Centre for Nano Science and Engineering

INDIAN INSTITUTE OF SCIENCE

From science to society

INDIAN INSTITUTE OF SCIENCE


Centre for
Nano Science
and Engineering
FROM SCIENCE TO SOCIETY
CeNSE

Contents

CeNSE 2017-2018

Overview

Centre for Nano Science and Engineering

The Centre for Nano Science and Engineering (CeNSE) is one of the world's leading centre for nanotechnology research. Established in 2010 and spawned inside the prestigious Indian Institute of Science, researchers in the Centre pursue interdisciplinary research and education across various disciplines with focus on key enabling technologies – nanoelectronics, MEMS/NEMS, nanomaterials and devices, photonics, nano-biotechnology, solar cells and computational nano-engineering, amongst a host of other exciting crossovers. Inspired by endless possibilities of nanotechnology and aided by facilities that rank among the very best on the globe, research at CeNSE is often cited as highly competitive, of high quality and frequently ground-breaking.

Research at CeNSE begins with discovering materials with enhanced properties at nanoscale such as higher strength, lighter weight, increased control of light spectrum, and greater chemical reactivity than their larger-scale counterparts. Breakthroughs with these high performance materials drive the scientific process at CeNSE, resulting in design of structures, devices and systems. Science at CeNSE culminates at delivering technology for diverse application areas including electronics, sensors, photonics, defence, space, energy, healthcare and agriculture.

By putting Nanotechnology at work, we at CeNSE are trying to solve some of the most meaningful challenges in our world today. Poised at the confluence of science, engineering and technology and conducted at the nanoscale, our research harnesses the power of this emerging technology, making available a resource that has the potential to improve our lives in many ways. Our research endeavors are aligned to key national initiatives of the government and we are pioneering the initiative to building a scientifically empowered nation.

Nanotechnology is the global economy's fastest growing investment sector. Our prolific collaborations with industry captains give CeNSE the opportunity to act as a catalyst in the development of new initiatives. Close partnerships with academics and institutions across the world help to create a nano hub for the country and regional networks across the geography.

Stimulated by the vibrant technology environment and a robust entrepreneurial culture in Bangalore, CeNSE successfully manages the complete cycle, starting from science to the incubation of business ideas. From the onset, CeNSE has envisaged to become an engine of the Indian Nanotechnology dream into the future and is well on its way to realizing its goals.

IISc

A world-class institution with focus on emerging frontiers of science and engineering

Founded in 1909, as a result of joint efforts of Jamsetji Nusserwanji Tata, Government of India, and Maharaja of Mysore, the Indian Institute of Science has become the premier institute for advanced scientific and technological research and education in India. Over the 105 years since its establishment, IISc has grown rapidly to the position of the best university in India as well as 27th in Asia.

Beginning with 2 departments and 21 students in 1911, today IISc has 43 departments, units and centres, 4000 students, and about 500 academic and scientific staff, supported by 600 administrative personnel. Research students make up more than 70% of the entire student body at IISc.

Academics at IISc conduct research in several areas of science and engineering including space science, material science and engineering, environmental and atmospheric sciences, endocrinology and genetic engineering. Amongst the areas identified by IISc for special research emphasis are nanoscience and nanotechnology.

Chair's Message

CeNSE

Welcome to the Centre for Nano Science and Engineering (CeNSE) at Indian Institute of Science. Established in 2010, and formally dedicated to the nation in 2015, by the Prime Minister of India, CeNSE has emerged as a melting pot of different disciplines in science and engineering.
The interdisciplinary research at the centre is defining new horizons through scientific discovery and engineering innovation at nano scale. The National Nano Fabrication Centre (NNFC), anchored in CeNSE, is one of the best university foundries in the world. The Micro and Nano Characterization Facility (MNCF) is only one of its kind in an academic setting anywhere in the world. This unmatched physical infrastructure is complemented with an exceptional human capital of the centre, consisting of faculty, students, technical, administrative and support staff. The confluence of these ingredients, provides a unique platform to experiment and innovate with nanomaterials and nanodevices, with unprecedented precision. The research and education at the centre is targeted towards diverse application areas including electronics, sensors, photonics, defence, space, energy, healthcare and agriculture. The underlying theme is to create societal impact by translating the academic research into useful products.

