CSIR-NPL

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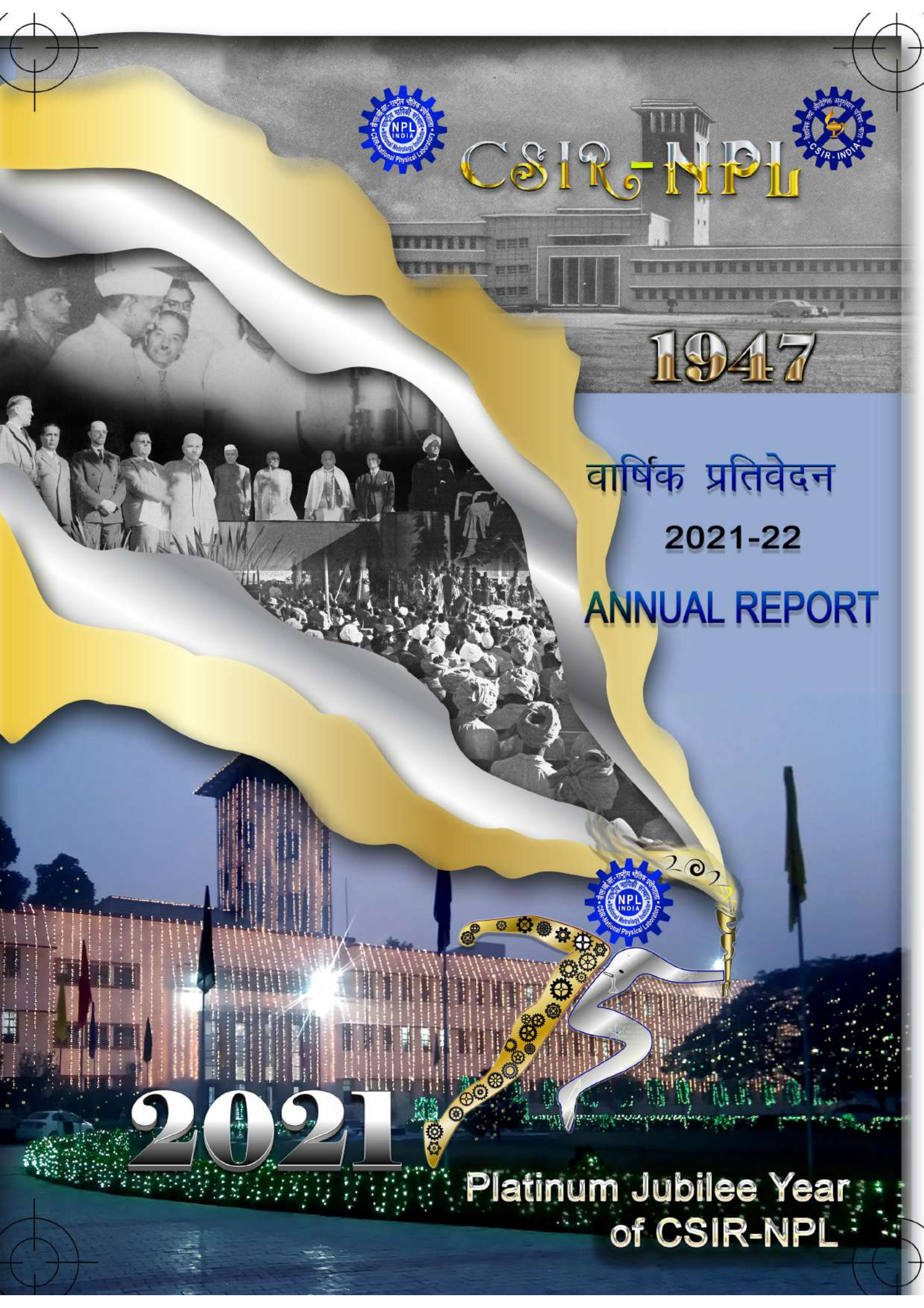
वार्षिक प्रतिवेदन

2021-22

ANNUAL REPORT



2021

Platinum Jubilee Year
of CSIR-NPL

Annual Report

2021-2022

सीएसआईआर - राष्ट्रीय भौतिक प्रयोगशाला
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)

डॉ. के. एस. कृष्णन मार्ग, नई दिल्ली - 110012, भारत / Dr. K. S. Krishnan Marg, New Delhi - 110012, India
www.nplindia.in

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

Shri Narendra Modi
Hon'ble Prime Minister
President, CSIR

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

Dr. N Kalaiselvi
Director General,
CSIR and Secretary DSIR

Prof. Venugopal Achanta
Director, CSIR-NPL

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....

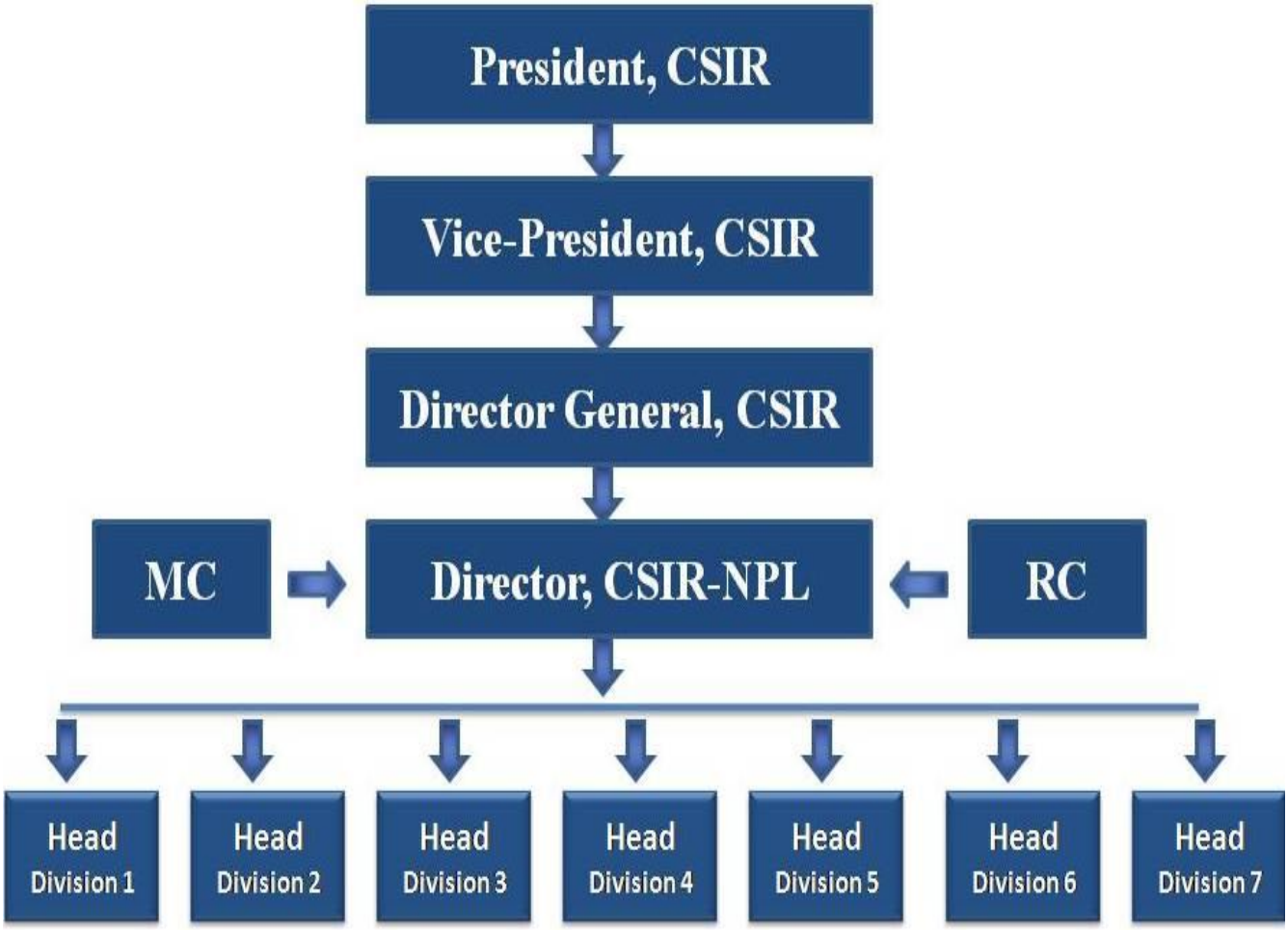
a) *Developing India's measurement standards that are internationally accepted and disseminating the measurement capabilities to industry, government, strategic and academia that underpin the India's prosperity and quality of life.*
b) *Conducting multidisciplinary R&D with a mission to establish the 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.*

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.

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:	**Bharatiya Nirdeshak Dravya (BND®): Indian Reference Materials**
Division 6:	**Indian Standard Time Metrology**
Division 7:	**Directorate**

Contents

Preface

I am delighted to present the Annual Report 2021-22 of the CSIR-National Physical Laboratory (CSIR-NPL). Despite the fact that the world has faced enormous challenges this year due to COVID19, CSIR-NPL has continued to carry out the metrological traceability, R&D activities, promotion of research culture, and societal work through science and technology intervention, skill development among youth, and knowledge dissemination. Thus, this year has been full of achievements and milestones for the institute.

The year 2021-22, witnessed the Platinum Jubilee Year celebration of CSIR-NPL between 4th and 6th of January 2022. **Dr. Jitendra Singh**, Hon'ble Minister of State (Independent Charge) of the Ministry of Science and Technology & Earth Sciences graced the inaugural function and inaugurated various facilities. Among them are the **LED Testing Facility, the responsive website of CSIR-NPL**, the **certification process for Indian-made low-volume $PM_{2.5}$ samplers and ambient ozone analysers, calibration facility for infusion pumps** as well as released several **Bharatiya Nirdeshak Dravya (BND®) – CRMs** to the nation. Hon'ble Minister praised the enormous efforts made by the Indian scientists for nation-building and appreciated the role of CSIR-NPL as "***National Metrology Institute (NMI)***" of India in advancing metrology towards self-reliant India.

As the custodian of national measurement standards in the country, CSIR-NPL has pioneered in setting up and disseminating standards within the country. Further, as an active partner of Quality Council of India (QCI), Bureau of Indian Standards (BIS), Legal Metrology Department and their constituents, CSIR-NPL is consistently contributing to the development of quality infrastructure in the country. During the period 2021-2022, CSIR-NPL has significantly contributed to the fundamental and distinct thrust areas of Physical Sciences by establishing a suitable linkage among 'Academia- R&D laboratories- Industries' with a focus on sharing of resources, ideas and expertise.

In 2021-2022, a number of externally funded and in- house projects were undertaken to address several national issues to support **Make-in-India** and '**Self-reliant India (Atmanirbhar Bharat Abhiyaan)'** missions of the Indian Government to boost the GDP of the country. During the current period, the laboratory has established several new significant standard facilities for testing and calibration to address national issues related to health, wealth, energy, and the environment. In addition, efforts were made to further strengthen the existing facilities like – establishment of clinical thermometer testing facility at Regional Reference Standard Laboratories (RRSLs) Varanasi and Ahmedabad, preservation of the original calligraphic copies of the **Constitution of India** kept at parliament library, national testing and calibration facility for LED lighting sources, established a 5 kN fully automatic dead weight force machine, and established facility for blood pressure device testing/calibration system at RRSLs. Further, many outstanding researches carried out that are reported in several high impact journals. New initiatives are taken up to combat Covid-19, like testing facilities for personal protection equipment (PPE), ventilators, and IR thermal body scanners; covid-19 and respiratory health implications study based on PM Physico-chemical characteristics over Delhi, and many others. Efforts were made towards bilateral comparison of 1 Ω and 10 kΩ standard resistors (BIPM.EM-K13.a and K13.b) between CSIR-NPL, India and BIPM, France, establishment of DC low current traceability in the range of 1 pA to 1μA using Ohm's law method, establishment of clean air delivery rate test facility for air purifier/cleaner/device. On the R&D and equipment development front, a 3-D printer for perovskite solar cells, a novel method of water remediation of organic pollutants and industrial wastes by solution- route processed CZTS nanocrystals, blue laser induced phosphor coated white light, and lattice and quasiparticle dynamics study of APCVD grown $MoSe_2$ and WSe_2 monolayer to validate the quality of 2D materials for electronic

as well as metrological grade, were taken up. Many strategic materials have also been developed by using bio-waste like pineapple peel derived porous carbon/PANI composite electrode for asymmetric supercapacitor application, and human hair derived porous carbon/polypyrrole composite electrode for asymmetric supercapacitor application.

Further, as we all know, energy can be viewed as the currency of any country. Its demand is always more than its supply. Keeping this in view, CSIR-NPL took an initiative to develop carbon paper for PEM fuel cell. Further, CSIR-NPL has designed a new technologically advanced luminescent security ink for bank cheques and passports, established CNT-activated carbon composites for efficient dye removal, and synthesised CNT sheets by fluidized chemical vapour deposition. Apart from this, CSIR-NPL has also released four BNDs related to gold and silver on 4th January 2022. Additionally, CSIR-NPL has developed a calibration standard for UV-Vis spectrometers (BND® 2022). Also, CSIR-NPL tested the ultra-precise time traceability link over a long distance utilizing white rabbit network, new parameter **'Gain and Linearity'** of nanovoltmeter from the PJVS system for the precision measurement and traceability, and re-established the traceability of multi-Junction thermal converter.

Also, CSIR-NPL researchers received distinct honours in the year 2021-2022. The major ones are Dr. S.S.K. Titus has been elected as the APMP-TCM Chair in November 2021; Dr. Sanjay Yadav appointed as Member Governing Council, FCRI, Palakkad, Kerala, for two years; Dr. V.P.S. Awana elected Fellow, Institute of Physics (UK); Dr. Monika J. Kulshesta elected Fellow, Metrology Society of India; Dr. Govind, elected Senior Member, IEEE, USA; Dr. Sumit Kumar Mishra elected Fellow of Indian Social Science Academy (ISSA), Allahabad. The institute has 312 publications in SCI journals, 06 patents granted in India, and 04 foreign patents granted.

Apart from being a key research and development institute, CSIR-NPL plays a vibrant role in Human Resource Development in the areas of Metrology. CSIR-NPL also provides academic training to students from various educational institutions across the country, specifically in the research areas of CSIR-NPL. During the period from 1st April, 2021 to 31st March, 2022 a total of 69 students were trained towards the fulfilment of their academic degree requirements. Also, 30 research fellows (JRFs/SRFs) joined CSIR-NPL and AcSIR Ph.D. Programme, resulting in a

total strength of 319 Research Fellows (JRFs+SRFs) in CSIR-NPL as on 31.03.2022. The institute has also conducted 09 training programmes under the Skill Development Programme.

In addition, for any technology development and its successful implementation close association and interaction among the various stakeholders is required. For this, the laboratory has always attempted to reach out to existing and prospective collaborators through various forms of engagements like MoUs, Technical Services Projects, Licensing of Technology/Know-How etc. with organizations such as Life Force New Delhi, Indian Oil Corporation Limited Mumbai, Aashvi Technology LLP Ahmedabad, National Council for Cement and Building Materials (NCB) Ballabgarh, Voltas Limited Faridabad, Nagman Flow-Level Systems and Solutions LLP Chennai, Global Systems & Technology Kanpur, Life Force New Delhi and many more. I am confident that such collaborations will yield high-impact technologies and products that will benefit the masses by improving their quality of life.

For all of the laboratory's achievements, I would like to acknowledge and sincerely thank the DG-CSIR, CSIR Headquarters, members of the Research Council, and the Management Council for their continued guidance and support in managing the activities of the laboratory. The support of various funding agencies and end-users is also highly appreciated. I hope that our association with all our partners would continue to benefit society and our nation as a whole. Finally, I would like to acknowledge and thank all scientists and other staff members of CSIR-NPL for their continued dedication, and commitment to the institute’s objectives and goals. I am confident that as a team, we will continue to pursue scientific excellence with courage, and do our best to make India proud through Metrology and Research and Development.

(Prof. Venugopal 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.

Significant Contributions

Established the Clinical Thermometer Testing Facility at RRSLs Varanasi and Ahmedabad

We have successfully established the Clinical Thermometer testing/calibration facility at Legal Metrology Department (LMD), Regional Reference Standard Laboratories at Varanasi and Ahmedabad. The set-ups were developed under the Technical Services Project entitled, "Development, fabrication and establishment of testing and calibration facility for clinical thermometers with maximum device at 2 RRSL Labs", from Legal Metrology Department. These set-ups are fully capable for testing of clinical glass thermometers and digital thermometers as per national and internation standard's requirements.

Clinical thermometer calibration/testing set-up established at RRSLs

CSIR-NPL temperature and metrology team at RRSL Varanasi to install and demonstrate the set-up

Preservation of the Original Calligraphic Copies of the Constitution of India kept at Parliament Library

For the preservation original calligraphic copies of the Constitution of India, CSIR-NPL has successfully established the hermetically sealed glass receptacles in 1994 with the collaborations from M/s Getty Conservation Institute, USA. The receptacles are designed to maintain a nitrogen micro-environment of less than 1% oxygen concentration at 45% relative humidity (RH). Since 1994 these receptacles are kept in a designated strong room at Parliament Library and the team of CSIR-NPL along with the Parliament Library has successfully maintained both the receptacles of English and Hindi version of copies by monitoring the stated parameters and manuscripts are in very good condition.

Professor Venu Gopal Achanta, Director CSIR-NPL and team have made a visit to Parliament Library on 01-02-2022 to Review the Preservation of the Original Constitution of India, maintained by the CSIR-NPL and Parliament Library.

Prof. Venu Gopal Achanta, Director CSIR-NPL and team at Parliament Library with the receptacles made for the preservation of the Constitution of India

National Testing and Calibration Facility for LED Lighting Sources

With the advent of energy efficient LED lighting technology, it has led to manifold increase in the use of LED lights which in turn resulted in the growth of LED lighting industry and phasing out old thermo-luminescence based lightings at the same time.

A National testing and calibration facility for LED lighting sources has therefore, become inevitable to establish the unbroken chain of traceability from SI units and pave the way for raising quality infrastructure in the country for LED lightings. In this direction, the Optical Radiation Metrology Section has recently completed the installation of two of its high end major metrology grade systems, C-type Goniophotometer and Optical Radiation

Test Systems in an externally funded project for the measurement, calibration and testing of various photometric and radiometric parameters to disseminate the scale of radiation.

C-type Goniophotometer System

Optical Radiation Test System

The testing and calibration facility for LED lighting sources being developed at CSIR-NPL

The state of the art facility, once fully equipped, would not only help significantly in stopping arrival of substandard/hazardous lighting products in market, reducing international trade barrier, dependence on foreign calibrations and generation of trained manpower but also would enhance visibility of CSIR-NPL India in the area of LED metrology among the leading NMIs.

Established a 5 kN Fully Automatic Dead Weight Force Machine

A 5 kN fully automatic dead weight force machine was established and characterized for its performance through Infra project for calibrating force proving instruments from 50 N to 5 kN with the applied force uncertainty of 0.008% which is shown in figure. As the performance of a manually operating 5 kN machine deteriorated very badly, this new machine was commissioned so that we can continue to maintain our CMC. This machine was also inter-compared with another 50 kN dead weight machine for its performance which reaffirms its CMC of 0.008% and also builds our confidence to fulfill our mandate.

5 kN fully automatic dead weight force machine established at Force Metrology

Established Facility for Blood Pressure Device's Testing/Calibration System at Regional Reference Standard Laboratories

In align with the mandate of the CSIR-NPL we have established the calibration/testing system for non-invasive blood pressure (NIBP) devices at Regional Reference Standards Laboratories, which provided the national traceability of non-invasive sphygmomanometer. This, in turn, has enabled India to develop a mechanism to test and calibrate the imported and indigenous digital and mechanical blood pressure measuring devices. Studies about the traceability and regulation of non-invasive sphygmomanometers were also conducted. This was performed under the project of the Legal Metrology Department, New Delhi, for the calibration and testing of the non-invasive blood pressure simulation technique and its metrological traceability while enhancing capabilities to fulfill the mandate of CSIR-NPL. In order to establish this system, different designs were proposed, and one final design was fabricated. After the completion of the fabrication, two systems were delivered to Regional Reference Standards Laboratories located at Varanasi and Faridabad.

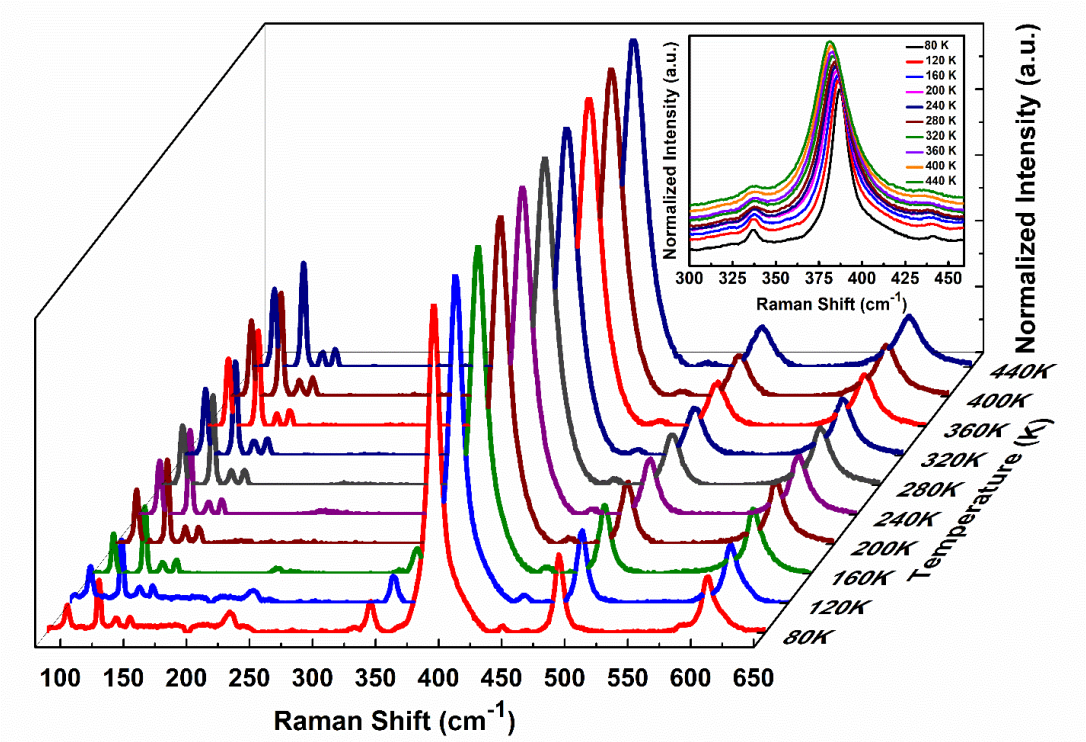
Facility establishment at RRSL, Faridabad

Facility establishment at RRSL, Varanasi

Final assembled system during testing as per OIML R-16

Temperature Dependent Raman Studies on Tm_2O_3 from 80 K to 440 K

The temperature dependent phonon variation investigations revealed the phase stability as well as the anharmonic behavior of nano-crystalline thulium sesquioxide. The most intense stretching F_g+A_g is found to be asymmetric which could be successfully analyzed with a BWF line shape. The asymmetry parameter showed a decrease from 80 K to about 200 K after which it increased marginally and therefore could not be attributed to heating effects alone. The phonon modes demonstrated softening with an increase in temperature from 80 K up wards along with an increased line-width which is attributed to the lattice expansion and perturbation of the Hamiltonian. Three phonon process is found to be contributing majorly to frequency shift as well as broadening. The total anharmonicity was relatively higher for phonon modes with higher frequency shifts as a function of temperature.

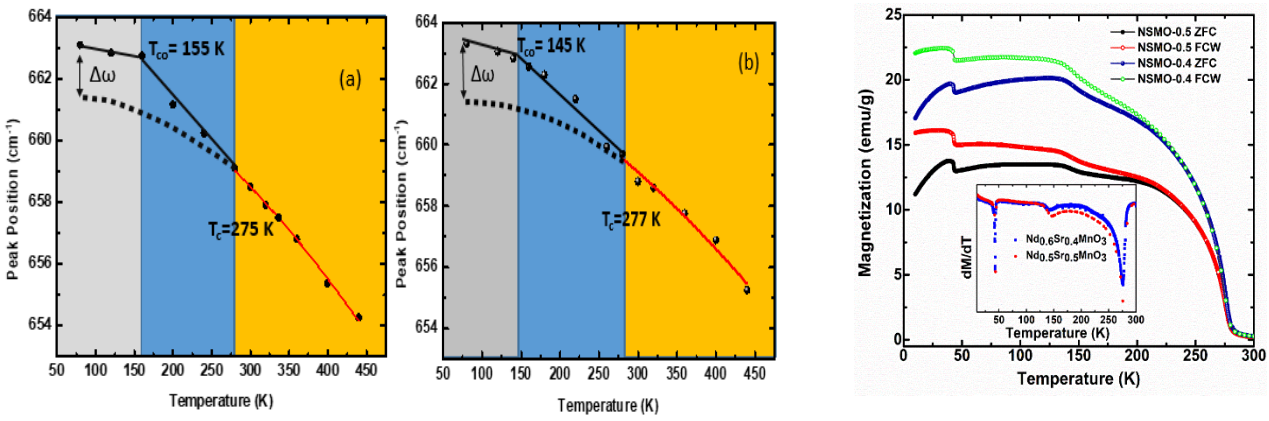


Phonon line shape with the increasing temperature. For mode at 393.1 cm^{-1}, the asymmetry, the peak broadening and shift with the temperature can be observed in the inset

Temperature Dependent Raman and Magnetic Studies on $Nd_{1-x}Sr_xMnO_3$

A study was made on the temperature-dependent magnetic transitions correlated to variations in the phonon modes in $Nd_{1-x}Sr_xMnO_3$ (x = 0.4 & 0.5). The phase-separated nature is manifested through the occurrence of various phases, e.g., spin-glass (SG), charge order (CO), ferromagnetic (FM), and paramagnetism (PM), as the temperature is varied from 20 to 300 K. The temperature-dependent Raman measurements revealed that although the material is structurally stable in the studied temperature range of 80

K – 440 K, noticeable discontinuities in the phonon mode shifts were noticed. These phonon mode shifts are found to directly correspond to the magnetic transitions. The change in the frequency of the Raman modes with temperature, which causes the observed shift, could be attributed to various factors such as lattice expansion, anharmonic interactions, spin-phonon coupling, electron-phonon interaction, etc. Here, we have used spin-phonon coupling along with lattice expansion as well as anharmonic interactions to predict the behavior of modes below the PM-FM transition and lattice expansion and anharmonic interaction above it. The work is of great significance in terms of how two structural investigating techniques can be correlated and give the indication of structural and magnetic behavior of the sample.



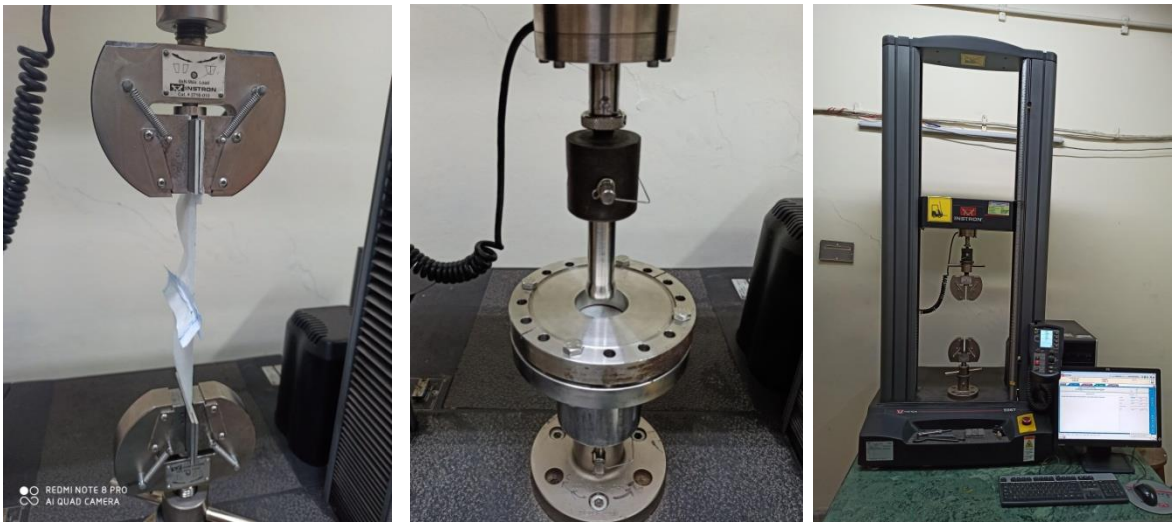
Correlation between two techniques highlighting the transition behaviour using temperature-dependent Raman and magnetic measurements

Covid-19 Initiatives: Towards the Establishment of Testing Facilities for Personal Protection Equipment (PPE), Ventilators, and IR Thermal Body Scanners

The sudden novel COVID-19 outbreak in March 2020 had thrown an unprecedented and humongous challenge resulting into nationwide lockdowns, health hazards and precious loss of lives. The main cause for this situation is Corona virus which is understood to be spreading at a very fast rate in the community.

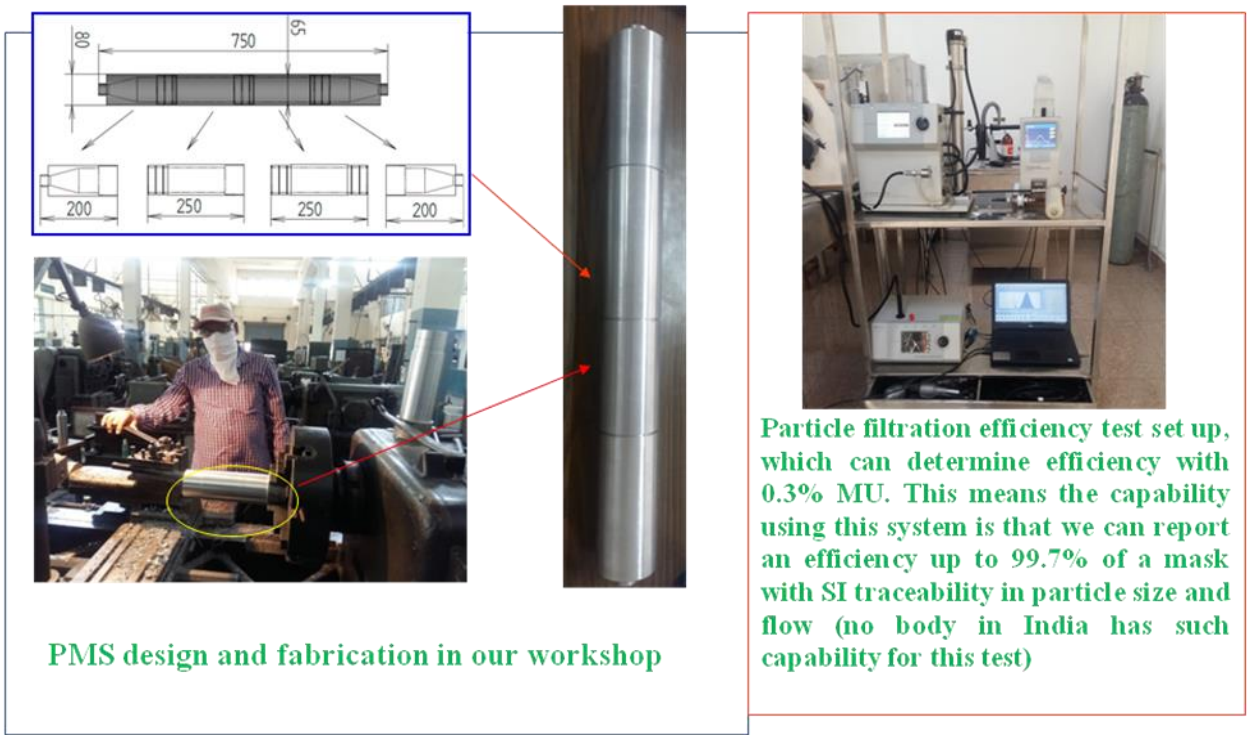
The efforts of the government policymakers, administrators, police and security personnel, health and sanitization workers, daily dwellers to maintain the supply of essential commodities and finally medical doctors and paramedical staffs are praiseworthy but simultaneously they are under the constant threat of virus infections. The present work environments have become a higher risk of transmission and aerosolized transmission. Wearing a mask is an important safeguard to get protection from sub-micron droplets and microbial particles suspended in air, especially during COVID-19 contagious environment. These personals providing such dedicated services deserve appropriate quality Personal Protective Equipment [masks, face shields, gloves, goggles, gowns, coverall etc.) and life-saving medical devices (ventilators, oxygen concentrators, IR thermal scanner, etc.) for patient health and safety. The most prominent symptoms of Corona disease are rising temperature and breathing problems.

For initial screening of fever of the human body, the IR thermal scanners are being used at airports, shopping malls, offices, etc. The use of ventilators is required for proper breathing of patients. Therefore, PPE, ventilators and IR thermal scanners are required for the proper health and safety of all involved as well as patients. Therefore, the calibration and testing of PPE, ventilators and thermal scanners is not only extremely essential for the proper functioning of the instruments but also for health and safety point of view. Keeping in view of the above, CSIR-National Physical Laboratory (CSIR-NPL), New Delhi, being **National Metrology Institute (NMI) of the India** initiated to set up the Testing Facilities at CSIR-NPL for PPEs (i.e. Face Masks, Gloves, Gowns), Medical Ventilators, IR Thermal Scanner etc. and provide testing & calibration services for these items. Initially, the feasibility of the project was done through using our own existing set-ups and resources and later on excel the project after receipt of the fund. Some of the works done in-house in our Central Workshop are shown below.



(a) Set-up for Seam/Tensile/Tear Test (b) Set-up for Ball Burst Test (c) Universal Testing Machine (UTM) (Instron, 5967) for PPE samples

(d) Set-up for Water Wave Transmission Rate (WVTR) testing for PPE samples



(g) Fabrication of Spray Head of Impact Penetration set -up

In-house design and development work of some of the PPE and mask testing facilities initiated at CSIR-NPL in early phase of Covid-19

Bilateral Comparison of 1 Ω and 10 kΩ Standard Resistors (BIPM.EM-K13.a and K13.b) between NPL, India and BIPM, France

A comparison of values assigned to 1 Ω and 10 kΩ resistance standards was carried out between the BIPM (Bureau International des Poids et Mesures) and the National Physical Laboratory, India. Four travelling standards provided by the BIPM were used for this comparison.

Outcomes: The final expanded uncertainty assigned to the 10 kΩ travelling standards is 0.15 μΩ/Ω and to 1 Ω travelling standards is 0.85 μΩ/Ω.

Establishment of DC Low Current Traceability in the Range of 1 pA to 1μA using Ohm's Law Method

As per the demand from industries (semiconductor and radiation dosimetry applications) we have initiated traceability route for low current (dc) and charge measurements. The current measurement range is from 1 pA to 1 uA. The traceability is established through Ohm's law by linking the Josephson voltage standard for voltage measurements and Quantum Hall resistance standards for resistance standards. The uncertainty for current measurements is 0.5% for 1 pA and 0.8% for the 100 pA.

Covid-19 and Respiratory Health Implications: A Study Based on PM Physico-chemical Characteristics over Delhi

Respiratory Deposition Dose of $PM_{2.5}$ and PM_{10} Before, During and After COVID-19 Lockdown Phases in Megacity-Delhi, India has been studied during evaluation period. Considerable changes in particulate matter (PM) during COVID-19 lockdown in major cities around the world demand changes in exposure assessment studies of PM. The present study shows the variations in respiratory deposition dose (RDD) of both fine ($PM_{2.5}$) and coarse (PM_{10}) particles before, during and after Covid-19 lockdown phases at three sites (with different pollution signatures) in Delhi—Alipur, Okhla and Pusa road. Exposure assessment study showed mean $PM_{2.5}$ RDD (± S.D.) (μg/min) for walk and sit mode during before lockdown (BL) as 2.41(± 1.20) and 0.84(± 0.42) for Alipur, 2.71(± 1.60) and 0.94(± 0.56) for Okhla, and 2.54(± 1.28) and 0.88(± 0.44) for Pusa road, which decreased drastically during Lockdown 1(L1) as 0.85(± 0.35) and 0.30(± 0.12) for Alipur, 0.83(± 0.33) and 0.29(± 0.11) for Okhla, and 0.68(± 0.28) and 0.23(± 0.10) for Pusa road, respectively. Significant decrease in RDD concentrations (Both $PM_{2.5}$ and PM_{10}) than that of BL phase have been found during Lockdown 1(L1) phase and other successive lockdown and unlock phases - Lockdown 2(L2), Lockdown 3(L3), Lockdown 4(L4) and Unlock1 (UL1) phases. Changes in RDD values during lockdown phases were affected by lesser traffic emission, minimized industrial activities, biomass burning activities, precipitation activities, etc. Seasonal variations of RDD showed Delhites are found exposed to more fine and coarse particles' RDD (walk and sit modes) before and after lockdown, i.e. during normal days than during lockdown phases showing potential health effects. People in sit condition found less exposed to fine and coarse RDD comparison to those in walk condition both during normal and lockdown days.

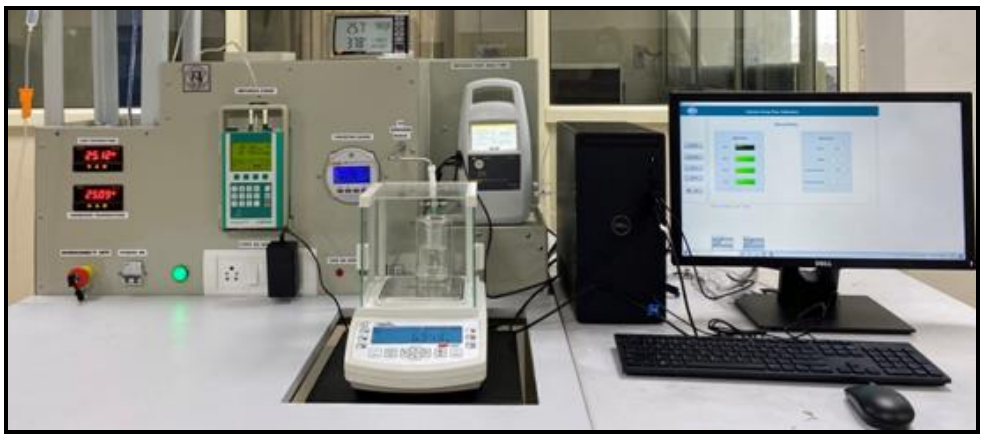
Certification Processes of Indian Make Low Volume $PM_{2.5}$ Samplers and Indian Make Ozone Analyzers with the Minimum Acceptability Criteria as Recommended by NPLI CS Certification Committee has been Launched on Jan. 04, 2022, by Hon'ble Minister Dr Jitendra Singh

Launching of certification of Indian made low volume PM2.5 samplers & Ozone Analyzers

Lunching of Certification process for Indian made low volume $PM_{2.5}$ samplers and Ozone Analyzer by Hon'ble Minister Dr. Jitendra Singh in the presence of Dr. S. C. Mande (DG-CSIR) & Prof. Venu Gopal Achanta (Director, CSIR-NPL).

Calibration Setup for Infusion Pump Analyzer

Group has designed the calibration setup for infusion pump analyzer as per IS 13450 (Part 2/Sec 24): 2009 equivalent to IEC 60601-2-24 describes a calibration procedure particularly for the medical electrical infusion pump device. The schematic of the designed infusion pump analyzer set up is shown in the figure. In a typical calibration procedure of infusion pump analyzer, the volumetric flow rate is calculated by directly converting the mass into volume with respect to a reference temperature normally at 20oC, as per methodology mentioned in ISO/TR 20461 (determination of uncertainty for volume measurements by gravimetric method).



Set up for calibration of Infusion Pump Analyzer

Calibration certificates have been issued for defibrillator analyzer to biomedical testing laboratories viz. Electronic Test & Development Centre (ETDC) Guwahati, Godrej& Boyce, Lawkim Motors Group, Mumbai, Maharashtra , Tektronix, Mumbai.

Establishment of Clean Air Delivery Rate Test Facility for Air Purifier/Cleaner/Device

Clean Air Delivery Rate (CADR), expressed in $m^3\ h^{-1}$, is defined as the measure of the delivery rate of purified air by an air purifier. CADR is calculated by subtracting the natural decay rate constant from the total decay rate constant and multiplying the difference by the volume of test chamber, as measured in m^3. CADR calculation is independent of technology used in air purifier for particle removal. However, same sized particles of different materials may have different density so removal may be affected, hence in this facility, particle types can be generated, e.g. dust, smoke, salts, etc. All parameters like, glass room size and volume, material, air handling unit, etc. are as per IS 17531: 2021. Using this indigenously designed and developed facility, CSIR-NPL is now providing services to several industries, including MSMEs.

CADR test facility at CSIR-NPL

Perovskite Solar Cells Printer

CSIR-NPL has undertaken to develop futuristic flexible perovskite solar cells (PSCs) and make them commercially viable. In most research laboratories the PSCs are fabricated by spin coating or thermal evaporation techniques, which not only limits the size of solar cells but these techniques are also not feasible for large scale production of these devices on commercial scale. Since PSCs could be solution processed on any substrate, global efforts are being made to develop them via conventional printing techniques, which will enable them to produce roll to roll on commercial scale. We have also

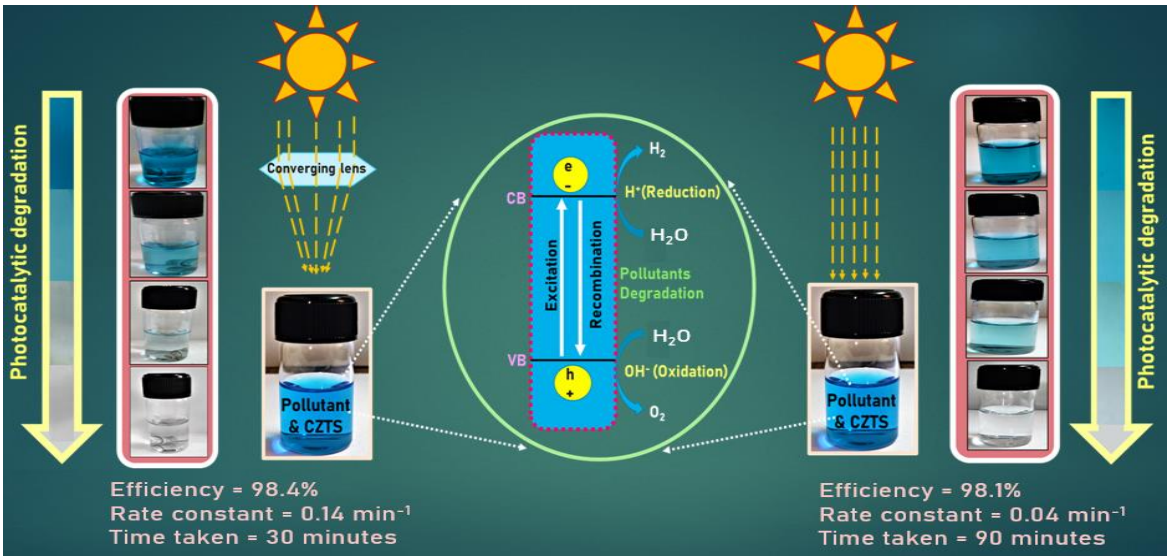
initiated to develop PSCs via conventional printing techniques and for printing of these solar cells we have in-house designed and developed a printer, which can print the solar cells in 30 x 30 cm^2 area. To control the operation of the printer we developed a LabView program. The printer can print any kind of material from their solutions on any kind of substrate. The only limitation of this printer is the print size and it can't print the metal electrodes. The following figure shows the photograph of the printer. The computer program is also shown in the photograph along with other components of the printer.

Photograph of the perovskite solar cell printer, which can print different layers of perovskite solar cells in 30 x 30 cm^2 area. The program, which controls the operation of the printer, is also shown in the laptop.

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

CZTS (Cu_2ZnSnS_4), 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. In this work, CZTS is prepared by an ingenious, cost-effective colloidal route using the 'hot-injection' method with the usage of different ligands. The XRD and Raman spectroscopy shows the single-phase highly crystalline CZTS nanoparticles with kesterite structure. The TEM results show that the size of CZTS nanoparticles is about 2-5 nm and monodispersity is confirmed by DLS (Dynamic Light Scattering). FTIR confirms the presence of different ligands used in CZTS preparation. The Uv-vis absorption shows the direct bandgap of 1.5-1.7eV. The contact angle study shows the hydrophobic nature of as-synthesized CZTS nanoparticles which were further ligand exchanged with L-cysteine hydrochloride to make it hydrophilic to study the photocatalytic degradation activity of organic pollutants and industrial waste in the water. The photocatalysis experiments were performed under two conditions: (i) Under bare sunlight (Intensity ~ 900W/m^2) (ii) focusing the sample under the sunlight via converging lens (1800W/m^2). The photocatalytic efficiencies were then compared and the best photocatalytic efficiency achieved 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. To the best of the author's knowledge, a rapid and highly efficient photocatalysis of CZTS NPs employing a converging lens for water-remediation without the usage of noble & transition-metals has been reported for the first time (graphically shown in figure below).



Graphical abstract showing photocatalysis procedure

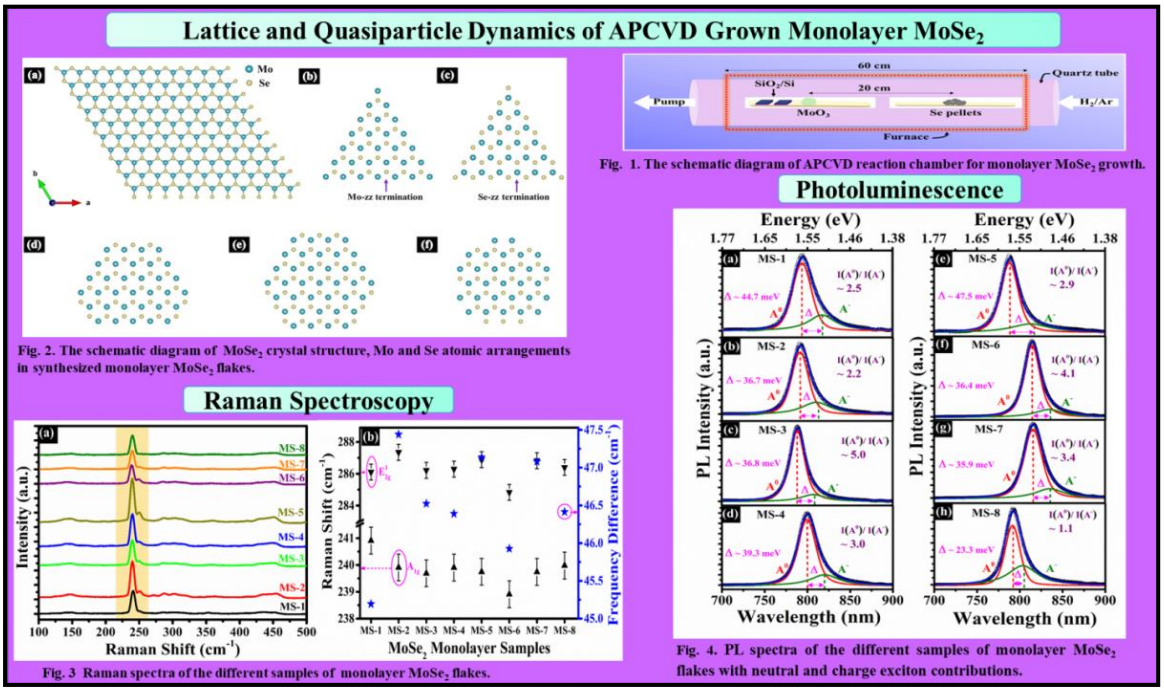
Blue Laser Induced Phosphor Coated White light – Future Technology

The blue laser induced white light is a promising candidate to revolutionize the luminous intensity of the white light by several orders of magnitude as compared with the existing blue light-emitting diodes based white light. This emerging technology has an extremely bright future with endless uses of tunable power of the laser that controls the intensity of the emitted white light for several applications such as head lights in automobile industries, rail engines, playground and many more.CSIR-NPL has designed and developed a prototype device based on phosphor-incorporated sapphire disc (PISD) on excitation by a blue laser diode produces highly-efficient white light. The CSIR-NPL has developed this prototype under a consultancy project entitled "Development of YAG: Ce yellow phosphor integrated with blue diode laser to produce white light for a car headlight application" funded by Fiem Industries Limited, Sonepat- Haryana, India. This new approach provides a paradigm shift to produce highly-efficient white light based on PISD integrated with a blue laser diode as compared with the conventional technology. Recently, Fiem Industries conducted a joint meeting of industries collaborative discussion (Yamaha, Japan and Fiem) for futuristic lighting systems development and related demonstration on 13th October 2021 for automobile head lights with leading international two wheeler company Yamah, Japan at Fiem Industries Limited, Sonepat, Haryana, India. CSIR-NPL and Fiem Industries limited jointly presented and demonstrated a prototype based on Laser Assisted Remote Phosphors (LARP) white light generation for automotive lighting for automobiles. This joint effort is a stepping stone towards make in India (Vision of Nation) for future technology based on Blue Laser Induced White light.

