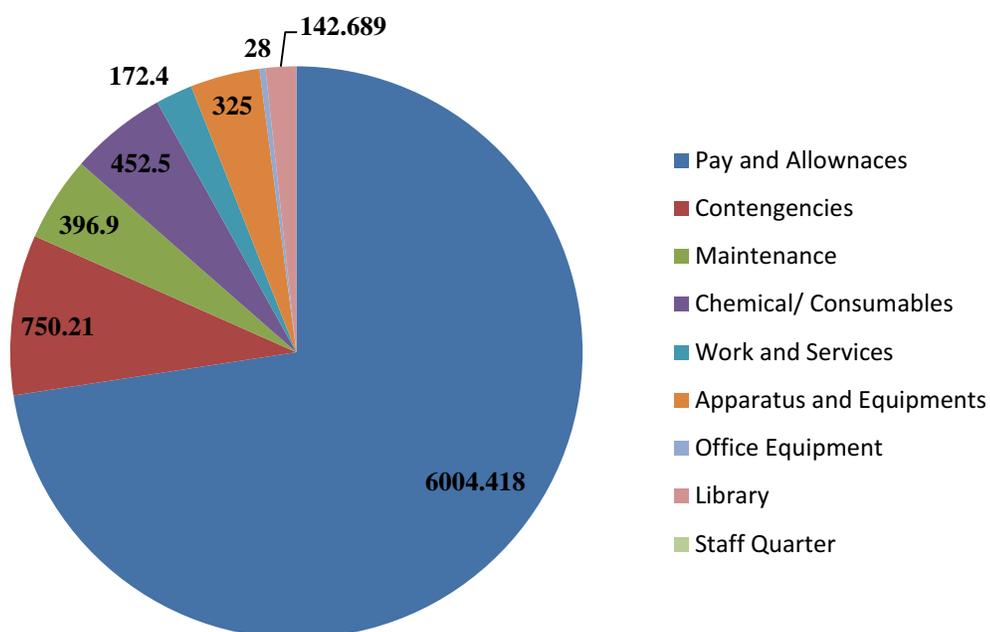
SI. No.	Name	Designation	Date of Joining
1	Dr (Ms) Avni Khatkar	Scientist	14-Oct-2020
2	Sh Anshul Vashnay	Scientist	14-Oct-2020
3	Ms Divya Singh Yadav	Scientist	14-Oct-2020
4	Sh Arun Kant Singh	Scientist	20-Oct-2020
5	Dr Neeraj Bhanot	Scientist	22-Oct-2020
6	Dr Nitin Kumar	Scientist	9-Nov-2020

7	Dr Megha Singh	Scientist	9-Nov-2020
8	Sh Unnikrishnan V T	Scientist	9-Dec-2020
9	Sh Alok Prakash	Scientist	14-Dec-2020
10	Sh Surya Kumar Gautam	Scientist	1-Jan-2021
11	Sh Arun Ram Prasath R.T.	Scientist	5-Jan-2021
12	Ms Hemavathi	Scientist	18-Jan-2021
13	Sh Rajesh P	Scientist	19-Mar-2021

- **Patents and Reports**

- Patents Applications filed in India: 02
- Patents Granted in India: 06
- Patents Granted Abroad (US): 04

- **Budget flow (in Lakh)**



Annexure IV

Patents

Filed in India

SNo	Title	Inventors	Prov. Filing Date	Comp. Filing Date	Application No.	Status
1	A Microbial UVC Disinfection Casket	Nahar Singh, Rajesh, Virendra Kumar Jaiswal, Parag Sharma, Gajjala Sumana, Anuj Krishna, Radhakrishnan S R, Devesh Kumar Shukla, Anuj Purohit, Subham Rathore, Dinesh Kumar Aswal	20/May/2020	16/May/2021	202011021206	PP
2	Tangential Six-Inlet Co-Cylindrical Cyclone for PM10 Sampling	Shankar Gopala Aggarwal, Prashant Patel, Khem Singh, Daya Soni, Prabha Johri, Vijay Narain Ojha, Dinesh Kumar Aswal, Thi Cuc Le, Chuen-Jinn Tsai	---	31/Mar/2021	202111014940	PP