Our outreach programs are designed to ensure that CeNSE family extends beyond the physical confines, thereby creating a larger pool of people and resources. This enables us to achieve our collective vision, as a 'team', by leveraging complementary expertise. The Indian Nanoelectronics Users Program (INUP) has spread the awareness of nanotechnology to the remote corners of the country. A strong community of well trained researchers, more than 2000 in number from about 200 institutions, is now accessible through INUP network. We are also engaged in research collaboration with several universities in India and abroad. The Industry Affiliate membership Program (IAP) bridges the gap between academia and industry through sustained scientific interactions and joint research project execution. Nanotechnology start-up incubation program has already created four start-up companies cofounded by faculty, students and technical staff of the centre.

Because of generous funding and unstinting support provided by MeitY, DRDO, ISRO, DAE, DST, MHRD and other agencies, CeNSE stands today as a national resource, with facilities that are internationally benchmarked. The journey has just begun and we have miles to go. We need the synergy among multiple stakeholders to chart out our future path. The future looks bright and clear. While we march forward to become one of the finest research centres in the world, we are equally determined to touch the lives of every citizen, by focusing on the bottom of the pyramid. We want to bring positive change in the society, through the intervention of nanoscience and engineering.

Together, we can realize this dream. Come and join us, be part of this exciting journey...

– Navakanta Bhat

CeNSE

History

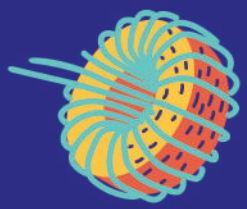
Transforming Indian Nanotech

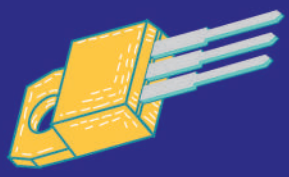
"Knowledge, science, and growth has to be a continuous process. New thinking, new research, new innovation augment the path of progress strongly. Science and research/innovation are necessary elements of the path of progress.

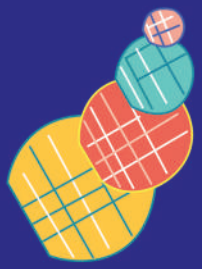
The journey of progress inspired by Swami Vivekananda and commenced by Jamshedji 100 years ago has been doing an amazing job helping improve human life.

Best wishes/Congratulations to the scientists who are dedicated to science."

- PM Shri Narendra Modi







Germination of Nanofab vision

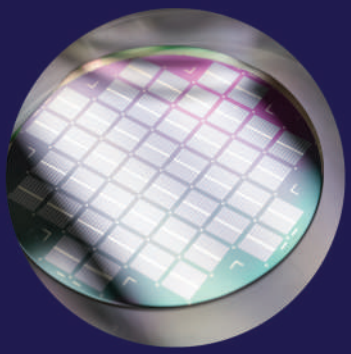
2000

PSA's office along with MCIT launch National Nanoelectronics initiative

2002

IISc Bangalore and IIT Bombay are identified as leading institutes for setting up Centre of Excellence in Nanoelectronics (CEN)