Demonstration of a blue laser induced phosphor coated white light prototype device developed at CSIR-NPL

Lattice and Quasiparticle Dynamics of APCVD Grown $MoSe_2$ Monolayer

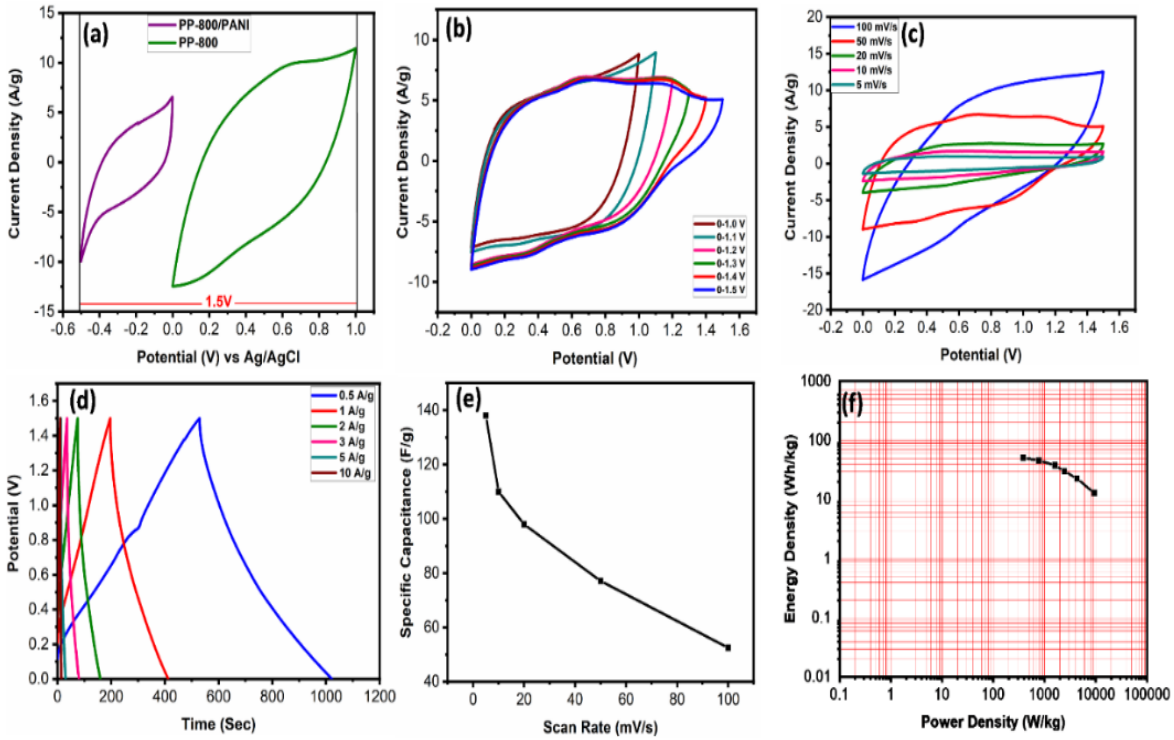
Monolayer $MoSe_2$ is one of the fascinating 2D structures in TMDs, which has high optical absorbance, good thermal stability, and exhibits photoluminescence enhancement compared to its bulk counterpart. For designing optoelectronic and quantum devices, the optical properties need to be studied. CSIR-NPL have been synthesized monolayer $MoSe_2$ flakes using a lab-built CVD setup and a broad range of shapes including, sharp triangle, truncated triangle, hexagon, and rough edge circle has been achieved. The quality of as-grown monolayer $MoSe_2$ flakes are analyzed by optical microscopy, Raman spectroscopy, and photoluminescence (PL) successively. The lattice and quasiparticle dynamics are examined under different growth conditions using Raman and PL spectroscopy. This study will be highly suitable to control the optical properties.



Tunability of excitonic quasiparticles in CVD grown monolayer $MoSe_2$

Development of Pineapple Peel Derived Porous Carbon/PANI Composite Electrode for Asymmetric Supercapacitor Application

Pineapple peel was chosen as biowaste precursor to synthesize activated carbon (PP-800). Further in-situ chemical oxidation method was used to synthesize composite of PP-800 with polyaniline (PANI). PP-800/PANI when tested in 1M H_2SO_4 in three-electrode configuration achieved a high specific capacitance (377 F/g), at a current density of 2 A/g. This is due to the incorporation of PANI into PP-800 which introduces polarity of the material which in turn significantly enhances the diffusion contribution for PP-800/PANI (86.25%).The supercapacitor device PP-800/PANI//PP-800 fabricated delivered a high energy density of 51.2 Wh/kg at a decent power density of 380 W/kg. It demonstrated 98% coulombic efficiency and retained 90% of its initial specific capacitance after 10000 charge-discharge cyles.

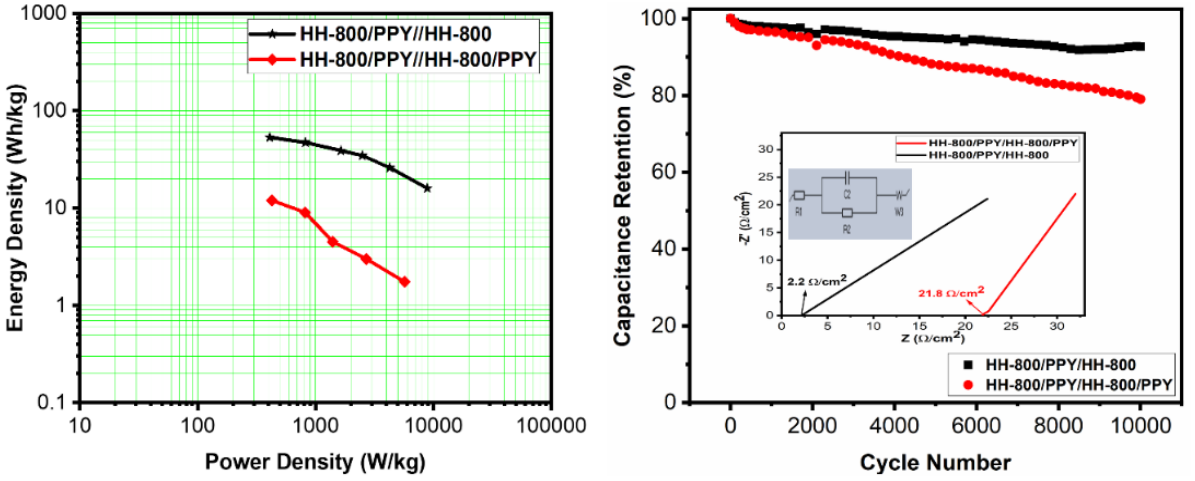


Electrochemical performance of assembled PP-800/PANI//PP-800 asymmetrical supercapacitor comprising PP-800/PANI as negative electrode and PP-800 as a positive electrode: (a) combined potential window of PP-800 and PP-800/PANI in three electrode system for 1M H2SO4 electrolyte, (b) CV at different potential window (c) CV at different scan rates (d) GCD at different current densities, (e) Variation of specific capacitance wrt different current densities and (f) Ragone plot

Development of Human Hair Derived Porous Carbon/Polypyrrole Composite Electrode for Asymmetric Supercapacitor Application

Human hair has been utilized as biowaste precursor (because of inherent heteroatoms present in them) to yield activated carbon HH-800. In-situ chemical oxidation technique

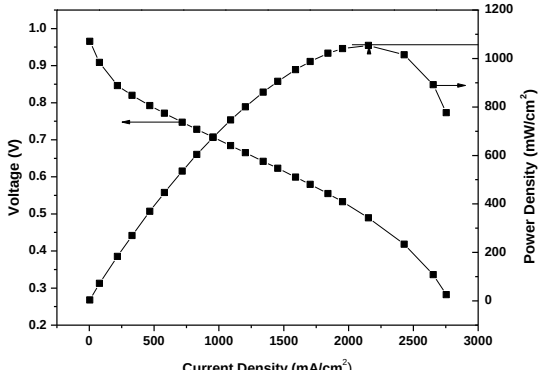
was used to generate human hair derived carbon and polypyrrole composite (HH-800/PPY). The HH-800/PPy composite when evaluated in a three-electrode configuration in 1M H_2SO_4 electrolyte, outperforms HH-800 and PPy, with a higher specific capacitance of 358 F/g compared to 274 F/g and 53 F/g obtained for individual components respectively (at current density of 0.5 A/g). Both symmetric and asymmetric devices were fabricated wherein the HH-800/PPY//HH-800 asymmetrical supercapacitor device delivered an ultra-high energy density of 53.3 Wh/kg with a respectable power density of 408.5 Wh/kg.



Electrochemical performance comparison of both device HH-800/PPY//HH-800/PPY and HH-800/PPY//HH-800 device: (a) Ragon plot (b) capacitance retention vs cycle number with the inset of Nyquist plot

Development of Carbon paper for PEM Fuel Cell

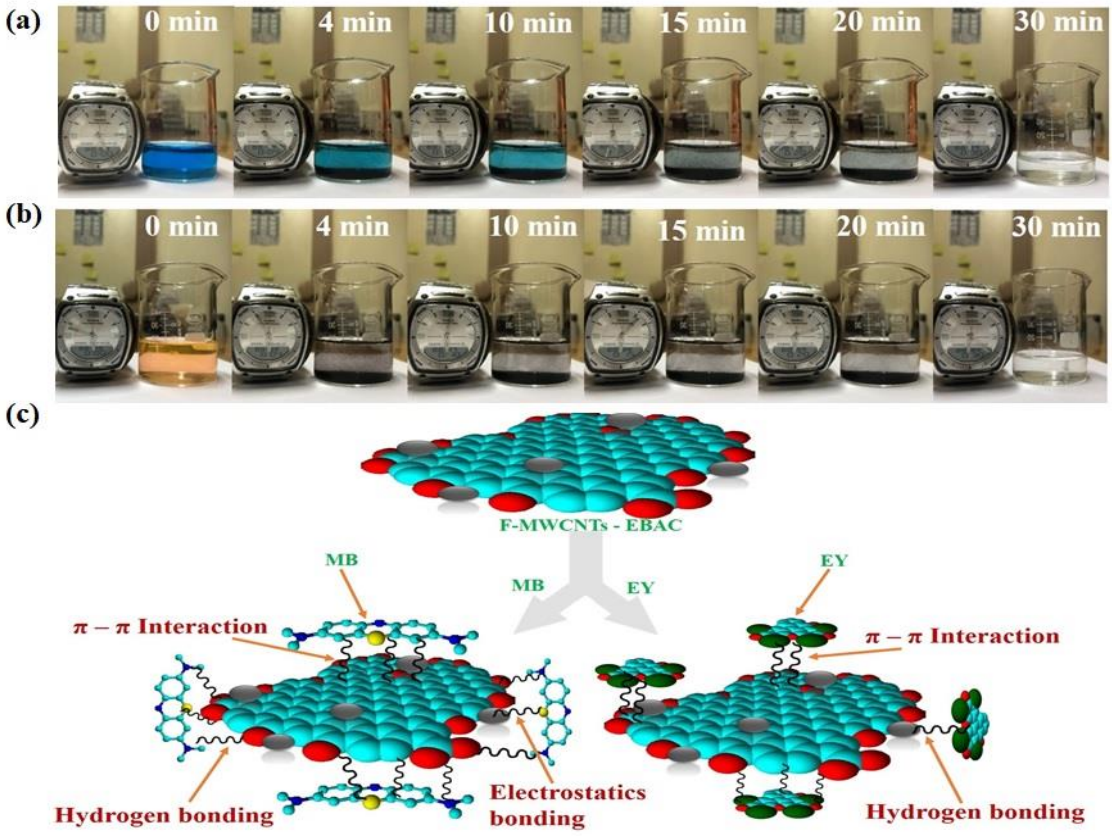
Porous conducting carbon fiber paper has been identified as the most suitable electrode backing material in a fuel cell. Studies have been carried out to modify the carbon paper by inclusion of Pitch fibers in place of PAN fibers. Different concentrations of PAN fibers and pitch fibers were used for the preform preparation. A significant improvement in the physical and electrical properties of the carbon paper, due to the modification in fiber constituent has been observed. The sample with all pitch fiber, delivered a peak power density of 1053.7 mW/cm2, which is the highest reported till date.



Polarization curve of the unit PEM fuel cell with NPL carbon paper sample

CNT-Activated Carbon Composites for Efficient Dye Removal

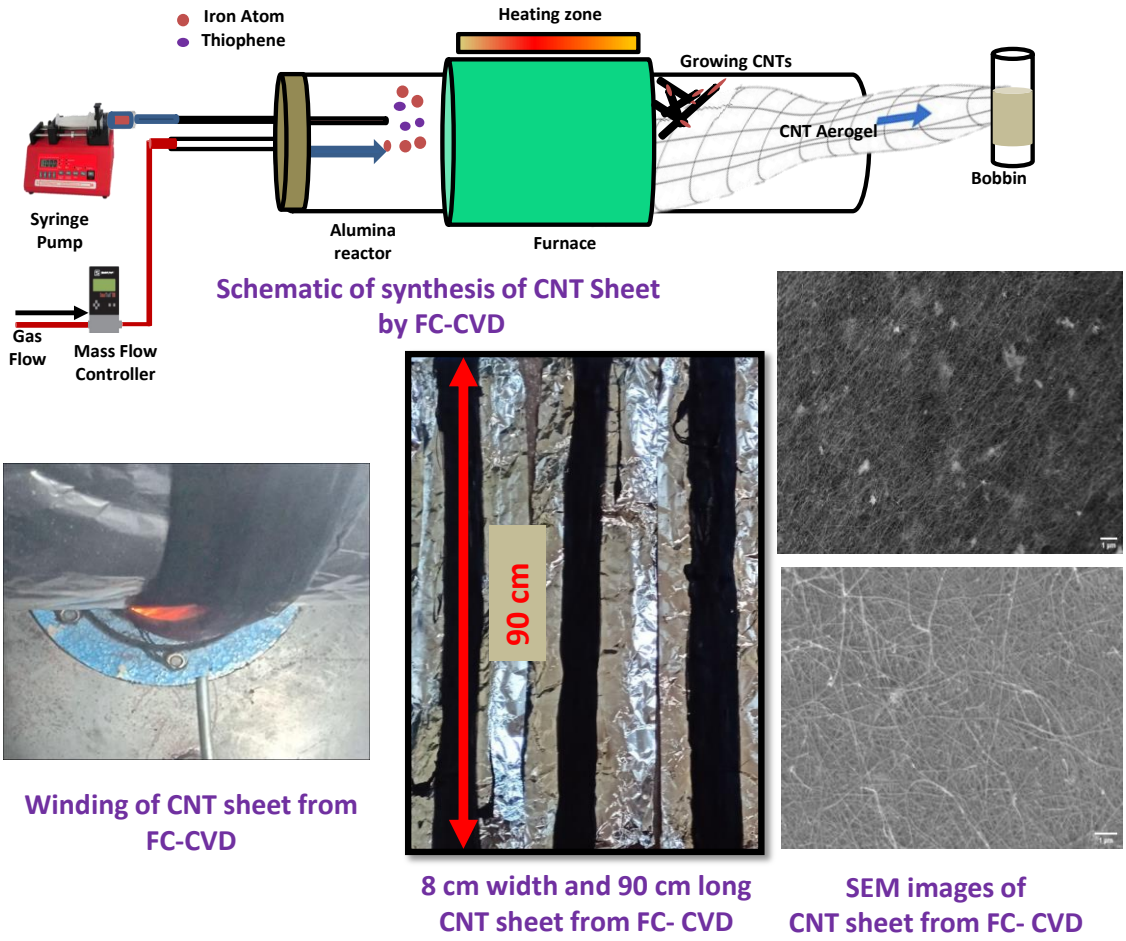
The acid functionalized multiwall carbon tubes (MWCNTs) incorporated activated carbon composite (MWCNTs/AC) was synthesized by eucalyptus bark powder and CNTs by a novel route. The as prepared composite was systematically and comprehensively investigated for the removal of cationic dye methylene blue (MB) and an anionic dye eosin yellow (EY) from the waste water. In 15 minutes, this composite removed more than 90% of the dyes, whereas pure activated carbon took three hours to remove 90% of the dyes.



Demonstration of (a) MB (b) EY dye removal and (c) Proposed mechanism for MB and EY adsorption by F-MWCNT EBAC

Synthesis of CNT Sheets by Fluidized Chemical Vapour Deposition

Further, CNT sheet of size 8 cm width and 90 cm length has been prepared by fluidized catalytic chemical vapor deposition. These CNT sheets are advantageous over the bucky paper prepared by powder CNTs in terms of their mechanical and electrical properties due to the orientation of CNTs in the sheets at the time of processing.



Schematic of synthesis of CNT Sheet by FC-CVD

Winding of CNT sheet from FC-CVD

8 cm width and 90 cm long CNT sheet from FC- CVD

SEM images of CNT sheet from FC- CVD

CNT sheet by FCCVD technique

Certified Reference Materials (CRMs) Development

The accurate and precise measurement of any material and product requires a certified reference material (CRM). CRMs are essentially the reference materials with a certified value, in which the measurements are traceable to National Measurement Institutes (NMIs). Currently in India, all the CRMs are being imported, either from the NMIs of USA i.e. NIST or others. All the developed countries have very strong program on certified reference materials. Unless the products produced have been certified with the help of metrological institutes it will not be acceptable in the international market. At present, the certified reference material program in India is not very strong. Some of the major existing industries in India are taking SI traceability or reference materials from other NMIs. These reference materials have to be procured at very high cost and they need to procure it again and again after the validity of the reference material.

From the past few decades, India faces a huge problem due to poor quality import on one hand, and rejection of our export at foreign borders on the other hand, causing a huge economic loss to the country. The main reason for this is the non-availability of reasonably priced CRMs to the various test labs. India has nearly 4 lakhs testing laboratory dealing with the quality control of in-house material/products/services and import/export business. In many cases, in order to export the Indian product, the

testing is done in foreign country, which not only expensive but also taking away our jobs related quality control and testing. Therefore, in-house production of the BNDs/CRMs is essential for import/export as well as the job creation. On 4th January 2022, CSIR-NPL has released four BNDs related to gold and silver.

India is the largest consumer of gold, silver, and platinum jewelry. Not only these but there are also so many other artificial pieces of jewelry. Humans use jewelry. It is an ancient part of Indian culture. Also, jewelry is used in temples, etc. The business of jewelry in India is nearly a trillion dollars. Different jewelry has different colors like gold is yellow, silver, and platinum is white. There are various other metals/alloys which have similar coloring. If they are mixed, for an ordinary person without any sophisticated instrument, it isn't easy to know which metal is used. Many cheating and forgeries go on when a person goes to the market to purchase jewelry. Sometimes one does not get the purity for which he has paid. While selling, one does not get the price for the material.

Therefore, through the Board of Indian Standards, the Government of India has a proposition that only gold with a certain purity, 8 carats, 14 carats, 18 carats, and 22-carat, will be available with the jewelers. Another gold purity is not allowed in the market. There will be a certification mark on the gold with Hallmark and other symbols. For calibrating the XRF, certified reference materials (CRM) are required. Right now, India is procuring CRMs for various metals at a considerable cost. If the CRMs for these materials can be produced locally, then they can be made available to all the jewelers and made mandatory to calibrate their equipment. Therefore, there is a need to make different grades of certified reference materials for metals like gold, silver, platinum, etc. CSIR-NPL India, in collaboration with Mint Mumbai and M/S Jalan, has initiated making of these CRMs.

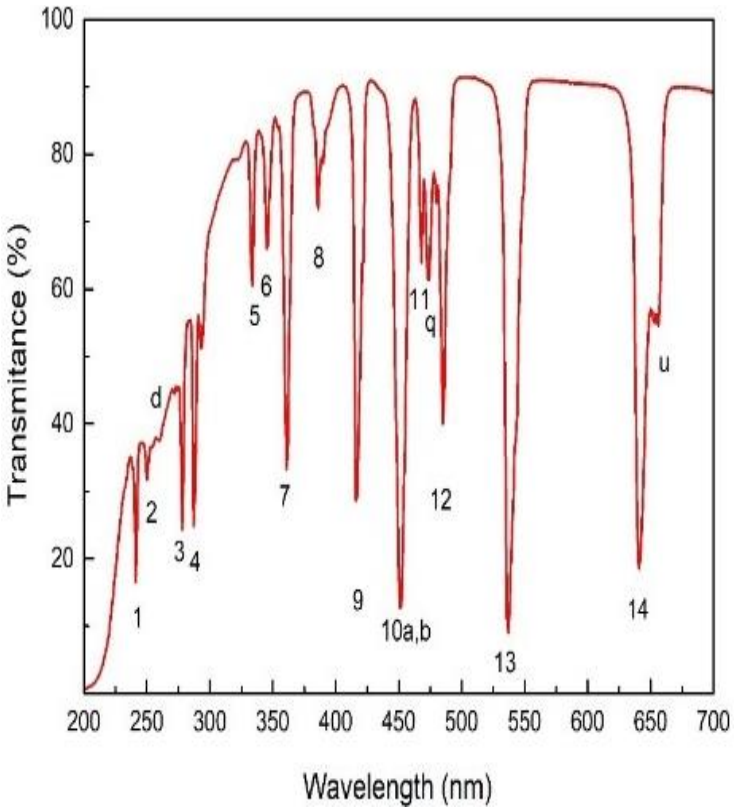
In recent days, CSIR-NPL is joining hands with various reference material producers (RMPs), and CSIR-NPL will help them to establish SI traceability linking to the Primary Standards exist at NPL or by developing method employed for the production of the CRM and will also issue BND certificates considering all the norms for authenticity of the CRM/BND. Using the BND for the respective parameter will certainly ensure the reliability in the measurement for the product being tested by will help to develop the quality of products to be exported without any hurdle involved in the export process. Additionally, the quality product thoroughly checked with BND will bring a paradigm shift in yielding major revenue generation to our country and it will indirectly boost our GDP too.

Four numbers of BND (Indian Certified Reference Materials) related to gold and silver purity has been released on CSIR-NPL foundation day 04.01.2022 in collaboration with Reference Material Producer (RMP) M/s Jalan, N. Delhi.

1. BND® 4101 high purity silver
2. BND® 4102Silver Alloy.
3. BND® 4201A High Purity Gold
4. BND® 4202Gold Alloy.

Calibration Standard for UV-Vis spectrometer (BND® 2022)

The wavelength calibration standard using 4% Ho_2O_3 solution in perchlorate acid is prepared as indigenous reference material (**BND® 2022)** for the wavelength calibration of Uv-Vis spectrophotometer. The transmission spectra for Ho_2O_3 solution have been collected in the wavelength range of 200-700nm. The associated uncertainty has been evaluated using an uncertainty budget for 11 transmission bands. The associated uncertainty is found to be within ±1.5 nm with coverage factor 2 at 95% confidence level. The results are in good agreement with that of SRM 2034 produced by NIST.



Towards Establishment of State-of-the-art Time Laboratories at Five Cities

Under the mission of 'One Nation – One Time'; the timing laboratories of the Legal Metrology Department in five RRSLs, namely, Guwahati, Bangalore, Faridabad, Ahmedabad, and Bhubaneswar, and one Disaster Recovery Center in Bangalore are being established. CSIR-NPL has piloted this task and provided counselling for these critical infrastructure setups, including the complete lab design, antenna structure design, and civil and electrical layout for deploying sensitive Time & Frequency equipment at various locations. In addition, the detailed project execution plans and procurements of all assigned equipment have also been carried out.

Newly established Time laboratory at RRSL Faridabad and antenna structure for mounting GNSS antennae for the time link

Demonstration of Atomic Clock Model and Time Dissemination Devices at the Technology Pavilion during 75th NPL Foundation Day

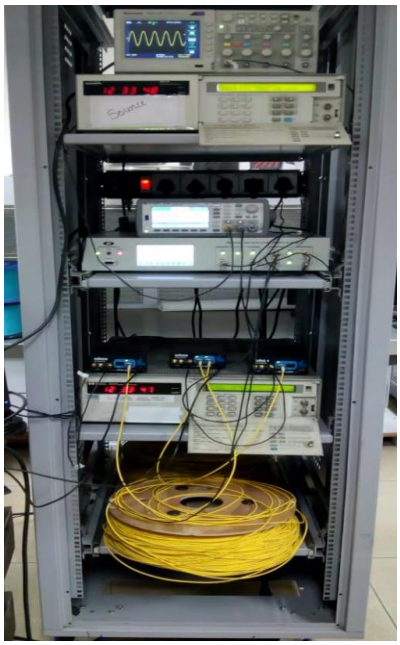
The working models of the 'Cesium clock' and the 'Time dissemination devices' were demonstrated as a part of the 'Technology Pavilion' to commemorate the '75th Foundation Day' celebration at CSIR-NPL. This demonstration was highly appreciated by the Hon'ble Minister, DG CSIR, and many other dignitaries.

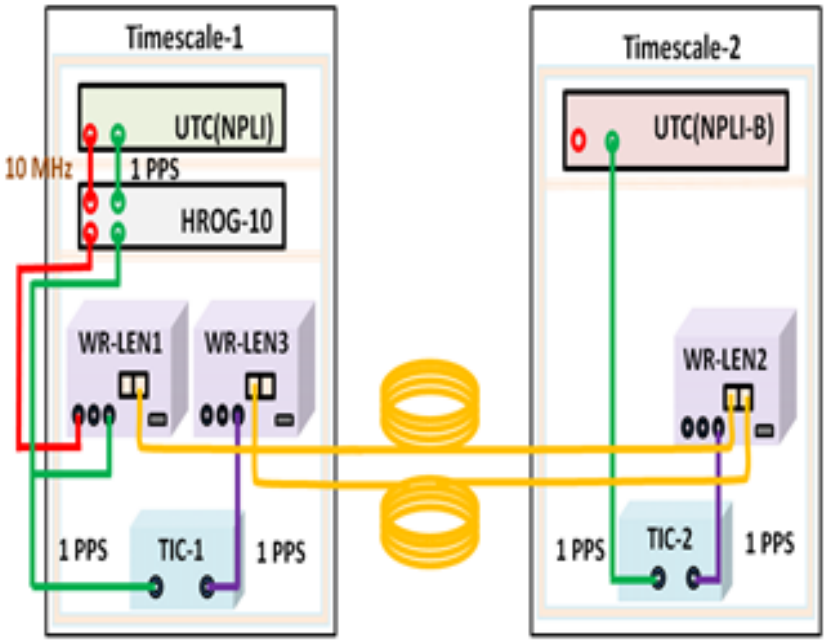
Interactive working model of the Cesium Atomic Clock

Establishment of Ultraprecise Time Traceability Link over a Long Distance Utilizing White Rabbit Network

The time traceability between the two timescales has been established utilizing a white rabbit network-based optical fiber link. Satellite-based methods such as Global Navigation Satellite System (GNSS) and two-way satellite time and frequency transfer (TWTFT) are commonly used for time and frequency transfer within a few nanosecond accuracies. The stability and accuracy of this optical fiber-based time traceability link in different scenarios, mainly under varying ambient temperature conditions, have been studied. Under this context, WR lite embedded node (WR-LEN) that integrates WR technology has been used to build a WR network. A programmable high-resolution phase and frequency offset generator has been incorporated with the WR network to enhance the performance of the time-traceability link in terms of its stability and accuracy. The introduction of active phase compensation improves the frequency stability and reduces the uncertainty of the link. The frequency stability of the link reaches 10^{-17} within one day of integration time, while the uncertainty of the link

remains within ±50ps. The performance of two timescales has been compared utilizing the established optical fiber link for several days, and fractional frequency offset and relative frequency drift between them were also estimated.





Establishment of the New Parameter 'Gain and Linearity' of Nano voltmeter from the PJVS System for the Precision Measurement and Traceability

High precision digital voltmeters (DVMs) serve to calibrate many reference instruments in electrical and electronic industries. The typical way of calibrating a DVM in a particular range is to calibrate the voltage level close to its full scale. But in practice, the whole range is used, which results in the deviation of the values from the perfect linearity. Thus, the linearity analysis of the DVM is even more critical than its gain analysis. The metrological application of the Programmable Josephson Voltage Standard (PJVS) has been extended to analyze the gain and linearity parameter of DVMs apart from generating quantized voltage levels. The PJVS system provides the one-order better uncertainty than the best linearity specification of DVMs. The experimental evaluation for the gain and linearity characterization of DVM, measured with the programmable Josephson voltage standard, which is the quantum voltage standard, has been completed successfully. The uncertainty components of the measurement are also estimated. This work has finally helped to establish the calibration setup of the DVMs for their gain and linearity parameters. The calibration of nanovoltmeters has been provided to the internal group of CSIR-NPL. Earlier, this calibration measurement and traceability were acquired from other NMIs. The establishment of this new parameter contributes toward the significant service to CSIR-NPL India in its efficient functioning & image building and also leads to foreign exchange savings.

Re-established the Traceability of Multi-Junction Thermal Converter

The traceability of the Multi-junction thermal converter (MJTC), which serves as the Primary Standard of LF Voltage and Current, has been re-established with an improvement in the uncertainty reduced to ±4 ppm. Also, for the microwave power parameter, the traceability of the Coaxial Microcalorimeter has been re-established up to 50 GHz for a 2.4 mm connector with an improvement in uncertainty to ±0.43% and for an n-type connector with an improvement in uncertainty to ±0.40%. The long-term stability analysis for the Measurement Class of Phasor Measurement Unit at CSIR-NPL has been carried out successfully from Jan 2021 to Dec 2021. The PMU under test is evaluated to measure the critical class parameters for steady and dynamic performance analysis at 50 fps reporting rate with a nominal frequency of 50 Hz. The performance of PMU is evaluated and tested in conformance with IEEE synchrophasor standard IEC/IEEE 60255-118-1:2018. A very stable reference PMU at CSIR-NPL has been successfully demonstrated to transform and enrich the power sector enabling an adaptive, reliable, sustainable, and digitally robust ecosystem.

Developments of Bharatiya Nirdeshak Dravyas by In-house and through Reference Material Producer

- **Toxic Elements in Rice Flour BND® 3001**: Toxic elements in Rice Flour, Bharatiya Nirdeshak Dravya, BND® 3001 is an indigenous Certified Reference Material of Toxic elements viz. Lead, Cadmium, Arsenic and Mercury in Rice Flour being developed by CSIR-NPL. It is intended to be used as a primary calibration standard for the quantitative determination of Lead, Cadmium, Arsenic and Mercury; calibration of instruments and validation of method for the quantification/characterization of the measurands/analytes.

Toxic elements in Rice Flour BND® 3001

This indigenous BND/CRM is cultivated at CSIR-NPL using Basmati rice of PUSA 1121 and induced with toxic elements. Traceable measurement supported by calibration with matrix based Certified Reference Materials (CRMs) is a very important requirement for international trade of food and food safety. BND® 3001 will ensure high quality in measurements and provides traceability to the analytical measurements with national /international measurement system (SI unit).

To minimize the difficulties faced by the rice testing laboratories while importing CRMs of heavy metals in rice with traceability at an affordable cost and prompt supply, dissemination of SI traceable BND® 3001 will certainly cater the need and thus minimize the difficulties faced by the Rice testing laboratories of India.

- **Portland Slag Cement BND® 5053 & Blast Furnace Slag BND® 5059 Chemical Parameters**: Bharatiya Nirdeshak Dravya of Portland Slag Cement- Chemical Parameters, BND® 5053 and Blast Furnace Slag-Chemical Parameters, BND® 5059 are the Certified Reference Materials, intended to use as primary standard for calibration of instruments, validation of method for the characterization of the measurand for the analysis of cement & cementitious product as well as proficiency test for quality assurance. CSIR-NPL supported the Reference Material Producer NCCBM, Ministry of Commerce and Industry, Govt. of India for the development of these BNDs. These are supplied to various Indian Cement plants, construction industry, accredited laboratories etc. by NCCBM. In addition, NCCBM also supplied BNDs to overseas countries like SAARC, Middle east countries, Europe and expanding market for other countries like USA, Australia etc.

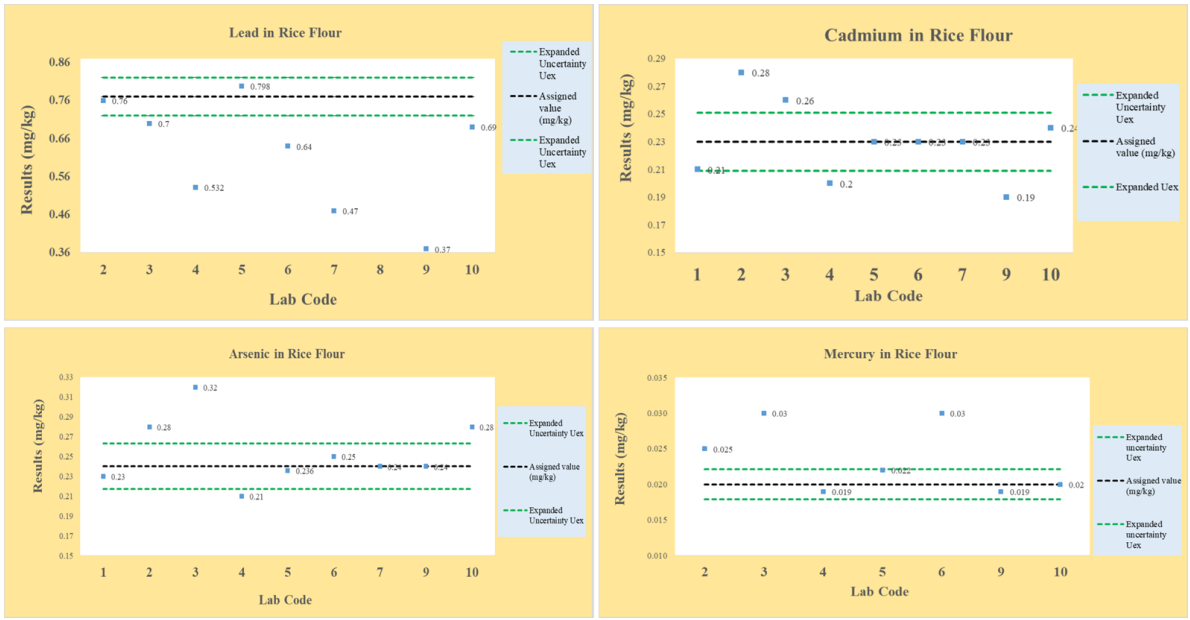
Portland Slag Cement BND® 5053 & Blast Furnace Slag BND® 5059 Chemical Parameters

- **Barium Standard Solution BND®1031:** This Bharatiya Nirdeshak Dravya, BND® 1031, an Indian Certified Reference Material of Barium Standard solution produced by the Reference Material Producer, Aashvi Technology LLP. It is intended to be used as a primary calibration standard for the quantitative determination of Barium, calibration of instruments and validation of method for the quantification/characterization of the measurand.

Barium standard solution BND®1031

Support to the Stake Holders by Conducting Proficiency Testing Program on Heavy metals in Rice Flour

A Proficiency Testing (PT) program has been conducted for the testing of lead, cadmium, arsenic and mercury in rice flour. It was carried out as a consultancy project sponsored by Assurance Laboratory of M/s LT Foods Limited, Sonipat, Haryana. The main purpose of this proficiency-testing program was to evaluate the performance/ measurement capability of participant laboratories in toxic elements in rice flour and develop a practical application of traceability and measurement uncertainty in measurement of heavy metals in rice matrix. There were nine nos. of rice testing laboratories had been participated and the z-Score obtained by the participants were satisfactory for most of the laboratories



z-Score of PT participants for Pb, Cd, As & Hg analytes in Rice flour

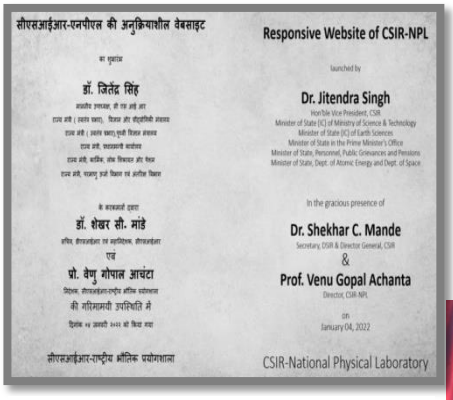
Glimpses of Events

CSIR-NPL Platinum Year Jubilee Celebration [4th -6th Jan.2022]

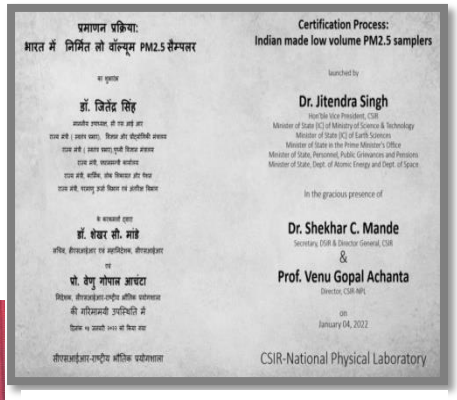
CSIR Technology Demonstration Pavilion

Dedication of LED Photometry Laboratory

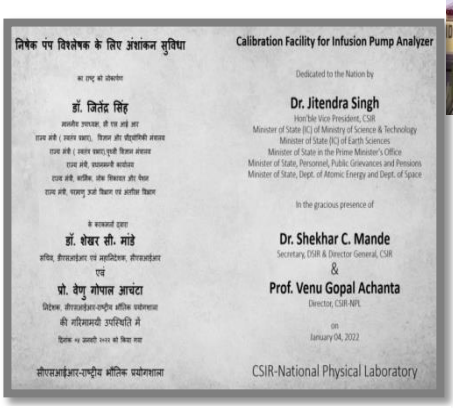
Arrival of Hon'ble Minister to CSIR-NPL Main Building



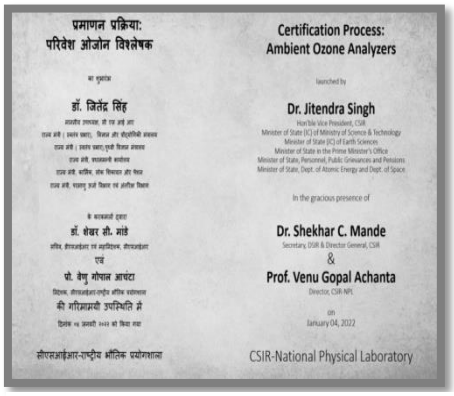
Launch of Responsive Website



Launch of Certification Process for Indian Made Low-Volume $PM_{2.5}$ Samplers



Dedication of Calibration Facility for Infusion Pump Analyser



Launch of Certification Process for Indian Made Ambient Ozone Analysers

Release of Bharatiya Nirdeshak Dravya (BNDs)

Release of CSIR-NPL Compendium

Release of Customized My Stamp and Special Cover

Technical Programme Metrology Conclave- 2022

MSME Meet (05/01/2022)

Stakeholder meeting on “Certification of Air Pollution Monitoring Equipments” (06/01/2022)

Award and Valedictory Function (06/01/2022)

Scientific Interaction Programme for SAARC Countries [10th -28th Jan. 2022]

The SAARC-PTB project sponsored by PTB Germany focuses on capacity building in the quality infrastructure of SAARC NMIs. In this line, CSIR-NPL is playing a Leading Role in strengthening the Metrology Infrastructure of the SAARC region through the provision of technical expertise. Key activity areas include i) scientific interaction among NMIs of SAARC Member States at CSIR-NPL, ii) training of metrologists at NMIs of the concerned SAARC Member State, iii) inter-laboratory comparisons, and iv) other fields of common interest.

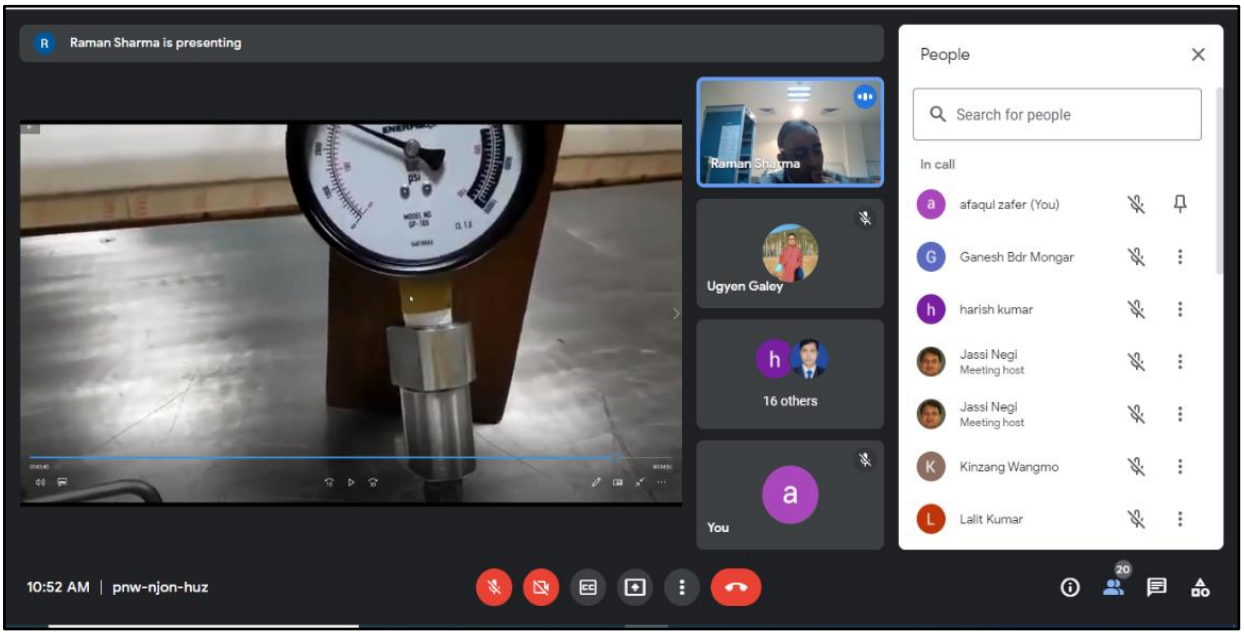
The online scientific interaction programme was organized by CSIR-NPL under the Aegis of SAARC PTB project for NMIs of Bhutan and Bangladesh. CSIR-NPL organized a scientific interaction programme in the area of length, mass, volume, density, viscosity, temperature and humidity, pressure and vacuum, force and hardness, and fluid flow.

The inauguration of the event took place under the chairmanship of Prof. Venu Gopal Achanta, Director CSIR-NPL. He talked about the importance of cooperation among SAARC NMIs and appreciated the effort of PTB. The technical sessions covered – talks, video demos from both sides and discussions on uncertainty in measurement in the areas mentioned above, and were attended by over 12 participants.

SAARC NMI participants in the Online SIP Inaugural Programme 10th Jan 2022 (10/01/2022)

Scientific interaction programme for SAARC countries in mass related parameters organized in virtual mode (12th -14th & 24th -25th January 2022)

A scientific interaction program in pressure & vacuum metrology was organized from 17th Jan to 19th, 2022 for SAARC NMIs through virtual mode. The program was attended by 12 participants from SAARC countries (10 from BSB, Bhutan and 2 from BSTI, Bangladesh. This program included online lectures, demonstration of facilities, calibration procedures for various pressure gauges, and estimation of measurement uncertainty.



Presentation during the Scientific Interaction Program (online) on Hydraulic Pressure calibration of a dial gauge

Online Training Program on Workshop Practices and Dimensional Metrology [October 4th-5th, Oct. 2021]

A two days training program on workshop practices and dimensional metrology was organized for ITI and diploma students from the mechanical/production/industrial engineering branch, under the aegis of the CSIR integrated skill initiative. 130 participants from various institutes and industries participated in this training program.

Demonstrated Activities of Mass Metrology and Related Parameters to the Department of Consumer Affairs [07th Mar. 2022]

Glimpses of the visit of Department of Consumer Affairs delegation to Mass Metrology Section of CSIR-NPL

Workshop on Standardization of Healthcare and Medical Devices held at CSIR-NPL [15th -16th Dec. 2021]

A workshop on standardization of Healthcare and Medical Devices was held at CSIR-NPL in hybrid mode. Eminent scientists, professional doctors, regulators, laboratories, and manufacturers gave the presentations. Healthcare and medical device technologies such as non-invasive digital blood pressure NIBP measurements, clinical thermometers, defibrillators, medical masks, ventilators, etc. developed at CSIR-NPL were demonstrated. More than 300 participants from various laboratories, and industries participated in this workshop.

Group photograph at the Inaugural Function of Healthcare and Medical Devices Workshop

International Conference 'Frontiers in Terahertz Technologies and Applications' [9th - 11th Dec. 2021]

A three-day International Conference 'Frontiers in Terahertz Technologies and Applications' was successfully concluded by CSIR-NPL in collaboration with the Academy of Scientific & Innovative Research.

The participants were from the following leading institutes:

National Physical Laboratory, IIT Guwahati, Korea, Tata Institute of Fundamental Research, Osaka University, ÉTS - École de technologie supérieure, CSIR-CEERI, Virginia Tech, University of Hyderabad, DRDO, Institut national de la recherche Scientifique - INRS Nanyang Technological University, Singapore, IISERTVM, Metu Odtu, SINP Kolkata, Instruments R&D Establishment Dehradun India, IISER Bhopal, S. N. Bose National Centre for Basic Sciences, NISER, Fyzikální ústav Akademie věd ČR, CCS University, TeraLumen Solutions Private Limited, Raja Ramanna Centre for Advanced Technology, etc.

Participants at FTTA-2021

International Workshop on Noise Pollution Monitoring, Mapping and Control [17th Dec. 2021]

An International Workshop on Noise Pollution Monitoring, Mapping and Control was organized by CSIR-NPL in collaboration with the Metrology Society of India. More than 250 participants from all corners of the country joined the workshop held in hybrid mode (online and offline). The eminent international experts of noise mapping and noise pollution control from various countries like U.K, Germany, Japan, Netherlands and France and national experts from IIT Delhi, CSIR-NPL, CSIR-NEERI, SVNIT, Gujarat shared their valuable insights and experiences in noise mapping and noise pollution control in urban cities. The participants were mainly from pollution control bodies, academia, industry and research laboratories in India. The objective of the workshop was to discuss the issue of noise pollution faced all over the world and develop a harmonized strategy for noise mapping and control in India. Dr. Ashish Kamalakar Darpe, Professor, Mechanical Engineering Department, IIT Delhi was the "Chief Guest" of the workshop and Dr S. K. Tyagi, Former Additional Director and Divisional Head, CPCB was the "Guest of Honor".

International Workshop on Noise Pollution Monitoring, Mapping and Control

A compendium on National Policy and Action Plan for Environmental Noise Management & Control in Metropolitan cities of India was released by CSIR-NPL. The compendium presents suggestions and recommendations on a national policy roadmap for noise pollution control that shall be helpful for the development authorities and pollution control bodies to appropriately devise and implement suitable noise control measures for reducing the noise pollution in urban scenario in India.

Release of a compendium on National Policy and Action Plan for Environmental Noise Management & Control in Metropolitan cities of India

International E-conference on Nanomaterials & Nanoengineering: APA Nanoforum-2022 [24th – 26th Feb. 2022]

CSIR-NPL has organized International e-conference on Nanomaterials & Nanoengineering: APA Nanoforum-2022 along with Asian Polymer Association. This conference is to bring together scientists, faculty, experts and students in the field of '*Nano*' to a common platform where nanoscience and nanoengineering with a precise understanding of the molecular and atomic architecture of nanomaterial with several applications in the emerging field of nanotechnology.