Granted in India

SNo	Title	Inventors	Prov. Filing Date	Comp. Filing Date	Application No.	Status	Grant Date	Patent No.
1	Carbon Nanotube-metal Nanocomposites as Flexible, Free Standing, Binder Free High Performance Anode for li-ion Battery	Maheshwari Heda Priyanka, Elizabeth Indu, Singh Bhanu Pratap, Gupta Chanchal, Mathur Rakesh Behari, Sukumaran Gopukumar	---	12/Jun/2014	1592DEL2014	IF	15/Jul/2020	341611
2	Smart Coatings of Conducting Polymer Composites for Corrosion Protection in Marine Environment	Dhawan Sundeep Kumar, Anoop Kumar Sasidharan, Bhandari Hema, Ruhi Gazala, Sharma Brijesh	30/Dec/2013	23/Sep/2014	3813DEL2013	IF	06/Oct/2020	348657
3	A Process for the Preparation of Low-Density Multicomponent Graphite Composite Bipolar Plates	Mathur Rakesh Behari, Dhakate Sanjay Rangnath, Sharma Shaveta, Dhami Tarsem Lal	31/Mar/2010	10/Mar/2011	0766DEL2010	IF	10/Nov/2020	351261
4	A Process for Growing a Cathode to Improve the Lifetime of Polymer Solar Cells	Ali Farman, Sharma Abhishek, Tiwari Jai Prakash, Suresh Chand	01/Apr/2014	27/Mar/2015	0943DEL2014	IF	04/Dec/2020	353060
5	Novel Composite Material for Removal of Crude Oil from Sea Water and A Process for the Preparation Thereof	Dhawan Sundeep Kumar, Farukh Md, Adhikari Itisha, Sambyal Pradeep, Dhawan Ridham, Pant Rajendra Prasad, Kotnala Ravinder Kumar	17/Mar/2016	14/Mar/2017	201611009249	IF	29/Jan/2021	357100
6	Electrostatic Dissipative Foams and Process for the Preparation Thereof	Saini Parveen, Puri Chandni, Arora Manju	01/Apr/2014	27/Mar/2015	0944DEL2014	IF	17/Mar/2021	361638

Granted in Foreign Countries

SNo	NFNO	Title	Inventors	Comp. Filing Date	Application No.	Status	Grant Date	Patent No.
1	0060NF2016/US	A Process for the Preparation of Uniform Sized Phosphor Aerogel	Divi Haranath, Singh Nahar, Chawla Sneha	02/Jun/2017	15/612540	IF	28/Apr/2020	10633257
2	0048NF2015/US	Lithium substituted Magnesium Ferrite as Hydroelectric Cell and processing method thereof	Ravinder Kumar Kotnala, Jyoti Shah	11/Mar/2016	15/067496	IF	25/Aug/2020	10752515

3	0062NF2017/ US	Design and Development of a High-Volume PM2.5 Impactor	Aggarwal Shankar G, Patel Prashant, Tsai Chuen Jinn, Soni Daya, Singh Khem, Kotnala Ravinder Kumar, Tomoaki Okuda, Gupta Prabhat Kumar, Ojha Vijay Narain, Aswal Dinesh Kumar	16/Apr/2018	15/954097	IF	22/Sep/2020	10782212
4	0290NF2014/ US	Preparation of Anti-Reflection And Passivation Layers of Silicon Surface	Pathi Prathap, Kalpana Rani, Vandana, Srivastava Sanjay Kumar, Rauthan Chandra Mohan Singh, Singh Parakram Kumar	23/May/2018	15/778509	IF	20/Oct/2020	10811546

CSIR-NPL: The National Metrology Institute of India Member, BIPM and Signatory CIPM-MRA Director

Director, CSIR-NPL

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- Dr. Sunil Singh Kushvaha, Principal Scientist (Member)
- Dr. Arun Kumar Upadhayaya, Principal Scientist (Member)
- Dr. Bipin Kumar Gupta, Principal Scientist (Member)
- Dr. Sanjay Kumar Srivastava, Principal Scientist (Member)
- Dr. Nirmalya Karar, Principal Scientist (Member)
- Ms. Sandhya Malika Patel, Senior Scientist (Member)
- Dr. Rajesh, Senior Principal Scientist (Member)
- Mrs. Deepti Chaddha, Principal Scientist (Member)
- Mr. Ashok Kumar, Principal Technical Officer (Member)
- Dr. Abhishek Kumar Yadav, Technical Officer (Member)

Honorable Prime Minister
Sh. Narendra Modi
Commemorate 75th foundation day of CSIR-NPL

Foundation Stone of
National Environmental Standard Laboratory
laid by
Shri Narendra Modi
Honorable Prime Minister
(Through Video Conferencing)

☪ In the august presence of ☪
Dr. Harsh Vardhan
Union Minister of Science & Technology,
Earth Sciences, Health & Family Welfare

CSIR – National Physical Laboratory
Monday, 4 January, 2021

**Bharatiya Nirdeshak Dravya
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(Through Video Conferencing)*
by
Shri Narendra Modi
Honorable Prime Minister

☪ In the august presence of ☪
Dr. Harsh Vardhan
Union Minister of Science & Technology,
Earth Sciences, Health & Family Welfare

CSIR – National Physical Laboratory
Monday, 4 January, 2021

Indian Standard Time (IST™)
(with an accuracy of 2.8 nanosecond)
*Dedicated to the Nation
(Through Video Conferencing)*
by
Shri Narendra Modi
Honorable Prime Minister

☪ In the august presence of ☪
Dr. Harsh Vardhan
Union Minister of Science & Technology,
Earth Sciences, Health & Family Welfare

CSIR – National Physical Laboratory
Monday, 4 January, 2021

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4th JANUARY 2021

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In the presence of
Dr. Shekhar C Mande
Deputy General
Director of Scientific & Industrial Research

Dr. Harsh Vardhan
Union Minister of Science and Technology,
Earth Sciences & Health and Family Welfare

Dinesh K Aswal
Director
National Physical Laboratory

75th
FOUNDATION DAY Jubilee

4th January, 2021

75 Years of CSIR-NPL in Service of Nation

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