2003



MCIT sanctions Rs 50 crores for IISc to set up CeNSE

2005

CeNSE is born. Receives ~ Rs 250 crores from multiple agencies

2010

CeNSE dedicated to the Nation by the Prime Minister Mr. Modi

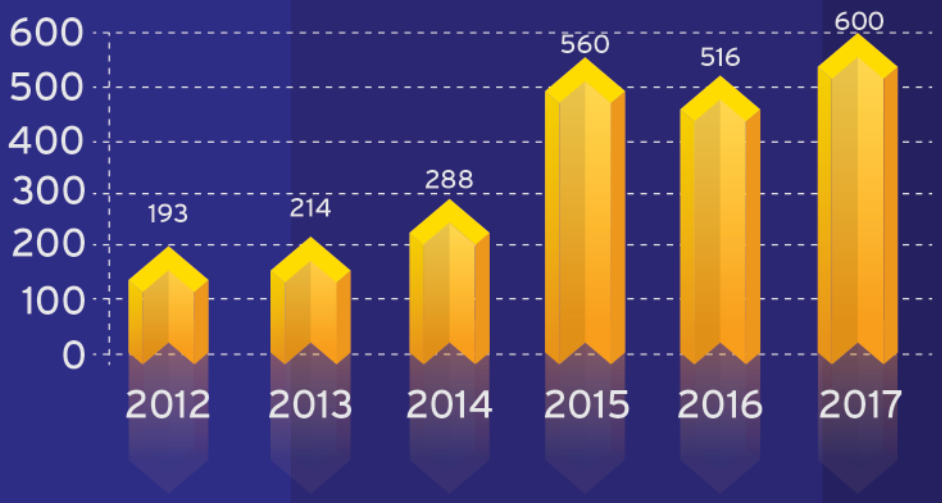
2015

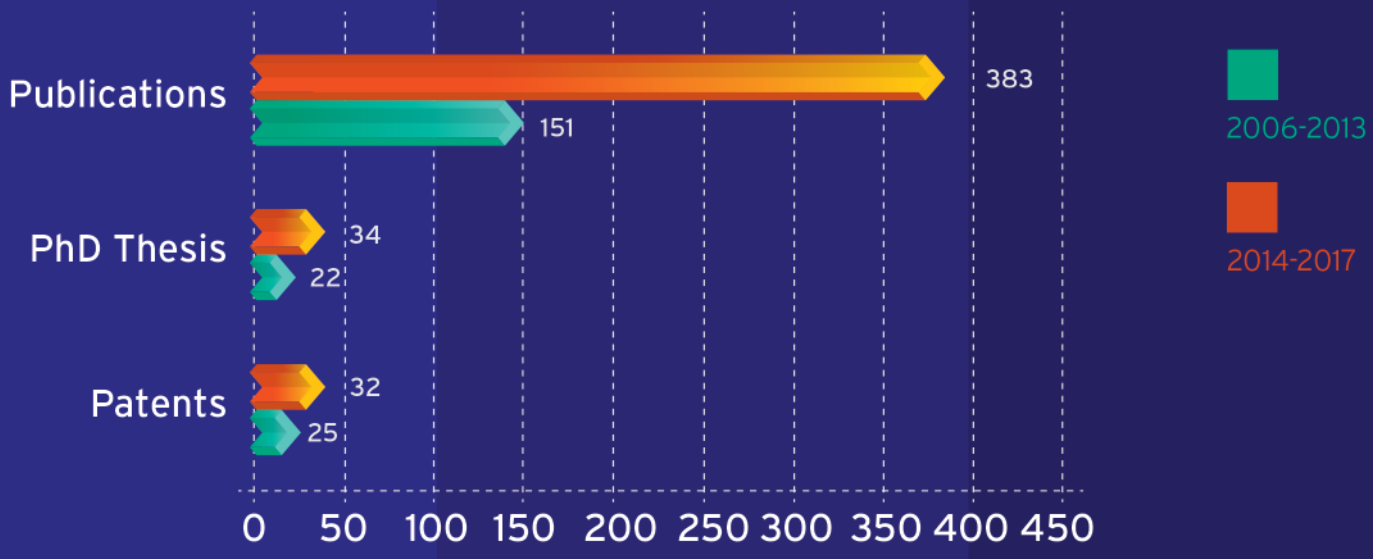
In Numbers

CeNSE

During 2012-2017, CeNSE research has resulted in:

Manpower Trained





Making CeNSE of the numbers

Faculty 17

Regular faculty: **12**
Emeritus faculty: **5**

Students 219 (2006-2017)