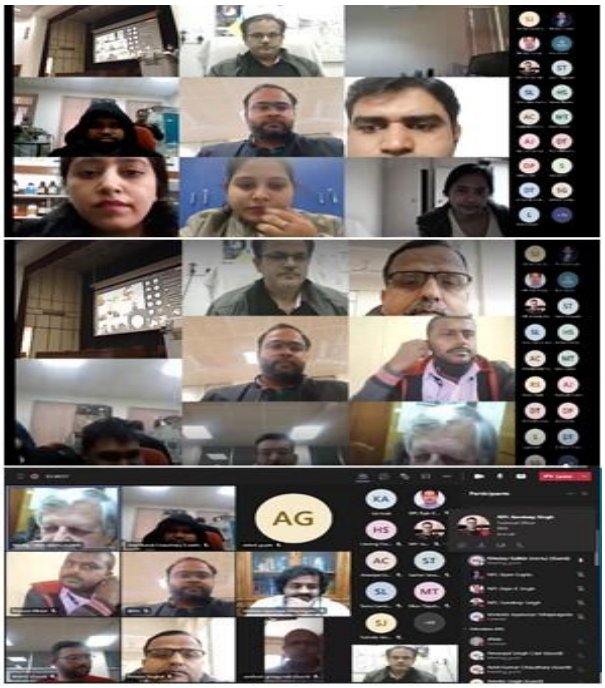
A MOU was signed between NIPER-Guwahati and CSIR-NPL with the Objectives of "Establishment of Testing and Calibration Facilities for Medical Devices in Northeast Region at NIPER-G" [15th Nov. 2021]

National Science Day – 2022 [28th Feb. 2022]

A Poster display symposium was arranged for Ph.D. students. AcSIR Ph.D. students have participated and display their recent research results. Posters were evaluated by external jury members and 13 posters were awarded in three different theme areas.

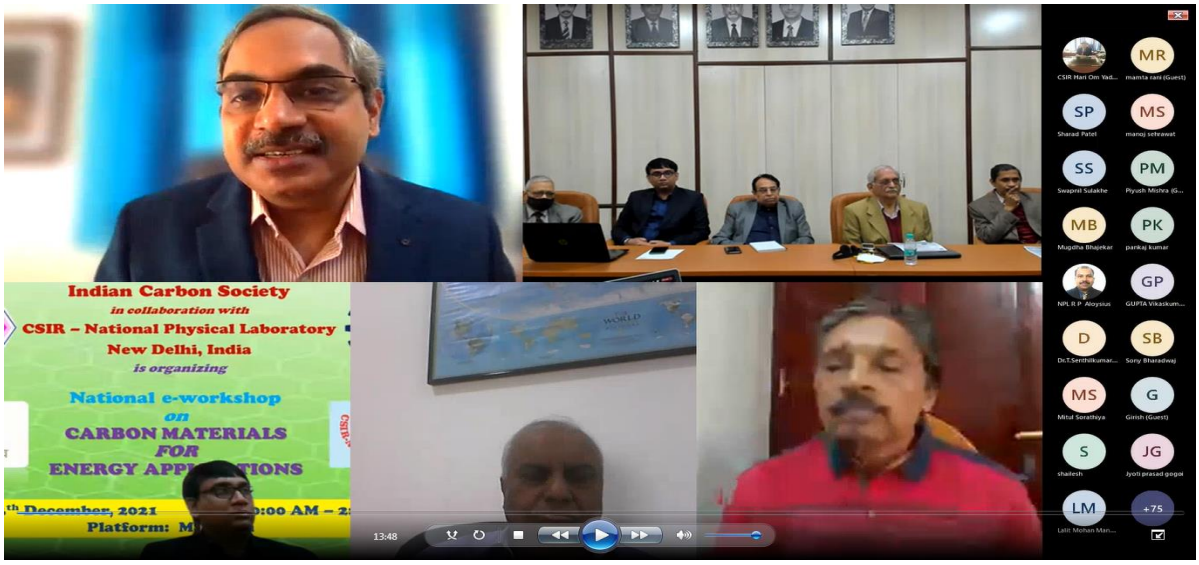
Inauguration and Celebration of NSD 2022 at CSIR-NPL

E-Workshop on "Advanced Spectroscopy for Emerging Materials" CSIR-NPL (22nd- 23rd Dec. 2021)



National e-Workshop on Carbon Materials for Energy Applications [13th Dec. 2021]

This workshop was organized by Indian Carbon Society in collaboration with CSIR-NPL.



E-workshop on "Role of Traceable PMU in Smart Grids" [29th Mar. 2022]

This workshop was organized to bring together scientists, engineers, young researchers, academia, and professionals in the applied research area to understand the role and functioning of the Phasor Measurement Unit in the smart grids and discuss the needs for its implementation across the country.

Divisional Activities

Physico-Mechanical Metrology

The mandate of the Physico-Mechanical Metrology (PMM) division is to establish, maintain, disseminate and continuously upgrade the Physico-mechanical standards. We are responsible for establishing four SI base units and derived units. The division activities include Mass, density and viscosity; Length, dimensions and nanometrology; Temperature, humidity and moisture; Optical radiation; Force, torque and hardness; Pressure, vacuum & ultrasonic; Acoustic and vibration, and Fluid flow metrology. These physico-mechanical parameters are crucial metrology activities that impact our users' science and engineering endeavors. The world-leading measurement solutions provided by us are important to new start-ups, industries and government R&D organizations. These activities help to accelerate research and innovation, thereby improving quality of life and enabling trade opportunities.

This year we could get the financial support for a range of projects from CSIR and other agencies:

a. Facility Creation Project SMART-PM, "Strengthening Metrological Activity for Research and Technology in Physico-Mechanical", consisting of setting up of few primary and secondary standards facilities
b. Setting up a testing facility at CSIR-NPL for personal protection equipment's, ventilators and IR thermal scanners as per national/ international standards
c. NCP Project for Boltzmann Constant and FBR project for quantum pascal
d. Establishment of LED Testing Facility, etc.

We substantially contribute to train the Human Resources in Metrology through a one-year Post-Graduate Diploma (PGD) course on Precision Measurement and Quality Control (PMQC) under AcSIR. Several undergraduate and MSc/M.Tech students performed their summer projects in metrology. During the year 2021-22, the division has published over 70 SCI papers, about 65 conference presentations, 2 books, and a few book chapters, three patents, several Invited Talks, and about five students got Ph.D. in PMM Metrology. A glimpse of the activities of each subdivision is described below.

Mass Metrology

Mass measurements are essential for trade, technology, fundamental research etc. Reliable measurements of mass and its derived parameters which include volume, density, force, pressure, hardness, etc. are indispensable to support many diverse areas. Mass Metrology section maintains the apex level standards for Mass, Volume, Density and Viscosity and provides traceability to the various sectors such as Legal Metrology, Space, Atomic Energy, MSMEs, Delhi Jal Board, Indian Oil Corporation, CPCB, various industries, etc. One of the important sectors is the pharmaceutical industries which are making drugs and medicines. During the year 2021-22, the section has continued its efforts for unceasing upgradation of the national standards and providing traceability to the whole nation. Mass metrology is undergoing two international intercomparisons in volume currently to enhance the range of CMCs organized by APMP.

Some of our achievements in 2021-22 as mentioned below;

a. Intercomparison for volume metrology under the collaborative project of SAARC-PTB under GAP-181232. This will help to establish the CMC in volume in the microlitre range.
b. Intercomparison for volume metrology under the collaborative project of APMP key comparison APMP. M. FF-K4.2.2021. This will help to establish the CMC in volume in the microlitre range.
c. Working towards up-gradation of two pan balance into 100 g Kibble Balance under OLP-214832.
d. Reestablishment of the secondary standards of mass through subdivision technique against the NPK-57(National Prototype of Kilogram in India). This strengthens the traceability of the mass and related parameters.
e. During the COVID-19 pandemic second wave, Mass Metrology Section has provided traceability of E1 and E2 accuracy class weights to the pharma companies like Macleods Pharma, Zydus, Ajanta Pharma, and IPCA labs which are lead producers of Paracetamol and HCQ drugs.
f. Provided continuous traceability to the various fields (derived parameters) related to mass like Pressure, Force, Hardness, Vacuum, Fluid Flow, Gas, Environment, Biomedical, Advanced Materials.
g. Detailed testing of the Digital Alcoholmeters and reports formulation for the consultancy project evaluation of metrological characteristics of digital alcohol meters supplied to U.P Excise Department, TSP-210332
h. Calibration of the volumetric vessels and micropipettes for the BND section that helps to provide CRMs for the country.
i. High precision Laboratory Environmental data logger system has been installed. This system is vital for carrying out comparison experiments and study effect of minute variations in the environment of the lab on the final calibration results.
j. Robotic mass comparator has been established at CSIR-NPL and the operation will commence in the following month with training session for all the professionals from Mettler-Toledo, Switzerland.

Length, Dimension and Nano-metrology

1. Dimensional metrology is an essential element of technological infrastructure for industrial and economic development of a country. Reliable dimensional measurements play vital roles in various aspects of social life and significantly empower numerous scientific and technical fields such as; manufacturing, aerospace, automobile, defense and semiconductor etc. This section provides apex level calibration services for various dimensional measurement instruments to maintain unbroken chain of traceability across the nation and the SAARC countries. Length, dimension and nano metrology section fulfill the parliamentary mandate to maintain the primary standard of length for realization of SI unit

Primary Standard of Length at CSIR-NPL

"meter" through Iodine stabilized He-Ne laser, wavelength 633 nm. This section has various state-of-the-art facilities such as; Coordinate Measuring Machine, Length Measuring Machine, 3D Optical Profiler, Roughness and Contour Measuring Machine, Flatness Measuring Interferometer, Linear Displacement Measuring Interferometer, Gauge Block Interferometer and Roundness Tester etc., to cater the ever-increasing demands of various industrial and R&D segments. Additionally, continuous research and development in the field of precision dimensional metrology for advanced measurement techniques/ standards/ instruments is one of the prime objectives of our section. This group is involved in R & D activity for augmenting and upgrading the standards at par with other leading National Metrology Institutes (NMIs) and continuously participates in international inter-comparisons to establish international equivalence to the international measurement system. Furthermore, we conduct technical workshops and training programs and provide consultancy services to various industries for capacity building across India.

International inter-comparisons during 2021-2022:

a. Piloted the international intercomparison APMP.L-S7 (supplementary comparison on step height standards ranging from 8 nm to 10 μm) with NMI Thailand, AIST Japan, BEV Austria and NMC/A*STAR Singapore. The final report was published in "Metrologia" in August 2021.

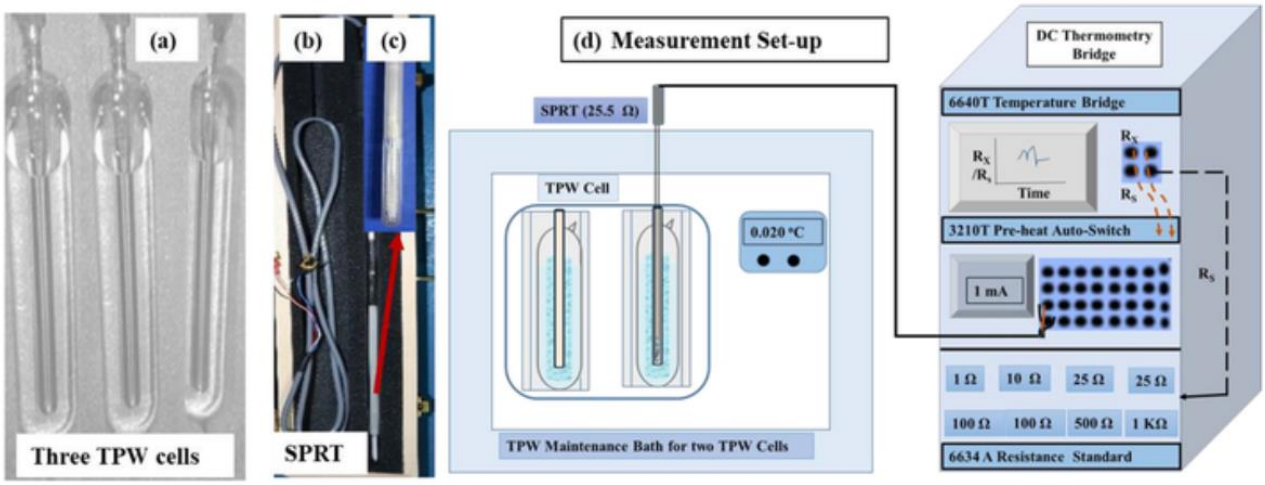
b. APMP Key Comparison APMP.L-K4.n01: Calibration of Diameter Standards

c. EURAMET.L-K3.01 Key Comparison Calibration of Angle Standards

Temperature and Humidity Metrology

The subdivision maintains the primary temperature and humidity parameters standard from -200 ^{o}C to 3000 ^{o}C and 10 % RH to 95 % RH. Apex level calibrations and traceability to SPRTs, RTDs and various resistance sensors, LIGTs, thermocouples, pyrometers, blackbodies, thermo-hygrometers, dew/frost measurements, moisture measurements and mercury-free (electrical and IR based) clinical thermometers to NABL accredited Labs, SAARC NMIs and the government sectors lies in the mandate of this sub-division. During this year, our research activities include (i) development of some of the components for Acoustic Gas Thermometry to realize new kelvin based on the Boltzmann constant, with financial support from CSIR under NCP scheme (ii) developed in-house traceability for the calibration of radiation pyrometer upto 3000 ^{o}C. Development of Ni-C eutectic fixed point [1329 ^{o}C] for high temperature thermometry, (iii) improved the measurement uncertainty in the realization of Triple Point of Water using an ensemble of three TPW cells which will be used to realize the Boltzmann constant based new definition, at the initial step, (iv) study of self-heating effect in different type of platinum resistance thermometers, (v) development of Humidity sensor based on SnO_2, ZnO, carbon materials and electrodeposition of IR absorber layers based on InSb, (vi) development of various components for the testing facility for establishing the traceability to IR Thermal Imagers in India for febrile body screening purpose, under the Testing Facility Development support from CSIR. (vii) designed and developed hot and cold plates for ongoing work of Guarded-hot plate primary standard for thermal conductivity measurements. (viii) successfully established the Clinical

Thermometer Testing Facility at RRSL Varanasi and Ahmedabad under the Technical Services project from Legal Metrology Department. (ix) developed the long probe-based temperature measurement facility and successfully thermal mapping and validated the 4 ^{o}C and -20 ^{o}C cold storage vault rooms for the storage of plant seeds at National Genebank, ICAR-National Bureau of Plant Genetic Resources, Pusa. This is one of the world's largest seed conservation facilities.



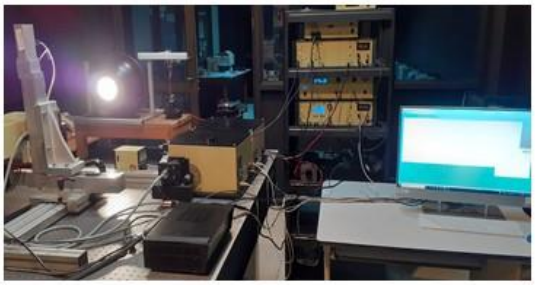
Measurement scheme to realize the ensemble of TPW cells using standard platinum resistance thermometers for uncertainty improvement upto 0.1 mK

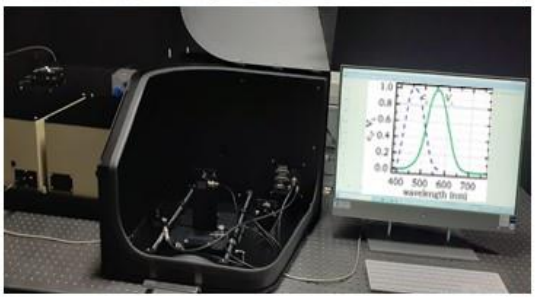
Optical Radiation Metrology

Photometry is the branch of metrology which includes the measurement and quantification of the light and its attributes as perceived by the human eye. LED based lighting, being energy efficient as compared to the other available classical sources, longer life time, most rugged and eco-friendly to nature, are being adopted by the society as a popular solution of illumination today. Govt. of India is also running its major flagship programs, namely Unnat Jyoti, UJALA etc., towards promoting LED lighting sources to save electricity and reduce carbon footprints of India.

a. The Optical Radiation Metrology Section has been entrusted with a project of national importance by the Bureau of Energy Efficiency (BEE) to establish an apex level calibration and testing facility for LED based lighting, funded by the Ministry of Power, India. The project envisages creation of an apex level measurement facility to characterize and provide traceable measurement of LED lighting as per national and international standards. In the ongoing efforts civil infrastructure for installation and housing of high-end metrology grade systems has been created with controlled and precise environmental conditions over a big space.
b. The installation of two major metrology systems C-type Goniophotometer and Optical Radiation Test Systems in the externally funded project has recently been completed, and their performance is under evaluation.

Creation of civil infrastructure for the Installation of a 30 m long optical tunnel for the installation of C-type Goniophotometer and other Systems as per the requirement of IES, IEC and IS standards





C-type Goniophotometer System

Optical Radiation Test System

c. After the derivation of the most desired traceability for UV radiation measurements the Section has started disseminating the traceability of UV irradiance scale through precision measurement and calibration on regular basis. It not only saved the foreign exchange of India but also the process time of getting it during such a pandemic struck high time amid foreign restrictions which otherwise, could be obtained from foreign NMIs or their accredited testing and calibration laboratories.

Force and Hardness Metrology

The role of Force, Torque and Hardness Metrology is very important to achieve quality assurance in various engineering sectors of the country such as Infrastructure, Space, Automotive and Aviation, Defense, Energy, Mining, Metallurgy, etc. CSIR-NPL is primarily responsible for the establishment and maintenance of the national standards without which we will not be able to provide the necessary traceability to the industries across the county. This will directly affect the quality of product manufactured which in turn will affect the overall industrial growth, trade and economy of the country.

The dissemination of these standards benefits several stakeholders, including Government organizations, Public and Private sectors. The Indian Cement Industry is

one of the booming sectors for the economic development of the country and next comes the iron and steel industry. The compressive strength of concrete cubes are tested by subjecting it to compressive load using a compression testing machine (CTM) in civil engineering laboratories following a defined loading sequence. These CTM are first verified for their accuracies of generated forces against a set of reference force transducers which are duly calibrated either directly by CSIR-NPL or through some NABL accredited laboratories. This enables them to maintain an unbroken chain of measurement traceability to the primary standard established at CSIR-NPL and also provides the quality assurance related to the cement produced across the country. We are providing the measurement traceability in the above mentioned parameters to UTMs, CTMs, Torque wrenches, and hardness testing machines used in wide range of Industries. This would help the nation to improve producing highly competitive quality products, develop confidence in strengthening the R&D activity, overall economy and better living conditions.

An experimental study was conducted to explore the feasibility of vertically aligned carbon nanotube (VACNT) nanocomposites impregnated in different polymer matrixes as highly efficient piezoresistors in sensor applications. Polymer nanocomposites are selectively designed and fabricated using three different polymer matrixes, i.e., polydimethylsiloxane (PDMS), polyurethane (PU), and epoxy resins with ideal reinforcement of VACNTs to enhance the thermal stability, conductivity, compressibility, piezoresistivity, and sensitivity of these nanocomposites.

The piezoresistive responses of the VACNT/polymer nanocomposites were tested using a custom-designed experimental set-up for applying precision compressive forces using calibrated loading hanger and masses. The samples were placed between two discs, with metallic contacts (for electrical resistance measurement), for uniform distribution of the applied forces across the entire area, and the change in electrical resistance was measured using a Source Meter. The samples were tested by employing the calibrated hanger and masses, firstly in step of 2 N loading up to 20 N, secondly in step of 5 N loading up to 50 N and thirdly in steps of 10 N till 150 N. The relative change in resistance with the applied forces were measured and from these observations it is inferred that the PDMS/VACNT nanocomposite is capable of sustaining large force with almost complete recovery and enhanced sensitivity, thereby fulfilling the desirable need for a highly efficient conductive and flexible force sensor as compared to PU/VACNT and epoxy/VACNT nanocomposites.

Pressure, Vacuum & Ultrasonic Metrology

Pressure, Vacuum & Ultrasonic Metrology Section provides the metrological traceability of derived parameter ‘pressure’. The section establishes apex level calibrations in pressure, vacuum, and ultrasonic measurements and maintains the international level's traceability of pressure and vacuum measurements. The main objective and activities of the section are to establish, upgrade and maintain national measurement standards of pressure and ultrasonic measurements as par to international pressure measurement standards through continuous research and development. Over the years, the section has achieved the global status of competent pressure measurement standards and disseminated the national traceability to the industries and laboratories. The section provides traceability to many government organizations as well as industries, including

Indian Oil, VSSC (ISRO), Ordinance Factory, BHEL, Field Gun Factory, GAIL, NTH Kolkata, ERTL (N), RRSL, Intertek, Safran India Private Limited, IIT Roorkee, Fare labs etc. Furthermore, the section provides training and technical services in pressure metrology.

The section has procured and successfully installed a new base of the reference pressure standard. For the up-gradation of the existing facilities and to cater to the need of high pneumatic pressure of industries, the section has initiated the process of procurement of high-pressure pneumatic primary standard up to 100 MPa.

Device to Use Conventional Ultrasonic Flaw Detector as EMAT based Flaw Detector (Technology is ready for transfer)

Ultrasonic Flaw Detectors (UFDs) are extensively used for the detection of flaw, cracks or voids in the field of Non-Destructive Testing (NDT). The material thickness measurement is utilized in various places, including industry. It uses piezoelectric based contact transducers generally called as ultrasonic probes and requires a suitable couplant to test the material. On the other hand, electromagnetic acoustic transducer (EMAT) is a non-contact method of generation and detection of ultrasonic waves in electrically conducting materials. CSIR - National Physical Laboratory has recently developed a technology by which the conventional UFD can be utilized as EMAT-based couplant-free UFD. All the inherent powerful data analysis capabilities of the conventional UFD can be utilized with EMAT based testing of electrically conducting metallic structures.

Acoustic and Vibration Metrology

Since its inception, the Acoustics and Vibration parameters of CSIR-NPL have played a key role in the industrial growth and reducing air and noise pollution in the country. The major activities involved are calibration of acoustical instruments, evaluation of industrial products and 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. The section had been able to provide apex level calibration and testing services and technical advisory consultancy in architectural acoustics to the industry and institutions of the Country. Till date, 34 Calibration and Measurement Capabilities (CMCs) in the field of sound and vibration had been included in the BIPM database. Efforts are targeted to increase the number of CMCs in the BIPM database to solve the problems and challenges faced by industries and other stakeholders. The important applications of acoustics and vibration parameters are in:

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 acoustics and vibration standards activity has been involved in the up-gradation of the primary sound and vibration standards with reduced measurement uncertainty at par with the other NMIs is the APMP region. The sub-division participated in an APMP MEDEA Project focused on conducting an International Key Comparison for Sound Level with NMI Japan as pilot laboratory and six participating laboratories in March to August 2021. The activity was also involved in completing the consultancy assignments from the M/s West Bengal Electronics Corporation Ltd, Kolkata on developing the indigenous Noise Monitoring Terminals and by M/s Anutone Acoustics Ltd., Bengaluru, on the evaluation of sound absorption characteristics of sound absorbing materials. The sub-division also actively participated in various institutional committees set up for noise pollution measurement and control, such as the development of noise guidelines for construction sites; noise pollution control in NCT, Delhi; noise mapping for two cities of Punjab etc. The sub-division has been focused on developing new technologies on developing new sandwich acoustic partition panels providing higher sound insulation and absorption characteristics tested in the Reverberation chambers with the lowest levels of measurement uncertainty for technology transfer to the industries.

Fluid Flow Metrology

The Fluid Flow Metrology section operates and maintains primary water flow calibration facility, water meter testing facility and gas flow calibration facility. It provides traceability to fluid flow measurements in the country. It provides testing and calibration of various types of water flowmeters and gas flowmeters such as coriolis mass flowmeters, electromagnetic flowmeters, turbine flowmeters, differential pressure type flowmeters, rotary positive displacement (RPD) flowmeters, water meters, laminar flowmeters, sonic nozzles, orifice flowmeters, mass flow controllers, thermal

mass flowmeters, rotameters, piston flow calibrators, gas flow analyzers/ ventilator testers, PM samplers, infusion device analyzers, syringe pumps, infusion pumps etc. to various user organizations in the country and abroad. During period under report, 101 test and calibration reports were issued and an ECF of 24.96 lakhs was generated for CSIR-NPL. It also completed a Technical Services Project entitled "Inspection of Water Meter Test Benches of Municipal Corporation of Greater Mumbai" funded by M/s. Nagman Flow Nagman Flow-Level Systems and Solutions LLP, Chennai. Further, the section also participated in APMP Supplementary Comparison (APMP.M.FF-S3.2020) of water flow using coriolis mass flowmeter to support our CMC claims and completed the measurements in April 2021. The measurement results were sent to pilot laboratory (i.e. NIMT, Thailand) in July 2021.

Electrical and Electronics Metrology

The major activities of this division are based on the research and indigenous development of quantum 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; AC/DC high voltage and AC high current; AC power & energy; and quantum standards which includes quantum hall resistance (QHR), quantum current (QC) and quantum nanophotonics (QN). The traceability of the above said parameters are based on Josephson Voltage Standard (JVS), QHR standard and frequency standards (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 metrological services of the division are internationally recognized by the International Committee for Weights and Measures through mutual recognition arrangement (CIPM-MRA) and follow the quality system as per ISO/IEC 17025:2017. The division is continuously putting efforts to upgrade the facilities for various electrical and electronics parameters to cater the demand and needs of the country. Calibration and Measurement Capabilities (CMCs) of this division are published on Key Comparison Database (KCDB) of BIPM. The division also participates in international inter-comparisons regularly to establish degree of equivalence in the above mentioned parameters. The division also works on various quantum materials such as graphene, 2D materials, topological insulators and nitrides based thin film for the development of quantum standards like single photon detection, quantum current, quantum Hall resistance. Glimpses of activities of each subdivision are described below.

LF, HF Impedance and DC Metrology

LF, HF Impedance and DC Metrology sub-division is responsible for maintaining national and reference standards of impedance parameters (up to radio frequencies), precise ac voltage ratio, dc voltage, dc current, and dc resistance, charge (Coulomb) and dc high voltage up to 100 kV. The metrological traceability to SI units is derived from Josephson Voltage Standard (JVS) and Quantum Hall Resistance (QHR) standard, which are being maintained at CSIR-NPL. The primary standard of current (Ampere) is derived from JVS and QHR through the Ohm's law of electrical conductivity.

Along with metrological services the division also carries out cutting edge and fundamental research in frontier areas of condensed matter such as:

a. Quantum Current Standards (QCS)
b. Quantum Condensed Matter Research and Applications

- **DC Metrology**

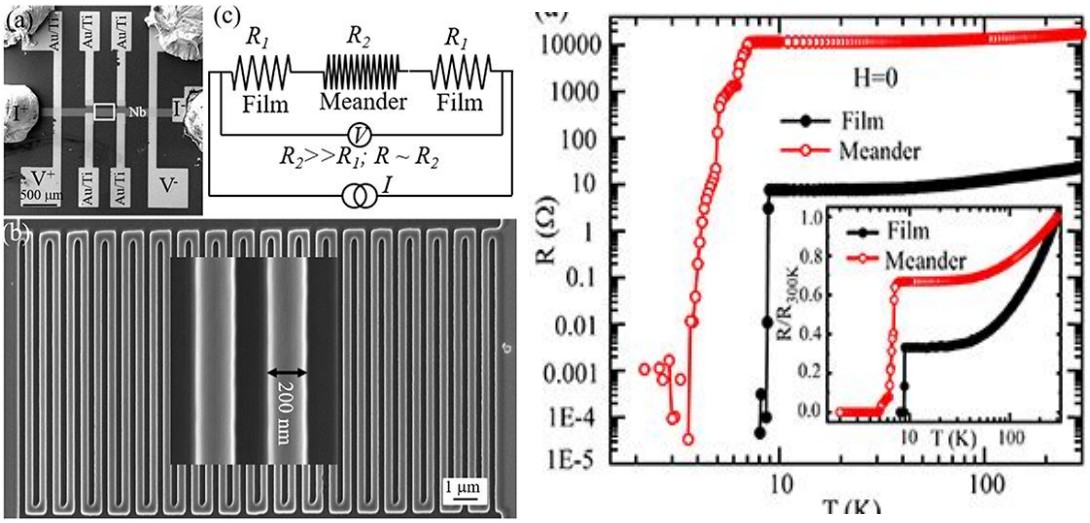
DC Metrology maintains and disseminates units related to DC voltage, DC current and DC resistance. The sub-division has 22 CMCs in the DC parameters for DC voltage; DC current and DC resistance and 3 CMCs in DC High voltage.

- **LF and HF Impedance Metrology**

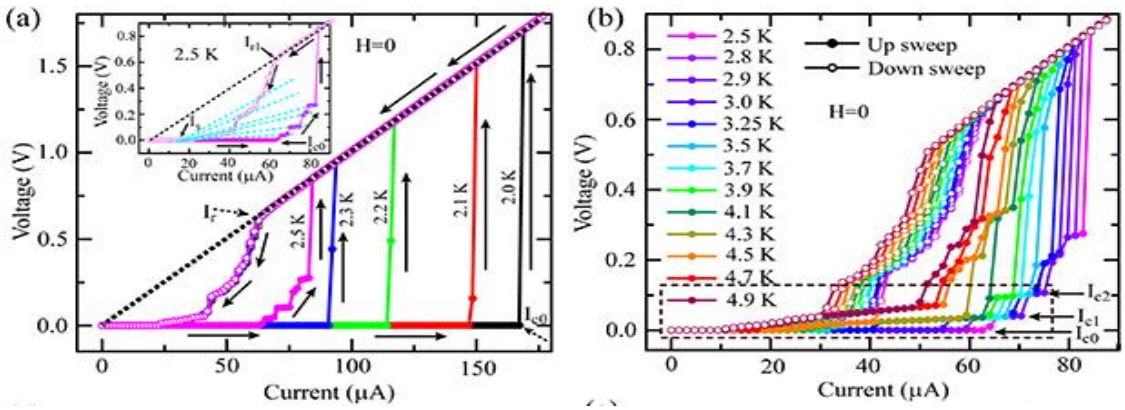
The mandate of the LF, HF Impedance Metrology is to maintain and disseminate the units related capacitance, inductance, AC resistance, inductive-voltage-divider (IVD), ratio transformers, LCR meter, impedance analyser and capacitance bridge. All these quantities are linked to the respective Primary / National standards through an unbroken chain of traceability. With a total number of 8 CMCs, this sub-division is internationally competent in almost all quantities related to impedance parameters.

Research and Development on Quantum Current Standards (QCS)

The R&D on quantum current standards is being actively undertaken by the group through the phenomenon of quantum phase slip (QPS) in superconducting nanowires. Recently, we have demonstrated QPS phenomena in a Niobium superconductor in the form of meander structures. The figure given below shows the image of the Nb meander structures, which is interconnected between Nb films. Along with the image, we also show the results of low temperature measurements of transition temperature and the current-voltage characteristics, which clearly shows the steps indicative of phase slips triggering either in the form of phase slips centers or phase slip lines.



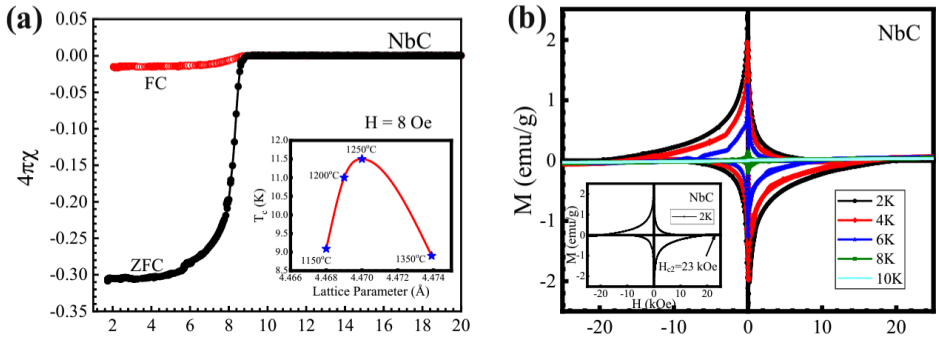
Left panel figure shows the SEM image of the meander structure fabricated from a Nb thin film. The device structure is shown on the top and an equivalent circuit of the device is also shown for the clarity purpose. The meander is sandwiched between the Nb films



IVC of the meander structure at temperature range from 2.0 to 2.5 K in the left panel, and from 2.5 K to 4.9 K in the right panel. On the inset of the left panel is shown the IVC at 2.5 K, where the IC onset and re-trapping current are clearly shown, and steps in the IVC, a clear indication of the phase slip events

Research and Development on Quantum Condensed Matter and Topological Insulator and Related Systems

The group has active R&D on topological system and related materials for fundamental R&D towards quantum applications involving sensor development. The group has established superconductivity and the signature of weak localization in various topological systems such as SnAs, Sn_4Au, NbC etc. Sn_4Au, and NbC are predicted to be superconductors by DFT techniques. The figure given below shows the magnetization results of NbC measured using PPMS.



Magnetization measurements of NbC in the ZFC and FC mode (shown in (a)), and isothermal magnetization results of NbC done at various magnetic fields. The results clearly indicate superconducting transition around 8 K

AC High Voltage and Current Metrology

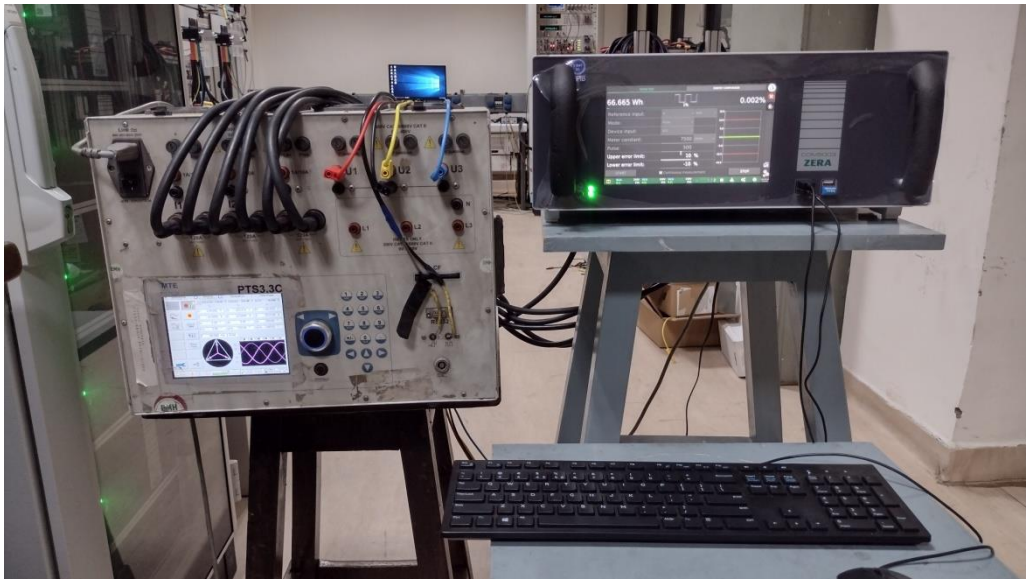
This sub-division is maintaining the National Standards of AC High Voltage Ratio upto 100 kV, High Voltage Capacitance & Tan δ facility upto 200 kV and AC High Current Ratio upto 5 kA. It is providing Apex Level Calibration Services for Current Transformers, Current Transformer Test Sets, AC High Current Sources, Clamp Meters, Current Probes, CT Burdens, Voltage Transformers, Voltage Transformers Test Sets, HV Probes, HV Break Down Test Sets, Voltage Transformer Burdens, AC High Voltage Sources, HV Dividers, kV Meters, etc. to Power Utilities, Electrical Equipment Manufacturers and Electrical Testing and Calibration Laboratories.

Research and Development on Insulating Materials using Nanofluids/Nanomaterials for HV Application

Condition assessment studies in HV power apparatus plays a major role to keep the electrical system healthy and reliable. In recent years, the nanosolid and nanofluid insulations are considered as an alternative insulation for HV applications which results in 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 for the development of different nano-based insulation which involves the investigation of electrical properties like AC BDV test, loss tangent, dielectric permittivity tests, partial discharge characteristics to be conducted with different Nanofluids/ Nanomaterials for the condition assessment studies for HV application as according to IEC/ASTM/IEEE & BIS standards.

AC Power and Energy Metrology

The activity at CSIR-NPL involved in the maintenance and upgradation of national standards of AC power and energy parameters and dissemination of measurement traceability along with 12 CMCs at par with international level. The primary and reference power/energy standards with measurement uncertainty from 10 ppm to 150 ppm are being used to maintain traceability chain with in the country.



Setup for calibration of reference standard for ac power and energy

Testing Services provided to Government Bodies/Industries

The performance of energy meters are tested at par international/ national standards such as IEC: 62053-21, IEC: 62053-22, IS: 13779, IS-14697, IS: 13010 and CBIP-325. Various tests are performed on energy meters before rolling out into actual field such as

a. Test of accuracy requirements
b. Test of electrical requirements
c. Test for electromagnetic compatibility
d. Test for climatic influence
e. Test for mechanical requirements
f. Test of influence quantities: Influence of voltage variation, frequency variation, phase sequence, 3rd harmonics and 5th harmonics, voltage unbalance should not affect accuracy class of meter as per standard specifications.
g. Test of influence of AC/DC magnetic inductions
   i) Test of influence of AC magnetic inductions
      AC abnormal magnetic induction of 10 milli Tesla ±5%
      AC abnormal magnetic induction of 0.2 Tesla ±5%
   ii) Test of influence of dc magnetic inductions
      DC stray magnetic induction of 67 milli Tesla ±5%
      DC abnormal magnetic induction of 0.27 Tesla ±5%
      DC abnormal magnetic induction of 0.5 Tesla ±5%

h. Tamper and fraud protection Tests: Single Phase Energy Meter
   i) Interchange of phase & neutral wires
   ii) Reversal of line and load terminals
   iii) Reversal of line and load terminals with phase and neutral exchange
   iv) Load Earthing: The meter should keep on registering energy even when the load is not terminated back to the meter and instead current is drawn partially or fully through earth.
   v) Earth Load (Forward): The supply to the meter is connected as normal but the load is returned to earth.
   vi) Earth Load (Forward) with phase neutral exchanged
   vii) Earth Load (Reverse): The line and load terminals are reversed, and load is returned to earth.
   viii) Earth Load (Reverse) with phase neutral exchanged
   ix) Earth Load with neutral disconnection
   x) Any other tamper feature is also checked/tested as per customer's requirement.

i. Tamper and fraud protection Tests: Single Phase Energy Meter: Three Phase Energy Meters
   i) Interchange of phase and neutral
   ii) Missing potentials
   iii) CT polarity reversal
   iv) Phase sequence reversal
   v) The working of the energy meter is checked in unbalanced condition
   vi) The detection of CT short/open condition
   vii) Tampering against magnetic field
   viii) The meter functioning for accuracy on all phases individually
   ix) All single-phase meter tampering conditions applied

However, tampering condition are unknown to all, nevertheless tamper events can be tested and verified as per customer's requirement.

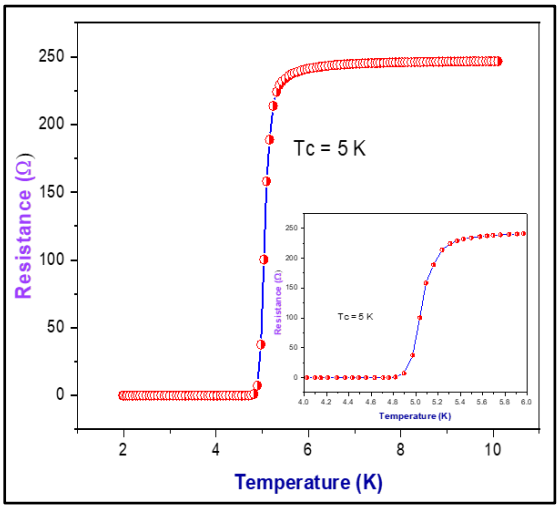
Compliance Testing of smart energy meter using multi-position meter test system

Acceptance tests including anti-tamper tests related to voltage, current and magnetic induction are being carried out on Smart Energy meters as per requirements of power industries and manufacturers. This group is also working for compliance test facilities for smart energy meters as per IS-16444/IS-15959/ CBIP -325 specifications for the growing demands of Smart Grids and smart cities.

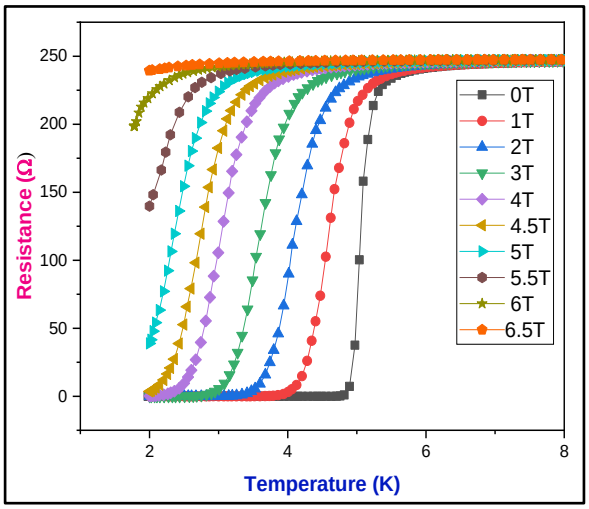
Quantum Nanophotonics Metrology

This section works towards realization of superconducting nanowire devices capable of single photon detection for quantum information processing. From Metrological point of view, the aim is to realize photon-based quantum standards for optical radiation under National Quantum Mission (2020-2025). This will bring standardization and will assist optimizations taking place in the field of quantum information sciences and technologies. Potential users for calibration services include industries and research labs working on quantum communication, single photon devices etc. such as ISRO, DRDO, TIFR etc.

Under the activity, different materials are being explored for developing single photon detectors such as VN, NbTiN etc. The transport measurement for a few VN thin films with different magnetic fields are shown in figure.

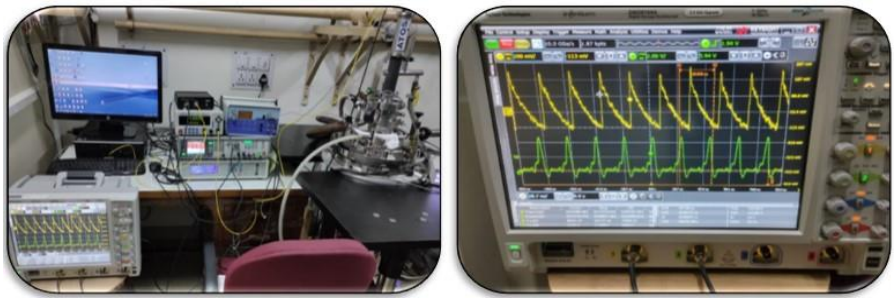


R-T curve of VN (Substrate: MgO)



R-T curve of VN at different Magnetic field

The critical temperature for 5 nm ultra-thin films is 5 K with ΔT around 0.5 K. The diffusivity was calculated for 5 nm ultra-thin film, which was 0.54 cm^2/s. The customized optical probe with SNSPD has been procured and it has been tested with the optical setup developed for characterizing SNSPDs. It showed single photon response.



Measurements with the customized probe

Quantum Hall Resistance Metrology and 2D Physics

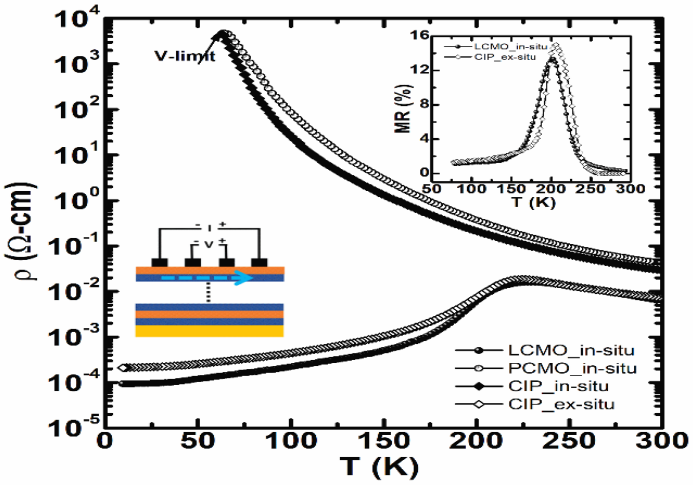
Quantum Hall Resistance metrology sub-division maintains the national standards for the resistance measurements based on Quantum Hall Effect (QHE). Quantum Hall resistance standard (QHRS) is realized in perfectly quantized 2-dimensional electron gas (2DEG) GaAs/AlGaAs quantum wells system at low temperature and intermediate to high magnetic field. The group also carries out exhaustive R&D works on oxide heterostructures, graphene, topological insulators and Heuslar alloys. Several experiments based on 2DEGs are well supported by computational studies using the density functional theory.

Quantum Hall Resistance Standard: Measurement of 1 kOhm Standard Against QHR

The QHRS system was used to provide tractability to the DC/LF-HF standards through measurement of two 1 kOhm standard resistors at 25 °C and 27 °C stabilized in constant temperature bath. The measurements were carried out using a DCC bridge in the 13:1 ratio and the R_K (i=2) plateau. The combined expanded uncertainty (k=2) was found to be better than 0.08 ppm in all the cases.

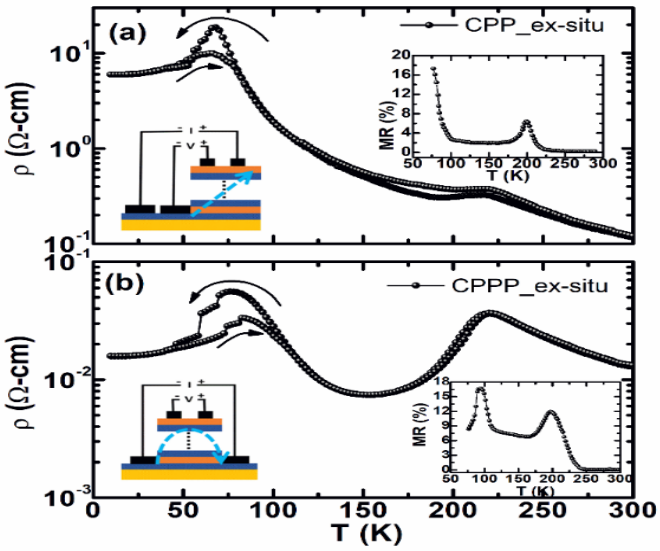
Magnetic Superlattices: Interface Induced Reemergent Insulator-metal Transitions

Superlattices comprising of 10 layers of $La_{0.7}Ca_{0.3}MnO_3$ (LCMO, thickness ≈ 8.8 nm) and $Pr_{0.58}Ca_{0.42}MnO_3$ (PCMO, thickness ≈ 4.4 nm) with layer periodicity of ≈ 13.2 nm have been grown by RF magnetron sputtering on (001) oriented $LaAlO_3$ substrates. These superlattices show strong magnetic anisotropy with the easy magnetic axis lying in the plane and hard axis along the normal to the layers. The *in-situ* O_2-annealed superlattices do not display any insulator-metal transition (IMT) either in current in-plane (CIP) or current perpendicular to plane (CPP) geometries. However, the *ex-situ* annealed superlattices show warming IMT of ≈ 220 K and another reemergent IMT at ≈ 68 K and ≈ 83 K in the CPP and "current parallel and perpendicular to plane" (CPPP) geometries. The CIP configuration is dominated by transport along the superlattice planes, which is also the easy magnetic plane of the system. The resulting transport behavior resembles that of the ferromagnetic LCMO film. The other two geometries, viz. current perpendicular to plane (CPP) and "current



The temperature dependence of resistivity of the individual PCMO and LCMO films and the [LCMO (8.8 nm)/PCMO (4.4 nm)]$_{10}$ superlattice measured prior to oxygen annealing. The insets depict the CIP contact schematic and the temperature-dependent magnetoresistance

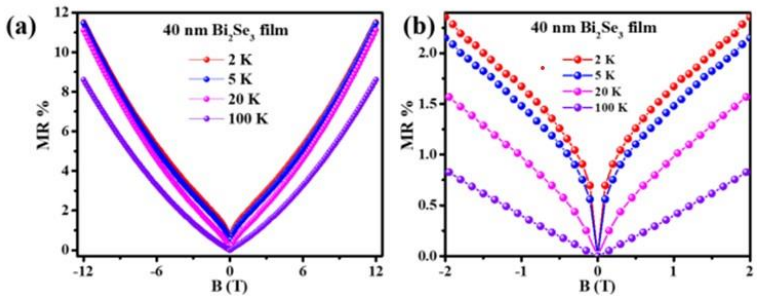
parallel and perpendicular to plane" (CPPP), unravel completely new and unique transport behaviors. Both these transport geometries give rise to additional IMT in the lower temperature region, which shows hysteresis and meta-resistive characteristics. The hysteresis and meta-resistive behavior are more dominant in the CPP configuration in which the transport is along the hard-magnetic axis and across the magnetically disordered interfaces. The occurrence of the new behavior manifested in the form of the second IMT embodying thermal hysteresis, and resistivity jumps are attributed to the combined effect of interfacial magnetic liquid-like phase due to phase separation and magnetic anisotropy. The competing $3d(z^2- r^2)$ and $3d(x^2- y^2)$ orbital orders could play an important role in such a phenomenon.