PhD: **181**
MTech: **38**

Staff 127

Postdocs: **6**
PA/RA: **28**
Admin: **17**

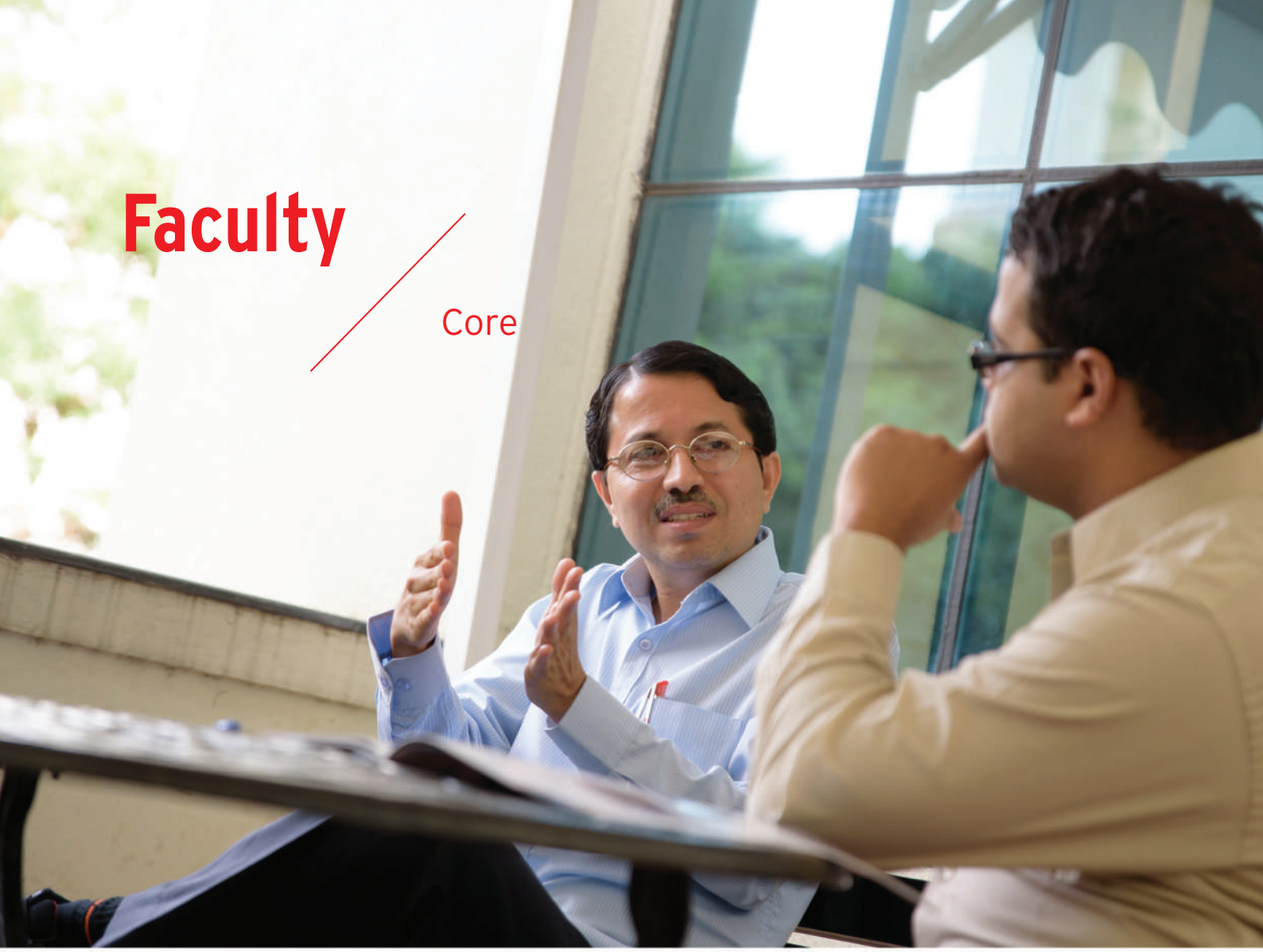
NNFC: **50**
MNCF: **19**
INUP: **7**

Total = 363

The Centre hosts over 150 researchers from outside academic institutions, governmental and industrial research labs every year, so that they can avail of the world-class nano facilities at CeNSE. The Centre offers PhD and MTech programs in a wide range of areas, and has close interactions with the industry.

Faculty

Core



CeNSE faculty members have excellent academic credentials who have carried out pioneering research in their respective sub-disciplines. Their accomplishments have only contributed to their genuine excitement at work and passion to teach.

Apart from creating groundbreaking science with strong collaborations across the world, the 17 core faculty at CeNSE ably nurture the next generation of nanotechnologists and budding researchers.

40 associate members from various IISc departments contribute to the multidisciplinary scientific environment and promote science that demands a collaborative spirit for it to thrive.

Akshay Naik

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Research Interests

- Nonlinear dynamics in 2D nanoelectromechanical systems
- Noise in nanoelectromechanical systems
- Strain engineering in 2D materials

Publications and Collaborations

- Parametric Amplification in MoS_2 Drum Resonator, Parmeshwar Prasad, Nishta Arora & **Akshay Naik,** *Nanoscale,* (Advance Article), 2017
- Graphene Electrodes as Barrier-Free Contacts for Carbon Nanotube Field-Effect Transistors, PR Yasasvi, Punith Lokesh, KN Bhat & **Akshay Naik,** *IEEE Transactions on Electron Devices,* 64 (10), 2017
- Nonlinear mode coupling and internal resonances in MoS_2 nanoelectromechanical system, Chandan Samanta, PR Yasasvi & **Akshay Naik,** *Applied Physics Letters,* 107 (17), 173110, 2015
- Dynamic range tuning of graphene nanoresonators, Marsha Parmar, PR Yasasvi & **Akshay Naik,** *Applied Physics Letters,* 107(11), 113108, 2015
- Gallium-Doped Piezoresistive Sensor With Optimized Focused Ion Beam Implantation, A Sharma, BN Suma, KN Bhat & **Akshay Naik,** *IEEE Journal of Microelectromechanical Systems,* 26 (1), pp 127–134, 2017

Research Vision

We are studying the noise and nonlinearities in ultrathin nanoelectromechanical systems. The studies are expected to help develop next generation of ultra-low noise sensors. We are also studying the mechanisms of energy transfer between different vibrational states of mechanical resonators.

Ambarish Ghosh

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Research Interests

- Magnetic nanoswimmers for nanobiotechnology and microfluidics
- Electron bubbles in quantum fluids
- Driven and active colloids
- Integration of plasmonics and 2D materials

Publications and Collaborations

- Role of entropy in the expulsion of dopants from optically trapped colloidal assemblies, Hreedish Kakoty, Rajarshi Banerjee, Chandan Dasgupta and **Ambarish Ghosh,** *Physical Review Letters,* 117, 258002 (2016) Editor's suggestion

- Independent Direction Control of Magnetic Nanomotors, Pranay Mandal, Vaishali Chopra and **Ambarish Ghosh,** *ACS Nano,* 9 (5), pp 4717-4725, 2015

- Ultrahigh Field Enhancement and Photoresponse in Atomically Separated Arrays of Plasmonic Dimers, Debadrita Paria, K Roy, Johnson H Singh, Shishir Kumar, Srinivasan Raghavan, Arindam Ghosh and **Ambarish Ghosh,** *Advanced Materials,* 27 (10), 1751-1758, 2015

- Studying Electrons on Curved Surfaces by Trapping and Manipulating Multielectron Bubbles in Liquid Helium, Vaisakh Vadakkumbatt, Emil M Joseph, Anustuv Pal & **Ambarish Ghosh,** *Nature Communications* 5, 4571, 2014

- Conformal Cytocompatible Ferrite Coatings Facilitate the Realization of a Nano-voyager in Human Blood, Lekshmy Venugopalan Pooyath, Ranajit Sai, Yashoda Chandorkar, Bikramjit Basu, Srinivasrao Shivashankar, and **Ambarish Ghosh,** *Nano Letters,* 2014, 14 (4), pp 1968–1975

Research Vision

We have developed a system of magnetic nanorobots that can impact diverse application domains: microfluidics, targeted drug delivery, on-chip nanoassembly, and can also be used to address fundamental questions in non-equilibrium statistical mechanics. In addition, we study plasmonic metamaterials for optical sensing and actuation applications, and electron bubbles in liquid helium for probing fundamental questions in self-assembled quantum phases.