Temperature dependent resistivity of oxygen annealed superlattices in (a) CPP and (b) CPPP geometries. Insets display the schematic of the corresponding transport configurations with the possible current flow paths (arrow). The measured LFMR also shown in the respective figures

Growth of Topological Insulator Thin Films using Magnetron Sputtering

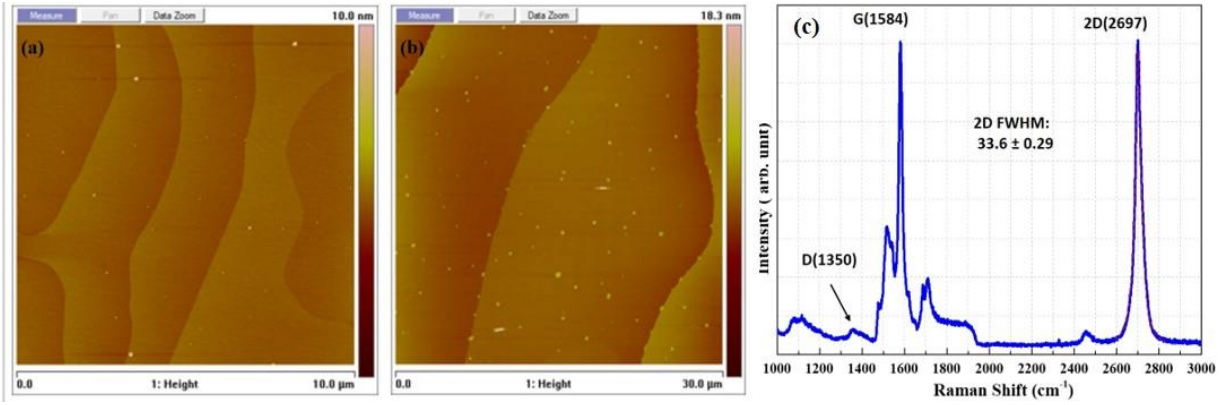
Mostly topological insulator thin films and hetero-structures have been grown using molecular beam epitaxy and thereby limiting their use at device integration level. The multi-source magnetron sputtering (base pressure: ≤ 2×10^{-7} mbar) facility has been used to deposit large area Bi_2Se_3 thin films on sapphire (0001) substrates. Further, sputtered Bi_2Se_3 films were post-selenized in tubular furnace and x-ray diffraction analysis revealed the c-axis oriented film on sapphire (0001) substrates. Temperature dependent magneto-resistance (MR) data of ~ 40 nm thin film in the figure shows that in a perpendicular low magnetic field of (-2 to 2) T and at temperature of 2K and 5 K, MR forms a sharp cusp like characteristic around B = 0 T [Fig. (b)]. This is a quantum interference phenomenon known as weak anti-localization (WAL) effect and is thought to be responsible for this cusp. At 20 K, this WAL signature reduces and vanishes at 100 K and this cusp takes a parabolic shape which is opposite to WAL and classical in nature. This study shows the capability of magnetron sputtering system to grow Bi_2Se_3 thin films with WAL phenomena which suggest the futuristics applications of large area sputtered films for quantum-based devices.



Magneto-resistance of Bi2Se3 thin film at: (a) -12 to 12 T and(b) -2 to 2 T

Epitaxial Monolayer Graphene with Large Terraces using Graphene Epitaxy (GrapE) System

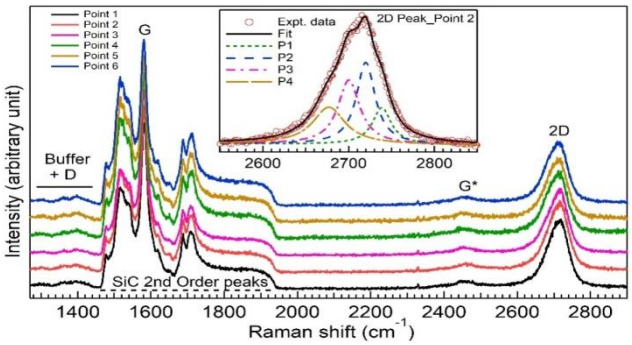
It is known that quantum Hall effect realized in Hall bar devices spread across steps gets adversely impacted due to finite bilayer patches at step edges. Therefore, Hall bar devices fabricated on a single terrace may perform better in realization of epitaxial graphene-based quantum Hall resistance standard. Generally, reported terrace width of monolayer epitaxial graphene ranges from 0.5 to few (3 – 5) µm. Growth parameters of GrapE system have been carefully tuned to grow epitaxial monolayer graphene on SiC with very large terraces. The below figure (a, b) show AFM topology images of grown epitaxial graphene and it shows that terrace width can be as large as ~20 µm. AFM images show smooth step-terrace morphology with carpet like spread of epitaxial graphene on underlying 4H-SiC (0001). Corresponding phase images (not shown here) confirm only one type of contrast except at step edges, confirming only one type of height of grown graphene. We have captured several similar AFM images at various regions of the same sample. We have also recorded several Raman spectra at various regions of the sample and one of the representative Raman spectrums is shown in figure (c). Peak position and FWHM of 2D peak confirm growth of monolayer graphene.



Topographic AFM images of monolayer epitaxial graphene grown on SiC: (a) 10 x 10 µm^2 and (b) 30 x 30 µm^2. (c) Raman spectra of epitaxial monolayer graphene grown on SiC. Peak position and FWHM of 2D peak are obtained by single Lorentzian fitting. All the Raman characteristic feature are marked

Controlled Growth of Large Area Epitaxial Bilayer Graphene using GrapE System

Even though monolayer graphene is very attractive as it hosts various exotic physical phenomenon and properties, its gapless nature is a limiting factor for various applications, especially for semiconducting and optoelectronic devices. Therefore, bilayer graphene, having finite bandgap, is an exciting prospect for device applications and recently bilayer graphene has also attracted immense interest as it shows novel physical phenomenon



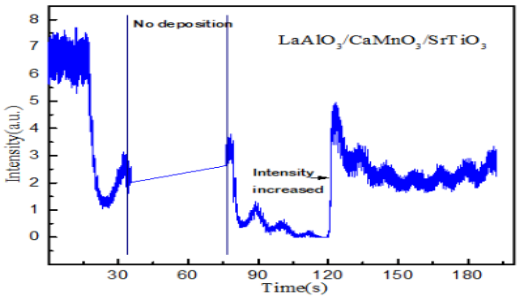
Raman spectra acquired at different points of epitaxial bilayer graphene sample grown on 4H-SiC (0001). Inset shows the 2D along with four Lorentzian fitting components. All the characteristic Raman features are marked

like quasicrystallinity, superconductivity etc. Usually, bilayer patches are grown at step edges during the growth of epitaxial monolayer graphene growth. However, growing large area (mm scale) homogeneous bilayer graphene is not as easy as growth of monolayer. We have used a different growth configuration (open configuration) in our GrapE system and initial results are very promising as we see evidence of large area, homogeneous bilayer epitaxial graphene growth. The figure shows the Raman spectra collected at six different points on the same sample and inset shows the 2D peak. This 2D peak can be well fitted by four Lorentzian components, as expected for bilayer graphene. We can clearly see that Raman spectra are very similar in line shape for all the different points. We have also acquired many Raman spectra at different region of the sample and on another sample grown using same growth conditions. All the Raman spectra confirm the reproducible bilayer epitaxial graphene growth, at least for 2 grown samples till now.

Suppression of Polar Effect by 1uc Buffer Layer at LAO/STO Interface

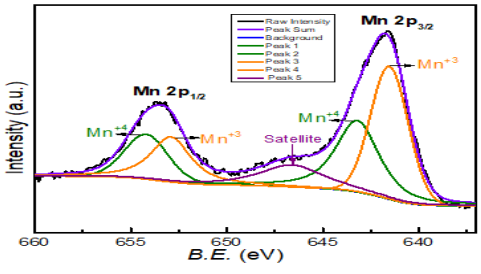
Two-dimensional electron gas (2DEG) observed at the interface of insulating oxides STO($SrTiO_3$) and LAO($LaAlO_3$) shows attractive transport properties (such as superconductivity, magnetoresistance, ferroelectricity, tunable metal- insulator transitions), but the mobility of electrons in these systems is comparatively less than that of semiconductor heterostructures. To enhance the electron mobility of carriers at interface, various methods such as growth at lower temperatures, use of polar solvents, changing substrate miscut angles and inserting buffer layer at interfaces have been employed. Recently, manganites such as $La_{1-x}Sr_xMnO_3$ have been studied as a buffer layer at LAO/STO interface resulting in increased mobility and enhanced performance of devices. We studied the effect of CMO($CaMnO_3$) as a buffer layer in LAO/STO heterostructure. A buffer layer of CMO of thickness 1unit cell (uc) was grown at the interface of LAO/STO using PLD technique, quality of film being monitored via in-situ Reflection High Energy Electron Diffraction (RHEED).

Growth parameters involve KrF laser (λ=248nm) with energy density of 1.3mJ/cm^2 and substrate temperature of 780°C in 10^{-3}mbar oxygen pressure at a laser frequency of 1Hz. At these optimized conditions, 1uc buffer layer of CMO followed by 10uc LAO was grown on TiO_2 terminated STO. The figure shows the RHEED intensity oscillations observed during growth which confirms the thickness of grown CMO(1uc) and LAO(10uc) films and presence of streaks before and after deposition implies the epitaxial nature of grown film.



RHEED oscillations observed during growth

XPS was performed to know the reason behind the insulating nature of sample. XPS data (survey scan) of LAO (10uc)/CMO(1uc)/STO shows mainly the peaks of La, Al and O. Even the depth profile analysis doesn't show the peak of Ca and Mn. We are interested in oxidation state of Mn on CMO buffer layer, so we reduced the



Mn core level XPS spectra

thickness of LAO layer from 10uc to 4uc. The figure shows the core level spectra of Mn. The $2p_{3/2}$ and $2p_{1/2}$ peaks, each were fitted with two peaks, showing the presence of Mn^{+3} and Mn^{+4} valance states. Moreover, the peak referring to the Mn^{3+} state has relatively high peak intensity and a larger area under the curve than the peak referring to the Mn^{4+} state, confirming the reduction of majority of Mn^{4+} ions to Mn^{3+} ions in CMO buffer layer. This reduction of majority of Mn^{4+} ions to Mn^{3+} ions is responsible for insulating nature of sample. Resistance of grown heterostructure is found to be of the order of 10^7 ohms. Previous observations show the critical thickness required to stop charge transfer between LAO/STO is 2-3uc, however our study shows that even 1uc buffer layer can stop the charge transfer at the interface.

Cryogenics Plants & Facilities at CSIR-NPL (Central Facility)

It is a central facility which caters the demand of liquid nitrogen (LN_2) & liquid helium (LHe) for the various low temperature based characterization, maintenance and operation of primary standards and synthesis facilities of the laboratory. Presently, we have two (nitrogen & helium gas) liquefaction plants:

- **Liquid Nitrogen Plant**: The liquid nitrogen plant, Model STIRLIN-4, was procured from M/s Stirling Cryogenics & Refrigeration BV, Netherlands and the production began from July 2003. This liquefier is a 4-cylinder Stirling cycle-based machine and has a capacity of generating about 35 litre/hr of liquid nitrogen. The total liquid nitrogen storage capacity at present is 8000 litres comprising of a 6000 litre vertical dewar and a 2000-litre horizontal dewar attached to the liquefier for automatic filling. In the Last FY (2021-22) annual production of liquid nitrogen is over 31,000 litres.

Liquid Nitrogen

Instrument Facilities of the Institute that are Supported by the Cryogen (Liquid Nitrogen) from Cryogenic Plants: Physical Property Measurement System, High Resolution Transmission Electron Microscopy, Scanning Electron Microscope, BET Surface Analysis, Triple Point Measurement , Primary Pressure Standard (UIM), Low Temperature RAMAN Spectroscopy, Thermal Evaporation Units, Diffusion Pumps and Different Material Synthesis Systems/Groups MBE, PLD, Solar, HEPP, Carbon etc.

- **Liquid Helium Plant**: At present we have Linde L-70 turbine based helium liquefier. It was procured from M/s Linde Kryotechnik, AG, Switzerland. The plant

is operational since October 2012. Its liquefaction process is based on a Claude cycle with dynamically balanced gas bearing turbo expanders. A purifier is also integrated into the coldbox to enable the liquefier to accept helium recovered from the users, which contains up to 10% air impurities. The total liquid helium storage capacity at present is 1000 litres. It has a production capacity of 25 litre/hour (without pre-cooling) and about 50 litre/hour (with pre-cooling). Last FY (2021-22) annual production of liquid helium is over 9,500 litres.

Liquid Helium

After the use of liquid helium at various laboratories in the institute, the evaporated helium gas is recovered back for re-liquefaction. The Institute has a large network of recovery lines extending to various laboratories of the Institute. Cryogenics Plants also have helium recovery system handles a large quantity of boil-off helium gas sent by various laboratories through the above recovery network, with about ~ 85% of helium gas recovery and re-liquefaction after compressing with the high pressure helium compressors & purifying.

Instrument Facilities of the Institute that are Supported by the Cryogen (Liquid Helium) from Cryogenic Plants: Physical Property Measurement System, Magnetic Property Measurement Primary Standard: (Quantum Hall Resistance & Josephson Voltage System). Low Temperature RAMAN Spectroscopy, Low Temperature Ultrafast Spectroscopy, Low Temperature EPR, MOKE setup and various low temperature based cryostat for transport measurements.

Environmental Sciences & Biomedical Metrology

The Environmental 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 sub-divisions 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 sub-division is described below:

Atmospheric Sciences and Metrology

Data quality is a major concern in the area of environmental monitoring as the credibility of such measurements needs to be discerned. Issues such as the role of instruments and calibration are grabbing eyeballs in today's scenario. USEPA, TUV, MCERT etc., are some of the important agencies involved in the certification of most of the imported instruments. The quality of measurements by the instrument operating in Indian conditions is hugely influenced by fluctuating and unstable environmental conditions. Hence, the certification system ought to be tuned for Indian conditions. However, any certification process for environmental monitoring equipment does not exist in India. The generation of reliable data is related to the traceable and accurate measurement. In December 2018, the Ministry of Environment, Forest & Climate Change (MOEF&CC) designated CSIR-NPL as the "Certification Agency" for monitoring air pollution equipment. In view of this, the subdivision has been assiduously working to establish a testing and calibration facility for numerous automated Air Monitoring Systems (AMS), especially Continuous Emission Monitoring Systems (CEMS) and Continuous Ambient Air Quality Monitoring Systems (CAAQMS). This would emerge as a new national facility to provide certification in the coming years by bolstering and removing the major barriers to ensuring the quality of environmental monitoring data from various sources. This sub-division also observes many atmospheric pollutants ranging from greenhouse gases (GHGs) and particulate matter to study their chemical and physical properties to identify their roles in affecting the ecosystem with the help of state-of-the-art instruments and models. ESBMD is presently developing reliable practices/approaches for accurate measurement of atmospheric trace species for espousal by various agencies and institutions in India engrossed in atmospheric monitoring. The work in this area holds utmost and grave importance since air quality and atmospheric change significantly impact human health and the biosphere. The advancement in measurement quality would bring about societal benefits such as fostering better policy formulations to improve air quality and mitigation of climate change. This subdivision is also involved in developing low-cost indigenous monitoring equipment to measure air pollutants. Further, the characterization of the ionized and non-ionized atmospheric media over Indian latitudes, Polar regions and terrestrial environmental conditions are the burning issues this subdivision is also currently working upon. The crucial study of radio propagation for the betterment of radio communication and navigation, atmospheric coupling processes (in lower and upper atmospheres), ionospheric earthquake precursor studies and other societal/strategic applications are involved in this scientific activity. This sub-division also delivers

ionospheric forecasting to users worldwide through the space weather Regional Warning Centre (RWC, NPL-India).

- **A Study of Ionospheric Response to Sudden Stratospheric Warming Events Across Longitudes during Solar Cycle 24**

Solar cycle 24 from December 2008 to December 2019 had an unusual progression and was the weakest cycle in a century, providing an ideal scenario to study perceivable effect of wave forcing from lower atmosphere. Ionospheric response to meteorological phenomenon of sudden stratospheric warming (SSW) during solar cycle 24 (Arctic winter 2008/2009 to 2018/2019) was examined using Global Positioning System-derived total electron content (VTEC) and its deviation from monthly median (ΔVTEC) for four longitudinal chains. Each chain comprises eight stations, covering varied latitudes in both hemispheres. A longitude- and latitude-dependent response of VTEC is observed within ~3 weeks of peak polar stratospheric temperature anomaly (ΔT_{max}), with maximum variations seen for low-latitude stations at American and Australian-East Asian sectors. It is seen that variations during minor warming events are comparable or at times even larger than during major warming events. These responses increase with an increase in solar activity, with major SSW events primarily seen during moderate and low solar activity periods and minor SSW during high solar activity period. Under similar ionizing conditions, a quite similar ionospheric response is observed irrespective of ΔT_{max} and of SSW type (major or minor); however, under similar SSW strength, no prominent pattern in ionospheric response is observed. Latitude-dependent semidiurnal ionospheric behavior is observed for only a few events. This vertical coupling between lower and upper atmosphere during SSW is predominantly influenced by 13–16 days periodicities in VTEC, along with other periodicities of 9, 7, 5, and 3 days.

- **Study of Interaction between Nighttime MSTID and Mid-latitude Field-aligned Plasma Depletion over the Transition Region of Geomagnetic Low-mid Latitude: First Results from Hanle, India.**

The interaction between a nighttime Medium Scale Traveling Ionospheric Disturbance (MSTID) and geomagnetic north-south oriented field-aligned plasma depletion structure is examined over Hanle, Leh Ladakh (32.7°N, 78.9°E; Mlat. ~24.1°N), India on a geomagnetically quiet night (06 May 2019, Ap = 4). The results are based on the observations carried out using a newly established airglow imager operating at 630.0 nm at Hanle which is a transition region of geomagnetic low-mid latitudes. A sequence of processes constituted this unique interaction that includes developing phase of the MSTID within the imager's field of view, gradual bending of the field-aligned plasma depletion structure and eventual merging with the MSTID, and propagation of the merged structure in the form of a single MSTID structure post-interaction. The mechanism appears to be controlled by unequal but oppositely directed polarization electric fields within the dark and bright bands of the developing MSTID, whose projection on the horizontal plane is observable in the airglow images. This work is the first observation illustrating the interaction between a developing phase of MSTID and plasma depletion structure over a geomagnetic low-mid latitude transition region, which assumes importance for understanding the underlying plasma irregularity processes.

- **Comparison of Polar Ionospheric Behavior at Arctic and Antarctic Regions for Improved Satellite-based Positioning**

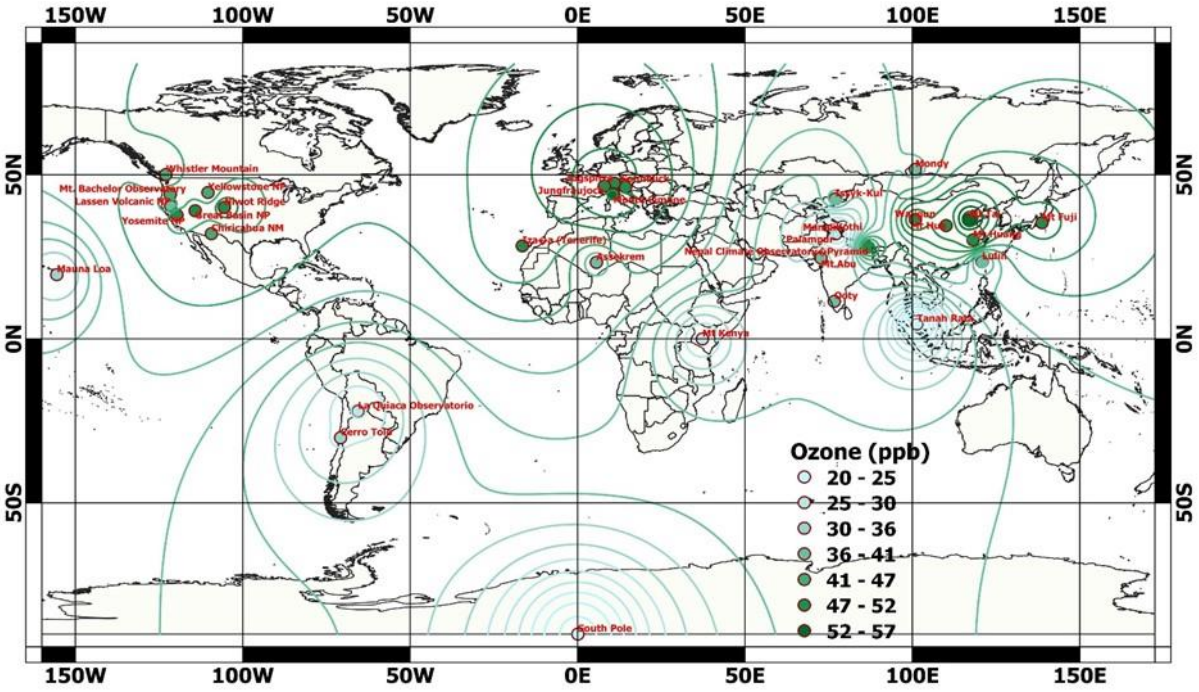
The main focus of this work is to investigate the hemispheric symmetric and asymmetric characteristics of ionospheric total electron content (TEC) and its dependency on the interplanetary magnetic field (IMF) in the northern and southern polar ionosphere. The changes in amplitude and phase scintillation are also probed through Global Ionospheric Scintillation and TEC monitoring (GISTM) systems recordings at North pole [Himadri station; Geographic 78°55′ N, 11°56′ E] and South pole [Maitri station; Geographic 70°46′ S 11°44′ E]. Observations show the range of %TEC variability being relatively more over Antarctic region (−40 % to 60 %) than Arctic region (−25 % to 25 %), corroborating the role of the dominant solar photo-ionization production process. Our analysis confirms that TEC variation at polar latitudes is a function of magnetosphere ionosphere coupling, depending on interplanetary magnetic field (IMF) orientation and magnitude in the X (*Bx*), Y (*By*), and Z (*Bz*) plane. Visible enhancement in TEC is noticed in the northern polar latitude when $Bx < 0$, $By < -6$ nT or $By > 6$ nT and $Bz > 0$ whereas the southern polar latitude perceives TEC enhancements with $Bx > 0$, -6 nT $< By < 6$ nT and $Bz < 0$. Further, investigation reveals the intensity of phase scintillation being more pronounced than the amplitude scintillation during the disturbed geomagnetic conditions with excellent correlation with the temporal variation of TEC at both the stations. Corresponding variations in the parameters are studied in terms of particle precipitation, auroral oval expansion; Joule's heating phenomena, and other ionospheric parameters. The studies are in line with efforts for improving ionospheric delay error and scintillation modeling and satellite-based positioning accuracies in polar latitudes.

- **Study of Tropospheric Ozone**

Tropospheric ozone is one of the blistering subject of the present world, although ozone is a minor component of our planet's atmosphere but still it plays an important role in the atmospheric chemistry. An enhancement in tropospheric ozone levels can affect human health & inhibit plant growth, and it can also alter the ozone distribution and influence the weather system of the globe as it is a greenhouse gas. Therefore, it is essential to have a proper understanding about the long-term variability of ozone and the factors influencing it. In the past numerous continuous pollutant measurements in ambient air were carried out, but most of them were made at low altitude sites. This is very reasonable, as the maximum number of individuals tend to reside in low-altitude areas. The measurements at low-altitude sites are generally influenced by local emission sources.

Mountains are considered as the cleanest places on the Earth. The harsh topography and sparsely settled human population lead to low or no local anthropogenic emissions over the mountain regions. Generally, the high-altitude sites, typically above 1200 m above mean sea level (AMSL), are often considered "above the boundary layer" or "the representative of the free troposphere". It is well known that the background ozone level rises with altitude in the lower troposphere, and its concentration also gets lowered near the surface due to the processes like deposition and titration, which dominate under the boundary layer. Keeping in view of the solemnity of the issue, the global distribution of ozone over high altitude sites were studied using the reported

data provided in the literature and compared with the measured ozone values recorded at theremote atmospheric monitoring station of CSIR-NPL located in the campus of CSIR-Institute of Himalayan Bioresource Technology (CSIR-IHBT), Palampur, Himachal Pradesh (32.12°N, 76.56°E) at 1347 m Above Mean Sea Level (AMSL).



Variability of ozone over high altitude sites

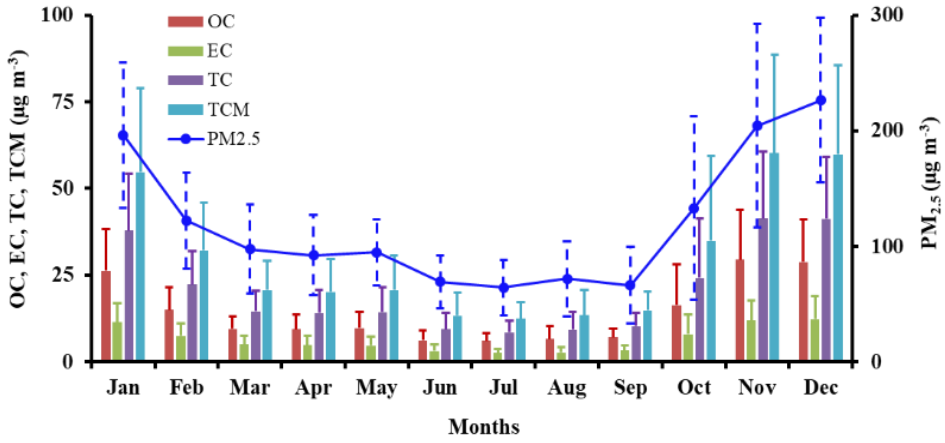
(Source: Masiwal, R., Sharma, C., Ranjan, A., Radhakrishnan, S. R., Shukla, D. K., Bambal, V. K., &Uniyal, S. K. (2021). Long-term variability of trace gases over the Indian Western Himalayan Region. Science of the Total Environment, 150127)

The figure is showing the global distribution of ozone at the high altitude stations above 1000 m AMSL. The mean mixing ratio of ozone showed a significant variability, varied from 19-51 ppb over the global high altitude sites. Whereas, over the Indian western Himalayan regions (CSIR-IHBT) the annual mean mixing ratio of ozone varied from 20-35 ppb. The study revealed that the ozone levels over the pristine background sites are not stable. Most of the studies reported alterations in seasonal cycle of ozone, varied during each season and also varied with latitude and altitude. Seasonal factors influence the seasonal trend of ozone. The seasonal analysis of ozone trend reported that ozone attains its maxima during the spring season in the northern hemisphere. The main reason behind the ozone spring maxima has been attributed to the accumulation of ozone precursors during winters and their photochemical destruction during spring season in the northern hemisphere. The ozone precursor's life gets enhanced during the winter season due to the decrease in intensity of solar radiation and exposure time. As spring approaches, availability of high solar radiation and temperature lead to high ozone formation and its transport across the hemisphere. The stratosphere to troposphere exchange is also reported as a major reason behind the enhanced springtime ozone level over high altitude sites. The maximum ozone monitoring stations of the northern hemisphere have observed high ozone concentration during the month of April and May. The study concluded that the ozone trend over a high altitude site is influenced by factors such as availability of precursors, sunlight/temperature, humidity, the height of boundary layer, free troposphere exchange, etc. so change in the

one of the condition can influence the regional ozone production and that can affect the regional climate.

- **Long-term Variation in Carbonaceous Aerosols in Delhi**

Carbonaceous species of $PM_{2.5}$[organic carbon (OC), elemental carbon (EC), elemental matter (EM), primary organic carbon (POC), secondary organic carbon (SOC), total carbon (TC), and total carbonaceous matter (TCM)] were analyzed to study the seasonal variability and long-term trend of carbonaceous aerosols (CAs) in megacity Delhi, India from January, 2012 to April, 2021. The average concentrations (± standard deviation) of $PM_{2.5}$, OC, EC, TC, EM, TCM, POC and SOC were 127±77, 15.7±11.6, 7.4±5.1, 23.1±16.5, 8.2±5.6, 33.3±23.9, 9.3±6.3 and 6.5±5.3 μg m^{-3}, respectively during the entire sampling period. The average CAs accounted for 26% of $PM_{2.5}$ concentrations during the entire sampling period. The linear relationship of OC and EC, OC/EC and EC/TC ratios suggested that vehicular emissions (VE), fossil fuel combustion (FFC) and biomass burning (BB) are the major sources of CAs at megacity Delhi, India.



The monthly average (pooled estimate of 2012 to 2021) variation in concentrations (error bar: ± SD) of PM2.5, OC, EC, TC and TCM in Delhi

(Source: Sharma et al (2022); Bulletin of Environmental Contamination and Toxicology, doi:10.1007/s00128-022-03506-6)

- **Exposure to $PM_{2.5}$ Chemical Species on Human Health in Delhi**

In this study we examined the associations between mortality and acute exposure to $PM_{2.5}$ mass concentration, sources and their chemical components using data from 2013 to 2016 in megacity Delhi using a semi parametric quasi-Poisson regression model, adjusting for mean temperature, relative humidity, and long-term

Percentage contribution of different species and sources to total PM2.5 for winter and post-monsoon seasons in Delhi *(Source: Joshi et al (2022); Environmental Science & Technology, doi:10.1021/acs.est.1c06864)*

time trend as the major potential confounders. The subspecies of NO_3^-, $NH_4NO_3^-$, Cr, NH_4^+, EC, and OC showed a higher mortality impact than the total $PM_{2.5}$ mass. Males were at higher risk from NO_3^-, SO_4^{2-} and their NH_4^+ compounds along with carcinogen Cr, whereas female group to EC and OC. The major mortality risk from all hazardous species arose from their winter exposures. The study provides the first evidence of association between acute exposure to $PM_{2.5}$ chemical species and mortality anywhere in India and recommends similar studies in other regions so that sectoral mitigation emitting the most toxic species can be prioritized to maximize the health benefits.

- **Source Apportionment of PM_{10} at High Altitudes Himalayas**

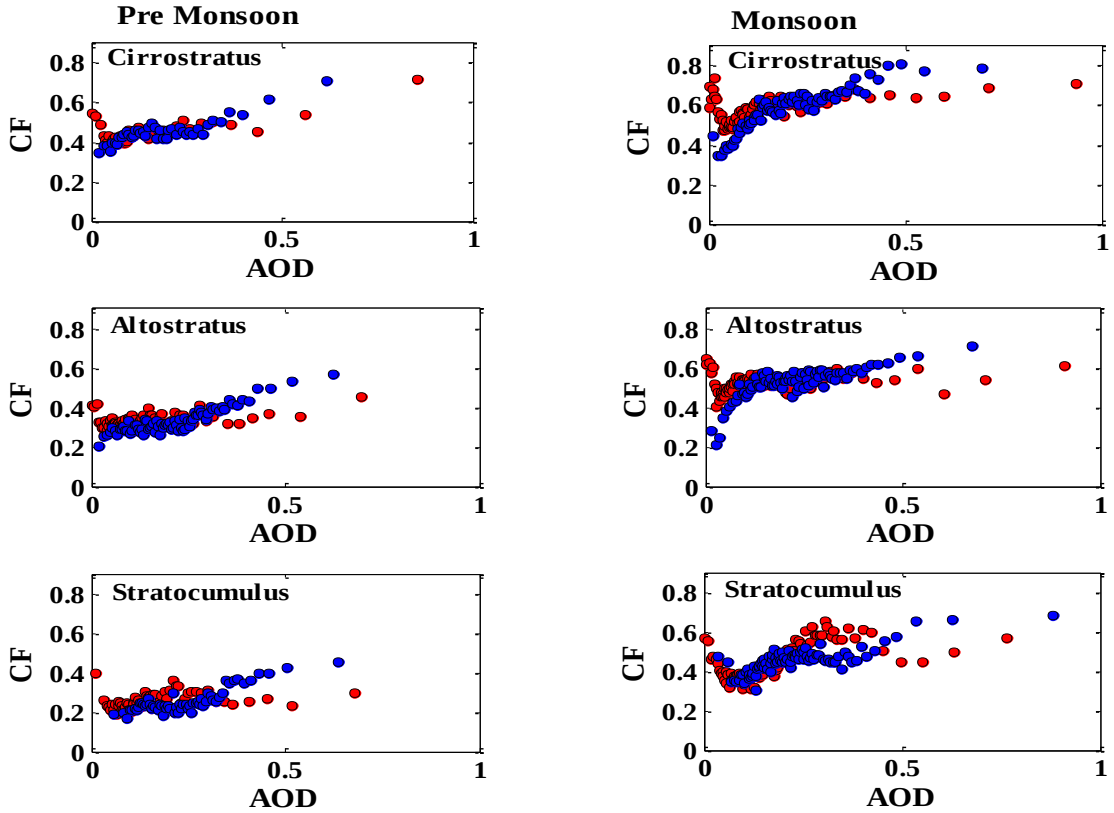
The study represents the annual and seasonal concentration of PM_{10} over different sites (Darjeeling, Nainital, Mohal-Kullu) across the Himalayan region of India from July 2018 to December 2019. The annual average concentrations of PM_{10} over Mohal-Kullu, Nainital, and Darjeeling were recorded as 57 ± 32 μg m^{-3}, 65 ± 41 μg m^{-3} and 54 ± 17 μg m^{-3}, respectively. The high OC/EC ratio and significant correlation of OC with EC and WSOC with OC indicated a significant effect of biomass burning aerosols over the study sites. Enrichment factor of trace elements present in PM_{10} reveals the abundance of crustal elements over the study sites. Principal component analysis/absolute principal component score (PCA/APCS) resolved four major sources: crustal/soil dust, biomass burning/fossil fuel combustion, vehicular emissions, and industrial emissions/coal combustion.

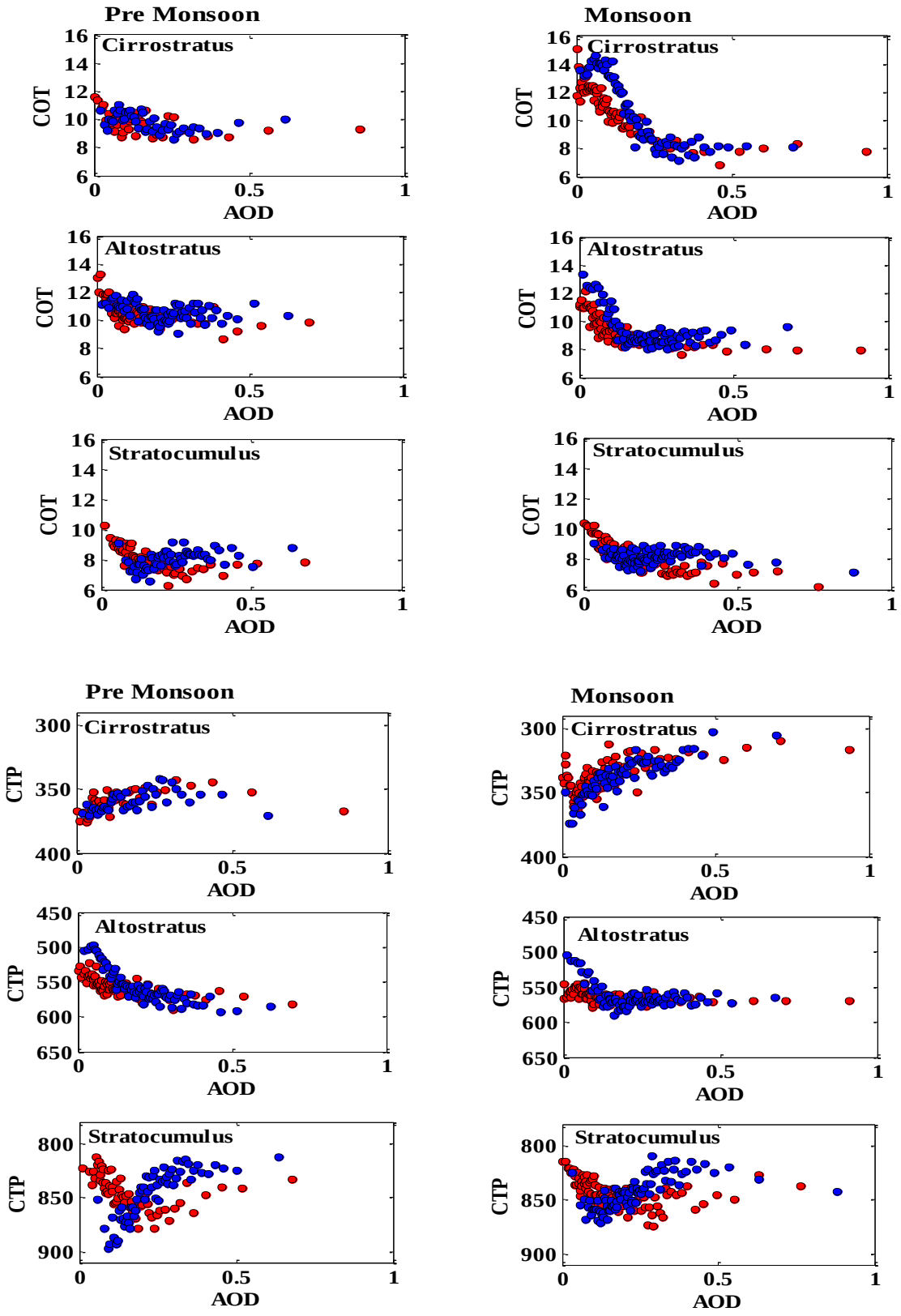
- **Study of Variation of Aerosol Optical Properties Over a High-altitude Station in Indian Western Himalayan Region, Palampur using Raman Lidar System**

A Raman lidar system was operated along with the Microtops sunphotometer measurements to carry out the study of the variation of the optical properties of aerosols over Palampur (32.11° N and 76.53° E), India from 17th April to 11th May 2019. The lidar system is furnished with Raman (N_2) channel and depolarization channel allowing independent measurement of Lidar Ratio (LR) and linear depolarization ratio. The study reveals that the majority of the aerosols approximately were restricted within the planetary boundary layer (PBL) and very less loading was present in the free troposphere over the study location. The particle loading over the study period was found to be very less with aerosol backscatter coefficient (at 355 nm) ranging from ~0.13 $Mm^{-1}sr^{-1}$ to ~7.25 $Mm^{-1}sr^{-1}$ with mean value of 2.67 ± 0.82 $Mm^{-1}sr^{-1}$ and it is well supplemented by the mean aerosol optical depth (AOD) of 0.37 ± 0.13 obtained from Microtops sunphotometer. The average lidar ratio values for 0-1 km altitude (L_1) 72 ± 13sr, for 1-2 km (L_2) altitude 55 ± 8sr, for 2-3 km(L_3) 54 ± 15sr were observed as suggesting dominance of the biomass burning aerosols and anthropogenic aerosols. The particle depolarization ratio (355 nm) values were found from approximately 4.8 ± 2.7% to 11.5 ± 1.9% with the mean value of 7 ± 1.3% suggesting the presence of non-spherical particles. To trace the sources of the pollution, we derived the HYSPLIT trajectory which shows the majority of the movement was from local sources.

- **Effect of Size Differentiated Aerosols on Monsoon and Pre-Monsoon Cloud Properties over IGB**

The particle size is a critical parameter in deciding the cloud condensation nuclei activation efficiency and hence largely influential in the cloud formation and dynamics. The size differentiated influence of aerosol optical depth (AOD) on cloud properties for the densely polluted Indo-Gangetic Basin (IGB) has been studied for a period of 2000–2017 using satellite observations. Terra on board MISR derived AOD for two size ranges, small (aerodynamic radius < 0.35 μm) and large (aerodynamic radius > 0.7 μm) are correlated with MODIS derived cloud properties such as cloud fraction (CF), cloud optical thickness (COT), cloud top pressure (CTP), and cloud effective radius – liquid (CER-Liq) for monsoon and pre monsoon period, over the study area. Our study reveals that the size differentiated aerosols interacts differently with the cloud properties. Small aerosol particles have shown better correlation with cloud properties than coarser particle. Furthermore, estimation of aerosol indirect effect has shown that small particles favour the Twomey effect while large particles follow the anti Twomey effect over the IGB. The anti Twomey effect for large particles i.e., positive AOD-CER relationship could be due to the elevated absorbing aerosol over the region causing aerosol induced heating of the cloud. Aerosol-cloud interactions (ACI) are often overshadowed by internal cloud dynamics and upper air meteorology. Cloud segregated analysis using ISCCP classification suggests that the dominant clouds such as cirrostratus and altostratus influences the correlation statistics considerably.




Pre Monsoon
Monsoon
Cirrostratus
Altostratus
Stratocumulus
COT
CTP
AOD
16
14
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8
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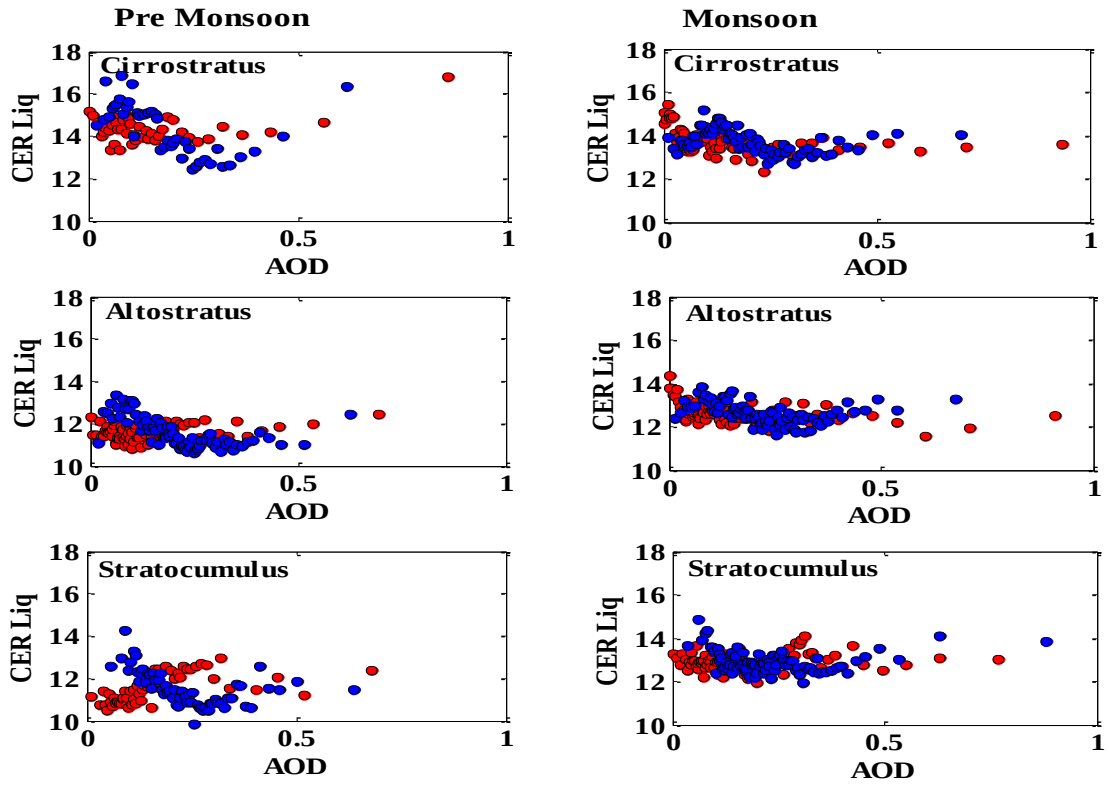


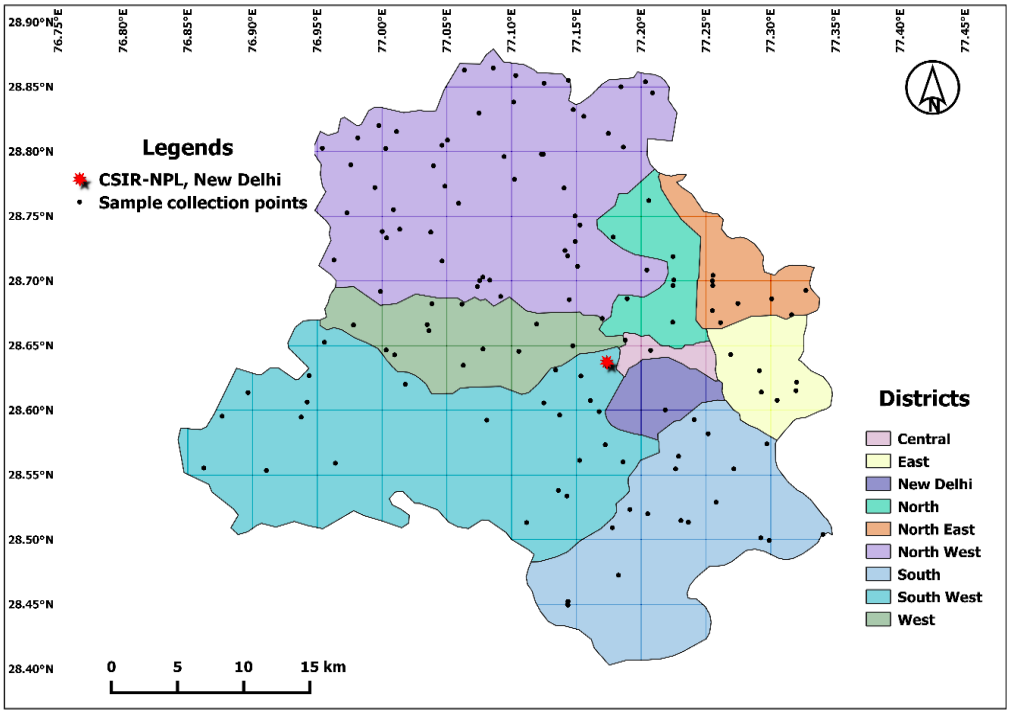
Cloud differentiated analysis of various cloud properties with respect to aerosol modes are shown here. AOD-S (fine mode) is denoted by blue and AOD-L (coarse mode) is denoted by red dots. The variation of cloud fraction (CF), cloud optical thickness, cloud top pressure (CTP) and CER-Liq for the three dominant cloud types over the IGB region for pre monsoon and monsoon period are shown from top to bottom panels. These parameters are crucial for understanding the 'aerosol indirect effect' over the study area, in the present case the Indo Gangetic Basis (IGB).

- **Dead Time Estimation of the Transient Digitizer of the Raman Lidar System Installed at a High-altitude Station Palampur**

The photon counts (PC) signal of the lidar backscattered signal is affected by the dead time of the transient digitizer. The dead time relies on the photomultiplier (PMT) characteristics and high voltage settings which results invariation of the dead time over time. In this paper, the dead time of the Raman lidar system installed at remote atmospheric monitoring station of CSIR-NPL in Palampur, Himachal Pradesh,India, is estimated and reported. Two different methods proposed by Whiteman et al. and Newsom et al. are used to derive the dead time of the lidar system from June 2016 to June 2019 and the results of both the methods are statistically compared. The results show that the dead time values were found to be increasing from 4 ns to 5.8 ns over the study period. For comparison, one sample t-test and Bland–Altman analysis were used along with the correlation and regression analysis and the results suggest that both the methods were found to be in agreement and there was no statistically significant difference between both the methods. The dead time corrected data was used to obtain glued signal and from that aerosol optical properties have been derived. The optical properties derived from glued signal, dead time corrected and uncorrected signal have been compared and we observed significant difference at the lower altitudes.

- **Emission Inventory of NMVOCs from Residential Fuels in Delhi**

In controlled laboratory conditions, 62 samples of domestic fuels collected from 56 grids of Delhi (Fig.6) were burnt to quantify the emissions of 23 non-methane volatile organic compounds (NMVOCs), i.e., alkanes (11), alkenes (6), alkynes (1) and aromatic compounds (5). The domestic fuels used for residential activities were comprised of 20 unique types of fuel woods, 3 species of crop residue, dung cakes and coal. These fuels are primarily used for cooking and water/space heating during winters. The current study reports the total emission budget of NMVOCs from domestic burning over Delhi.