Digbijoy N Nath

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Research Interests

- Gallium Nitride transistors for power electronics
- III-nitride deep-UV opto-electronics
- Gallium Oxide – deposition and devices for power and UV applications
- Integration of 2D materials with wide band gap semiconductors

Publications and Collaborations

- High responsivity in molecular beam epitaxy grown β-Ga_2O_3 metal semiconductor metal solar blind deep-UV photodetector, AS Pratiyush, S Krishnamoorthy, SV Solanke, Z Xia, R Muralidharan, S Rajan, **Digbijoy N Nath,** *Applied Physics Letters,* 110 (22), 221107, 2017

- Gain mechanism and carrier transport in high responsivity AlGaN-based solar blind metal semiconductor metal photodetectors, S Rathkanthiwar, A Kalra, SV Solanke, N Mohta, R Muralidharan, S Raghavan, **Digbijoy N Nath**, *Journal of Applied Physics,* 121 (16), 164502, 2017

- Temperature and bias dependent trap capture cross section in AlGaN/GaN HEMT on 6-in silicon with Carbon-doped buffer S Kumar, P Gupta, I Guiney, CJ Humphreys, S Raghavan, R Muralidharan, **Digbijoy N Nath,** *IEEE Transactions of Electron Devices,* Vol. (To be announced), Issue: 99, DOI: 10.1109/TED.2017.2757516, 2017

- Optical-phonon limited high-field transport in layered materials, H Chandrasekar, KL Ganapathi, S Bhattacharjee, N Bhat, **Digbijoy N Nath,** *IEEE Transactions on Electron Devices,* 63, 767-772, 2015

- Interface traps at Al_2O_3/InAlN/GaN MOS-HEMT-on-200 nm Si, S Kumar, N Remesh, SB Dolmanan, S Tripathy, S Raghavan, R Muralidharan, **Digbijoy N Nath,** *Solid-State Electronics,* 137, 117-122, 2017

Research Vision

We are working on advancing the understanding of high-power Gallium Nitride (GaN) transistors to enable devices with improved performance. As a part of multi-disciplinary initiative, we are also working on delivering a 5 Amp, 40 V GaN device technology. Such GaN transistors are promising for applications in the rapidly expanding power electronics market. We are developing wide band gap (III-nitrides, Gallium oxide) deep-UV photodetectors for a variety of strategic and space applications.

Manoj Varma

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Research Interests

- Noise in biochemical sensing
- Biosensors
- Autonomous robots

Publications and Collaborations

- High precision measurement of intensity peak shifts in tunable cascaded microring intensity sensors, PR Prasad, SK Selvaraja, **Manoj Varma,** *Optics letters* 41 (14), 3153-3156 (2016)
- Subdiffraction-Resolution Optical Measurements of Molecular Transport in Thin Polymer Films, S Pahal, AM Raichur, **Manoj Varma,** *Langmuir* 32 (22), 5460-5467 (2016)
- Bright-field Nanoscopy: Visualizing Nano-structures with Localized Optical Contrast Using a Conventional Microscope, Swathi Suran, Krishna Bharadwaj, Srinivasan Raghavan, **Manoj Varma,** *Scientific Reports* 6 (25011), (2016)
- Diffractive optical analysis for refractive index sensing using transparent phase gratings, N Kumawat, P Pal, **Manoj Varma,** *Scientific reports* 5, 16687 (2015)
- Detection limit of etched fiber Bragg grating sensors, BN Shivananju, M Renilkumar, GR Prashanth, S Asokan, **Manoj Varma,** *Journal of Lightwave Technology* 31 (14), 2441-2447 (2013)

Research Vision

We are interested in understanding error correction mechanisms operating in sensory signal processing in living organisms. In relation to this, we are also interested in building engineered systems endowed with such noise tolerant, robust behaviour.