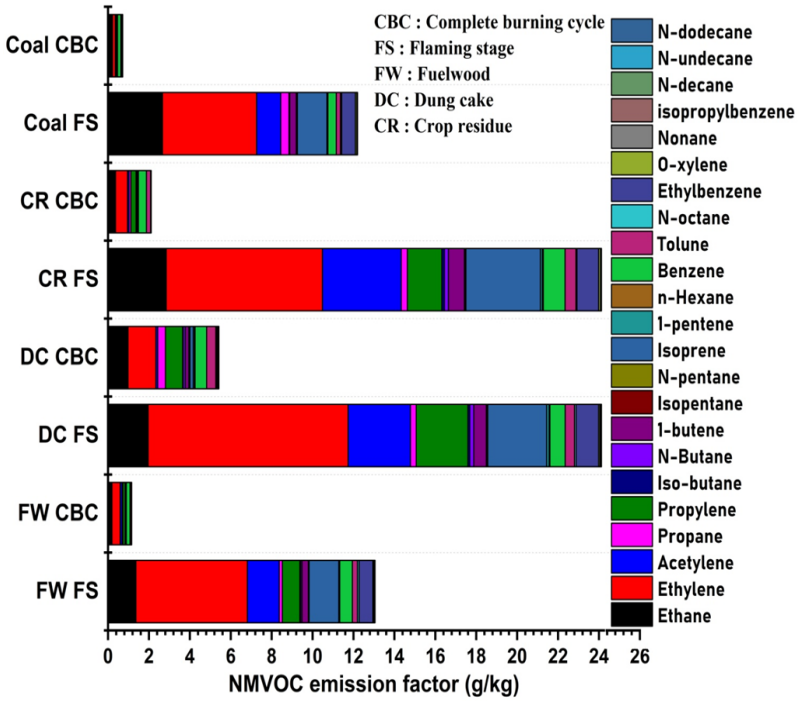


The gridded distribution of biofuel collection points over NCT region

Furthermore, this study also compares the differences in emission factors (EFs) of NMVOCs which are calculated for different burning cycles and sample collection methods. The EFs of NMVOCs calculated from the samples collected during the flaming stage using canisters were analyzed for 23 NMVOCs and then compared with same species emitted from complete burning cycle. In addition to this, 10 consumption and emission hotspot grids were also identified in Delhi; based on the ground survey and laboratory simulated results. The total annual usage of domestic fuels for the year 2019 was found to be 0.415 Mt/yr (million tonnes) in Delhi. 12.01 Gg/yr of annual NMVOCs emissions was calculated from domestic fuel burning in which the emissions from dung cake and fuel wood dominated with 6.6 Gg/yr and 5.4 Gg/yr, respectively.

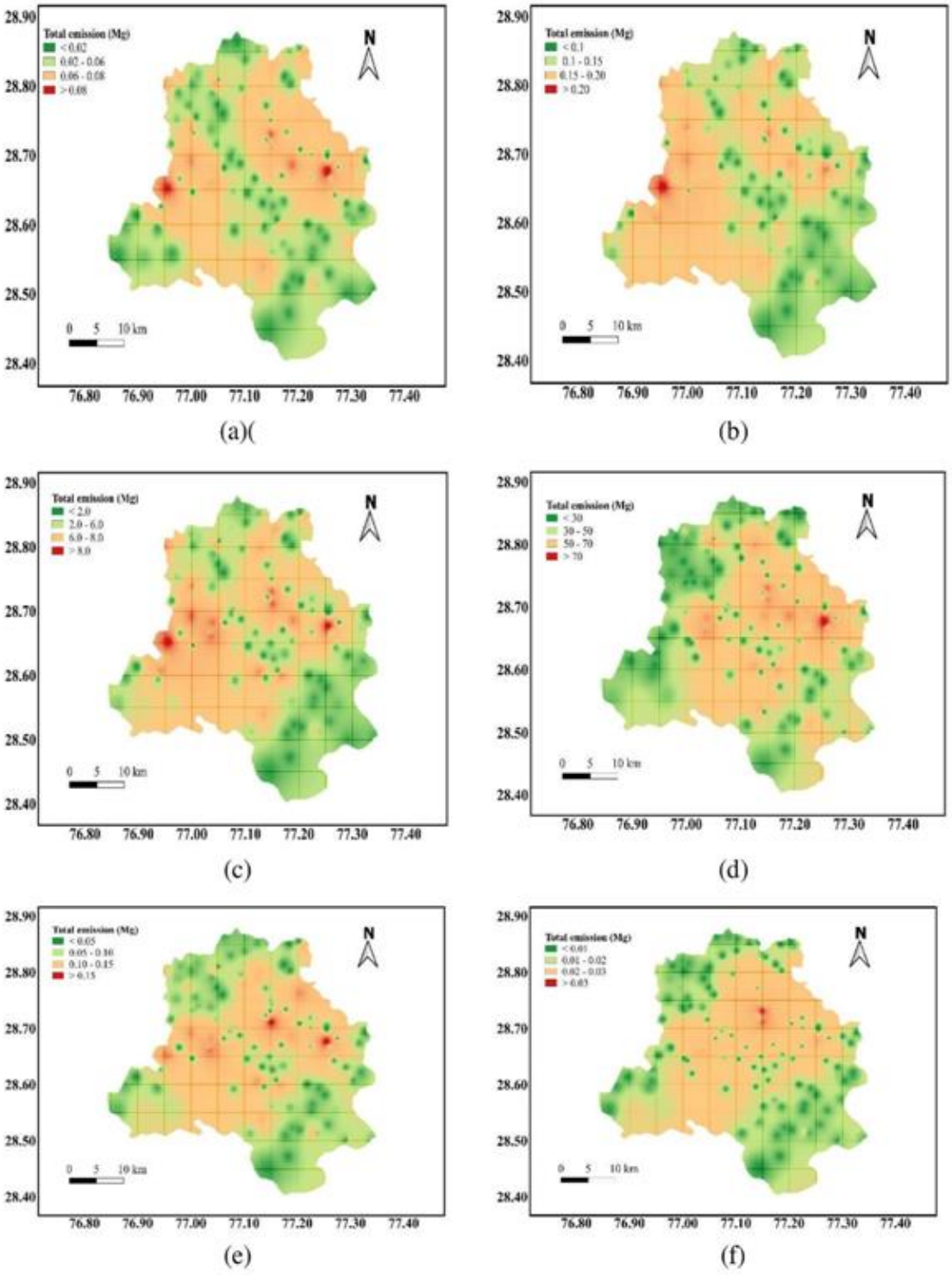
The EFs of NMVOCs calculated using canister and online collection method differ significantly from each other. The flaming stage presented enhanced emissions compared to the complete burning cycle by ~7 times which suggests that the method of data analysis and the period of sample collection play a pivotal role in the preparation of an emission inventory and estimating the budget. The EFs of NMVOCs have been reported for each domestic fuel following which the average value was calculated. A wide range (2–41 g/kg) of EFs of NMVOCs was reported from the flaming stage of

domestic fuel. The following figure presents the comparison of EFs of NMVOCs from different domestic fuels both for the flaming stage and the complete burning cycle. The EFs of NMVOCs have been reported for each domestic fuel following which the average value was calculated. A wide range (2–41 g/kg) of EFs of NMVOCs was reported from the flaming stage of domestic fuel.



EFs of measured NMVOCs emitted from domestic fuel burning during flaming stage (FS) and complete burning cycle (CBC)

There is no gridded emission inventory of trace gases from residential fuels over Delhi using NCT specific emission factor of trace gases from residential fuels and consumption data. I have determined experimentally the emission factor (in controlled laboratory condition) of trace gases (SO_2, CO_2, CO, NO, NO_2 and CH_4) from biofuels used in residential activities such as cooking, space heating, etc. in the NCT of Delhi. The highest EF of SO_2 (0.04±0.02 g kg^{-1}) is obtained in Central District, EF of CO (3.95±1.80g kg^{-1}) and CH_4(0.16±0.09 g kg^{-1}) reported highest in West District, the EF obtained from NO (0.09±0.04 g kg^{-1}) found higher in North and CO_2 (93.48±46.09 g kg^{-1}) is found higher in South District whereas EF of NO_2(0.02±0.02,0.03 g kg^{-1}) recorded higher in North and North West District. It is also noted that crop residue observed higher emitter of SO_2, CO and CO_2, similarly, saw dust observed higher emitter of CH_4, whereas, mixed fuel (DC+FW) observed a sound emitter of NO and NO_2. In addition, consumption of solid residential fuel is based on the survey among different slums and village population. Results inclined towards NO_X sensitive O_3 as it increased with high NO_X and was low at low to medium NO_X. High NMHC/NO_X ratios also specified that NO_X played a more critical role in controlling ozone concentration at the study site. Ozone production conditions were more favorable during pre-monsoon and post-monsoon seasons, as they were comparatively nearer to optimum ratio. The study also suggests positive, far-reaching implications of controlling NOx emissions, which in current scenario could be a solution for decreasing ground-level ozone.



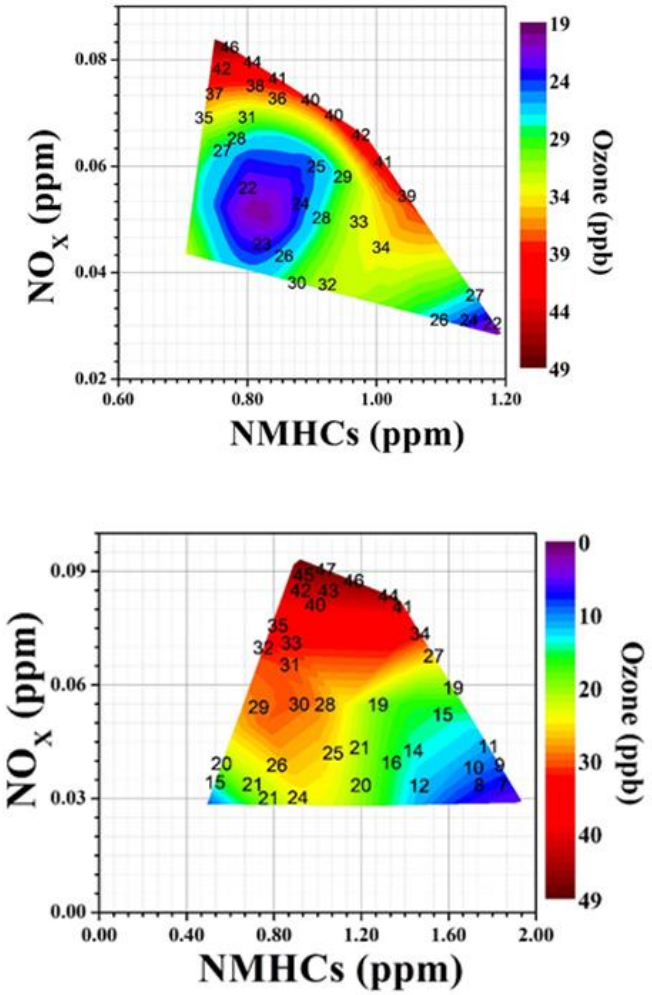
Spatial distribution of emission estimation (Mg)trace gases from biomass fuel over NCT region (a- SO2), (b- CH4), (c- CO), (d- CO2), (e NO) and (f- NO2)

- **NO_x vs VOCs Limited Regime of Surface Ozone Over Delhi**

A case study has been carried out to know the relations between surface O_3 and its main precursors, NOx and NMHCs due to its importance O_3 mitigation. Measurements and analysis of above-mentioned trace gases revealed relationships among them in an urban

location in Delhi, India during April to December 2014. Seasonal average mixing ratio of O_3 during the study period was 37 ± 13 ppb (pre-monsoon), 26 ± 8 ppb (monsoon) and 25 ± 16 ppb (post-monsoon). Monthly average NMHCs to NOx ratio for the study period was 18.3 ± 7.2. Ozone isopleths plotted to study ozone production as a function of NO_x and NMHC mixing ratios confirmed that the most effective ratio to produce high O_3 in the study area was ~0.1.

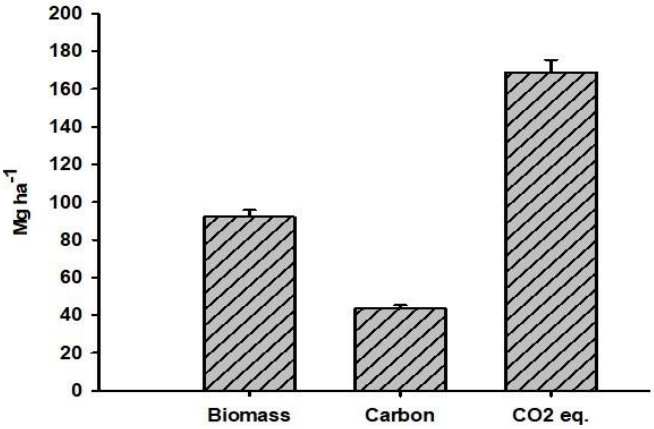
Results inclined towards NO_X sensitive O_3 as it increased with high NO_X and was low at low to medium NO_X. High NMHC/NO_X ratios also specified that NO_X played a more critical role in controlling ozone concentration at the study site. Ozone production conditions were more favorable during pre-monsoon and post-monsoon seasons, as they were comparatively nearer to optimum ratio. The study also suggests positive, far-reaching implications of controlling NOx emissions, which in current scenario could be a solution for decreasing ground-level ozone.



O_3 isopleth diagrams plotted by observational data from April to December 2014 at the study site. To plot, the maximum mixing ratios of NO_X and NMHCs in the early morning (00:00 to 04:00 h) were used, and the amount of O_3 increase (ΔO_3) was estimated from the difference between the maximum value in the afternoon (12:00–16:00 h) and the minimum value in the late night and early morning hours (00:00 to 04:00 h). (b) O_3 isopleth diagrams

- **Role of Urban Trees in Carbon Sequestration for the Mitigation of Climate Change**

In a highly urbanized city like Delhi, the urban forest plays a vital role in climate change mitigation by capturing and storing carbon dioxide (CO_2) from the atmosphere. Urban vegetation helps in increasing carbon (C) sink and CO_2 equivalent (CO_2eq) and also provides other aesthetic and psychological environmental benefits. To understand how urban trees are vital for carbon sink, we quantified the carbon density and CO_2eq in trees at National Zoological Park (NZP), New Delhi. For this, we estimated the total tree biomass of 25 species of Delhi. The total mean biomass, C density, and CO_2eq of NZP were 92.10 Mg ha-1, 43.61 Mg-C ha-1, and 168.83 Mg ha-1, respectively. The result indicates that the urban trees having the potential to store carbon are essential for mitigating the impact of climate change. Further, the quantification of the C density of NZP would be vital to know the actual carbon sink in Delhi. Furthermore, this study suggests that there is a substantial scope to increase the C density and CO_2eq in urban cities through adopting various management strategies *viz.* afforestation and reforestation program on degraded and abandoned land to maintain a clean and sustainable environment.



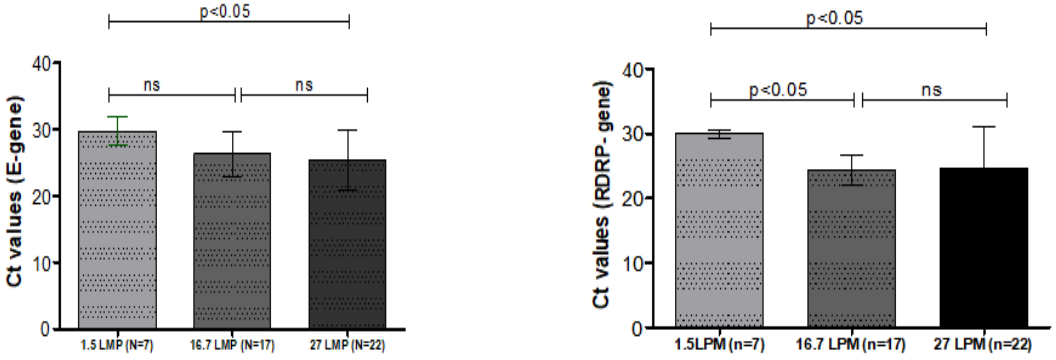
Total biomass density, total carbon and CO2 equivalent of National Zoological Park (NZP), Delhi. *(Source: Rajlaxmi, A., & Kumar, M. (2021). Urban tree carbon density and CO2 equivalent of National Zoological Park, Delhi. Environmental monitoring and assessment, 193(12), 1-13)*

- **Evidence of Presence of SARS-CoV-2 Virus in Atmospheric Air and Surfaces of Dedicated COVID Hospital**

The present study was conducted to find out the presence of SARS-CoV-2 virus in air and surfaces of emergency ward (reporting area of COVID-19 patients), medicine ward (treating mild or moderate COVID-19 patients) and ICU (treating very critical patients needing NIV or ventilator support) of a dedicated COVID hospital in order to find the evidence for possible mode of transmission of COVID-19 in these hospitals as many health care workers were found to acquire COVID-19 when they were working in such hospitals. TSP air sampler was used to capture particulate matter for detection of virus in the in air and swab from the surfaces. RT-PCR was used for detection of SARS-CoV-2 viral RNA.

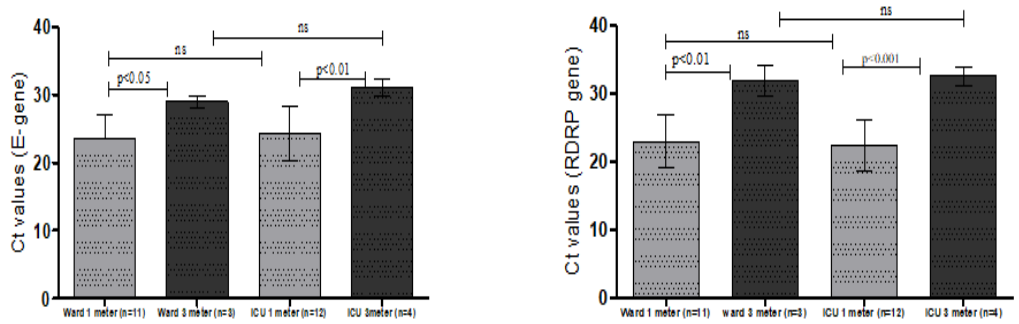
In the following figure, it is found that chance of detection of SARS-CoV-2 viral RNA is less when flow rate of TSP air sampler is fixed at 1.5 LMP for 1 hr and that probability increased with increase in flow rate. We tried to detect SARS-CoV-2 in the above-mentioned areas of the hospital by capturing particulate matter using TSP air sampler for 4 hrs. But, we did not find any positive results (except on one occasion when filter fixed at the channel having 1.5LPM flow rate showed positive result). Probably, such long duration suction was causing micropuctures in the PVDF membranes leading to escape of SARS-CoV-2 particles into suction tubes of air sampler. Therefore, we

recommend that TSP collection should be done for 1 hr at flow rate of 27 LPM for capturing SARS-CoV-2 from air for such studies.



Bar diagram showing mean and standard deviation of cycle threshold (Ct) for RDRP gene and E-gene of RT-PCR test conducted on dissolved particulate matter obtained by TSP air sampler with 1.5, 16.7 and 27 litre per minute (LPM) flow rates at 1 meter distance from newly diagnosed COVID-19 positive patients admitted to ward and ICU. P-value calculated by one way ANNOVA followed by Tukey's Post-hoc test using Ct values of RT-PCR positive samples. LMP = litres per minute

The RNA of SARS-CoV-2 was detected in atmospheric air of medicine ward, ICU and emergency ward of the dedicated COVID hospital. RT-PCR positivity rate was higher when TSP air sampler was placed to collect virus from air at 1 meter from patients with newly diagnosed COVID-19 than that collected at 3 meters from the patients. Viral load, in terms of cycle threshold (Ct) values for both the RDRP gene and E-gene of SARS-CoV-2 varied inversely with distance from the patients. It indicates that RNA of SARS-CoV-2 is present in atmospheric air of hospitals treating COVID-19 patients and its concentration decreases with the increase in distance from the positive patients shedding SARA-CoV-19 virus.



Bar diagram showing mean and SD of Ct for E gene and RDRP gene of RT-PCR test conducted on dissolved particulate matter obtained by TSP air sampler (flow rate 16.7 and 27 LPM at 01 and 03 meter distances from recently diagnosed COVID-19 patients from ward and ICU). P-value calculated by unpaired t-test using Ct values of RT-PCR positive samples only

Droplets produced during breathing, coughing, sneezing or talking usually get settled within one meter. However, the presence of SARS-CoV-2 RNA at 3 meter distance from the patients indicates that air-borne transmission of virus, probably through micro droplets, is possible, at least in hospital environment, although viral load decreases with

distance possibly due to (a) settlement of droplets within one meter and (b) dilutional effect on microdroplets (that can move beyond 1 meter) on their migration to distant places, which is now affirmed by WHO. PCR positivity rate and the Ct values of E-gene and RDRP gene at 1 and 3 meters in ICU did not differ from those at medicine ward. It indicates that viral concentration in air of ICU does not differ from that in medicine ward despite various medical procedures (intubation, suction, etc.) conducted in ICU, that generate lots of aerosols. However, one factor that might contribute to this observation is that number of patients and area: patient ratio in the ICU were always lower than that in the ward.

Air in emergency ward was also found to be contaminated with SARS-CoV-2 virus. Although the patients stay here for very short duration, yet the viral load in air was similar to that in atmospheric air of ICU and medicine ward (as found at 3 meter distance from the patients). Work stations in medicine ward and ICU had glass separation from the area where patients are admitted and in the air of those work station areas, viral RNA was not detected. Therefore, air-borne transmission probably does not occur in work-station areas. But in emergency ward, workstation did not have any wall or glass barrier to keep it separate from the environment where patients were admitted. Hence, the chance of air-borne transmission for health care workers from work-station at emergency ward might be more. Patients' bed, floor of the wards and tables in the work stations of nurses were found to contain RNA of SARS-CoV-2 indicating possible surface transmission of COVID-19 through contaminated surfaces. It is a known mode of transmission of COVID-19. So, hospital acquired COVID-19 by health care workers may occur through these contaminated surfaces

Gas Metrology

Gas Metrology is serving to the nation by providing testing, calibration and SI traceability dissemination services through Primary Reference Gas Mixtures (PRGM), i.e. Gas BNDs to many gas industries, government institutions, e.g. ISRO, SRL, automotive industries, etc. Demand of indigenously prepared SI traceable reference gas mixture is increasing day by day. BND series 6000 is for indigenously developed Gas Certified Reference Materials (CRMs) which are indented to be used for the calibration of analytical instruments, ambient and emission monitoring analyzers and quality assurance purposes. PRGMs are prepared as per the demanded composition and matrix. In the year 2021-22, following PRGMs are disseminated to different organizations for different purposes, e.g. ISRO for the Gaganyaan Mission Project, to automotive industry for calibration of instruments and their quality assurance and other in-house department for sensor testing purpose.

BND 6003 (CO in Nitrogen; 100 µmol/mol), BND 6007 (CO_2 in nitrogen; 1 % mol/mol), BND 6019 (Oxygen in nitrogen; 21 % mol/mol), BND 6020 (CH_4 in Nitrogen 5000 µmol/mol), BND 6021 (CO in Helium; 500 µmol/mol), BND 6022 (CO in Nitrogen; µmol/mol), BND 6006 (CO_2 in Nitrogen, 3 % mol/mol)

The amount-of-substance fractions given here are the nominal values, the certified values with measurement uncertainty (at $k=2$, at 95 % confidence level) are given in the respective Gas-BND certificates as per ISO 17034:2016.

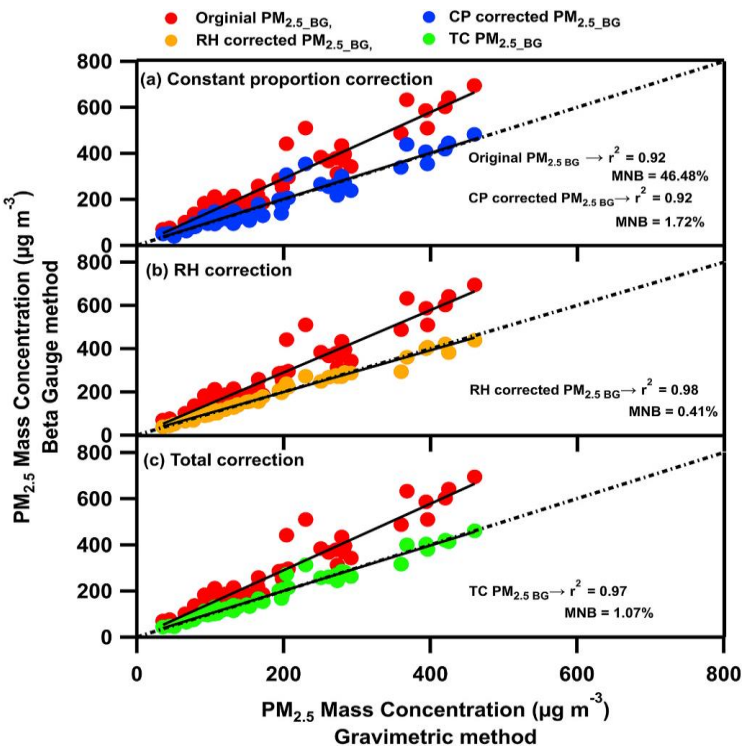
The gas metrology activity has successfully completed the quality management audit as per ISO17025:2017 and ISO 17034:2016. We continuously work to pilot/ participate in different international inter-comparison in order to establish our equivalence in international system of measurements.

- **Designed and Development of Bio-aerosol Sampler:** A six-stage bio-aerosol sampler is designed, developed and patent has been filed. This sampler can be used for both bacterial filtration efficiency of a face mask types, and also for bio-aerosol sampling in ambient air. This is first bio-aerosol sampler indigenously designed and developed. Specifications and design parameters are validated theoretically as well as experimentally successfully using in-house developed facility, e.g. wind-tunnel setup including high end particle instruments with SI traceability.

Designed and developed bio-aerosol sampler

- **First Time Under Indian Environment, Performance of Beta Attenuation Method (BAM) is Checked and Found that BAM can Overestimate $PM_{2.5}$ Mass Concentration >30% at High Mass Loading and RH Conditions**: Briefly, in available literature, performance of the beta gauge method has been checked and reported under real ambient conditions and fine particle concentration up to ~100 µg m^{-3}, although its measurement capability is claimed in different documents for more than 1000 µg m^{-3}. Here, for the first time, we reported performance of the beta gauge method at varying meteorology and high particle mass loading, i.e. up to >500 µg m^{-3} under urban ambient conditions. Year-round sampling in 2019 was performed at CSIR-NPL, New Delhi to cover a wider range of variability in meteorological parameters, i.e. temperature (8–38 °C), relative humidity (30–97%), ventilation coefficient (217–6761 m^2s^{-1}) and boundary layer height (160–1386 m), and mass loading, i.e. $PM_{2.5}$ mass concentration from 17 -670 µg m^{-3}(annual mean 142 ± 122 µg m^{-3}). During high concentration period, i.e. in winter (December–February) and post-monsoon (October–November), the mean concentration and associated deviation were high (i.e. in winter 236 ± 106 µg m^{-3} (±45%) and post-monsoon 227 ± 154 µg m^{-3}(±68%)) which may be due to large

variation and high particle mass loading caused by lower boundary layer height (winter 300 ± 86 m and post-monsoon 420 ± 87 m) with low ventilation coefficient (winter 731 ± 401 $m^2s^{-1}$and post-monsoon 899 ± 402 m^2s^{-1}), and most importantly, high RH (winter 84% ± 7% and post-monsoon 72% ± 6%). Beta gauge method while comparing with collocated gravimetric method, demonstrated an excellent correlation (r^2>0.90) and the observed bias between the methods was within 10%, when RH was <60% and $PM_{2.5}$ was <130 µg m^{-3}. More than 30% overestimation was observed especially when RH reaches over 60%. These performance results suggest that overestimation of PM mass concentration by beta gauge method occurs especially at high RH and increases by a factor up to ~5 when particle mass loading also becomes high. To overcome this problem, two onsite correction factor approaches are suggested and applied to the beta gauge measurements. After correction, the mean normalized biases were decreased from 46.48 ± 26.78% (original $PM_{2.5\_BG}$) to 1.72 ± 18.60% (constant proportion correction) and to 0.41 ± 6.11% (RH correction) which resulted in an acceptable level of accuracy thereby enhancing the field performance of the beta gauge monitor under Indian meteorological conditions.



Comparison plots of PM2.5concentration measured by continuous beta gauge method and gravimetric method after applying, (a) Constant proportion correction, (b) RH correction, and (c) Total correction

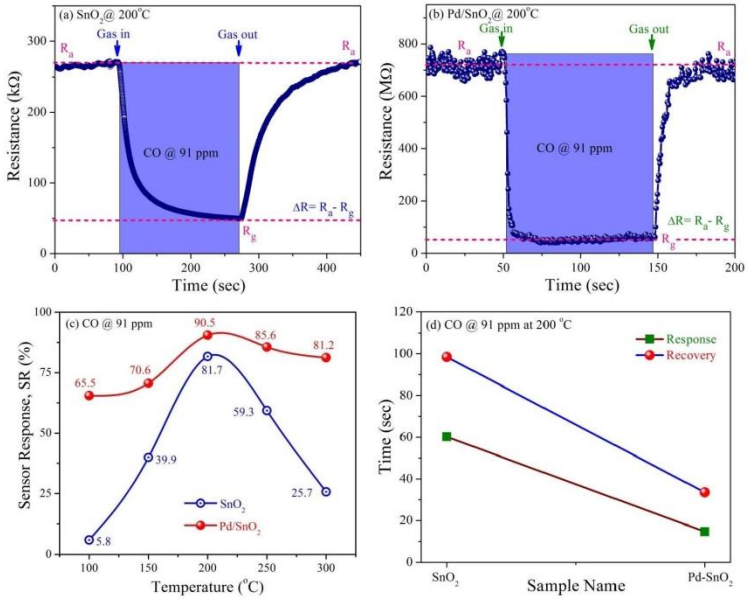
Sensor Devices and Metrology

Sensor Devices & Metrology group focuses on the development of smart sensors for the detection of electromagnetic radiations (UV, Visible, NIR) and atmospheric pollutant gases like CO_x, NO_x, SO_x, H_2S, NH_3, VOCs, etc. based on thin-film/nanostructures of III-nitrides, metal oxides, Two-dimensional layered materials. The group is well-equipped with state-of-the-art thin film growth and characterization techniques and sensor characterization facilities. Highly responsive self-powered optical detectors (UV, Vis) are designed and developed by utilizing novel III-nitride and hybrid structures. A prototype metal-oxide-based gas sensing device has been designed and fabricated with an integrated platinum hot plate.

- **Development of Metal Oxide based CO Gas Sensors by PVD Process:**

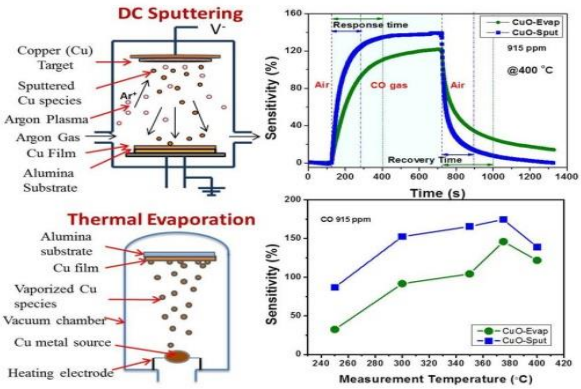
(i) Pd/SnO_2 thin films deposited by magnetron sputtering for CO gas sensing: Nanocrystalline SnO_2 thin films functionalized with Pd nanoparticles were prepared by reactive magnetron sputtering. The CO gas sensor based on Pd/SnO_2 thin films

demonstrates an excellent sensing performance with the highest sensor response of ~ 90.5% and fast response/recovery time of 15 s/34 s for 91 ppm CO gas concentration at 200 ^{o}C operating temperature. Also, we have achieved an excellent sensor response of ~ 65.5% even at a low operating temperature of 100 ^{o}C. Moreover, Pd/SnO_2 thin films are efficient to detect the lower concentrations of CO gas as the calculated detection limit was achieved ~ 4.7 ppm. Further, Pd/SnO_2 thin films were highly selective towards CO gas compared to other reducing and oxidizing gases such as NH_3, H_2S, NO_2, NO, C_2H_5OH, etc. Therefore, it can be concluded that Pd functionalized SnO_2 thin films with nanocrystalline nature deposited by reactive magnetron sputtering exhibit efficient CO gas sensing performance with high sensor response, sensitivity, selectivity, and stability, including fast response/recover time.



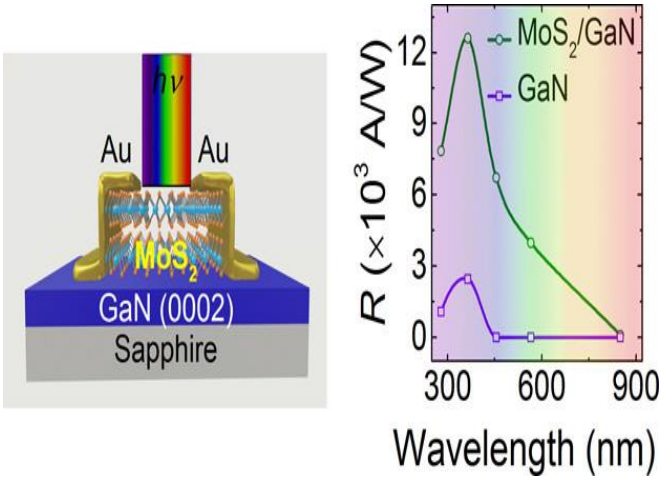
(a) & (b) Dynamic responses, (c) Variation of sensor response with temperature and (d) The response/recovery time of SnO2 and Pd/SnO2 thin films

(ii) CuO thin films based CO gas sensor: Development of CO gas sensor based on CuO thin films by the thermal oxidation of Cu metal thin films deposited by vacuum evaporation and DC sputtering process. The surface morphology, crystallite size and film composition of CuO]films are found to have a strong influence on their CO gas sensing properties. It is found that sputtered CuO films have a better sensitivity of 145 % against 120 % of vacuum evaporated films against 915 ppm of CO gas concentration at 400 °C due to a larger presence of Cu^{2+} sites for CO adsorption in the sputtered film.



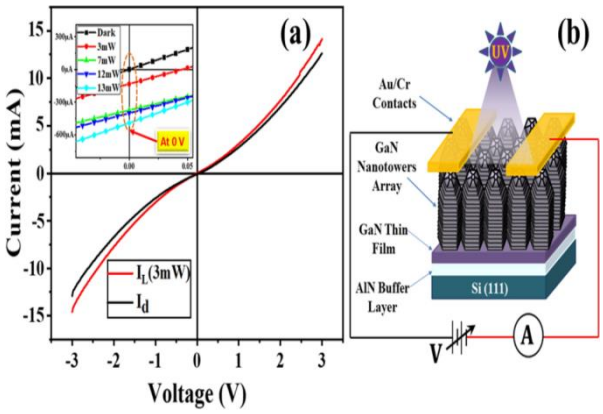
Development of Nitride heterostructure based optical detectors

(iii) Development 2D/3D hybrid of MoS2/GaN for a high-performance broadband photodetector: Design & developed heterostructure of two-dimensional molybdenum disulfide (MoS2) and epitaxial gallium nitride (GaN) films to create an enhanced spectral absorption profile. This combination utilizes complementary optical absorption of MoS_2 (visible) and GaN (UV) driven by type II band alignment at their interface to showcase highly sensitive photodetectors spanning across the UV–NIR regime. Concurrently, the heterostructure exhibits significantly enhanced responsivity (order of 10^4 A/W) and external quantum efficiency that are 500% higher than the bare GaN photodetectors. Demonstrating this heterostructure as a broadband photodetector with high figures of merit opens up opportunities for designing efficient optoelectronic junctions and imaging applications, given the available, scalable synthesis approaches that the research community has now designed for both constituent materials.



Schematic of hybrid devices and responsivity vs wavelength for fabricated devices

(iv) Fabrication of GaN nano-towers based self-powered UV photodetector: The fabrication of a unique taper-ended GaN-Nanotowers structure based highly efficient ultraviolet photodetector is demonstrated. Hexagonally stacked, single-crystalline GaN nanocolumnar structure (nanotowers) grown on AlN buffer layer exhibits higher photocurrent generation due to high-quality nanotowers morphology and increased surface/volume ratio, which significantly enhances its responsivity upon ultraviolet exposure leading to an outstanding performance from the developed detection device. The fabricated detector display low dark current (~ 12 nA), high ILight/IDark ratio (> 10^4), fast time-correlated transient response (~ 433 µs) upon ultraviolet (325 nm) illumination. A high photoresponsivity of 2.47 A/W is achieved in the self-powered mode of operation. The fabricated device display excellent responsivity of 35.4 A/W @ –3 V along with very high external quantum efficiency (~ 10^4%), lower noise equivalent power (~ 10^{-13} $WHz^{-1/2}$), and excellent UV–Vis selectivity in photoconductive mode. The utilization of these GaN-Nanotower structures can potentially be useful for the fabrication of energy-efficient ultraviolet photodetectors.



I-V characteristics of fabricated GaN-NTs UV-PD under dark & 325 nm UV illumination. Inset: indicate self-powered characteristic at various optical powers, (b) Schematic image of the fabricated GaN-NT array based device

Advanced Materials & Device Metrology

A brief detail of the activities of each sub-division is described below:

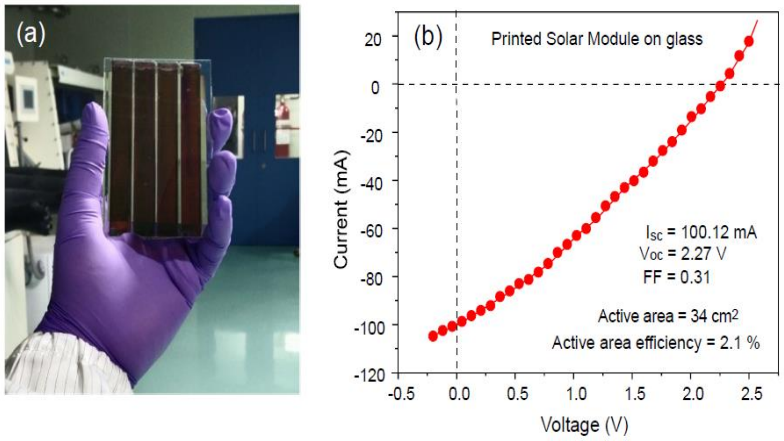
Photovoltaic Metrology Section

The photovoltaic metrology group is working on basic to applied research, namely wafer based silicon photovoltaic technology and thin-film solar cells and advanced concepts of organic and perovskites based photovoltaic devices development, testing and measurements. The research activities mainly focus to develop protocols for precise and accurate measurements of photovoltaic cells and modules as well as generating skilled manpower for supporting the Indian photovoltaic sector in the following area:

i. Setting of National Primary Standard for solar cell calibration, secondary cell standard and national centre for photovoltaic module testing
ii. Validation of solar cell efficiency
iii. Unit process development for addressing optical, electronic and electrical losses of silicon-based photovoltaics
iv. Organic, perovskites, nano-crystalline silicon and perovskites/silicon heterojunction solar cells device fabrication
v. Materials development of solar cells and solar/e-waste management
vi. PV Modules analysis, energy yield and degradation related investigations specific to Indian climatic conditions

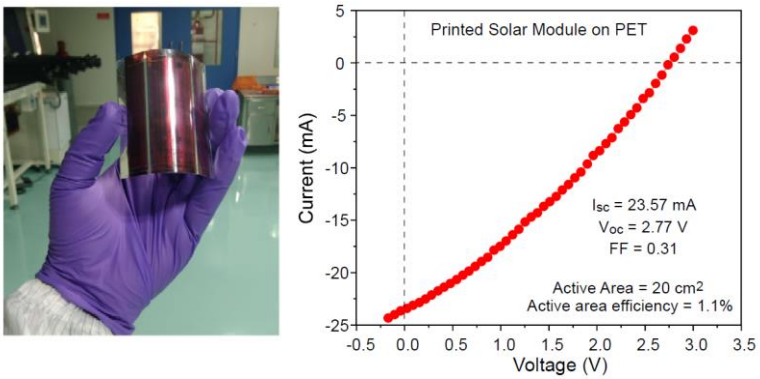
- **Perovskite Solar Cells**

The perovskite solar cells printer, which we have developed at CSIR-NPL, can print different layers of solar cells on both the rigid as well as flexible substrates. For the printing of solar cell on glass substrates, we used ITO coated glass substrates and printed electron transport layer (ETL) of SnO_2, which was followed by printing of $CH_3NH_3PbI_3$ perovskite and P3HT hole transport layer (HTL). To complete the solar cell, we deposited Ag as the top metal electrode by thermal evaporation in vacuum chamber. Before printing of next layer the previous printed layer was dried via annealing at an optimum temperature in an oven to remove the solvent and get a solid film. One of the printed solar cells on glass substrate in ~7 × 10 cm^2 area (active area ~ 34 cm^2) exhibited ~ 2% power conversion efficiency (PCE) under 100 mW/cm^2 irradiance of a class AAA solar simulator. Here, figure (a) shows the photograph of the printed solar module on ITO coated glass substrate and figure (b) shows its current-voltage (*I-V*) characteristics under light.



(a) Photograph of the all printed PSCs module (except the top thermally evaporated Ag electrode) on ITO coated glass substrate. (b) I-V characteristics of the PSCs module under 100 mW/cm^2 irradiance form a class AAA solar simulator

The PSCs printed on ITO coated PET substrates in a similar way as that for ITO coated glass substrate exhibited ~1% PCE. Figure shows the photograph of a 7 x 7 cm^2 printed solar module on ITO coated PET substrate and also shows the *I-V* characteristics of the flexible printed solar module on ITO coated PET substrate.

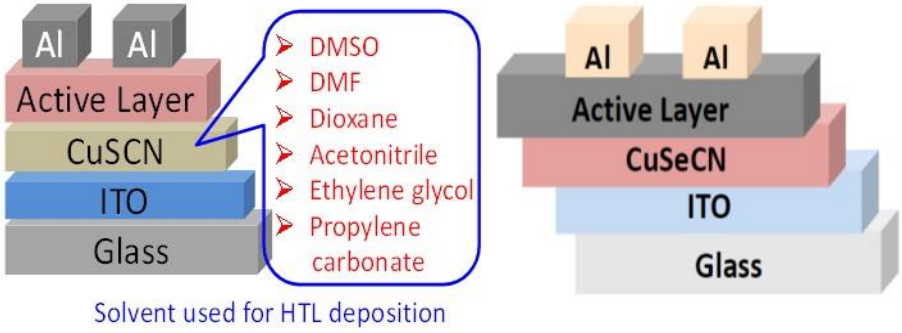


Photograph of the all printed PSCs module (except the top thermally evaporated Ag electrode) on ITO coated PET substrate. (b) I-V characteristics of the PSCs module under 100 mW/cm^2 irradiance form a class AAA solar simulator

Though the PCE of these printed PSCs are not very high at the moment but we are continuously printing PSCs on both the glass and PET substrates and doing device engineering via incorporating new charge transport layers and modifying the perovskite material to improve their performance. We are working on detailed optimization of device parameters and processing conditions and hopefully we will soon achieve higher efficiency in printed PSCs modules.

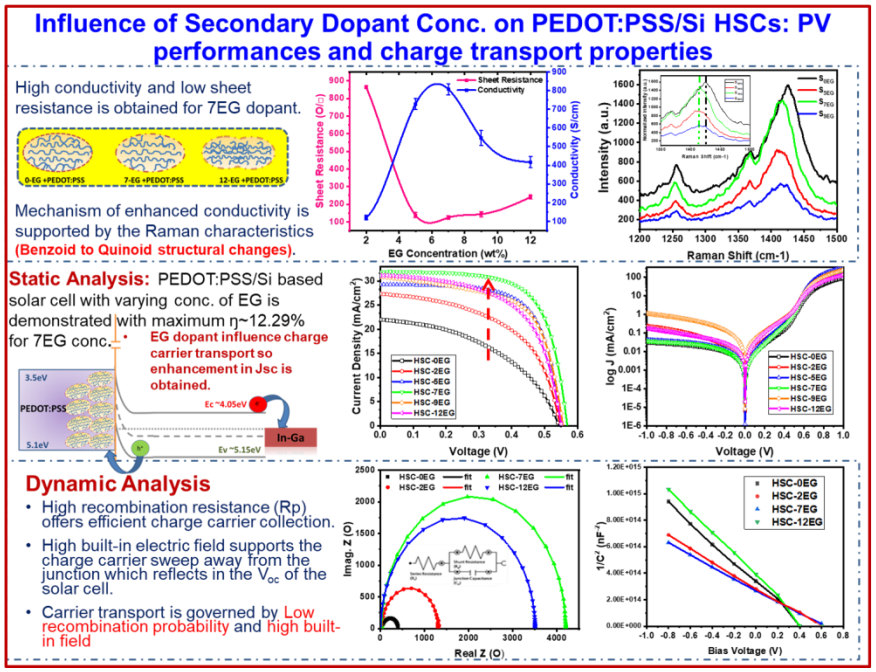
- **Solution-processable Hole Transport Layer for Organic Solar Cells**

Recently, a lot of progress on solution-processable deposition of copper (I) thiocyanate as an efficient hole transport layer (HTL) for solar cells has been reported. However, the choice of solvents for solution-processable deposition of CuSCN as HTL has been limited. A wide range of solvents (dimethylformamide (DMF), dioxane, acetonitrile, ethylene glycol, propylene carbonate, DMSO) for solution-processable deposition of CuSCN as HTL in solar cells were used. The effect of change of solvents on the morphology of HTL and device performances was studied. Two active layers PTB7:$PC_{71}BM$ and PCDTBT:$PC_{71}BM$ were used for solution-processable device fabrication and maximum efficiency 4.56% has been achieved. The higher chalcogen analogue copper (I) selenocyanate (CuSeCN), as efficient HTL for organic solar cells. DMSO and DMF solvents were used for solution-processable deposition of CuSeCN thin films. The optical, electrical, and morphological properties of the HTL were studied. Density functional theory calculations were performed to understand the energy level and band gap of the material. Photovoltaic devices were fabricated with a device structure ITO/CuSeCN/PCDTBT:$PC_{71}BM$/Al and maximum power conversion efficiency was achieved up to 4.03% under ambient conditions.



Device structures are used for organic solar cells fabrication

- **Organic/silicon Hybrid Solar Cells: Unveiling the Role of Secondary Dopant for Enhanced Device Performance and Working Mechanism**



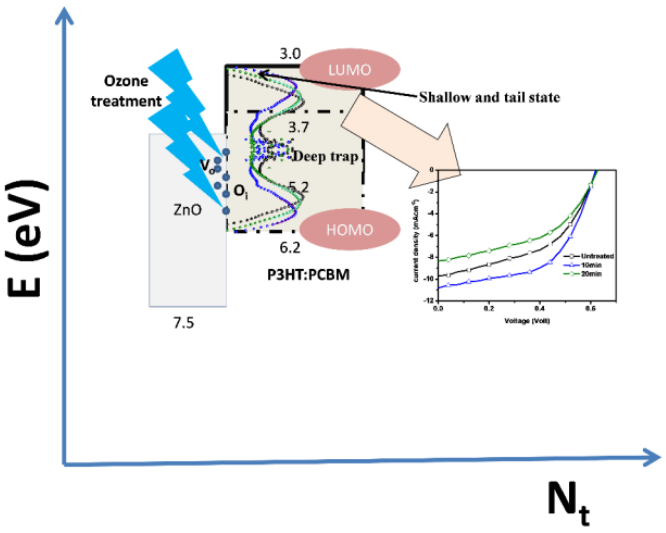
Highlights on contributions on role of secondary dopant on the structural, optical, electrical properties of PEDOT:PSS polymer and PEDOT:PSS/Si junction formation for enhanced performances

Organic/inorganic heterojunctions provide a viable option to replace the conventional high-temperature dopant diffusion-based p–n junction owing to their low manufacturing cost. This is because of its low thermal budget, simple, rapid and solution based processes which can be implemented in heterojunction fabrication. Since most of the incoming light is absorbed in silicon therefore hetero junction solar cell may have, in principle, efficiency comparable to a silicon p-n junction solar cell. Thus, there has been increasing interests in low temperature heterojunction solar cell concepts particularly polymer/Si-based heterojunction solar cells. With the objectives, efforts have been made to develop the heterojunction-Si solar cells with enhanced performances. Recently, hybrid solar cells (HSCs) based on PEDOT: PSS and silicon heterojunction have drawn significant attention owing to their potential for high performance and low-cost processing. Pristine PEDOT:PSS, however, due to its limited electrical conductivity, cannot yield highly efficient HSCs. Process of enhancing the optical, structural, electrical performance of PEDOT:PSS by doping of secondary dopants such as ethylene glycol (EG) or DMSO in PEDOT:PSS was investigated in addition to fabrication of PEDOT:PSS/Si hybrid solar cells with enhanced performances. It was established that optimal EG induced a strong inversion layer (p^+-n junction) in n-Si at the PEDOT: PSS/Si interface enabling the efficient separation and transportation of photo-carriers and hence enhanced solar cell performances. Role of EG in making an efficient PEDOT:PSS/n-Si solar cell was explained which may pave the way for further advancement of the cost-effective hybrid solar cell technology**.**

- **Defect Density and Performance Influenced by Ozone Treatment of ZnO Interface in Inverted Organic Solar Cell**

Zinc oxide (ZnO) has great potential as an electron transport layer (ETL) for producing efficient and stable organic solar cells. The effect of ozone treatment on ZnO working as the ETL in the organic solar cell has been studied by analyzing crystallinity, the defect density of states, and charge carrier dynamics from transient absorption spectroscopy to understand its role in the improvement in the interface between ETL and active layers. We have observed that a 10-minute continuous ozone treatment of ZnO film

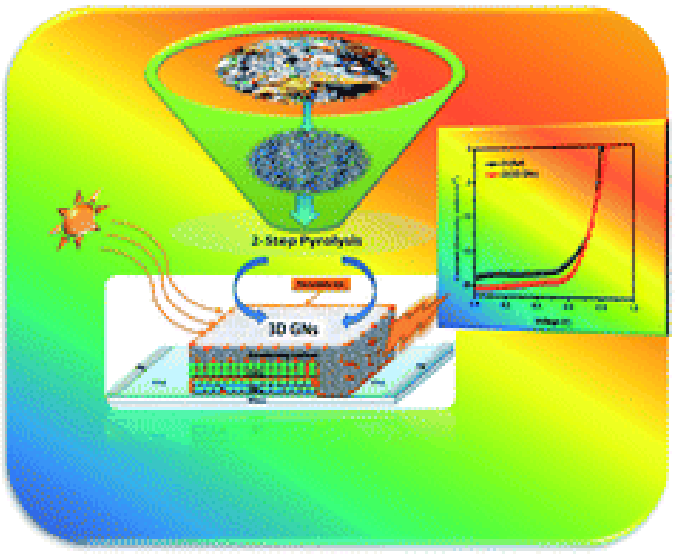
demonstrates improvement in its crystallinity leading to a 23% increment in short circuit current. The improvement in the crystallinity has been confirmed by the morphological and structural analysis using SEM and GIXRD. These analyses reveal the formation of a flake-like structure and an increase in peak intensity in GIXRD. It has been observed that ozone exposure has significantly affected the carrier recombination resistance, ideality factor of the device. From transient absorption spectroscopy, it has been found that for 10 min ozone-treated ZnO film has an average carrier transport time (661.79 ps), which is smallest as compared to untreated film or over treated film leading to faster carrier extraction through ETL. Further, the study of defect density of states shows that optimized ozone-treated film show 22.08% decrease in defects as compared to the control device, which primarily reflected as the improvement in the current density leading to increase in device efficiency from 2.95% to 3.75%.



The energy distribution of defect states in inverted organic solar cells for ozone-treated ETL with varying treatment time duration. The improved crystallinity in ZnO film and reduced defect state in optimized ozone-treated devices leads to better device performance compared to untreated devices

- **3D Graphene Nanosheets from Plastic Waste for Highly Efficient HTM Free Perovskite Solar Cells**

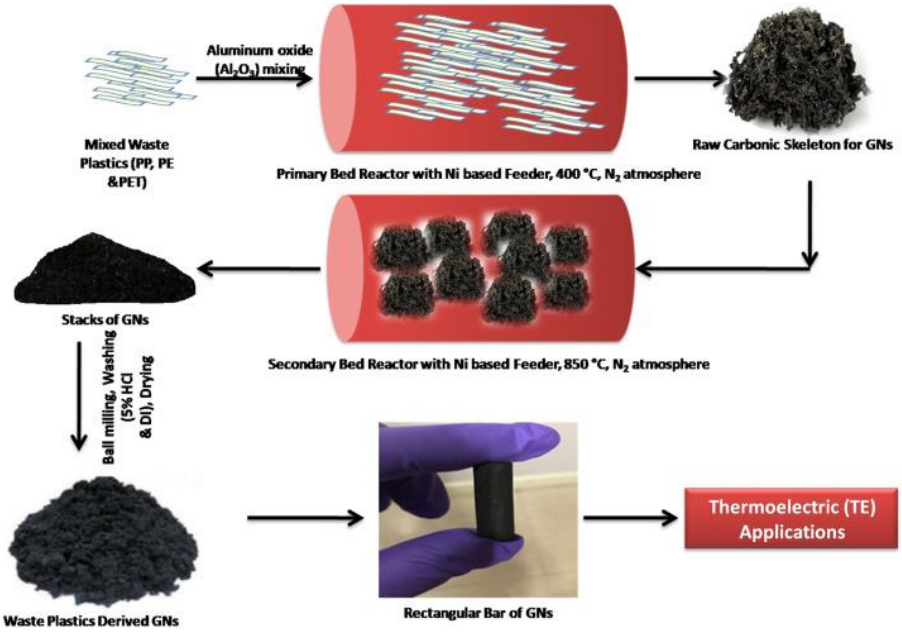
The first time application of waste plastic derived 3D graphene nanosheets (GNs) for hole transport material (HTM) free perovskite solar cells (PSCs), where 3D GNs have been employed as an electrode dopant material in monolithic carbon electrode based mesoscopic PSCs. Waste plastics were upcycled into high-quality 3D GNs by using two-step pyrolysis processes, where, a nickel (99.99%) metal mesh was taken as the catalytic and degradation template to get an acid free route for the synthesis of 3D GNs. Raman spectroscopy, HRTEM analysis and XRD analysis show the presence of 1–2 graphene layers within the 3D GNs. Further, the optical band gap study has also been performed to



The process of upcycling for plastic waste management by converting them into high-quality 3D Graphene nanosheets (GNs) for application in perovskite solar cells. The photocurrent study showed that the 3D GN device leads to better performance as compared to the reference device due to the larger diffusion current

analyze the applicability of 3D GNs for PSCs. The optimized device with 3D GNs shows a power conversion efficiency (PCE) of 12.40%, whereas the carbon-based control device shows a PCE of 11.04%. Further, all other device parameters such as short circuit current (J_{sc}), open circuit voltage (V_{oc}) and fill factor (FF) have been improved with the addition of 3D GNs. The performance enhancement in 3D GN doped HTM free PSC solar cells is attributed to the enhancement in conductivity and reduced recombination within the device. Further, the photocurrent study shows that the 3D GN device shows better performance as compared to the reference device due to the larger diffusion current. Thus, the upcycling of waste plastics into 3D GNs and their exploitation for application in energy conversion show an effective and potential way to convert waste into energy.

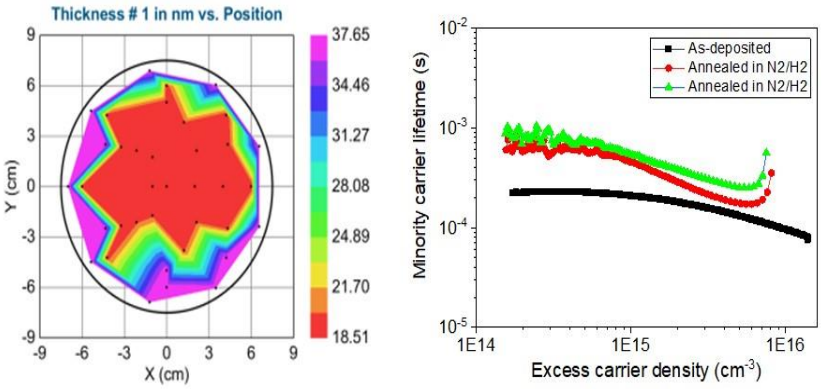
- **The Synthesis of Graphene Nanosheets (GNs) Derived from Plastic Waste for Cost-effective Thermoelectric (TE) Applications**



The synthesized low-cost Graphene nanosheets (GNs) from waste plastics by using low-cost Al_2O_3 by using our previously reported two-step pyrolysis process. The thermoelectric characteristics of the GNs show enhancement in the electrical conductivity and the Seebeck coefficient has been found, which showed good TE characteristics within the GNs

The synthesis of GNs was done as per our present process, where a two-step pyrolysis process was carried at the temperature range of 400 °C–850 °C by using Al_2O_3 as the catalytic and degradation template, while nickel metal-based catalytic beds were used to get high-quality GNs from our indigenously developed 100 Kg per batch pilot-scale plant. Raman, X-ray diffraction (XRD), and transmission electron microscopy (TEM) analysis showed the presence of 4–5 nm thick sheets of GNs. After the successful synthesis of GNs from waste plastics, the TE properties of thus synthesized GNs were investigated. GNs showed low resistivity of 3.93×10^{-2} Ω-m at room temperature, which are further decreases with an increase in temperature. The Seebeck coefficient values of the GNs show that the material behaves as a p-type semiconductor. The TE figure of merit ZT showed a signatory value of 0.1×10^{-6} at the temperature of 426 K corresponding to the TE properties within the synthesized GNs. The results of TE analysis indicate that waste plastic-derived GNs can be used for a variety of TE applications.

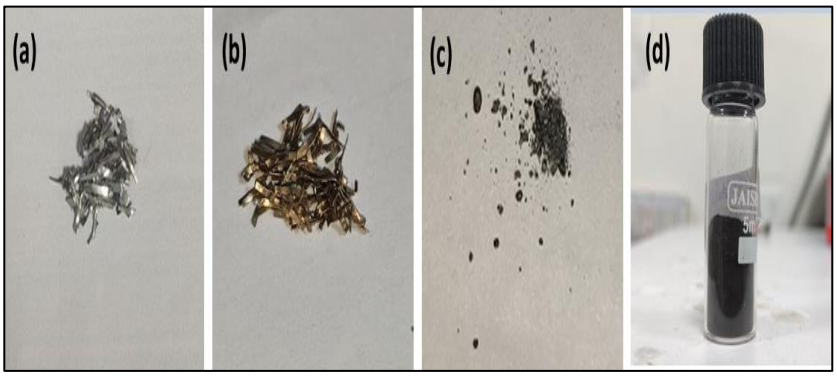
- **Development of Novel Passivation Layers for p-type Doped Silicon Surfaces**



(a) Thickness uniformity of the deposited layers acros the surface of silicon. (b) Minority carrier lifetime of silicon with $ZnO:Al_2O_3$ layers with respect to excess carrier density. The lifetime is found to be 525 μs at excess carrier density of 1E15 cm^{-3}

Solar power conversion efficiency of silicon (c-Si) solar cells is significantly affected by electronic recombination losses at the wafer surfaces. The surface recombination rate (Schottky–Read–Hall (SRH)) can be decreased by reducing the interface trap density by chemical passivation, and also by reducing the density of one type of free charge carrier at the wafer surface by field-effect passivation. Field-effect passivation using aluminium oxide (Al_2O_3), which has negative fixed charges near the Al_2O_3/c-Si interface, has been proved to be beneficial for passivating the p-type c-Si surface. Its field-effect passivation efficiency could further be improved by stack layers of Al_2O_3:ZnO by improving its fixed charge density. Therefore, a novel insulator structure of Al_2O_3:ZnO is being developed using thermal ALD. The ZnO has been adopted as an inter-layer to enhance the field-effect passivation characteristics in view of its diverse native accepter-like defects (V_{Zn}, O_i, and O_{Zn}) with the negative charge. The figure (fig. (a)) shows thickness uniformity of the thermal ALD deposited layers. The higher thickness on the wafer edge is obvious for both side deposited films. Minority carrier lifetime of silicon with $ZnO:Al_2O_3$ layers improved from 240 μs to 525 μs as shown in the figure (fig.(b)). The efforts are still in progress to improve the passivation quality of the layers.

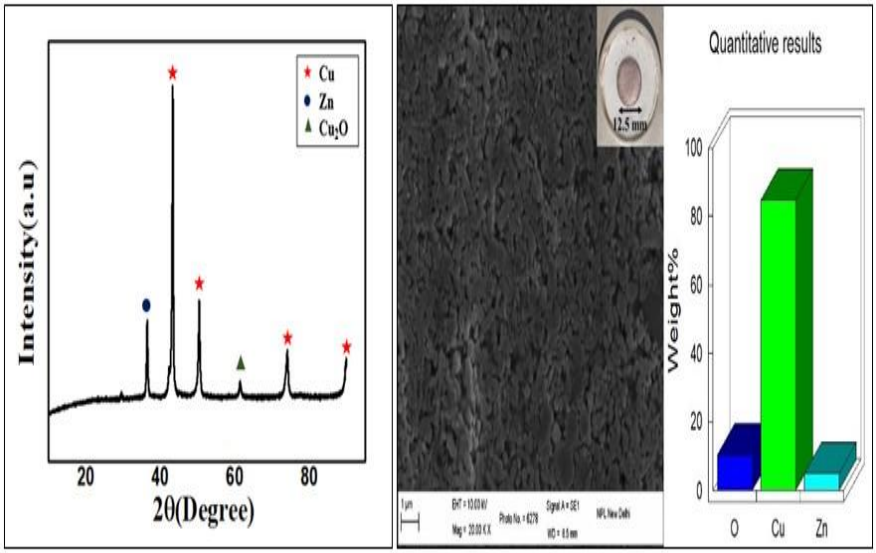
- **Extraction Recovery of Lead, Tin and Copper from Waste Silicon Solar Modules**



Extracted copper busbars from waste crystalline silicon solar module (b) Copper tape after the thermal treatment (c) Toxic lead and tin powder obtained after the thermal treatment of metallic

Various components of a crystalline silicon solar panel are glass (74%), silicon (3%), polymers (6.5%), tin (0.12%), copper (0.6%), lead (less than 0.1%), silver (less than 0.006%). Therefore, apart from silicon, the panel contains precious metals like silver, and copper and hazardous metals like lead and tin. The recovery of these metals becomes crucial for the economic and environmental sustainability of the recycling process adopted for neutralization of the hazard coming

from EoL panels. We, here, tried to extract various metals and materials from the silicon solar waste through different processes. Most of the lead, tin, and copper in the crystalline silicon panels come from connecting wires used to connect different solar cells in the panel. So, firstly we recovered connecting wires (fig. (a)) from the panel and thermally treated them in an automated PID controlled muffle furnace and heated at different temperatures from 400 ^{o}C to 800 ^{o}C for 5-7 hours to remove lead and tin coating (fig. (c)). After that, the obtained copper tapes (fig. (b)) were sequentially treated with nitric acid (HNO_3) and sodium hydroxide (NaOH) to get copper hydroxide ($Cu(OH)_2$) which is further converted to copper oxide (fig. (d)) through treatment at 170^{o}C.



(a) XRD spectra of copper powder and (b) SEM image and (c) EDS image of copper pellet

The obtained copper powder was characterized with the XRD, SEM-EDS techniqes. The XRD spectra of the copper powder has shown intense peaks at 2Θ value of 43.30^{o}, 50.43^{o}, 74.13^{o}, 89.9^{o} which corresponds to the reflection from 111, 200, 220, 311 planes of FCC structure of metallic copper respectively **(JCPDS card no. 00-004-0836)** as shown in fig. (a). However, in addition to these peaks, small peaks observed at 61.56^{o} corresponds to reflections from 200 planes of cuprous oxide (Cu_2O) **(JCPDS card no. 74-1230)** and the peak at 36.46^{o} corresponds to reflection from the 002 planes of zinc **(JCPDS card no. 004-0831)**. The presence of cuprous oxide in the extracted powder resulted from the oxide formation of copper ions on the surface during the extraction and drying process. The presence of zinc can be attributed to unreacted zinc during the cementation process. Scanning electron microscopy along with the electron dispersive spectroscopy and X-ray Fluorescent spectroscopy was carried out to analyze the morphology and purity of extracted copper powder. The surface of the copper pellet (image in inset figure) has shown randomly distributed granules of copper. The EDS analysis revealed that the purity of extracted copper was around 85% (by weight) as a small amount of unreacted zinc (~ 5%) used for cementation was also found. Nearly 10% of oxygen was also observed and it may be due to the formation of cuprous oxide during the extraction and drying process.

Photonic Materials Metrology

- **Spectroscopic Studies of Mechanically Exfoliated and APCVD Grown WSe_2 Nanosheets**

WSe_2 is a promising nanoscale layered semiconductor having extraordinary properties, including high quantum yield in PL, lowest thermal conductivity, strong spin-orbit coupling, and high absorption coefficient. The accurate and precise quantification of the number of layers along with influence of experimental parameters on the synthesized shapes of WSe_2 nanosheets are highly desirable for realization of spintronic and valleytronic devices. CSIR-NPL have been synthesized WSe_2 nanosheets using mechanical exfoliation method and atmospheric pressure chemical vapor deposition method. The quality, uniformity, and number of layers of WSe_2 are examined using Raman and PL spectroscopy. This study become useful in tuning the optical properties and guides the precise control of growth with desired morphologies.

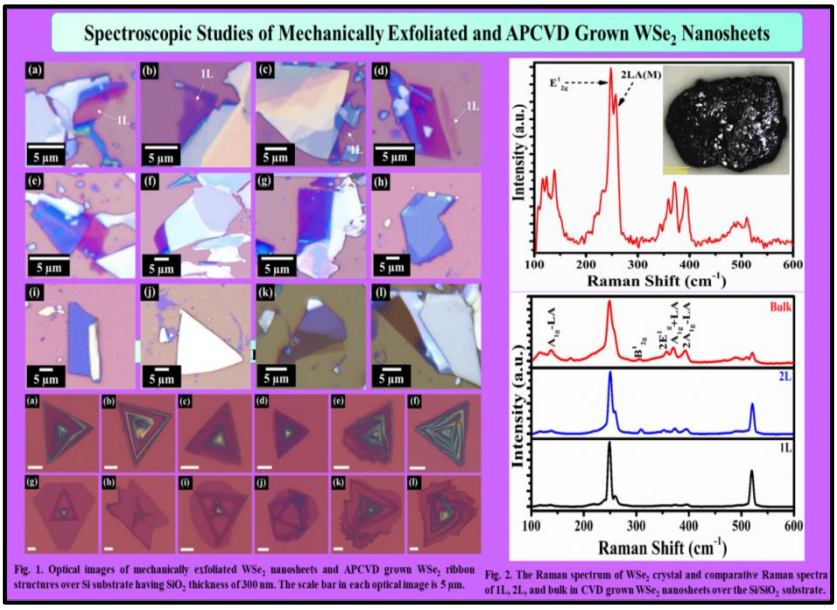


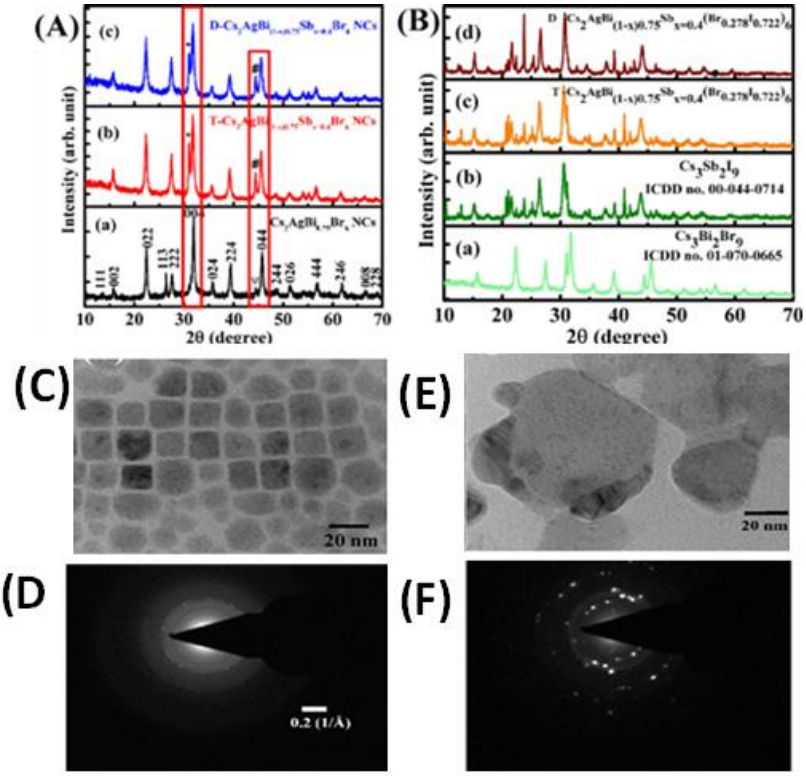
Fig. 1. Optical images of mechanically exfoliated WSe_2 nanosheets and APCVD grown WSe_2 ribbon structures over Si substrate having SiO_2 thickness of 300 nm. The scale bar in each optical image is 5 µm.
Fig. 2. The Raman spectrum of WSe_2 crystal and comparative Raman spectra of 1L, 2L, and bulk in CVD grown WSe_2 nanosheets over the Si/SiO_2 substrate.

Spectroscopic studies of Mechanically Exfoliated and APCVD Grown WSe2 Nanosheets

- **Development of Mixed Antimony-bismuth based Double Perovskite Nanocrystals for Photovoltaic Application**

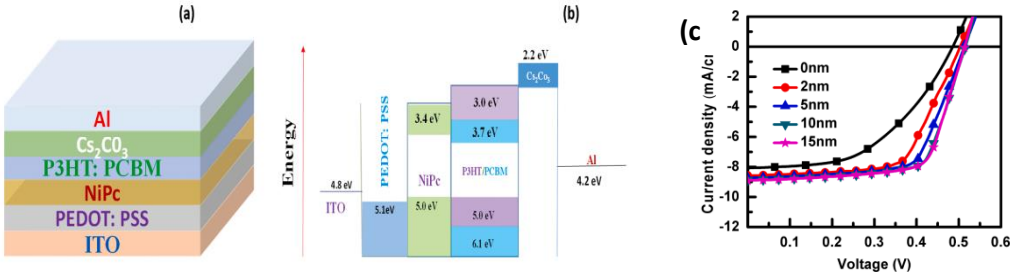
Lead-free double perovskite materials have attracted great attention due to their environmental friendliness, stability, and tunable optoelectronic properties. However, an effort is needed to explore more lead-free double perovskites and alter the properties for their further applications. Synthesis of Lead-free mixed antimony--bismuth based perovskite material $Cs_2AgBi_{(1-x)0.75}Sb_{X=0.4}Br_6$ and $Cs_2AgBi_{(1-x)0.75}Sb_{X=0.4}(Br_{0.278}I_{0.722})_6$] nanocrystals (NCs) have been done by hot injection method through benzoyl halide as bromide precursor and anion-exchange (Br into Br/I). $Cs_2AgBi_{0.75}Br_6$ having long carrier recombination lifetime is used as a host material and antimony was substituted on the bismuth lattice site for bandgap engineering. To measures the lattice constant of compound $Cs_2AgBi_{(1-x)0.75}Sb_{X=0.4}Br_6$ and $Cs_2AgBi_{(1-x)0.75}Sb_{X=0.4}(Br_{0.278}I_{0.722})_6$, XRD was performed. The formation of NC has been confirmed by using Transmission Electron Microscopy (TEM). TEM images of $Cs_2AgBi_{(1-x)0.75}Sb_{X=0.4}Br_6$ NCs show cubic structure of NCs with edge length 14.0 $\pm$ 5.3 nm and the selected area electron diffraction (SAED) pattern of $Cs_2AgBi_{(1-x)0.75}Sb_{X=0.4}Br_6$ shows the crystalline nature of the material, supporting the finding of XRD results. TEM images of $Cs_2AgBi_{(1-x)0.75}Sb_{X=0.4}(Br_{0.278}\ I_{0.722})_6$ NCs shows small particles having various sizes 20-70 nm. The SAED pattern of $Cs_2AgBi_{(1-x)0.75}Sb_{X=0.4}(Br_{0.278}\ I_{0.722})_6$ NCs shows the crystalline nature of the material and matched with the XRD results. The elemental analysis has been done by X-ray fluorescence (XRF). Optical and photophysical properties of these NCs have been carried out by Ultraviolet-Visible (UV–Vis) spectroscopy,

Photoluminescence (PL) spectroscopy, and Time-Resolved Photoluminescence (TRPL) spectroscopy. The perovskite NCs dispersed in various solvents (DCB and toluene) to investigate the effect of solvent on its optical properties. The shift in the PL spectrum has been observed in the various solvent which may be due to the difference in the strength of hydrogen bonding. Additionally, the effect of light on the current density-voltage characteristics of $Cs_2AgBi_{(1-x)0.75}Sb_{X=0.4}Br_6$ NCs device has been studied to ascertain its utility in solar cells. The device is fabricated using nickel oxide and PCBM as interface layers.



XRD pattern of $Cs_2AgBi_{0.75}Br_6$ NCs (host material) and $Cs_2AgBi_{(1-x)0.75}Sb_{X=0.4}Br_6$ (dispersed in various dispersing agent), (B) XRD pattern of $Cs_2AgBi_{(1-x)0.75}Sb_{x=0.4}(Br_{0.278}I_{0.722})_6$ NCs after anion exchange.(C&F) TEM images of cubic shaped $Cs_2AgBi_{(1-x)0.75}Sb_{x=0.4}Br_6$ and hexagonal-shaped $Cs_2AgBi_{(1-x)0.75}Sb_{X=0.4}(Br_{0.278}I_{0.722})_6$ NC at scales 20 nm (D&F) selected area electron diffraction (SAED) pattern of cubic shaped $Cs_2AgBi_{(1-x)0.75}Sb_{x=0.4}Br_6$ and $Cs_2AgBi_{(1-x)0.75}Sb_{X=0.4}(Br_{0.278}I_{0.722})_6$ NCs

- **Optimization of Nickel Phthalocyanine Thin Film and its Application in Organic Solar Cells**

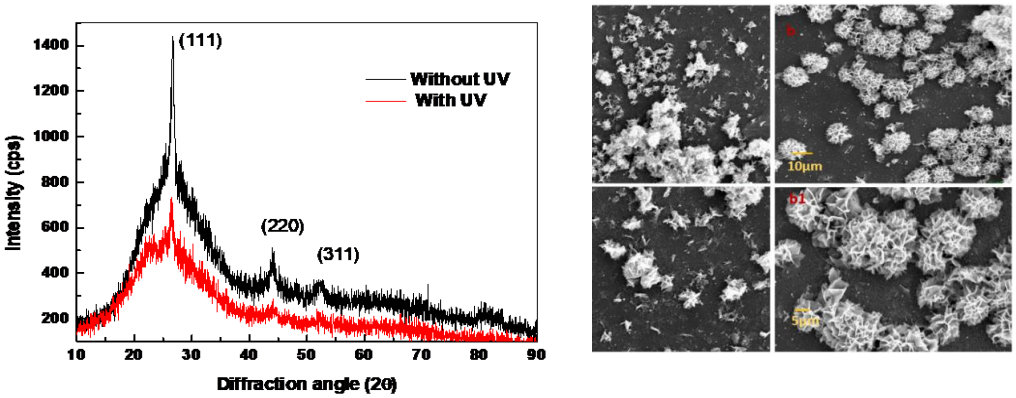


Schematic structure of organic solar cells (b) Energy level diagram of device B and (c) J-V characteristics of organic solar cells under illumination at different NiPc thicknesses

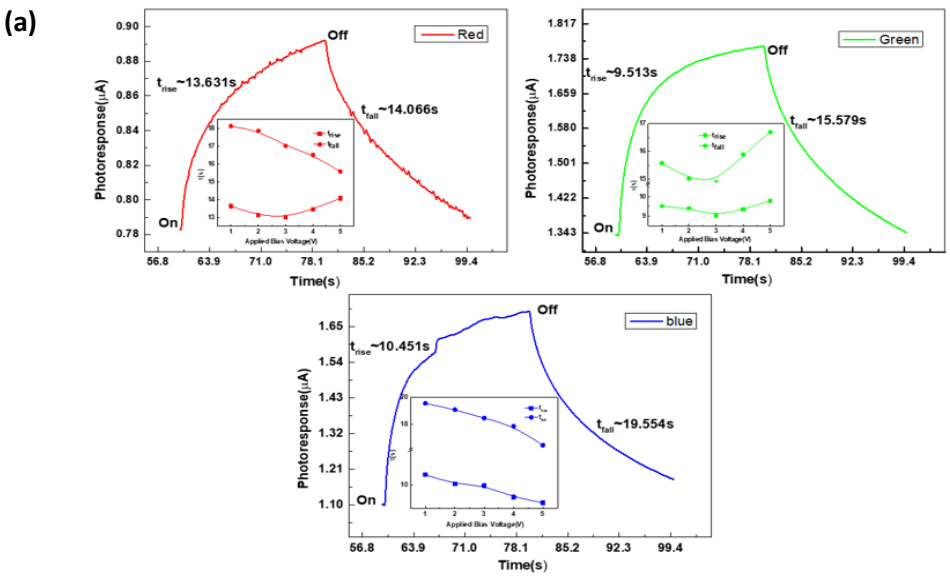
The Nickel phthalocyanine thin film was used as the hole transport layer in the organic solar cells. The highest efficiency and the life time of the solar cells increase by the use of hole transport layer. The power conversion efficiency (PCE) of the optimized solar cell with NiPc is ~3.17% and the fill factor (FF) is ~69%., these device parameters are higher (PCE increased by ~65% and FF by ~39%) as compared to the organic solar cells fabricated without NiPc thin films in the same batch. The improved performance of organic solar cells is attributed due to lowering the series and shunt resistance.

- **Photochemical UV Assisted CBD Grown CdS Thin Films Structural, Morphological, and Photo-response Properties**

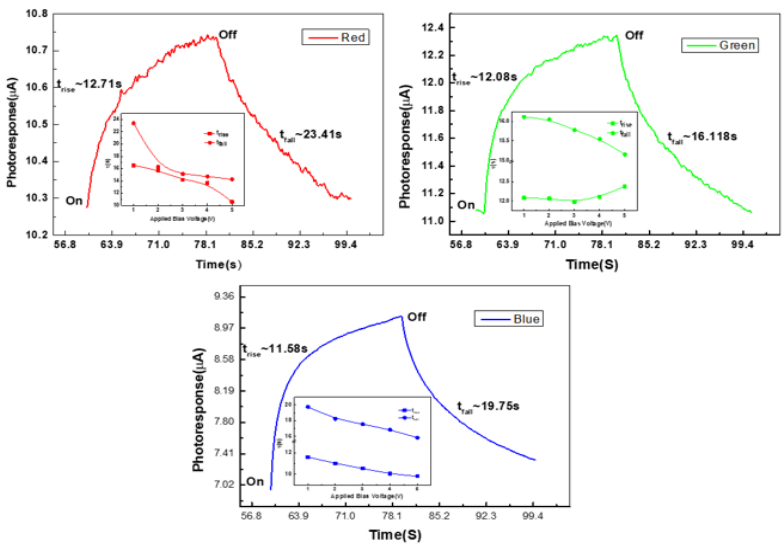
We report a comparative study of without and with UV exposed CdS thin films for photodetector applications. Both CdS thin films show face center cubic structure as per XRD analysis. The SEM analysis suggests that the average particle size for UV exposed CBD grown thin film is more prominent and acicular or flower-like structure. The optical band gap of CdS thin film is 1.9 and 2.1 eV for without and with UV exposure respectively. The ratio of light to dark current at an applied bias voltage of −1 V for both devices for red, green, and blue illuminations are 1.47, 1.55, 1.53 and 1.6, 2.08, 0.63 respectively. The highest sensitivity for without and with UV exposed CdS thin film devices are ~200 and 230 % respectively. The morphology of the CBD grown thin film can be tuned as per exposure of UV light and the photodiode sensor applications of the thin film may be optimized.



X-ray diffraction pattern of CBD grown thin film without and with UV exposure and SEM images of (a) without and (b) with UV exposure CBD grown CdS thin film on glass substrates

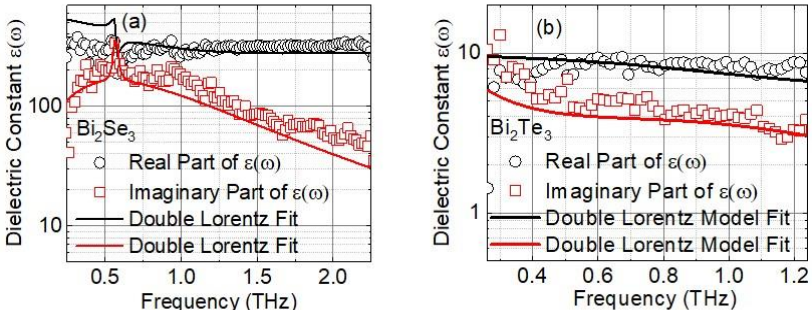


(b)



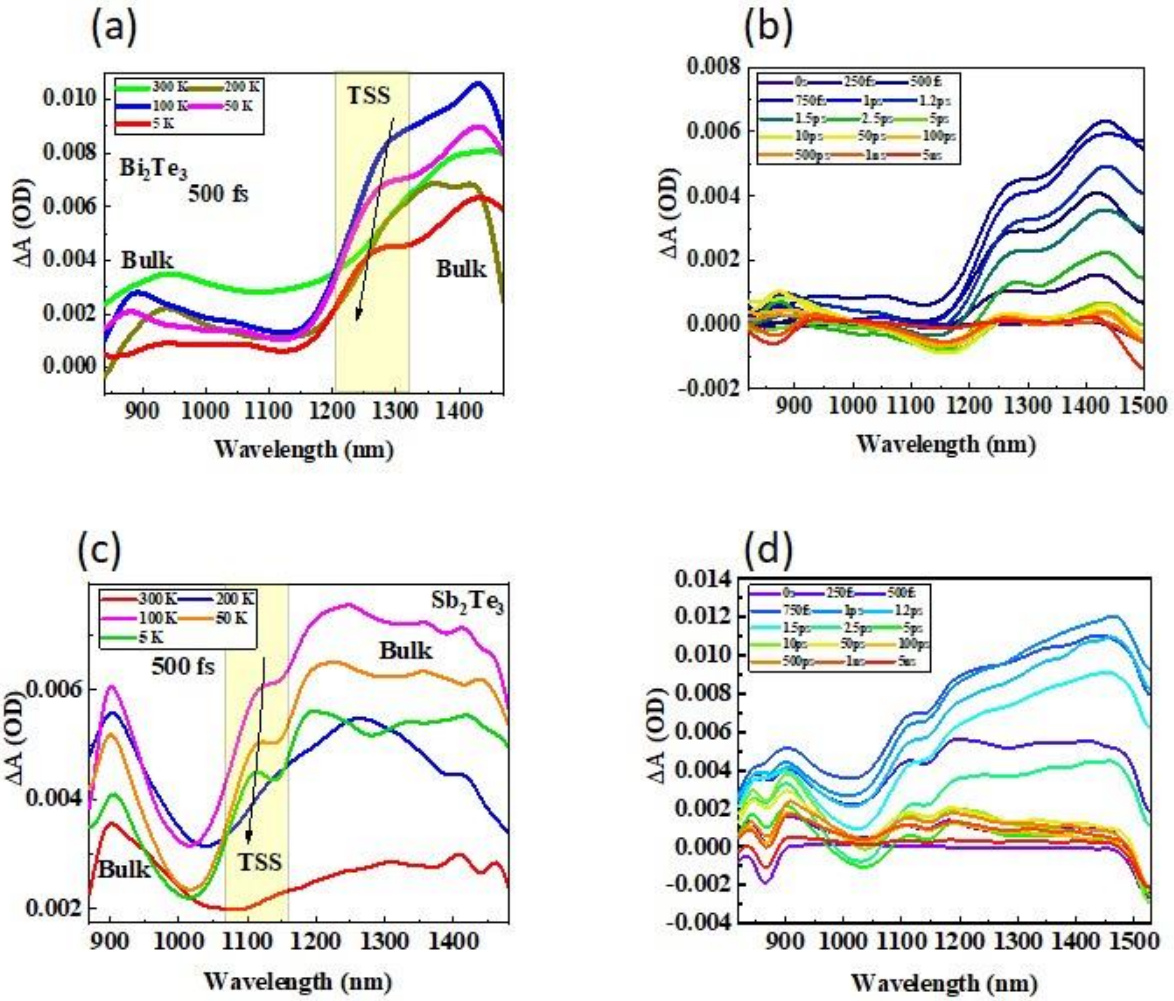
Optical switching behavior demonstrating a single ON/OFF cycle displaying t_r and t_f at an applied bias voltage of 1 V (a) without and (b) with UV exposed CdS thin film. Inset gives the variation of t_r and t_f as a function of applied bias

- **Charge Carrier Dynamics of Topological Insulators**



Frequency-dependent dielectric constant: real and imaginary part of the dielectric constant of (a)Bi_2Se_3 and (b)Bi_2Te_3 samples measured by THz time-domain spectroscopy and fitted with double Lorentz oscillator Debye model for Dielectric constant

Structural and optical analysis of the large area single crystalline topological Insulators of Bi_2Se_3 and Bi_2Te_3, has been performed comprehensively. The Terahertz time-domain spectroscopy is used to study the refractive index of these crystals at room temperature in a frequency range from 0.2 THz to 2.5 THz. Different resonant modes are observed in both the crystals samples due to the presence of residual carriers on the surface. The dielectric relaxation times are deducted from the theoretical fits to the experimental complex dielectric constant data for both the materials. In Bi_2Se_3, it is observed that one mode is quite a long-lived as compared to the modes present in Bi_2Te_3 crystal. The carrier's response of the materials are studied to distinguish the surface and bulk response using THz spectroscopy. The low-temperature TRUS is used to demonstrate the existence of dominant surface states. The temperature dependency of phonon modes in bismuth telluride and antimony telluride has also been established. Due to enhanced carriers in the surface conduction channel, the charge carrier dynamics indicates the transition from it. Studying TIs at low temperatures reveals the evolution of TSS-related transitions.

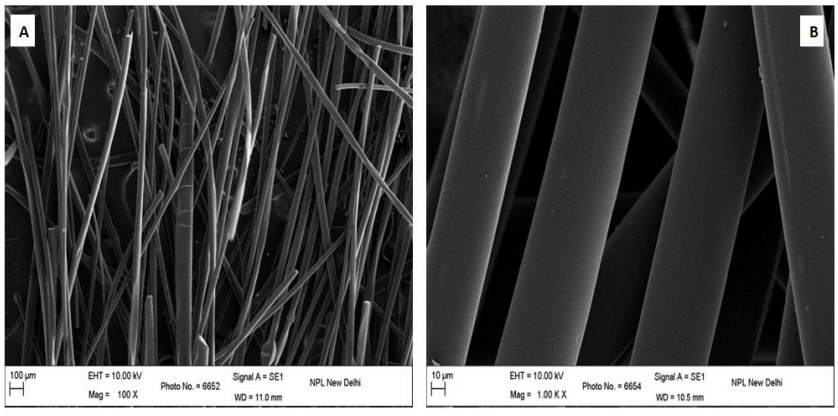


The variation of differential reflectance (DR) concerning temperature at 500 fs is analyzed in which the micro-flakes are excited at 3.02 eV and probed in the 1.55 eV-0.77 eV of different TIs (a) Bi_2Te_3 and (c) Sb_2Te_3, respectively. The peaks highlighted in the TSS region in both the TIs were found to have blue shift with lowering of temperature which is due to decrease in thermalisation process with the lowering the temperature. At the same time, the probe delay-dependent changes at the same pumped and probe regime but only at 5 K are shown for (b) Bi_2Te_3 and (d) Sb_2Te_3, respectively

Advanced Carbon Products and Metrology

- **Development of Pitch-based Carbon Fibers**

Coal tar pitch based carbon fibers can be divided into two categories, namely general purpose carbon fiber (GPCF) of inferior quality made from isotropic pitch and high performance carbon fiber (HPCF) of superior quality made from mesophase pitch. Thus,



SEM images of isotropic coal tar pitch based carbon fibers (1000°C)

research on development of indigenous carbon fibers using coal tar pitch as precursor is going on at CSIR-NPL. Two precursors, i.e. isotropic coal tar pitch and mesophase pitch have been prepared in the laboratory and utilized for making carbon fibers therefrom. Several strategies have been adopted to optimize the process parameters starting from precursor material synthesis to melt-spinning process to convert into pitch fibers followed by stabilization and carbonization.

- **Graphite Composite Bipolar Plate for Hydrogen PEM based Fuel Cell**

As the government of India announces the hydrogen mission it consists of three main verticals hydrogen generation, storage and utilization. The hydrogen can by utilized in different way for the production of clean energy. One of the ways is to utilize hydrogen as a fuel in polymer electrolyte membrane (PEM) fuel cell for the production of clean electricity. The PEM fuel cell consists of membrane electrode assembly, catalyst and bipolar plates. Bipolar plates which are made of graphite occupying maximum weight and volume in the fuel cell stack. To develop the indigenous graphite composite bipolar plate, CSIR-NPL is developing indigenous natural and synthetic graphite based composite bipolar plate from special high purity graphite developed by Indian industry for fuel cell applications. The mechanical and electrical properties are as per requirement for fuel cell applications.

- **Torrefaction of Biomass to Convert in to Biocoal for Generation of Electricity in Thermal Power Plants: Pilot Plant Facility**

India has large amount of agriculture, forestry and municipal solid waste, which consists lot of stored energy that can be utilized as source for generation of electricity in thermal power plant by partial replacement. But due inherent problems of biomass materials compared to fossil fuel resources (low bulk density, high moisture content, hydrophilic nature, and low calorific value) render it difficult to use on a large scale. These limitations greatly impact logistics and final energy efficiency. Due to its low energy density compared to fossil fuels, high volumes of biomass are needed, which multifaceted problems associated with storage, transportation, and feed handling at cogeneration, thermo-chemical, and biochemical conversion plants. To overcome these challenges and make biomass suitable for energy applications requires some form of pretreatment in order to meet the requirement for quality and homogeneity for the successful application. The raw biomass pre-treatment helps alter biomass physical properties and chemical composition and makes efficient conversion of biomass in to energy products. NPL is working on the torrefaction of biomass; it is a thermal pretreatment process that alters the physical and chemical

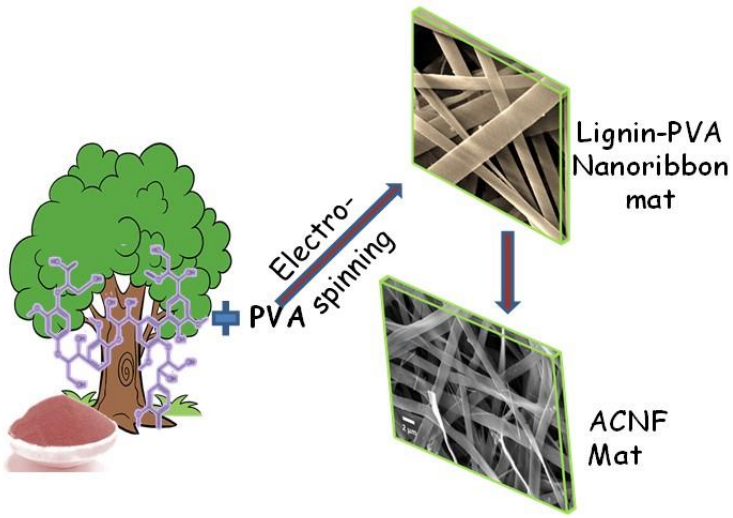
Indigenous torrefaction pilot for conversion of waste biomass in to biocoal

composition of biomass. Figure shows the indigenous torrefaction pilot plant for converting waste biomass in to biocoal which having properties that is particularly calorific value equivalent to that of sub bitimuous coal, low volatile and moisture content used in the thermal power plant.

- **Electrospun Nanofiber Mats for Advanced Energy Applications**

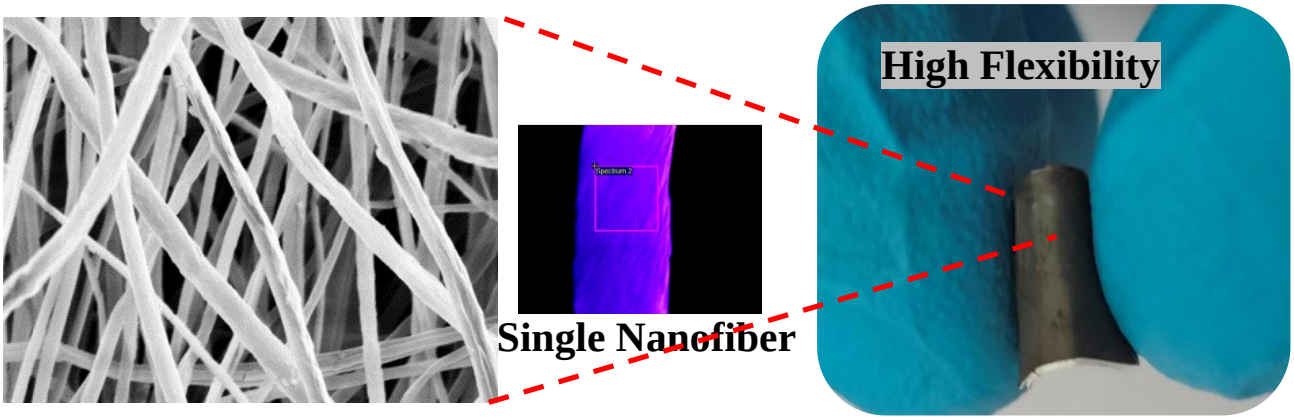
The ability to shape materials of different length scales including the nanoscale is important for many applications when high surface to volume ratio materials are required. Recently, polymeric materials have received high attention to achieve morphology and size from micron to nanoscale. There are number of synthesis and fabrication techniques demonstrated to generate polymer materials of different morphologies. Among these methods, electrospinning is a simple and versatile process to fabricate unidirectional (UD) nanoscale materials such as nanowires, nanofibers and nanotubes. In electrospinning process, high electric field is applied to viscous polymer solution held in syringe, inducing a charge density on the liquid surface. Mutual charge repulsion brings about a force which is directly opposite to the surface tension. When the electric field is sufficiently high, surface of the solution in the proximity of tip of the syringe is elongated and forms a cone named Taylor cone. A critical value of electric field exists for which the repulsive electrical force overcomes the surface tension. As the critical value is reached, charged jet of the solution is ejected from the tip of the Tailor cone. As the jet accelerates in presence of electric field, radial charge repulsion results in to the splitting of the primary jet into multiple filaments, is a process known as splaying. The final fiber size is primarily determined by number of subsidiary jets formed. NPL is working on the various electrospun nanofibers from different types of polymers which are solution in the particular type of solvent. Biopolymers are green source for synthesis of nanofibers.

Now, activated carbon nanofiber (ACNF) mats was developed from biopolymer-based polymers like cellulose and lignin for super capacitor applications. Main focus on lignin based nanofibers, which is more promising as a precursor and by-product of various paper industries and ethanol refineries. Bu utilizing the maximum content of lignin and at optimized processing parameters, ACNF was developed. The precursor we have chosen is green, and the process we have developed is green using green solvents (de-ionized water & acetic acid). Nanofiber morphology of the mats provides a high surface area and provides an interconnected network to the carbon for better charge transfer. Due to these excellent properties, these CNF mats as free-standing, binder-free, and highly flexible electrodes for energy storage devices explored. The prepared “Activated green carbon-based nano fabric mats are used as ultra-flexible all-solid-state supercapacitor”. The device exhibits



Schematic of the process of synthesizing electrospun ACNF mat

a high energy density of 65.52 Wh/kg and a power density of 1036.27 W/kg with high coulombic efficiency (99.6%) after 10,000 cycles.



Nanofiber based electrospun flexible thermoelectric materials

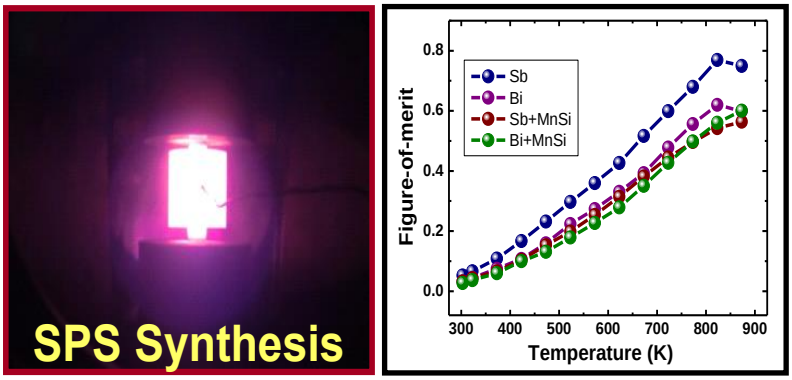
Furthermore, explored polymeric nano fabric mats as a substrate to develop flexible thermoelectric materials. In this, thermoelectric (TE) material is wrapped on the nanofiber morphology of the mats using DC magnetic sputtering. These TE material-wrapped nanofiber mats give high flexibility and higher connectivity to TE material guided by the morphology of the nanofiber mats. Also, the power factor attained by this flexible TE material is ~51.4 μW/m-K2 at 384K. Further, it is tested in an open atmosphere using a simple lab-made design. The maximum open-circuit voltage is observed ~ 3.6 mV.