Navakanta Bhat

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Research Interests

- Nanoelectronics device physics and technology
- Electrochemical Biosensors
- Metal oxide gas sensors
- Novel materials and processes for CMOS and MEMS applications

Publications and Collaborations

- A sub-thermionic MoS_2 FET with tunable transport, Shubhadeep Bhattacharjee, KL Ganapathi, S Mohan, **Navakanta Bhat,** *Applied Physics Letters* 111 (16), 163501, 2017 (Editor's pick)

- Honeycomb type ZnO nanostructures for sensitive and selective CO detection, Chandra Shekhar Prajapati, Dennis Visser, S Anand, **Navakanta Bhat,** *Sensors and Actuators B: Chemical,* 2017

- Aza-heterocyclic Receptors for Direct Electron Transfer Hemoglobin Biosensor, Vinay Kumar, DM Nikhila Kashyap, Suraj Hebbar, R Swetha, Sujay Prasad, T Kamala, SS Srikanta, PR Krishnaswamy, **Navakanta Bhat,** *Scientific Reports,* 2017.

- High-Performance HfO_2 Back Gated Multilayer MoS_2 Transistors, KL Ganapathi, Shubhadeep Bhattacharjee, S Mohan, **Navakanta Bhat,** *IEEE Electron Device Letters* 37 (6), pp 797-800, 2016

- Graphene based *E. coli* sensor on flexible acetate sheet, Palash Kumar Basu, Deepthi Indukuri, Sandeep Keshavan, Vikas Navratna, Siva Rama Krishna Vanjari, Srinivasan Raghavan, **Navakanta Bhat,** *Sensors and Actuators B: Chemical* 190, pp. 342-347, 2014

Research Vision

We have been focussing on technological interventions to develop point of care diagnostic devices for multiple chronic diseases such as diabetes, kidney disease, liver disease, anemia and malnutrition. The eventual aim is to provide mobile-Lab for multiple lab tests. We also aim to develop metal oxide gas sensor array for environmental pollution monitoring. In Nanoelectronics, our emphasis is to innovate high performance transistor architectures, utilizing alternative material options in conjunction with new device designs.

Prosenjit Sen

Assistant Professor

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Research Interests

- Interfacial Microfluidics for Lab-on-Chip & other applications
- Nanostructures for Self-Cleaning and Anti-Microbial Surfaces
- Using Interfaces to investigate Cells for Cytometry and Separation of CTC's
- 3D Heterogeneous Integration of Micro-Nano Scale Devices for System Scaling

Publications and Collaborations

- S Bansal and **P Sen,** "Axisymmetric and Non-Axisymmetric Oscillations of Sessile Compound Droplets in Open Digital Microfluidic Platform," *Langmuir,* 2017
- A Tripathy, S Sreedharan, C Bhaskarla, S Majumdar, S Peneti, D Nandi, and **P Sen,** "Enhancing the Bactericidal Efficacy of Nanostructured Multifunctional Surface using an Ultra-Thin Metal Coating", *Langmuir,* 2017
- A Tripathy, **P Sen,** B Su and WH Briscoe, "Natural and bioinspired nanostructured bactericidal surfaces," *Advances in Colloid and Interface Science,* 2017
- S Ryu, **P Sen,** Y Nam and C Lee, "Water Penetration through Superhydrophobic Mesh During a Drop Impact," *Physical Review Letters,* vol. 118, pp 014501, 2017
- S Bansal and **P Sen,** "Mixing enhancement by degenerate modes in electrically actuated sessile droplets," Sensors and Actuators B: *Chemical,* vol. 232, pp. 318-326, 2016

Research Vision

We investigate various interfacial phenomena for fluids and biological cells at micro-nano scale. We study their interaction with various micro-nano structured surfaces. These studies guide our development of technologies for wide variety of applications from lab-on-chip cytometry & sorting devices to antimicrobial surfaces. We are also interested in 3D integration of heterogenous micro-nano devices for scaling of whole systems. Such scaled systems will enable the next generation smart devices and nodes for IOT.