- **Self-healing Polymer**

Self-healing is the ability of material to repair its damages over time and to regain its strength up to a certain level. The self-healing phenomena is inspired from nature where self-healing is a common Phenomenon. Human inventions like devices, buildings, materials fail over time due to thermal, mechanical, fatigue and harsh environmental conditions. With time micro cracks develops in materials and these cracks reduces their strength and slowdowns the working of the devices. These micro cracks are difficult to detect with naked eyes and leads to catastrophic failure of the device and thereby reduces the lifespan of the material. With time there is need for smart materials, which possess self-healing ability. Thus, inspired by nature, researchers have synthesized different self-healing materials by various methods. Lot of research have been carried out on self-healing materials in the last 20 years. Self-healing polymers are a new class of smart materials. They possess the capability to repair themselves when they are damaged, without the need of repair by manual intervention of any kind. Different self-healing polymeric materials have been synthesized over the past years. Traditionally, synthesized polymers were repaired through welding or patching. Through welding we can only repair those damages which are visible to us. Therefore, to remove all this validations, self-healing polymers have been introduced. Just like biological material, whenever damage occurs in self-healing smart materials, the first step of healing is triggering action caused due to damage. The second step is the transport of healing materials to the site of damage. The third step, is the chemical repair process, which is dependent on the type of healing mechanism involved (e.g., polymerization, entanglement, reversible or non-reversible cross-linking. These materials provide a

range of applications in sensing, composites, paints, e-skin, self-healing coatings, aerospace, robotics, energy storage applications. Our group is working on synthesis of polymer that exhibit both good elasticity and intrinsic based self-healing properties. Self-healing polymer is being synthesized through one-pot aldimine poly-condensation (Schiff base condensation reaction) between an aldehyde and imine terminated PDMS.

- **Synthesis of Cost-effective $Mg_2Si_{1-x}Sn_x$ with High Thermoelectric Properties using the SPS Process**



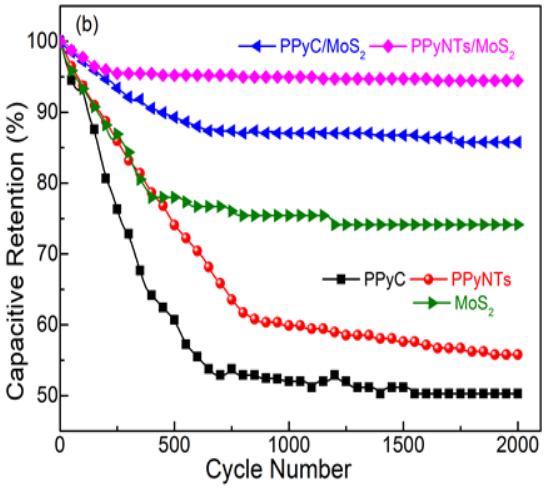
The synthesis process used to enhance the thermoelectric in n-type $Mg_2Si_{1-x}Sn_x$

Clean energy generation through thermoelectric devices currently emphasises the usage of eco-friendly thermoelectric constituent materials. We have developed a cost-effective n-type $Mg_2Si_{1-x}Snx$ material using a spark plasma sintering process. The maximum figure-of-merit value of $\simeq$ 0.77 at 873 K has been achieved in the n-type $Mg_2Si_{1-x}Sn_x$ material. Also, the characteristic nature of the $Mg_2Si_{1-x}Snx$ materials and their synthesis processes limit these elements for device fabrication. Hence, we have investigated a strategy to overcome these issues. We have achieved the enhanced power factor value of $\simeq 1.9 \times 10^{-3}$ W/mK^2 associated with a significant hardness value of $\simeq$ 5.2 GPa and fracture toughness value of $\simeq$ 2.18 MPa$\sqrt{m}$ in SPS processed $Mg_2Si_{1-x}Snx$ material, using Sb/Bi elemental doping and hard MnSi reinforcement additions. The concurrent increase in thermoelectric performance associated with mechanical properties employing the SPS process drive the route for achieving the commercial acceptability of $Mg_2Si_{1-x}Sn_x$ based thermoelectric material for real and practical device applications.

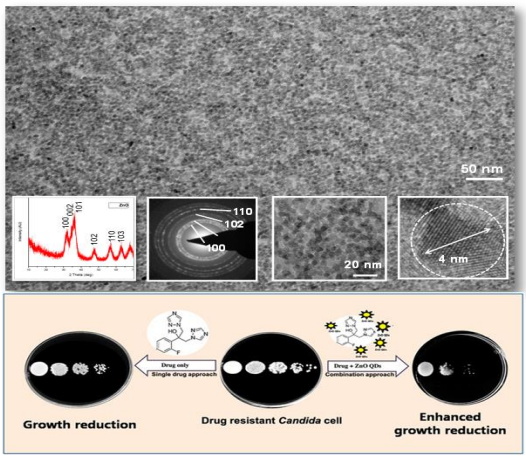
Bharatiya Nirdeshak Dravya (BND)

A brief detail of the activities performed is described below:

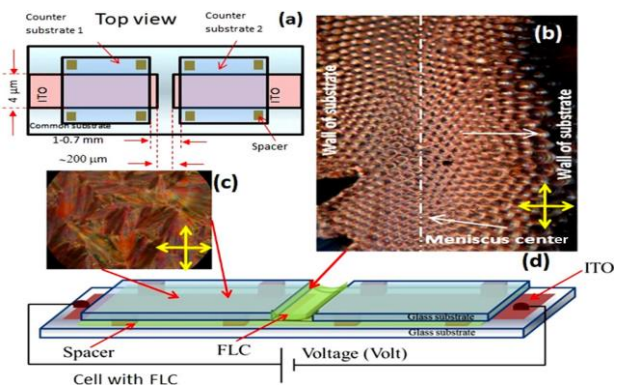
The PPy and MoS_2 nanosheets (MoS_2-NS) composites have been synthesized with specific morphologies and have exhibited excellent performance in super capacitor devices. The rational design of PPyNTs/MoS_2 NSs nanocomposite consisting of dense wrapping of PPyNTs on MoS_2 NSs greatly increases the specific capacitance up to 481 F/g at the current density of 0.5 A/g. After 2000 charge/discharge cycles, a decline of only 5.6 % in the specific capacitance of PPyNTs/MoS_2 NSs nanocomposite was observed as shown in the figure. The outstanding performance of PPyNTs/MoS_2 NSs nanocomposite holds great potential for next-generation flexible super capacitors.



A synergism between sub-inhibitory concentrations of both ZnO QDs (4-6nm) and individual antifungal drugs against all drug-susceptible and drug-resistant isolates of C. albicans has been studied. Results suggested that the combination of ZnO QDs with drugs potentiate antimicrobial activity through multi targeted action. The prepared ZnO QDs thus appear to be a potential adjuvant in combination antifungal therapy against MDR fungal pathogens (as shown in figure), wherein drug toxicity can be reduced and their simultaneous multi targeted synergistic action can limit development of fungal drug resistance.



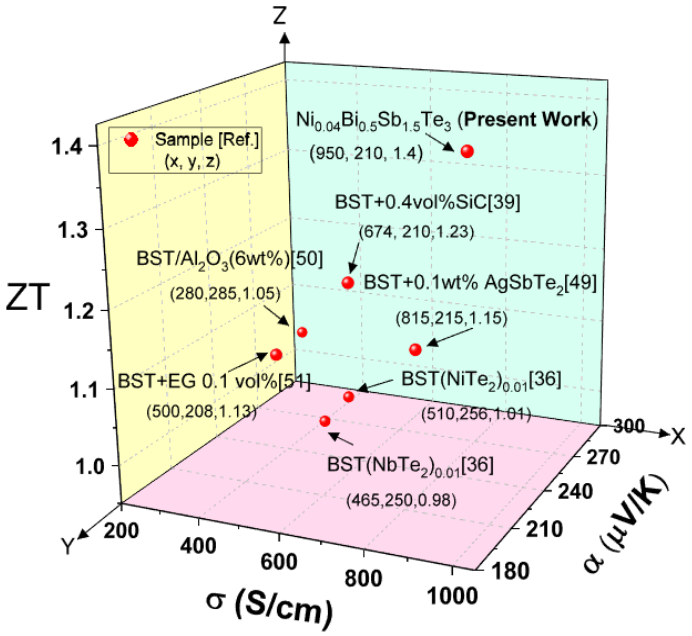
The formation of focal conic domains of the ferroelectric phase of a liquid crystal, chiral smectic C (SmC∗), in the meniscus geometry has been demonstrate. Focal conic domains (FCDs) in the physical cavity with dimensions of micrometer scale are investigated under an optical polarizing microscope which enables us to extract the information on the helical structure formation in the constraint and gradient topological meniscus interface.



The helical pitch in the FCD is observed to be shorter than in planar confined geometry. In-plane application of an electric field on a FCD revealed the asymmetric helical unwinding process whereas an increase in temperature has shown symmetrical unwinding. This helical structure-based observation is significant for understanding the ferroelectric phase in focal conic domains and their application in microlenses and optical components.

Five traditional ayurvedic herbs i.e. Gotucola, Brahmi, Curcumin, Tulsi and Rosemary have been evaluated for their neuroprotective activity to develop an effective natural drug for Alzheimer disease (AD). The in vitro studies have been carried out on SH-SY-5Y, neuroblastoma cell line. The results demonstrated that Gotucola (100µg/mL), Brahmi (100µg/mL), Curcumin (100µg/mL), Tulsi (100µg/mL) and Rosemary (10µg/mL) exhibited neuroprotective effects against AD, while the neuroprotective effect of Brahmi was most significant. The results strongly indicate that natural herbal extracts possess the potential for therapeutic management of Alzheimer's disease.

In an endeavour to develop high figure of merit (ZT) thermoelectric materials for power generation and cooling applications, the controlled Ni inclusion in $Bi_{0.5}Sb_{1.5}Te_3$ (BST) matrix with varying Ni concentration i.e. $NixBi_{0.5}Sb_{1.5}Te_3$ (x = 0, 0.01, 0.04 and 0.08) has been studied. The $NixBi_{0.5}Sb_{1.5}Te_3$ composition has exhibited higher electrical conductivity of 900 S/cm and Seebeck coefficient of 210 µV/K simultaneously as compared to pristine BST. Further, $Ni_{0.04}Bi_{0.5}Sb_{1.5}Te_3$ has exhibited ZT value of 1.4 at 373 K which is 12% higher than the ZT (~ 0.66 @ 373K) of pristine BST. The comparative graph of σ, α, ZT of reported BST based composite materials signifies the importance of present work.



Controlling spin wave excitations in magnetic materials underpins the burgeoning field of magnonics. Yet, little is known about how magnons interact with the conduction electrons of itinerant magnets, or how this interplay can be controlled. Via a surface-sensitive spectroscopic approach, we

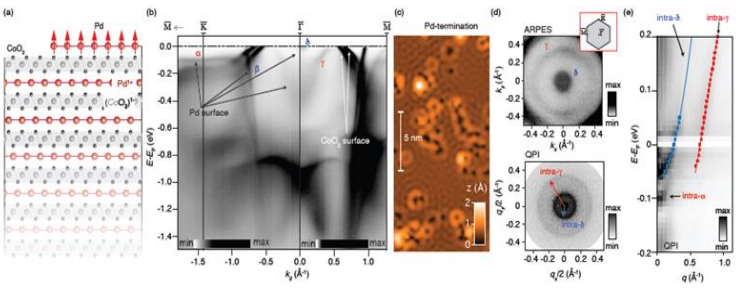


FIG. 1. **Electronic structure of the Pd-terminated ferromagnetic surface of $PdCoO_2$.** (a) Schematic of the crystal structure (side view) of $PdCoO_2$. After sample cleavage, a CoO_2 surface termination (left) and a Pd termination (right) are both present. (b) ARPES spectra ($h\nu$ = 80 eV along $\bar{\Gamma}$-$\bar{M}$ and $h\nu$ = 82 eV along $\bar{\Gamma}$-$\bar{K}$) show the superposition of spectral weight arising from both terminations. The labelled α-β and γ-δ bands derive from the Pd-terminated surface, and represent exchange-split pairs by a surface ferromagnetism. (c) STM topographic image of a Pd-terminated region. (d) The STM quasiparticle interference map (bottom) from a Pd-terminated region is in good agreement with the Fermi surface measured by ARPES (top), determined by the γ and δ bands. Signatures of such electron-like bands are also visible in energy-dependent QPI measurements (e) for intra-γ and intra-δ band scattering, reported together with the corresponding fits. Additional spectral weight at 0.1 eV binding energy can be attributed to intra-α band scattering, in good agreement with the flat top of the α band observed by ARPES.

demonstrate a strong and highly-tuneable electron-magnon coupling at the Pd-terminated surface of the delafossite oxide $PdCoO_2$, where a polar surface charge mediates a Stoner transition to itinerant surface ferromagnetism. We show how the coupling can be enhanced 7-fold with increasing surface disorder, and concomitant charge carrier doping, becoming sufficiently strong to drive the system into a polaronic regime, accompanied by a significant quasiparticle mass enhancement. Our study thus sheds new light on electron-magnon interactions in solid-state materials, and the ways in which these can be controlled.

Indian Standard Time Metrology

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. A glimpse of activities of each subdivision is described below:

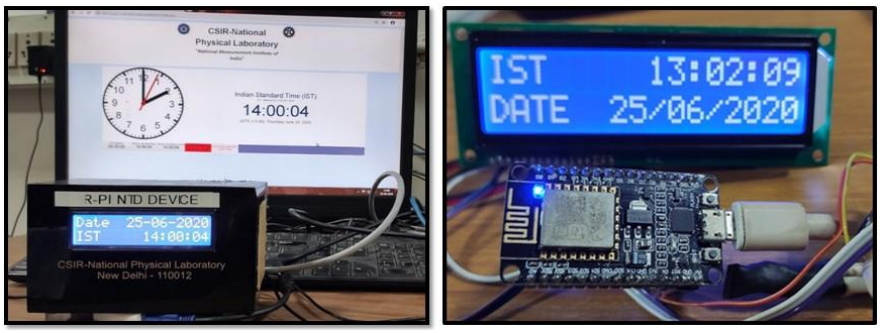
Time and Frequency Metrology

- **Cesium Fountain Primary Frequency Standards**

CSIR-NPL completed the development of its first Cesium fountain primary frequency standard known as NPLI-CsF1 a few years ago. This NPLI-CsF1 was approved as the 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 also being developed at CSIR-NPL. With the focus on Quantum Metrology, efforts are being facilitated to make the NPLI-CsF1 full-time operational. For this purpose, many sub-components, namely lasers, frequency stabilization, fountain sequence controller, shutters, etc., of the NPLI-CsF1 are checked and revived. An optical set-up for the NPLI-CsF2 is also under development. The lasers have been installed and characterized. The full-time operation of the NPLI-CsF21 will ensure the proper functioning and reinforce the efforts toward the quick assembly of the second fountain. In the long run, the entire activity aims to keep both fountains operational for redundant contribution to TAI and for steering the national timescale generating UTC (NPLI).

- **Compact and Affordable Time Dissemination Devices**

As CSIR-NPL is working toward the nationwide dissemination of IST, various time dissemination options, devices, and mobile applications need to be developed to achieve this task. Presently, a user can access the IST provided by the NTP server of CSIR-NPL via the network with the domain name "time.nplindia.in" which can be accessed using a computer only. To overcome this problem, the two network time display devices using Raspberry Pi and ESP8266 Wi-Fi modules, respectively, have been developed. These modules are programmed to obtain the proper time code from the CSIR-NPL's NTP service and display it. The realized compact and affordable IST display devices have been tested with available authenticated national time sources and offer ms-level accuracy of IST synchronization.



R-Pi based compact Network Time Display (left) and Wi-Fi module based NTD (right)

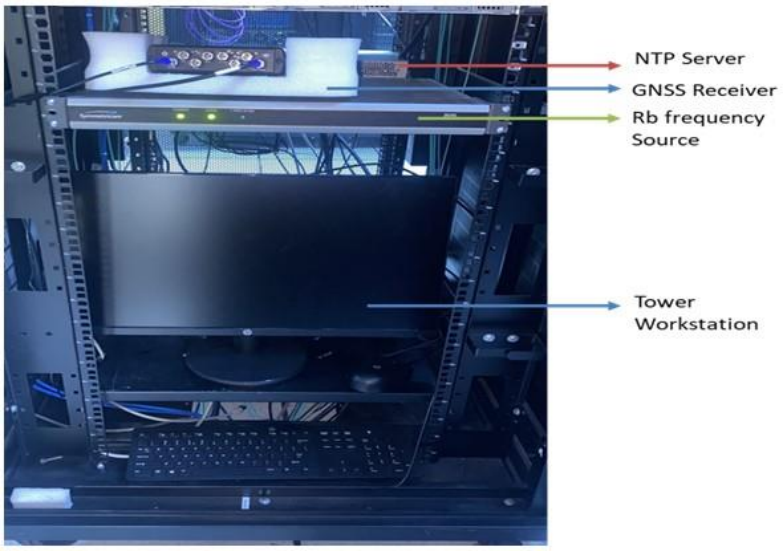
Once programmed for network configuration, these displays will work standalone, provided a stable internet connection is available.

- **Development of an Optical Frequency Standard**

In the near future, the primary standard of frequency and the SI definition of the time will be based on an atomic transition in the optical region and will be about 100 times more accurate than the current primary standard of time, which relies on the atomic transition of Cs atom in the microwave region. Being the NMI of the country, CSIR-NPL generates and disseminates the national time, i.e., Indian Standard Time (IST), by maintaining the National Time Scale. CSIR-NPL, by building the optical frequency standard, will defend the international standard and will be capable of supporting the primary standard in the field of Time & Frequency. Presently, CSIR-NPL is working 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 ($^{171}Yb^+$). This work involves several critical 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 producing ions in a separate vacuum chamber have been carried out and confirmed by spectroscopic techniques. Currently, work is in progress to realize the cooling lasers and their locking to pre-defined atomic cooling transitions and the development of associated electronics & instrumentation.

- **Use of Artificial Intelligence (AI) in NTP IST Dissemination Service**

All the NTP servers have been reconfigured and upgraded for the latest version of the software. The networking of these servers was also revisited and reconfigured. The performance of NTP services by various NMIS was studied and evaluated also. It has been successfully demonstrated that **CSIR-NPL's NTP services are providing IST dissemination with an offset below 5 ms.**



Installation @ Hyd site completed in September 2021

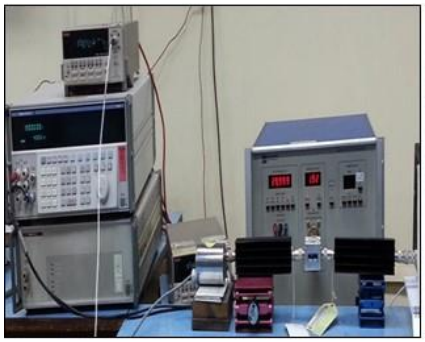
We have developed NTP Server Traffic Prediction Model using the new Artificial Neural Network, and this developed model showed an accuracy of 98.5%. We also analyzed the effects of cyber threats on the NTP IST dissemination service and measures for their effective Mitigation. Applied Genetic Algorithm (GA) technique was used to optimize the

performance of NTP servers. We successfully demonstrated **Novel Approach to synchronize National Knowledge Network with IST over the "Internet of Things (IoT)" Framework**.

LF & HF Voltage, Current and Microwave Metrology

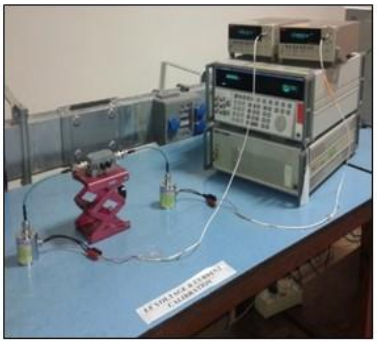
LF & HF Voltage, Current, and Microwave Metrology Section maintain the most comprehensive capabilities for measuring electrical parameters. It has well-established National Standards for Low-Frequency Voltage & Current up to 1000V & 20A, HF Voltage up to 50 V from 1 MHz to 1000 MHz, and Microwave Power which is upgraded up to 50 GHz. This activity defends 26 existing CMCs and has proposed 09 new CMCs to be validated and approved in the forthcoming Peer review. The section also has a well-established Phasor measurement unit calibration (PMU-CAL) facility to support the power industries. A traceable CSIR-NPL PMU-CAL system is fully operational. It has great potential in calibrating PMUs as per the IEEE synchrophasor standards and is used to monitor, control, and protect the power grid.

This activity provides Apex level calibration services to DRDO, ISRO, STQC Labs, CSIO, BEL, 13BRD Air force Palam, R&D, and industrial organizations to ensure traceable accurate, and precise measurements, which would support Indian industry and business to innovate. We regularly participate in BIPM and APMP key/Supplementary comparisons to establish the mutual degree of equivalence with other NMIs and ensure internationally recognized traceability of measurements.



AC/DC transfer difference

Coaxial micro calorimeter



AC/DC transfer difference

Programmable Josephson Volatge Standard

This section maintains important metrological activity "Programmable Josephson Voltage Standard," one of the Quantum standards established at CSIR-NPL. 'Programmable Josephson Voltage Standard' (PJVS) system serves as the primary voltage standard. This system also plays a vital role in electrical metrology as it is used to disseminate unit 'Volt' throughout the nation to maintain

Established PJVS system at CSIR-NPL India for quantum DC voltage metrology

traceability. The quantum accuracy of voltage levels in this system is derived from the 'Josephson Effect', due to which the superconducting junctions in the PJVS chip produce a voltage precisely proportional to the frequency of the applied microwave bias signal.

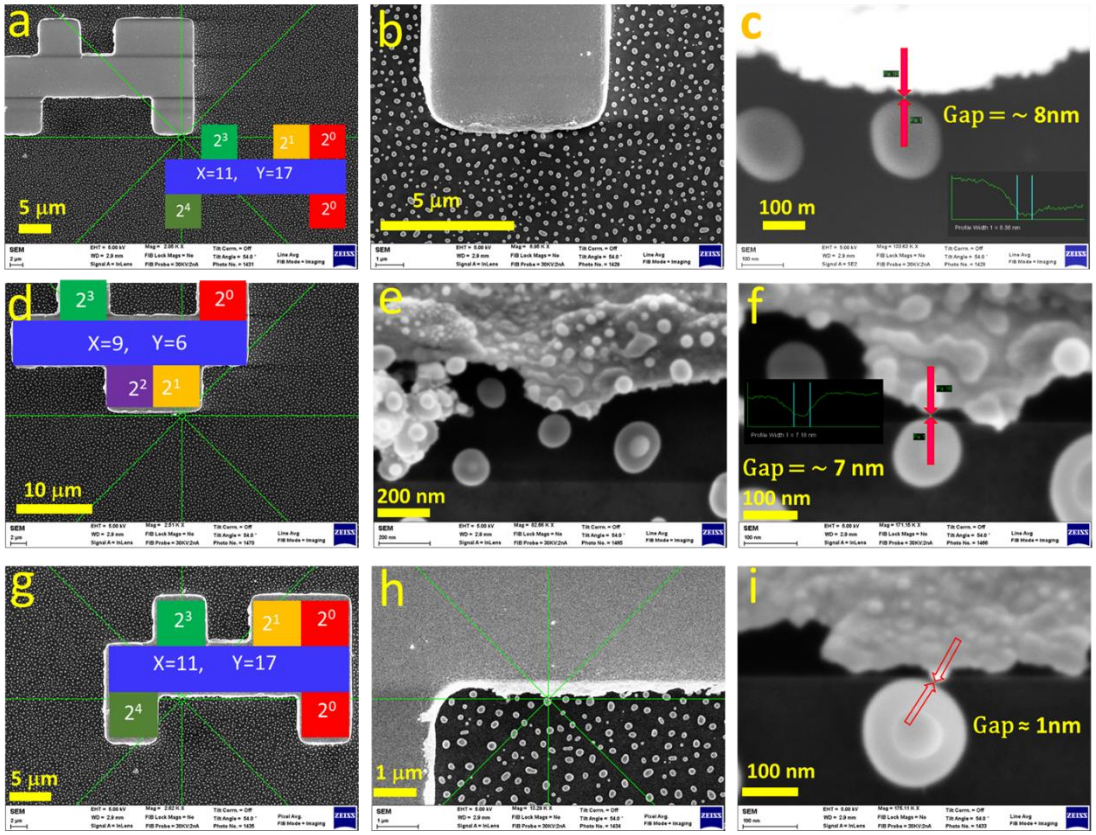
Presently this system is used to disseminate unit 'volt' in India through calibration of national standards (bank of Zener-diode based dc reference standard) at 1.018 V and 10 V as per the ISO/IEC standards. These Zener standards further provide traceability to all DC instruments to this primary standard. This PJVS system has been continuously optimized in the characterization of the system and has ensured the system's operation consistently and with better stability and reproducibility. This activity has participated in the BIPM bilateral Zener comparison program BIPM.EM-K11. This intercomparison program will enhance the image of CSIR-NPL as an NMI of the nation. An extensive study was made to perform this coveted program. These intercomparison measurements were conducted from October 2021 to January 2022 at CSIR-NPL India.

FIB Lab Nanofabrication

- **Estimation of SEM Resolution using a Marker Test Specimen Sample**

Gold nanoislands (GNPs) assembled on a substrate such as carbon or SiO2/Si are very useful for testing SEM instrument parameters, i.e., astigmatism correction, image quality, distortion, resolution, etc. These GNPs are of various sizes and shapes and separated by different distances. The GNPs are randomly separated on the substrate, and any two closest islands can be used for performing the resolution test. The low (gap more than 100 nm) and high resolution (gap less than 20nm) places are easy to find on the same chip. The high-end instruments can only resolve very fine gaps < 5 nm, whereas medium instruments have a slightly lower resolution.

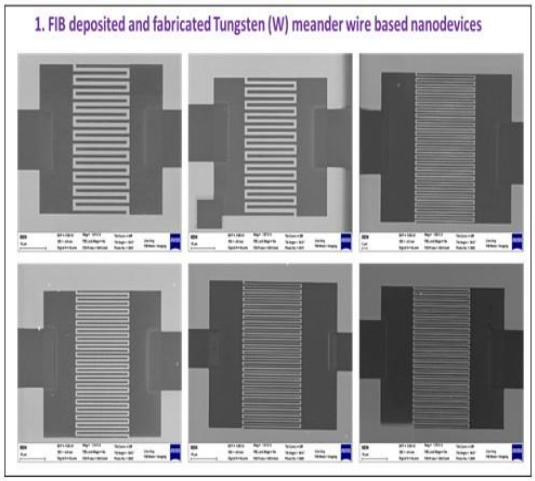
Since there are millions of nanogaps (distance between two nanoparticles), it is quite impossible to find a measured nanogap that can be used for traceability or intercomparison purposes. The commercially available resolution test specimens don't show any location maker to trace a particular nanogap. The following figure shows the resolution specimen chip with markers for the localization of the nanogap. The markers are arranged on a chip with vertical and horizontal bars possessing X and Y coordinates values. Due to the availability of GNPs on the marker chip, it is simple to locate a specific position and find the smallest distance measured between two particles. The location and measurement of high-resolution nanogaps of about less than 10 nm are shown in the following figure. The marker and its equivalent location coordinate (X=11, Y=17) are shown in the figure by the color schematics. The green lines indicate the tracking of the nanogap. In the figures d and g, the maker and their equivalent coordinates are superimposed on the SEM image. The figures (b, c & e, f and h, i) are zoom images of the figures (a & d and g), respectively. Thus, searching and tracking a nanogap is very easy in these samples. These marker chips are ultra-clean, vacuum compatible, non-magnetic, have no charging, and do not need additional metal coating. Chip size is more than 10 mm and easy to handle and mount on the SEM stub.



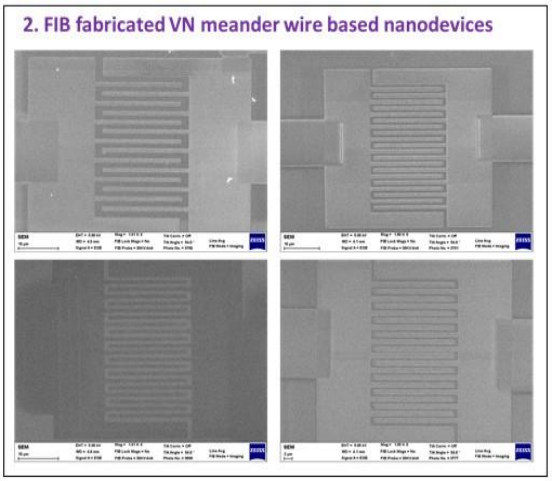
GNPs on a marker chip, nanogaps < 10nm. Fig a-c show location of nanogap ≈ 8 nm nearby marker (X=11,Y= 17). Fig d-f show location of nanogap ≈ 7 nm nearby marker (X=9,Y= 6). Fig g-i show location of nanogap down to 1 nm nearby marker (X=11,Y= 17)

- **FIB Nanofabrication of Superconducting Meander Lines**

FIB nanofabrication Lab has mastered the process of making meander patterns at the nanoscale level. These meander patterns made from a superconducting film can be used to study quantum phase slip mechanism and superconducting nanowire-based single-photon detection (SNSPD). The fabrication of the meander pattern needs at least 10 x 10 um^2 area. Here, we have optimized the fabrication recipe over 20x 30 um^2 for the superconducting Tungsten (W) and Vanadium nitrate (VN) films, as shown in the following figures.



FIB deposited and fabricated tungsten (W) meander wire based nanodevices



FIB fabricated VN meander wire based nanodevices

Electromagnetic Metrology

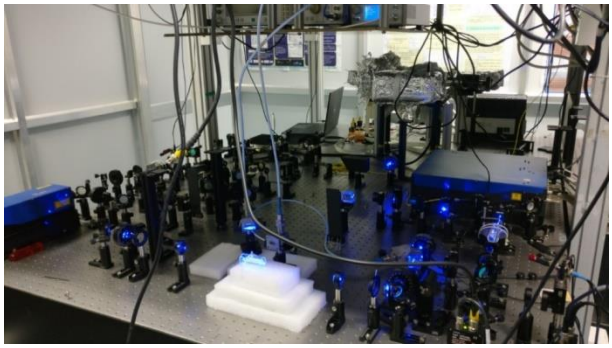
Electromagnetic metrology at CSIR-NPL has calibration and measurement capabilities for 1 Hz to 10^{11} Hz of the electromagnetic spectrum. These calibration and measurement capabilities cater to almost all sectors of electrical and electronics industries as well as other interdisciplinary areas and many more. Electromagnetic metrological services at the apex level in the country cover parts of the EM spectrum having day-to-day interaction in human life. The non-ionizing EM spectrum (1 Hz to 110 GHz) covers an area of services from household appliances to advance communication systems, defense to the strategic sector, electrical and electronics to the automobile industry, aviation to the naval dockyard, advanced material characterization to biological liquids and magnetic fields to electric field generation and measurement as per their broad applications. 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 the 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 the country's upcoming technological needs.

Microwave Metrology

Microwave Metrology at CSIR-NPL exhibits an international degree of equivalence for the various measurement parameters such as Microwave Power, Attenuation, Impedance, E-Field, Shielding Effectiveness, Radiated power density, and 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 a commercial open-ended Dielectric probe, along with VNA model ZNB 8. 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.

This section completed the technology transfer for "process-know how for Tissue Equivalent liquids as per IEEE-1528 standard" last year and now working to extend the scope of this by preparation or standard TELs for upcoming 5G frequencies. These TELs are being prepared as per the new IEEE/IEC-62209 1528: 2020 standard, which requires different chemicals from those used for previous studies. Also, for BND purposes, the properties of TELs are being measured and recorded at various temperatures from 10°C to 50°C, along with shelf-life study, stability, and temperature tolerance studies to be carried out.

This section has partnered with the EURAMET consortium to develop calibration methods for probe calibration of time-domain probes and arrays for vector SAR measurement systems. These probes measure simultaneous amplitude and phase much faster 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. This section has indigenously developed the SAR evaluation system, which has an E-Field Sensor, Tissue equivalent liquid, Robotic automation, and a controlled GUI. The system can evaluate SAR up to 3W/kg with an expanded uncertainty of ±0.15W/kg per 1.6W/kg.

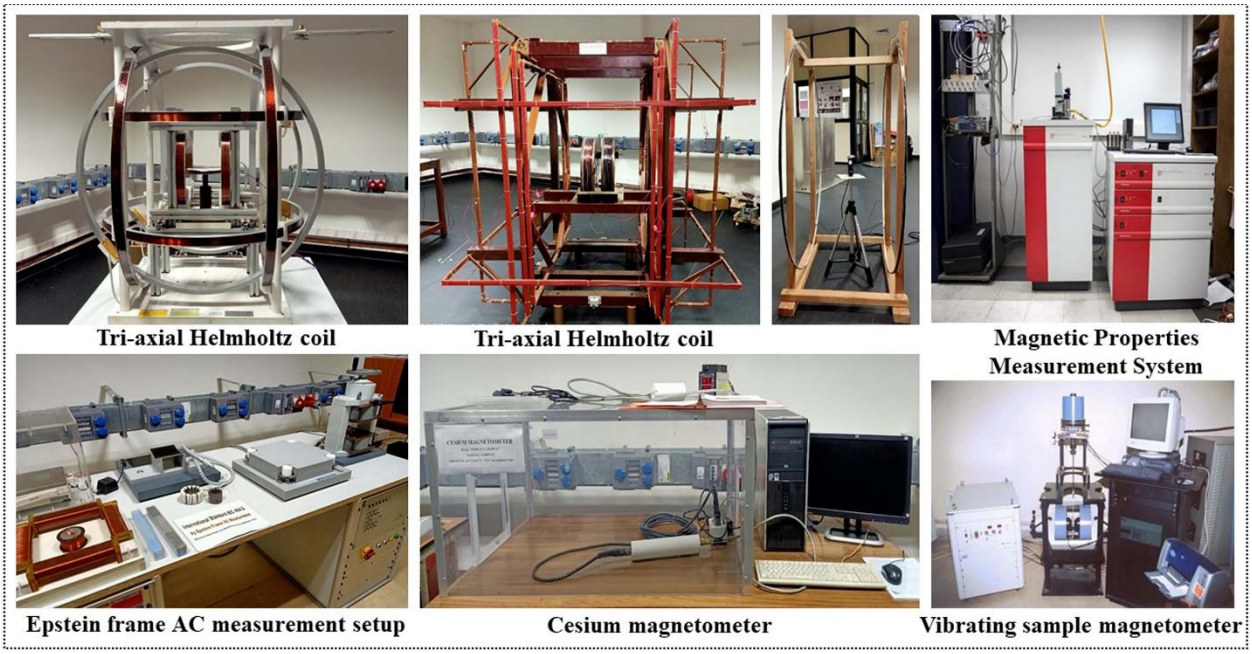


Experimental setup for RF E-field strength measurement using Rydberg atom-based quantum sensor (this setup is at NISER, Bhubaneswar; CSIR-NPL and NISER have worked in collaboration for initial set of experimental data)

Experimental setup for atom-based E-field sensing is shown in figure 1. The cylindrical cell placed at top of white platforms act as an antenna. At specific conditions mentioned in the absorption profile of probe beam splits in two peaks giving a transparent window at centre of absorption which is known as EIT. The Radio-frequency creates additional interferences resulting in increase in difference between the two split peaks, known as ATS in EIT regime. This behaviour of absorption profile is utilized in RF E-field strength measurement. As the power of incident microwave increases, the split between the two peaks.

Magnetic Metrology

This section has a significant role in maintaining and upgrading National Standard related to the magnetic parameters such as 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 including 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. The section is also responsible for R&D activities regarding magnetic device development and promoting metrological activities.



Available measurement facilities in the section are listed below:

- Low magnetic field measurement facility (DC): 1 to 2000 μT (expanded uncertainty 1.6-0.5 %).
- Low AC magnetic field measurement setup: range 10 mG to 20 G (50 Hz).
- DC magnetic field calibration facility: range 0.01 T to 1 T.
- AC magnetic field calibration facility: range 0.05 T to 0.2 T.
- Magnetic flux measurement of range 0.0001-10 weber with uncertainty of $\pm 0.005\ to\ 0.15$ %.
- Cesium magnetometer: measuring magnetic field of Nano tesla range i.e., 10000-1 nT.
- Epstein frame setup: measurement of parameters of electrical steel strips such as specific power loss, peak value of magnetic polarization, and peak value of magnetic field strength.
- VSM (Vibrating sample magnetometer): magnetic characterization of materials.

Directorate

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 2021-22 is 05. In the year 2021-22, three new GAP projects have started worth Rs. 2.71 Crores, while Two New MLP CSIR Funded projects have taken off, costing Rs. 13.50 Crores. A grant of Rs 13.90 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 liasioning with CSIR-HQ, Management Council (MC) and Research Council (RC) on project related matters. In 2021-22, PME has successfully conducted 01 Research Council and 13 Scientific/Project Review Meetings. PME has processed 761 indents worth Rs 28.68 Crores.

Business Development Group (BDG)

The Business Development Group (BDG) serves as an interface between CSIR-NPL and Government/Public/Private Organizations/Industries/Universities, etc. BDG facilitates the utilization of CSIR-NPL knowledgebase by licensing the technologies/knowhow to the Industries and other stakeholders. BDG plays an active role in show-casing technologies and know-how developed by CSIR-NPL to the stakeholders on various platforms including the CSIR-NPL website. BDG also facilitates consultancy and technical services to the clients in time-bound project mode for utilization of expertise available within CSIR-NPL regarding the development of new products/processes and for improvement of the Quality System in the country. Apart from this, BDG also processes the registration of the new Bharatiya Nirdeshak Dravya (BNDs) along with the handling of traceability and dissemination charges. One of the important roles of BDG includes the execution and signing of MoUs/Agreements/NDAs with the clients (Indian Industries, Institutes, Research Organizations, Reference Material Producers (RMPs), etc) for the purpose. In addition, BDG is highly involved in the management of S&T outputs including the

generation of various reports to be sent to various stakeholders including CSIR-Head Quarters.

The details of the technology/know-how licensed, MoUs/agreements signed, technical services projects (TSPs) undertaken, registration of new BNDs and traceability and dissemination charges received during this period are as follows:

- **Technical Services Projects (TSP)**

Sl No	Project Title	Client	Project cost (Rs) (including GST)
1	Performance Evaluation on PM and CO2 level control in a room by the ventilation device	Voltas Limited, Faridabad-121003	5,90,000
2	Inspection of Water Meter Test Benches of Municipal Corporation of Greater Mumbai	Nagman Flow-Level Systems and Solutions LLP, Chennai-600123	1,77,000
3	Evaluation of Meterological Characteristics of Digital Alcohol Meters supplied to U.P. Excise Department	M/s Global Systems & Technology, Kanpur-208005	10,00,000
4	Testing of electrical, magnetic and pollution related parameters of an air cleaning device	Freshcraft Technologies Private Limited, Ernakulam-682024	7,08,000

- **Registration Charges for Bharatiya Nirdeshak Dravya (BND) from Reference Material Producers (RMPs)**

Sl No.	Client	Project Title	Money received (Rs) (including GST)
1	M/s Jalan and Company, C-16, Lajpat Nagar-II, New Delhi, Delhi-110024	Registration charges for producing Bharatiya Nirdeshak Dravyas (BND) 4201A, 4101, 4202, 4102	47,200
2	Aashvi Technology LLP, Ahmedabad, Gujarat-380004	Registration charges for producing Bharatiya Nirdeshak Dravyas (BND) BND 1034, BND 1035, BND 1036, BND 1037, BND 1038)	59,000
3	Aashvi Technology LLP, Ahmedabad, Gujarat-380004	Registration charges for (i) BND 1004 (2nd Batch) and (ii) BND 1021 (4th Batch)	23,600
4	National Council for Cement and Building Materials (NCB), Ballabgarh, Faridabad, Haryana 121004	Registration charges for BND 5059	11,800
5	Aashvi Technology	Registration charges for BND	1,41,600

	LLP, Ahmedabad, Gujarat-380004	1029 (3rd & 4th batch), 1007 (5th & 6th batch), 1009 (3rd & 4th batch), 1033 (2nd & 3rd batch), 1008 (4th & 5th batch), 1028 (3rd & 4th batch)	
6	M/s Aashvi Technology LLP, Ahmedabad, Gujarat-380004	Registration charges for BND 1005 (8th & 9th Batch); BND 1006 (8th & 9th Batch), BND 1022 (3rd & 4th Batch), BND 1019 (3rd Batch)	82,600
7	National Council for Cement and Building Materials (NCB), Ballabgarh, Faridabad, Haryana 121004	Registration charges for BND 5002 (2nd Batch); BND 5003 (2nd Batch) & BND 5054 (2nd Batch)	35,400

- **Traceability and Dissemination Charges for Bharatiya Nirdeshak Dravya (BND) from Reference Material Producers (RMPs)**

Sl No.	Client	Project Title	Money received (Rs) (including GST)
1	Aashvi Technology LLP, Ahmedabad, Gujarat-380004	Traceability & Dissemination charges through the stock sale of Bharatiya Nirdeshak Dravyas (BND)	6,30,627
2	National Council for Cement and Building Materials (NCB), Ballabgarh, Faridabad, Haryana 121004	Traceability & Dissemination charges received from the sale of Bharatiya Nirdeshak Dravyas (BND) for the period of July 2019 to March 2021	9,59,098
3	Hindustan Petroleum Corporation Limited (HPCL), Visakhapatnam, Andhra Pradesh-530014	Traceability & Dissemination charges received from stock sale of 28 Bharatiya Nirdeshak Dravyas (BND) from 18-Jul-2018 to 31-Mar-2021	23,541
4	SUMS Techno Labs Private Ltd, Ballari (Bellary), Karnataka-583201	Traceability & Dissemination charges received from stock sale of 04 Bharatiya Nirdeshak Dravyas (BND) from 01-Apr-2021 to 30-Sep-2021	590

- **Licensing of Technology/Know-How**

Sl. No.	Name of the technology/Know-how	Name of the client	Date of licensing
1	Know-how for the development of "UVC based Air Microbial	M/s Life Force, Hasanpur, I.P. Extn,	28-Jun-2021

	Disinfection Unit", (joint development under project mode and further license); Project cost: Rs 2,36,000 including GST; Non-exclusive	New Delhi-110092	
2	Know-how for the development of "Process for Synthesis of Fullerene Acceptors for Organic Solar Cells" for [6,6]-phenyl-C61-butyric acid methyl ester (PC61BM)"; Lumpsum: Rs 3,36,000 including GST; Non-exclusive	Nmolab Equipments Pvt Ltd, Khera Garhi, Delhi-110082	31-Jan-2022

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

Sl. No.	Name of the company/Industry/Organization	Signing date
1	Agreement between CSIR-NPL & M/s Life Force, New Delhi for the licensing of know-how for the development of "**UVC based Air Microbial Disinfection Unit**" (joint development)	28-Jun-2021
2	Secrecy agreement between CSIR-NPL and Indian Oil Corporation Limited (IOCL), Mumbai, for evaluation of product pertaining to know-how for "**making graphite composites bipolar plates for PEM fuel cell applications"**	13-Jul-2021
3	Agreement with M/s Aashvi Technology LLP, Ahmedabad, Gujarat, for "**Production of Bharatiya Nirdeshak Dravyas** (BND™)"	29-Jul-2021
4	Agreement with National Council for Cement and Building Materials (NCB), Ballabgarh, Haryana for "**Development and/or Production of Bharatiya Nirdeshak Dravyas** (BND™)"	17-Dec-2021
5	Agreement with Nmolab Equipments Private Limited, Delhi for licensing of know-how **"Process for Synthesis of Fullerene Acceptor for Organic Solar Cells** [6,6]-phenyl-C61-butyric acid methyl ester (PC61BM)**"**	31-Jan-2022

Centre for Calibration and Testing Centre

CFCT acts as an interface for connecting metrological activities of NPLI to Industries & Govt. Agencies for National Growth, Quality Control & Trading. Currently, CFCT is supporting more than 4000 clients from industries, national laboratories, and government organizations from all over the country and abroad including SAARC nations. CFCT supports all the customer care related queries and deal the customers with outmost care to serve the Nation. CFCT plays an important role in creating awareness about the importance of metrology related activities. Also, at CFCT we have provided most of the information online so that our esteemed customers can freely

accessible to it. These services include CTBR Form, Calibration and Testing Charges, Specimen Copy of Calibration & Test Certificates and Payment Related Information with terms and conditions of instruments handling etc.

The following table shows some of the list of users availing the calibration and testing services from CSIR NPL through CFCT.

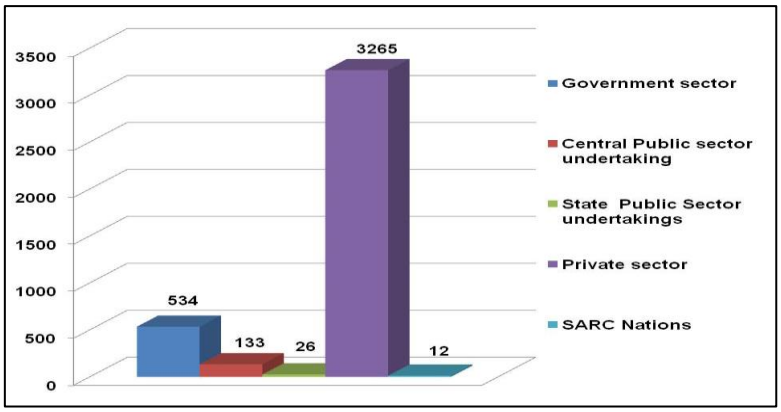
S.No	Organization	List of users/clients
1	Government/ PSU	DRDO, ISRO, Election Commission of India, CPCB, Indian Railways, Indian Airforce, Air India, BSF, BIS, Legal Metrology, DAE, CPRI, HAL, BHEL, BEL, GAIL, ONGC, IOCL, HPCL, Indian oil, State Electricity Boards, NTPC, Delhi Jal board, MSME Testing Centres, Ordinance Factory, Steel Authority of India and Scientific Institutes/Labs, Universities etc.
2	Private Sector/Industries	Tata Steel; Mysore Paints & Varnish; CK Birla Group; GE power systems; ABB India; ACC; AIMIL Ltd.; Alstom India; Ambuja Cement; Adani Electricity; Binani Cement; Blue Star; Bureau Veritas; Casio India; Crompton Greaves Limited; Diesel Locomotive Works; Essar Oil Ltd.; Godrej & Boyce Mfg. Co. Ltd; Havells India; Honda Cars; J.K. White Cement; JK Lakshmi Cement; Kirloskar Brothers; Larsen & Toubro; Maruti Suzuki; Philips India; Rapid Metro Rail Gurgaon; Samsung India; Honda Siel; Surya Roshni, Wipro consumer care & lighting; Orient Electric; ITC, Halonix Technologies, Astra lighting; Bharat Forge; Tektronix India; Fluke Technologies etc.
3	SAARC Nations	Nepal Bureau of Standards & Metrology (MBSM), Bangladesh Standards and Testing Institution (BSTI), Measurement Units, Standards and Services Department, Sri Lanka; National Physical and Standards Laboratory (NPSL), Pakistan; Bhutan Standards Bureau (BSB), Bhutan; Afghanistan National Standards Authority (ANSA), Maldives Standards and Metrology Unit

The following table shows the outcome of the calibration and testing services from CSIR-NPL through CFCT for the past 10 years.

S.No	Financial Year	Total Earnings in Rs. Crores	Certificates Issued	Cases Generated
1	2012-13	5.0	2436	1271
2	2013-14	6.5	2784	1396
3	2014-15	7.1	2760	1267
4	2015-16	7.2	2758	1284

5	2016-17	7.4	2539	1172
6	2017-18	7.6	2638	1098
7	2018-19	11.1	2601	1264
8	2019-20	11.4	2348	1145
9	2020-21	10.2	2014	1126
10	2021-22	11.3	2151	1241

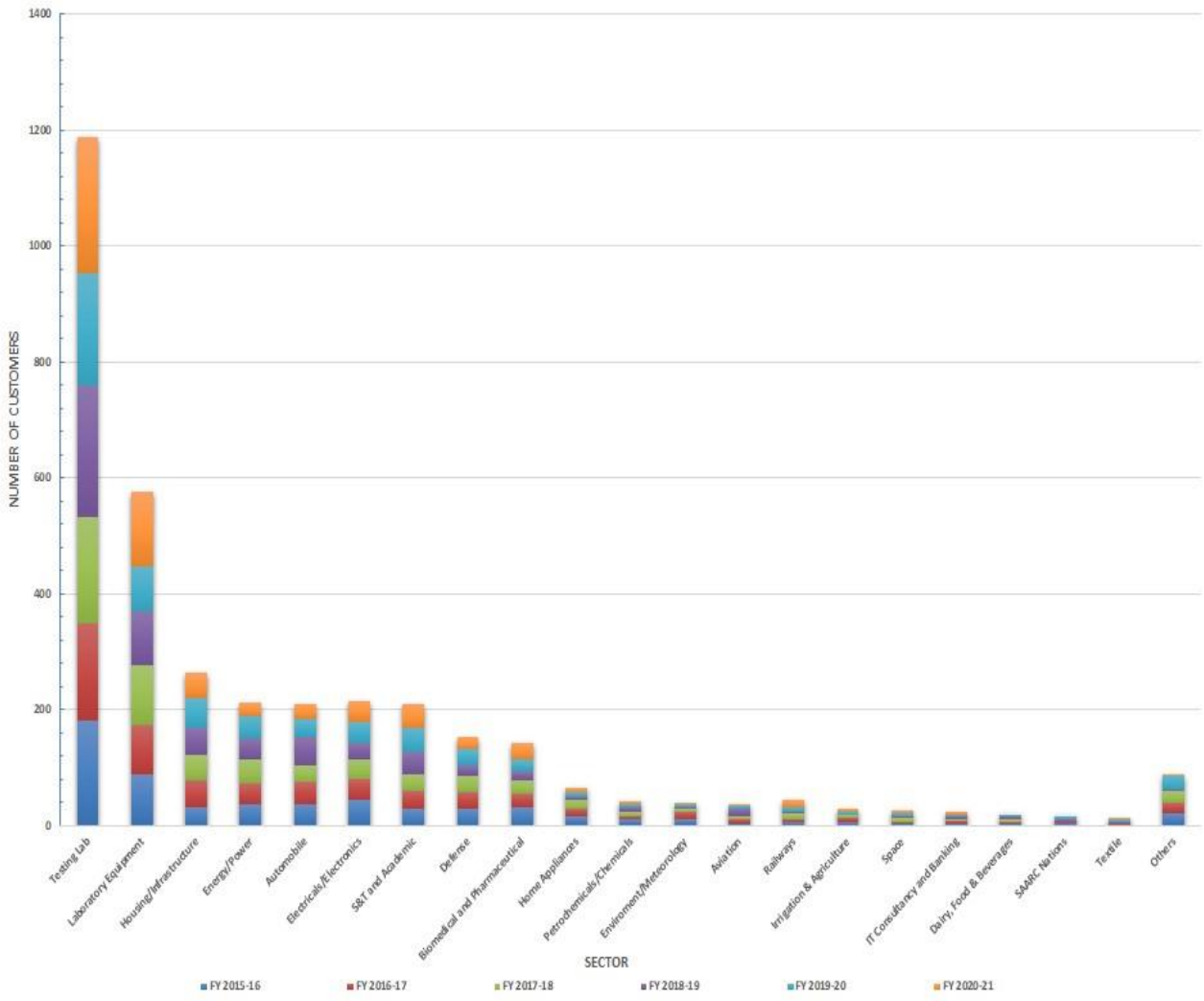
The following figure shows metrological services provided by CSIR-NPL through CFCT to various organizations and sectors. The beneficiaries of these metrological services include government ministries, regulatory bodies, public sector undertakings, private industries, MSMEs, strategic sectors, S&T organizations, etc. In addition, CSIR-NPL has been supporting the NMIs of neighbouring countries, especially those belong to South Asian Association for Regional Cooperation (SAARC) nations.



CSIR-NPL provides calibration and testing services through CFCT to several stake holders

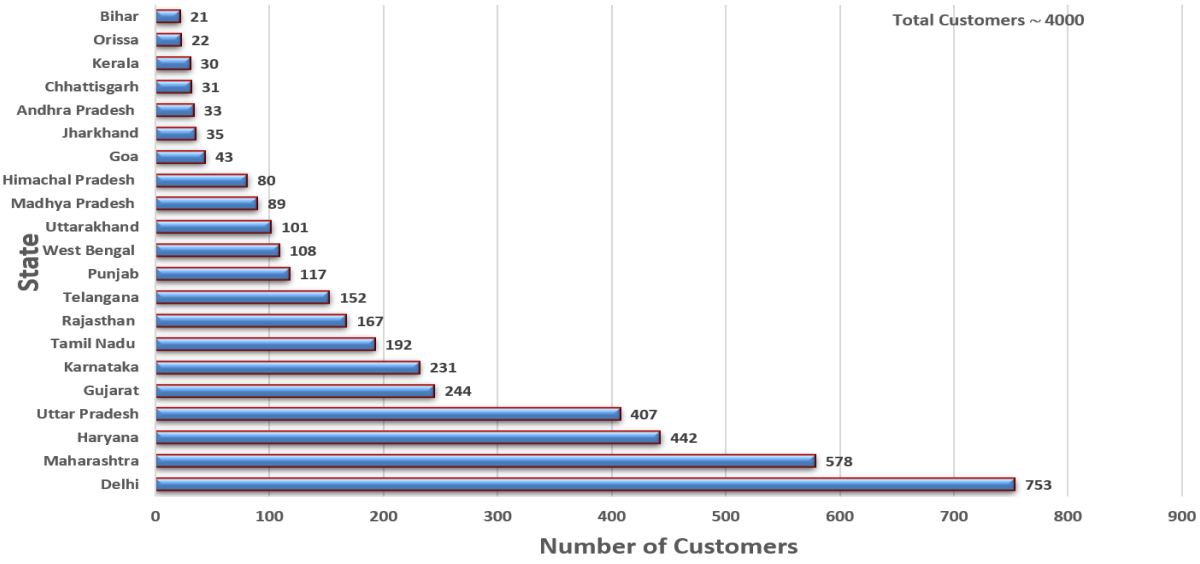
The fig. 2 shows the sector-wise distribution of metrological services of CSIR-NPL through CFCT for 2015-16 to 2020-21. CFCT data analysis in terms of metrological services provided to vital sectors, which contribute to the knowledge economy and knowledge society. These are categorized into following *twenty sectors*: automobile, aviation, biomedical and pharmaceutical, diary, food & beverages, defense, electrical/electronics, energy/power, environment metrology, home appliances, housing/infrastructure, irrigation & agriculture, IT consultancy & banking, laboratory equipment, petrochemicals & chemicals, railways, S&T and academic, space, testing laboratories, textile, SAARC nations and others. The "other" category includes data that could not fit into the above-mentioned specialized categories. The testing labs and laboratory equipment are the top sectors. This is quite expected because the NABL accredited laboratories across the country, need to obtain the mandatory metrological traceability to SI units through CSIR-NPL. It is understood that, most of the government ministries have their own secondary testing and calibration laboratories to ensure the conformity assessments for their regulations as well as for products manufactured in India or imported. Since these secondary laboratories are spread across the country, the state regulators approach these local laboratories for calibration and testing. This also explains why the number of state PSUs that approach CSIR-NPL is relatively lower in

number, as observed in Fig.1. These secondary laboratories have their traceability to the SI units through CSIR-NPL.



Sector-wise distribution of metrological services of CSIR-NPL for 2015-16 to 2020-21

The other major sectors which obtain measurement traceability to SI units from CSIR-NPL through CFCT are automobiles, biomedical and pharmaceutical, defense, home appliances, housing/infrastructure electrical and electronics, energy/power, S&T and academic, aviation, railways and space. The measurement traceability to sectors like diary, food & beverages, environment/ metrology, IT consultancy & banking, textile etc. though not significant at present in availing the facilities of CSIR-NPL, but possibilities exists that they may be using secondary calibration and testing laboratories. However, it must be ensured that all sectors utilize measurement *values traceable to SI units* for quality assurance.



Sector-wise distribution of metrological services of CSIR-NPL

As measurement traceability is linked to economic growth, organizations in the various states of India, availing the CSIR-NPL facilities are plotted. A total of 21 states data was analysed. New Delhi is frontrunner, which is expected as most of the government bodies and industries approach CSIR-NPL due to its proximity. The case with Haryana also, being an adjoining state. Otherwise, the ranking in measurement traceability to SI units through CSIR-NPL and the industrial growth appears to be correlated well. According to RBI's recent report, states like Maharashtra, Tamil Nadu, Gujarat, Utter Pradesh and Karnataka have high rate of industrial growth while north-eastern states have lowest industrial growth. Therefore, to improve the economy of the country, among many other parameters, the respective state governments should be encouraging industries and MSMEs to ensure the measurement traceability for industrial growth through manufacturing of products of international quality.

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.

During period under report, 440 jobs in workshop and 82 jobs in GTU were done. These jobs include fabrication of the accessories and components, vacuum sealing of quartz ampoules, cutting of quartz tubes & glass beakers, fitting of ring tubes. These are used for calibration, testing and other R&D and non-R&D activities. The photos of some of the jobs fabricated in the Central Workshop are

Fabrication of Hole Plates (Mild Steel)

Fabrication of SS Sample Holder

Fabrication of LED Holder

Fabrication of Aluminum Metal Mask

Vacuum sealing in quartz tube

Vacuum sealing in quartz tube

Fabrication of Stand for Holding Samples

Contribution of Central Workshop to support different R&D Activities

International Science and Technology Affairs Group (ISTAG)

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 2021-22. ISTAG also conduct PRC meetings for foreign deputations of Regular Staff. This year 02 PRC Meetings were organized. The group also encourages and facilitates the visits of young students to abroad. This year 02 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 2021-22 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:

- **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, 2021 to 31st March, 2022, 30 research fellows (JRFs/SRFs) joined CSIR-NPL and AcSIR Ph.D. Programme, resulting in a total strength of Research Fellows (JRFs+SRFs) in NPL is 319 as on 31.03.2022.

- **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, 2021 to 31st March, 2022 total 69 students were provided training oriented towards the fulfilment of their academic degree requirements in different areas of research under the guidance of senior scientists.
ECF Generated : 5,20,380/-

- **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, 2021 to 31st March, 2022 , total 101 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.

- **Skill Development Programme in CSIR-NPL**

Under Skill Development Programme, total training programme 9; total participant 1319.

- **Jigyasha Programme with Kendriya Vidhyalaya Sangathan**

We are planning to establish virtual labs under Jigyasha Programme.

Quality Management System

Quality Management System (QMS) of the CSIR-NPL (NPLI) is responsible for implementing and fulfilling the requirements of ISO/IEC 17025: 2017 and ISO 17034: 2016 at CSIR-NPL. At present, there are 28 sub-divisions covered under QMS. QMS coordinated the annual internal audits of the various sub-divisions, follow-up of corrective actions taken for closure of Non-conformances (NCs). QMS also organized Steering Committee (Management Review) meeting chaired by the Director, for ensuring the continuing suitability, adequacy and effectiveness of policies and objectives of quality system.

QMS provided the necessary inputs and information as required by Asia Pacific Metrology Programme (APMP) Technical Committee for Quality System (TCQS) from time to time. QMS also prepared the Annual report (November 2020 - October 2021) of QMS of NPLI, by taking the necessary inputs from the respective sub-divisions and submitted it to APMP TCQS for APMP General Assembly (GA) 2021. Mr. M. A. Ansari, Quality Manager and Mr. Goutam Mandal, Deputy Quality Manager attended and presented QMS Annual Report of NPLI in the APMP TCQS meeting held during 11th & 12th November, 2021 on the activities related to QMS, including participation in international inter-comparisons.

Under the MoU signed between CSIR-NPL (NMI of India) and Bhabha Atomic Research Centre (BARC, Designated Institute of India for Ionizing Radiation) in October 2020 for providing guidance and training to Radiation Standard Section (RSS), BARC on quality system based on ISO/IEC 17025 : 2017 and also for conducting peer review so that BARC can register Calibration and Measurement Capabilities (CMCs) on Ionizing Radiation in the International Bureau of Weights and Measures (BIPM) Key Comparison Database (KCDB), Scientists of QMS of CSIR-NPL conducted about 40 online meetings, during the period, with Scientists of RSS, BARC for the preparation of Quality Manual and Quality Procedures of BARC through detailed discussions. Team of Scientists from RSS, BARC visited CSIR-NPL for a week in February, 2022 to learn the implementation of Quality System at CSIR-NPL. QMS also arranged visit of this team to various metrological activities of CSIR-NPL and provided guidance on implementation and maintenance of Quality System based on ISO/IEC 17025: 2017.

The Ministry of Environment, Forest and Climate Change (MoEF&CC), Govt. of India has designated CSIR-NPL as national verification and certification agency for emissions and ambient air pollution monitoring equipment. QMS of CSIR-NPL is contributing for the preparation of Quality Manual based on ISO/IEC 17065: 2012 standard.

QMS of CSIR-NPL is also teaching a subject titled as “Quality Control and Management” for one-year course “Post Graduate Diploma in Precision Measurement and Quality Control (PGD-PMQC)” under AcSIR to engineering/science graduate students.

Quality Manager and Deputy Quality Manager delivered invited talks on "ISO/IEC 17025: 2017 (General Requirements for the Competence of Testing and Calibration Laboratories)" to scientific and technical personnel of CSIR (~ 80 Nos.) in an "Online Training Programme on ISO/IEC 17025 : 2017" organized by CSIR-HRDC, Ghaziabad held during 17th to 21st January 2022.

Knowledge Resource Centre

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

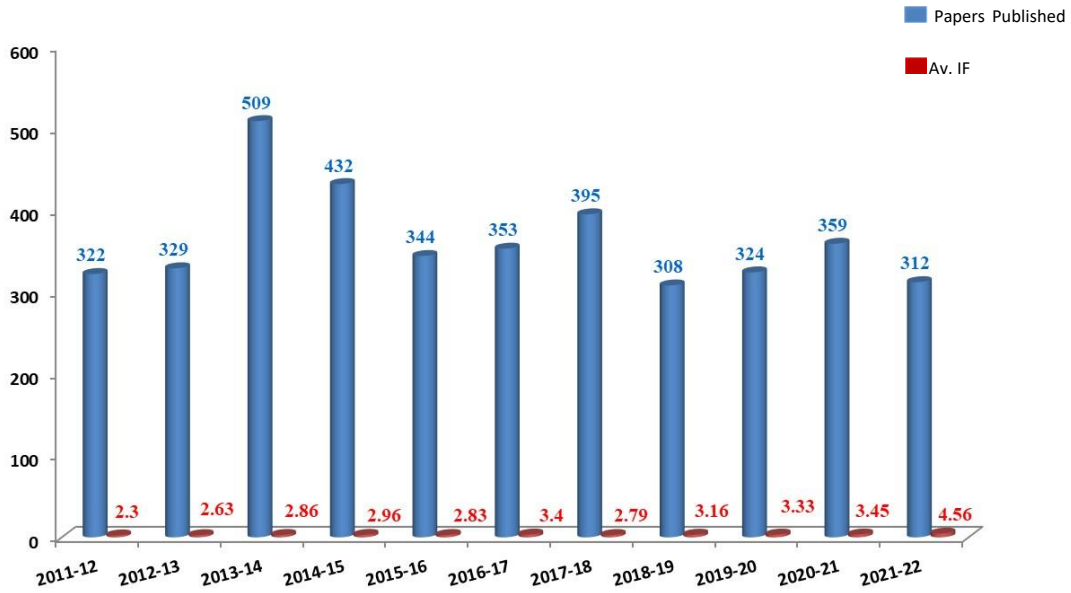
As far as library and information support is concerned, KRC over the years has developed a rich collection of scholarly books and journals, especially in the field of physics and related sciences. During the current year, KRC subscribed to numerous scholarly journals and added a variety of books both 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 108 | P a g e 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 3800 records have been added. Further, to provide the visitors a more intuitive and user-friendly experience that clearly states who we are, what we stand for, and what we can achieve for our clients, NPL-KRC has in-house created the website of CSIR-NPL, which was inaugurated by Hon'ble Minister Dr. Jitendra Singh Ji on 04th January 2022 i.e. on the 75th Year celebration of CSIR-NPL.

Apart from the library related activities, NPL-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 ।

<u>राजभाषा यूनिट के उत्तरदायित्व</u> :

1. कार्यान्वयन:

- संघ सरकार की राजभाषा नीति, राजभाषा अधिनियम के उपबन्धों तथा आदेशों से प्रयोगशाला के वैज्ञानिकों/ अधिकारियों/कर्मचारियों को अवगत कराना, अनुपालन कराना एवं अनुपालन हेतु सहायता प्रदान करना ।
- प्रत्येक तिमाही में निदेशक, एन पी एल की अध्यक्षता में राजभाषा कार्यान्वयन समिति की बैठक का आयोजन, कार्य सूची एवं कार्यवृत्त तैयार करना। बैठक में लिए गए निर्णयों पर अनुवर्ती कार्रवाई करना ।
- हिन्दी दिवस/ हिन्दी मास तथा प्रत्येक तिमाही में हिन्दी कार्यशालाओं/व्याख्यानों का आयोजन करना ।
- राजभाषा विभाग, गृह मंत्रालय, भारत सरकार से प्राप्त वार्षिक कार्यक्रम में निर्धारित लक्ष्यों को प्राप्त करने हेतु निरंतर प्रयास व 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 :

- जय नारायण उपाध्याय हिन्दी अधिकारी
- विजय सिंह निजी सचिव

<u>प्रयोगशाला द्वारा राजभाषा की प्रगति के लिए उठाए गए कदम एवं प्रयास</u>

- 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 पखवाड़ा/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 एक/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।

<u>'विज्ञान संचार और जनभाषा हिन्दी की भूमिका' विषय पर ऑनलाइन कार्यशाला</u>

यह सर्वविदित तथ्य है कि हम अपनी भाषा में अपनी संवेदनाओं, भावनाओं और ज्ञान को जितनी कुशलता से व्यक्त कर सकते हैं, उतनी किसी अन्य भाषा में नहीं कर सकते। जन-जन की भाषा हिन्दी सहित भारतीय भाषाओं में सर्वसुलभ वैज्ञानिक उपलब्धियों तथा विज्ञान से जुड़ी मूलभूत बातों को आम जन तक पहुंचाने के लिए सार्थक प्रयासों की आवश्यकता है। इसी को ध्यान में रखकर राष्ट्रीय भौतिक प्रयोगशाला में आज 'विज्ञान संचार और जनभाषा हिन्दी की भूमिका' विषय पर ऑनलाइन कार्यशाला का आयोजन किया गया।

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

कार्यशाला के बारे में बताते हुए श्री सुरेन्द्र कुमार, प्रशासन नियंत्रक, एनपीएल ने इस बात पर बल दिया कि प्रयोगशालाओं में नित नए अनुसन्धानों से प्राप्त ज्ञान- विज्ञान को आम जन तक उनकी ही भाषा में पहुंचाना आवश्यक है।

कार्यशाला की महत्ता पर प्रकाश डालते हुए डॉ. क्षेमेन्द्र शर्मा,प्रभागाध्यक्ष,पर्यावरण मापिकी व जैवचिकित्सा ने कहा कि वर्तमान वैज्ञानिक परिदृश्य में भारतीय भाषाओं को उच्चतर प्रौद्योगिकी तथा वाणिज्य-व्यापार आदि सहित विज्ञान के सृजन व प्रसार हेतु भाषायी माध्यम बनाया जाना आवश्यक है। जन-जन की भाषा हिन्दी सहित भारतीय भाषाओं में सर्वसुलभ वैज्ञानिक उपलब्धियों तथा विज्ञान से जुड़ी मूलभूत बातों को आम जन तक पहुंचाने के लिए सार्थक प्रयासों की आवश्यकता है ।

मुख्य अतिथि वक्ता प्रसिद्ध विज्ञान साहित्य सर्जक,लेखक व संचारक श्री देवेन्द्र मेवाड़ी जी ने अपने विस्तृत ज्ञानकोश से अनेक जनोपयोगी वस्तुओं के उदाहरण द्वारा विज्ञान की सरसता और जीवंतता को सिद्ध किया। साहित्य,इतिहास,भूगोल,चिकित्साशास्त्र आदि अनेक क्षेत्रों से उदाहरण देकर यह बताया कि कैसे विज्ञान को आमजन कि भाषा में उनतक पंहुचाया जाय।

कार्यक्रम का संचालन,अतिथि वक्ता का परिचय व धन्यवाद ज्ञापन श्री जय नारायण उपाध्याय, हिन्दी अधिकारी,एनपीएल ने किया। सीएसआईआर-एनपीएल के अलावा आईसीएआर, सीएसआईआर-निस्पर आदि संस्थानों से लगभग 65 स्टाफ सदस्य जुड़े।यह कार्यशाला अपने उद्देश्यों को प्राप्त करने में सफल रही।

<u>हिन्दी माह तथा हिन्दी दिवस समारोह-2021</u>

राजभाषा विभाग, गृह मंत्रालय, भारत सरकार द्वारा जारी कार्यालय ज्ञापन सं. **11034/02/2019**-राभा समिति, दिनांकित **31.07.2020** के अनुसरण में हिन्दी पखवाड़ा/हिन्दी माह आयोजन संबंधी निर्देशों को ध्यान में रखते हुए प्रयोगशाला में **18** अगस्त, **2021** से **14** सितम्बर, **2021** तक 'हिन्दी माह' मनाया गया । प्रयोगशाला के सभी स्टाफ सदस्यों को अपना अधिक से अधिक कार्य हिन्दी में करने के लिए प्रेरित एवं प्रोत्साहित करने के उद्देश्य से निम्नलिखित प्रतियोगिताएं यथासंभव ऑनलाइन/ऑफलाइन (कोविड-**19** प्रोटोकॉल के तहत) माध्यम से आयोजित की गयी।

क्रम सं.	**प्रतियोगिता का नाम**	**दिनांक**
1.	चित्राधारित कथा लेखन प्रतियोगिता	18.08.2021
2.	लोकोक्ति पल्लवन प्रतियोगिता	24.08.2021
3.	श्रव्य माध्यम आधारित श्रुतलेख प्रतियोगिता	27.08.2021
4.	वाद विवाद प्रतियोगिता	01.09.2021
5.	काव्य पाठ प्रतियोगिता	03.09.2021
6.	सामान्य ज्ञान-विज्ञान प्रतियोगिता	07.09.2021

दिनांक **14.09.202**1 को हिन्दी दिवस तथा हिन्दी माह समापन समारोह का आयोजन किया गया।


प्रो. वेणुगोपाल आचन्टा, निदेशक,एनपीएल संबोधित करते हुए


डॉ. क्षेमेन्द्र शर्मा, प्रभागाध्यक्ष, पर्यावरण मापिकी व जैवचिकित्सा संबोधित करते हुए


मुख्य अतिथि श्री देवेन्द्र मेवाड़ी जी व्याख्यान देते हुए


विजेता प्रतिभागियों को पुरस्कार प्रदान करते हुए माननीयगण

निदेशक महोदय ने कार्यक्रम का शुभारंभ आशीर्वचन से किया। निदेशक महोदय ने हिन्दी दिवस के अवसर पर उपस्थित स्टाफ सदस्यों को दैनिक सरकारी कामकाज में हिन्दी का प्रयोग करने के लिए प्रेरित एवं प्रोत्साहित करते हुए ज्ञान-सृजन विषय पर अत्यन्त सारगर्भित व्याख्यान दिया। साथ ही,स्टाफ सदस्यों को राजभाषा प्रतिज्ञा दिलायी।

डॉ. क्षेमेन्द्र शर्मा,प्रभागाध्यक्ष,पर्यावरण मापिकी व जैवचिकित्सा ने अतिथि वक्ता का परिचय प्रस्तुत किया तथा अपने सम्बोधन में कहा कि वर्तमान वैज्ञानिक परिदृश्य में हिन्दी सहित भारतीय भाषाओं को उच्चतर प्रौद्योगिकी तथा वाणिज्य-व्यापार आदि सहित विज्ञान साहित्य के सृजन व प्रसार हेतु भाषायी माध्यम बनाया जाना आवश्यक है। जन-जन की भाषा हिन्दी सहित भारतीय भाषाओं में सर्वसुलभ वैज्ञानिक उपलब्धियों तथा विज्ञान से जुड़ी मूलभूत बातों को आम जन तक पहुंचाने के लिए सार्थक प्रयासों की आवश्यकता है ।

इस पावन अवसर पर मुख्य व्याख्यान अतिथि वक्ता प्रसिद्ध विज्ञान साहित्य सर्जक,लेखक व संचारक श्री देवेन्द्र मेवाड़ी जी ने 'हिंदी में विज्ञान साहित्य की वर्त्तमान स्थिति और भविष्य' विषय पर दिया।उन्होंने अपने विस्तृत ज्ञानकोश से अनेक जनोपयोगी वस्तुओं के उदाहरण द्वारा विज्ञान और साहित्य के सम्बन्धों के साथ विज्ञान साहित्य की सरसता और जीवंतता को सिद्ध किया।साहित्य,इतिहास,भूगोल,चिकित्साशास्त्र आदि अनेक क्षेत्रों से उदाहरण देकर यह बताया कि हिन्दी भाषा में विज्ञान साहित्य सृजन की अपार संभावनाएं हैं और विज्ञान साहित्य के भण्डार में वृद्धि की अवश्यकता है।अपने सम्बोधन के अंत में 'माँ पृथ्वी' नामक सद्यःरचित कविता का पाठ किया।

समारोह के अंत में हिन्दी माह के दौरान आयोजित की गयी प्रतियोगिताओं में भाग लेने वाले 37 विजेता प्रतिभागियों को माननीय निदेशक महोदय व मुख्य अतिथि के करकमलों से पुरस्कार व प्रमाण-पत्र प्रदान किए गए।

स्वागत, कार्यक्रम का संचालन व धन्यवाद ज्ञापन श्री जय नारायण उपाध्याय, हिन्दी अधिकारी, एनपीएल द्वारा किया गया।

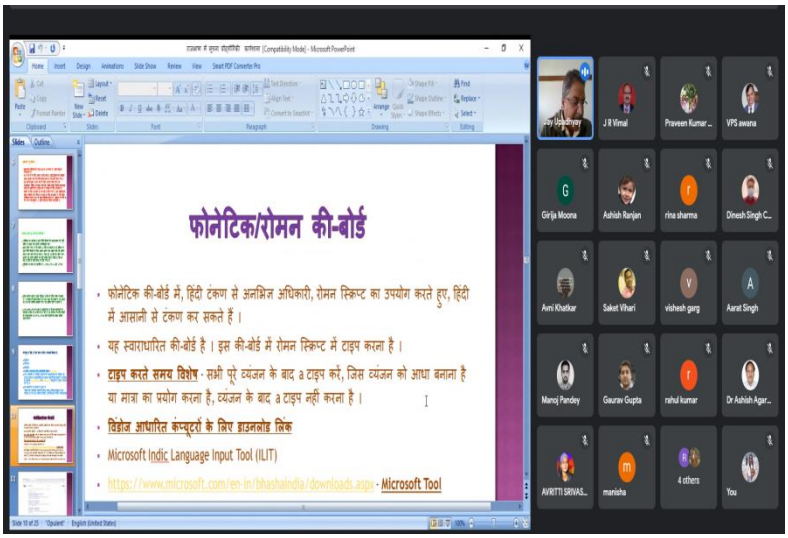
<u>"राजभाषा हिन्दी और सूचना तकनीक कार्यशाला"</u>

सीएसआईआर एकीकृत कौशल पहलके अंतर्गत "राजभाषा हिन्दी और सूचना तकनीक कार्यशाला" का आयोजन आभासी माध्यम से सीएसआईआर-एनपीएल द्वारा दिनांक 19 जनवरी, 2022 **;** समय : प्रातः 11 से 12 बजे तक आयोजित किया गया।

सम्प्रेषण मानव जीवन की अनिवार्य आवश्यकता है। सम्प्रेषण के लिए भाषा आवश्यक अंग है सूचना प्रौद्योगिकी ने सम्प्रेषण के आधुनिक स्वरूप का विकास किया है। भारतीय भाषाओं के साथ-साथ हिन्दी भी सूचना तकनीकों के अनुकूल अपने विभिन्न वैविध्य को विकसित कर रही है।

इस कार्यशाला में श्री जे एन उपाध्याय, राजभाषा अधिकारी, सीएसआईआर-एनपीएल ने हिन्दी में कार्य करने के बारे में महत्वपूर्ण जानकारी प्रदान करी।

कार्यशाला के मुख्य बिन्दु:*यूनिकोड टंकण, *वॉयस टंकण, *मानक वर्तनी, *फॉण्ट परिवर्तक, *मशीनी अनुवाद, *तकनीकी शब्दावली थे। इस कार्यशाला में हमारे साथ **30** प्रतिभागी जुड़े थे।



'अंतरराष्ट्रीय मातृभाषा दिवस' का आयोजन

राजभाषा विभाग, गृह मंत्रालय, भारत सरकार के 'अंतरराष्ट्रीय मातृभाषा दिवस' आयोजन संबंधी निर्देश का अनुपालन सुनिश्चित करते हुए प्रयोगशाला में दिनांक **21** फरवरी, **2022** को 'अंतरराष्ट्रीय मातृभाषा दिवस' मनाया गया । प्रयोगशाला के सभी स्टाफ सदस्यों के लिए (वैज्ञानिकों/अधिकारियों/ कर्मचारियों/शोध छात्रों के लिए एक बहुभाषी काव्य गोष्ठी का आयोजन किया गया । हिन्दी सहित भारतीय भाषाओं में (यथा : तमिल, तेलुगू, मलयालम, बांग्ला, भोजपरी, मराठी, हिन्दी आदि) में कविता/गीत का वाचन किया गया ।

क्र.सं.	नाम	पदनाम	भाषा
1.	डा. एम सेंथिल कुमार	वैज्ञानिक	तमिल
2.	डा. प्रणाली थोराट	प्रधान वैज्ञानिक	मराठी
3.	डा. डी डी शिवगण	प्रधान वैज्ञानिक	मराठी
4.	श्री एल श्रीधर	वरिष्ठ तकनीकी अधिकारी	तेलुगू
5.	सुश्री शिखा श्रीवास्तव	शोध छात्र	हिन्दी
6.	श्री जोखन राम	प्रधान तकनीकी अधिकारी	भोजपरी
7.	श्री मनोज कुमार	वैज्ञानिक	भोजपरी
8.	श्री शुभोजित मंडल	शोध छात्र	बांग्ला
9.	डा. शिबु साहा	वैज्ञानिक	बांग्ला

बहुभाषी काव्य—गोष्ठी सराहना समिति

- प्रो. वेणुगोपाल आचंटा, निदेशक
- डा. संजय आर धकाते, मुख्य वैज्ञानिक
- डा. क्षेमेन्द्र शर्मा, मुख्य वैज्ञानिक
- श्री सुरेन्द्र कुमार, प्रशासन नियंत्रक
- डा. एन विजयन, प्रधान वैज्ञानिक
- श्री जय नारायण उपाध्याय, संयोजक एवं हिन्दी अधिकारी

इस बहुभाषी काव्य गोष्ठी में एक समिति द्वारा निर्धारित मानदंडों के अनुसार सभी प्रतिभागियों का काव्य पाठ सराहनीय रहा ।

निदेशक महोदय व समिति सदस्यों ने हर्ष व्यक्त किया व 'अंतरराष्ट्रीय मातृभाषा दिवस' के लिए शुभकामनाएं दी । बहुभाषी काव्य गोष्ठी सफल रही ।

<u>विश्व हिन्दी दिवस, **2022**</u>

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 विश्व हिन्दी दिवस, **202**2 (दिनांक **10** जनवरी, **202**2) का आयोजन यथासंभव ऑनलाइन माध्यम से किया गया। दिनांक **10** जनवरी,**202**2 को विश्व हिन्दी दिवस 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 दिनांक 07 जनवरी को दो प्रतियोगिताओं का ऑनलाइन आयोजन किया गया।

क्रम सं.	**प्रतियोगिताएं**	**दिनांक**
1.	वाद-विवाद प्रतियोगिता	**07** जनवरी, **2022**
2.	काव्य पाठ प्रतियोगिता	**0**7 जनवरी, **2022**

इन सभी प्रतियोगिताओं में प्रयोगशाला के स्टाफ सदस्यों ने अत्यधिक रूचि प्रदर्शित करते हुए उत्साहपूर्वक भाग लिया।

दिनांक **10.01.2022** को "विश्व हिन्दी दिवस" (ऑनलाइन) का आयोजन निम्नानुसार किया गया।

॥कार्यक्रम॥	
1. स्वागत	श्री जय नारायण उपाध्याय
2. हिन्दी भाषा की महत्ता	श्री सुरेन्द्र कुमार, प्रशासन नियंत्रक
3. हिन्दी का वैश्विक परिदृश्य	श्री सुरेन्द्र कुमार, प्रशासन नियंत्रक
4. तकनीकी विषयों हेतु हिन्दी	डा. क्षेमेन्द्र शर्मा, मुख्य वैज्ञानिक
5. दैनिक जीवन में हिन्दी भाषा विषय पर सम्बोधन/आशीर्वचन	प्रो. वेणुगोपाल आचंटा, निदेशक
6. धन्यवाद प्रस्ताव	श्री जय नारायण उपाध्याय

श्री सुरेन्द्र कुमार, प्रशासन नियंत्रक ने हिन्दी भाषा की महत्ता के संदर्भ में उपस्थित स्टाफ सदस्यों को बताया।

हिन्दी का वैश्विक परिदृश्य विषय पर डा. सुशील कुमार, वरिष्ठ प्रधान वैज्ञानिक ने हिन्दी भाषा की गरिमामयी वैश्विक उपस्थिति पर सारगर्भित व्यख्यान दिया।

डॉ. क्षेमेन्द्र शर्मा, प्रभागाध्यक्ष, पर्यावरण मापिकी व जैवचिकित्सा ने तकनीकी विषयों हेतु हिन्दी विषय पर अपने सम्बोधन में कहा कि वर्तमान वैज्ञानिक परिदृश्य में हिन्दी सहित भारतीय भाषाओं को उच्चतर प्रौद्योगिकी तथा वाणिज्य-व्यापार आदि सहित विज्ञान साहित्य के सृजन व प्रसार हेतु भाषायी माध्यम बनाया जाना आवश्यक है। जन-जन की भाषा हिन्दी सहित भारतीय भाषाओं में सर्वसुलभ वैज्ञानिक उपलब्धियों तथा विज्ञान से जुड़ी मूलभूत बातों को आम जन तक पहुंचाने के लिए सार्थक प्रयासों की आवश्यकता है ।

इस पावन अवसर पर निदेशक महोदय ने विश्व हिन्दी दिवस के अवसर पर दैनिक जीवन में हिन्दी भाषा विषय पर संबोधित किया । स्टाफ सदस्यों को दैनिक सरकारी कामकाज में हिन्दी का प्रयोग करने के लिए प्रेरित एवं प्रोत्साहित करते हुए ज्ञान-सृजन विषय पर अत्यन्त सारगर्भित व्याख्यान दिया।

समारोह के अंत में विश्व हिन्दी दिवस के अवसर पर आयोजित की गयी प्रतियोगिताओं में भाग लेने वाले 10 विजेता प्रतिभागियों को माननीय निदेशक महोदय ने हार्दिक बधाई दी।

स्वागत,कार्यक्रम का संचालन व धन्यवाद ज्ञापन श्री जय नारायण उपाध्याय, हिन्दी अधिकारी, एनपीएल द्वारा किया गया।

Annexure I

Major R & D Projects during 2021-22

The major projects of value >50 Lakhs are listed below

Sl. No	Project Title	Funding Agency	Contract Value (in lakhs)	Amount Received during 2021-22
1	Study of seasonal variation of ozone precursor in relation with surface ozone over Delhi, a mega city	Physical Research Laboratory (A Unit of Dept. of Space, Govt. of India)	135.32	44.33
2	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	95.00	NIL
3	Implementation of IST service using NPL controlled remote oscillator system for national knowledge Network at National Informatics Centre	National Informatics Centre Services Inc. (NICSI)	94.36	NIL
4	Carbonaceous Aerosols Emissions, Source Apportioment and climate effects	Ministry of Environment, Forest and Climate Change (MoEF)	274.672	NIL
5	National Primary Standard facility for cell calibration	Ministry of New and Renewable Energy (MNRE)	1788.50	529.58
6	Growth and study of highly conducting delafossite single crystal: Device application in metrology	DST	89.00	NIL
7	Megacity Delhi atmospheric emission quantification assessment and impacts (Delhi Flux)	Ministry of Earth Sciences (MoES)	198.28	18.00
8	Chemical Composition and source apportionment of Aerosols using Receptor Models at urban sites of the Himalayan Region of India	DST	71.72	8.00

9	Creation of Testing and Calibration Facility for LED and LED based Lighting at NPL India as per National/International Standards	Bureau of Energy Efficiency (BEE)	2025.00	612.50
10	Studies of stabilization of ferromagnetism in MnX (X=Al,Ga) binary alloy thin films by ion beam irradiation	DST	58.26	21.73
11	Production of Certified Reference Materials-Bharatiya Nirdeshak Dravya (BND)	Ministry of Commerce & Industry, Department of Commerce	1627.00	NIL
12	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) Govt. of India	5660.00	NIL
13	Advanced Single Photon Detector & Establishment of Single Photon Defection Based Quantum Standard for QuEST	DST	578.14	NIL
14	Bulk preparation of p-type and n-type materials for excitonic solar cells	DST	58.24	NIL
15	Design and Development of flexible large area(156x156 mm2) modified perovskite mini modules	DST	98.83	42.61
16	GCRF South Asian Nitrogen Hub (SANH)	UK Centre for Ecology and Hydrology (UKCEH)	153.13	9.97

Annexure II

Awards & Achievements

Distinguished National/ International Award

- Dr. S.S.K. Titus has been elected for the TCM Chair position since November 2021 in the APMP to represent this activity of all the NMIs in the APMP region for three year.
  [APMP (Asia Pacific Metrology Programme) has 12 Technical committees (TCs) responsible for coordinating all the technical activities for each field covered by the CIPM and each of these TCs are managed by a Chair Person elected for each TCs. The TCM (Technical Committee for Mass) is one of the technical committees which covers all the mass related parameters such as mass, force, torque, hardness and pressure in the APMP region.]

- Dr. Sanjay Yadav appointed as Member Governing Council, FCRI, Palakkad, Kerala, for two years.

- Dr. V.P.S. Awana - Elected Fellow Institute of Physics (UK) - 22nd March 2022.

- Dr. Monika J. Kulshesta elected Fellow, Metrology Society of India since August-2021.

- Dr. Govind, Senior Principal Scientist is elected as Senior Member, IEEE, USA- 2021

- Dr. Sumit Kumar Mishra elected Fellow of Indian Social Science Academy (ISSA), Allahabad.

- Mr. Gaurav Gupta from Temperature and Humidity Metrology won the Outstanding Contribution Award in Mechanical Metrology on the occasion of 75th CSIR-NPL Platinum Jubilee Celebration, 4-6 Jan 2022.

- Dr. Jasveer Singh received Certificate of Excellence Award for the outstanding contribution in the field of Mechanical Metrology for the year 2021-22 from CSIR-NPL.

- Mr. Dinesh Chandra Sharma received a Certificate of Excellence for his outstanding contribution in the field of Mechanical Metrology on the occasion of 75th CSIR-NPL Platinum Jubilee Celebration, 4-6 Jan 2022.

Best Paper Award

- Dr Nidhi Singh received Best Poster Award in National Science Day (NSD 2022) on "Automated bridge for Calibration of AC Voltage Ratio using Software Lock-in Amplifier" during 28th Feb. 2022.

- Dr. Anuj Krishna, Scientist, IRM (BND) Division received Best Thesis Award in International Conference on Solution Grown Crystals and their Useful Applications (SGCA-2021) - For the work contributed in PhD thesis entitled "Crystallization and detailed investigations on characteristic features of organic single crystals for nonlinear optical applications.

- Mr. Anshul Singh from Temperature and Humidity Metrology received First Prize in poster presentation on National Science Day ((NSD 2022) on "Development of Precise Pressure Control System for Acoustic Gas Thermometry at CSIR-NPL" during 28th Feb. 2022.

- Dr. Prashant Tripathi, has received the Best Poster Presentation Award in the International Conference on Energy & Advanced Materials (ICEAM-2021) organized by Department of Physics and Materials Science & Engineering, Jaypee Institute of Information Technology, Noida, India during 21st -23rd Oct. 2021.

Editorial Board of Reputed Journals

- Dr. V.P.S. Awana - Guest Editor - "Superconductivity Research in India" - Superconductor Science & Technology (IOP-UK) during 2021-22.

- Dr. Sunil Singh Kushvaha and Dr. V. N. Singh edited book entitled "Types of Photodetectors and their applications" by Nova Science Publishers, USA (2021-22).

- K Govindan, Harish Kumar, Sanjay Yadav, Advances in Mechanical and Materials Technology: Lecture Notes in Mechanical Engineering, (Sub title: Select Proceedings of EMSME 2020), https://link.springer.com/book/9789811627934.

- Dr. Naveen Garg published One Book by Springer Nature, Switzerland covering 10 chapters and 500 pages approx. entitled "Environmental Noise Control: The Indian Perspectives in an International Context".

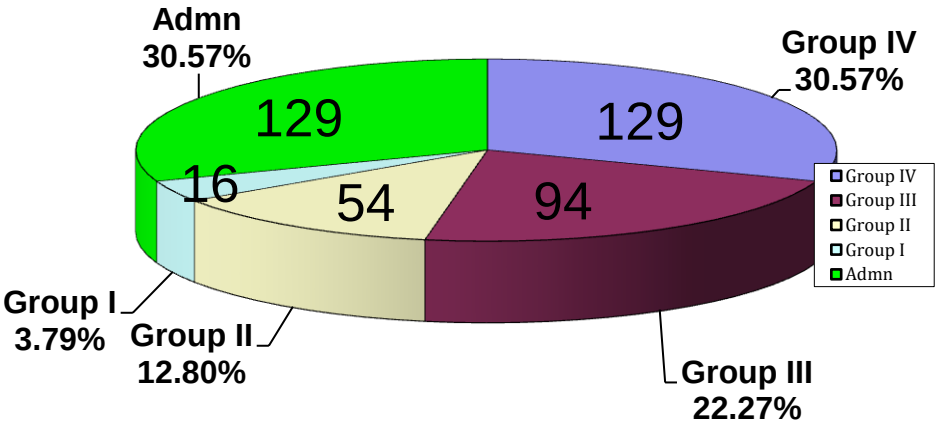
Other

- Dr. Nidhi Singh is associated as Nodal of the project (NWP-100) for training programs conducted under the Integrated Skill

Staff, Patents, Reports & Financial Outflow

- **Regular Staff in Position as on 31.03.2022**

TOTAL NUMBER = 422
Average Age 46.66

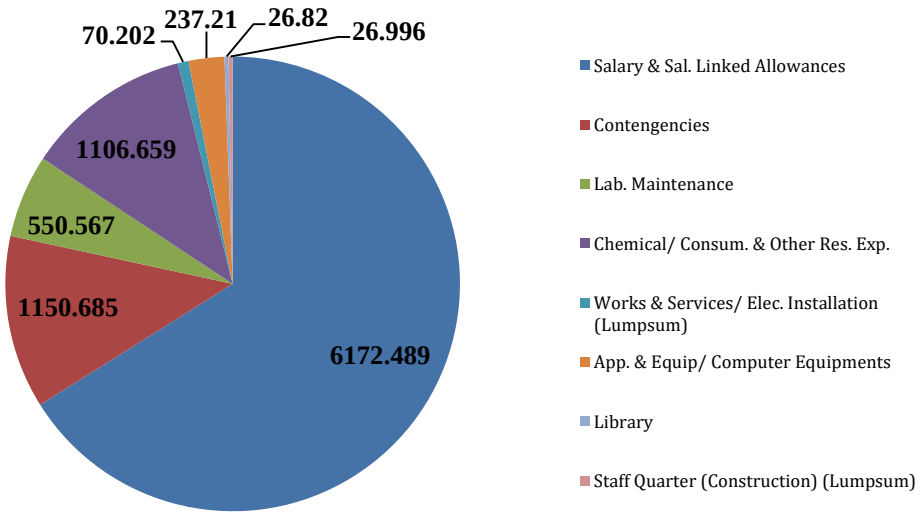


- **New Recruitments (2021-22)**

S. No.	Name	Designation	Date of Joining
NIL			

- **Patents & Reports**
  - Patents Applications filed in India:05
  - Patents Granted in India:06
  - Patents Granted Abroad:04
  - Copyright: 01

- **Budget flow (in Lakh)**



Annexure IV

Patents list

Filed in India

SNo	Title	Inventors	Provisional Filing Date	Complete Filing Date	Application No.
1	An ambient air microbial disinfector	Nahar Singh, Rajesh, Virendra Kumar Jaiswal, Parag Sharma, Gajjala Sumana, Radhakrishnan S R, Devesh Kumar Shukla, Shankar G Aggarwal, Khem Singh, Shiv Kumar Jaiswal, Dinesh Kumar Aswal, Vijay Sharma, Sandeep Khichi	4 Oct 21	---	202111045122
2	A process for the preparation of low power electro sensitive optical device based on ferroelectric liquid crystal	Ashok Manikrao Biradar, Amit Choudhary, Lokesh Kumar Gangwar, Ambika Bawa, Suraj Kumar, Surinder P Singh, Rajesh	29 Dec 21	---	202111061663
3	A mask testing setup	Shankar Gopala Aggarwal, Baban Kumar, Prashant Patel, Khem Singh, Daya Soni, Prabha Johri, Chhemendra Sharma, Sanjay Yadav	---	5 Oct 21	202111045226
4	An automatic calibration setup for multiple blood pressure measuring instruments	Sanjay Yadav, Rahul Kumar, Ashok Kumar, P K Dubey, Afaqul Zafer, Nita Dilawar Sharma, Om Prakash, Harish Kumar, V K Gupta, S K Jaiswal, Ashutosh Agarwal	---	21 Oct 21	202111048098
5	Ultrasonic pulse velocity tester device with threshold error correction	P K Dubey, Sanjay Yadav, Piyush	---	21 Oct 21	202111048097

Granted in India

SNo	Title	Inventors	Provisional Filing Date	Complete Filing Date	Application No.	Grant Date	Patent No.
1	An antimicrobial agent and process for the preparation thereof	Singh Nahar, Singh Rajni, Gupta Prabhat Kumar	---	21 May 14	1338DEL2014	16 Nov 21	381959
2	Lithium substituted Magnesium Ferrite as Hydroelectric Cell and processing method thereof	Ravinder Kumar Kotnala, Jyoti Shah	23 Mar 15	10 Mar 16	0792DEL2015	23 Jul 21	372619
3	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 Nov 15	3817DEL2015	7 Jan 22	386181

4	A process for the preparation of uniform sized phosphor aerogel	Divi Haranath, Singh Nahar, Chawla Sneha	---	6 Jun 16	201611019355	24 May 21	367384
5	Composite tiles prepared from waste plastics and a process for the preparation thereof	Dhawan Sundeep Kumar, Sharma Brijesh, Dhawan Ridham, Sambyal Pradeep, Farukh Md, Sharma Ram Dhan, Gurpal Singh, Dey Manojit, Bindal Rakesh Kumar, Kotnala Ravinder Kumar, Aswal Dinesh Kumar	22 Jul 16	19 Jul 17	201611025127	16 Dec 21	384481
6	A process for electrochemical deposition of pedot as htl useful in organic solar cells	Patra Asit, Agrawal Vikash, Shahjad, Bhargav Ranoo, Bhardwaj Dinesh, Kumar Rachana, Singh Kumar Rajiv, Chand Suresh	---	16 Aug 16	201611027796	19 Jul 21	372221

Granted in Foreign Countries

SNo	Title	Inventors	Country Code	Complete Filing Date	Application No.	Grant Date	Patent No.
1	Nucleic acid primers and probe for detection of neisseria gonorrhoeae	Sood Seema, Rachna Verma, Singh Renu, Gajjala Sumana, Manju Bala, Sumantaray Jyotish Chandra, Pandey Manoj Kumar, Malhotra Bansi Dhar	UG	27 Jan 12	AP/P/2012/006092	22 May 21	AP4571
2	Nucleic acid primers and probe for detection of neisseria gonorrhoeae	Sood Seema, Rachna Verma, Singh Renu, Gajjala Sumana, Manju Bala, Sumantaray Jyotish Chandra, Pandey Manoj Kumar, Malhotra Bansi Dhar	KE	27 Jan 12	AP/P/2012/006092	22 May 21	AP4571
3	Nucleic acid primers and probe for detection of neisseria gonorrhoeae	Sood Seema, Rachna Verma, Singh Renu, Gajjala Sumana, Manju Bala, Sumantaray Jyotish Chandra, Pandey Manoj Kumar, Malhotra Bansi Dhar	MW	27 Jan 12	AP/P/2012/006092	22 May 21	AP4571
4	Printable bi-luminescent security ink and process thereof	Gupta Bipin Kumar, Kumar Pawan, Dhar Ajay, Aswal Dinesh Kumar	US	18 Oct 18	16/163982	15 Feb 22	11247506

Copyrights

S No	Reference Number	Copyright Title	Filed/Granted
1	018CR2021 2021-22	Sonic detection and ranging (SODAR) system software for data acquisition and analysis	Filed

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