Rudra Pratap

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Research Interests

- Inertial, acoustic and ultrasonic MEMS transducers
- Piezo-MEMS and energy harvesting
- Mechanobiology of micro and nanoscale natural (insect) transducers
- Nanoscale patterning and material transport using electromigration

Publications and Collaborations

- Rammohan Sriramdas and **Rudra Pratap,** "Scaling and Performance Analysis of MEMS Piezoelectric Energy Harvesters", *Journal of Microelectromechanical Systems,* Vol. 26, Issue 3, pp 679-690, doi: 10.1109/JMEMS.2017.2689326, 2017

- SD Vishwakarma, AK Pandey, JM Parpia, SS Verbridge, HG Craighead, and **Rudra Pratap,** "Size modulated transition in the fluid-structure interaction losses in nano mechanical beam resonators", *Journal of Applied Physics,* Vol. 119, 194303, DOI: 10.1063/1.4950758, 2016

- Shishir Kumar, **Rudra Pratap,** and Srinivasan Raghavan, "Ultrahigh fluid diffusivity in graphene-lined nanochannels", *Applied Physics Letters,* Vol. 108, 091606, 2016

- Santanu Talukder, Praveen Kumar & **Rudra Pratap,** "Electrolithography – A New and Versatile Process for Nano Patterning", *Nature Scientific Reports,* 5:17753, DOI:10.1038/srep17753, 04 December, 2015

- Kaveri Rajaraman, Vamsy Godthi, **Rudra Pratap,** and Rohini Balakrishnan, "A novel acoustic-vibratory multimodal duet", *Journal of Experimental Biology,* Vol. 218, pp 3042-3050, 2015

Research Vision

Over the last 15 years, we have built expertise in exploiting extremely small-scale vibrations of MEMS devices for inertial, acoustic, ultrasonic, and optical sensing. Based on this experience, we are now developing a new field of multimodal spectroscopy that combines acoustic spectroscopy (using our own MEMS ultrasound transducers) and IR spectroscopy (in association with Prof Shankar Selvaraja's group) on a single chip. The hybrid system has huge potential in medical, agricultural, and environmental health monitoring.

Saurabh Arun Chandorkar

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Research Interests

- Energy loss mechanisms in micro/nano scaled resonators
- Wafer scale packaging for MEMS
- Human-computer modality enhancements
- Low cost system development for IC fabrication and characterization

Publications and Collaborations

- Dustin D Gerrard, **Saurabh A Chandorkar,** Janna Rodriguez, Ian B Flader, Lizmarie Comenencia Ortiz, Yunhan Chen, Dongsuk D. Shin, Thomas W Kenny, "Topology Optimization for Reduction of Thermoelastic Dissipation in MEMS Resonators", 2017 Transducers, *Kaohsiung,* 2017, pp. 794-797

- J Rodriguez, DD Gerrard, **Saurabh A Chandorkar,** Y Chen, GM Glaze, IB Flader, CH Ahn, EJ Ng, TW Kenny, "Wide-range temperature dependence studies for devices limited by thermoelastic dissipation and anchor damping," 2017 Transducers, *Kaohsiung,* 2017, pp. 1100-1103

- Dustin D Gerrard, Janna Rodriguez, **Saurabh A Chandorkar,** Ian B. Flader, Lizmarie Comenencia Ortiz, Yunhan Chen, Dongsuk D Shin, Thomas W Kenny, "Manipulation of heat flux paths in thermos-elastically damped resonators for Q Optimization," *IEEE MEMS,* 2017

- S. Ghaffari, **Saurabh A Chandorkar,** S Wang, EJ Ng, CH. Ahn, V Hong, Y Yang, and TW Kenny, "Quantum limit of quality factor in silicon micro and nano mechanical resonators," *Scientific reports,* vol. 3, 2013

Research Vision

Our research on robust MEMS packaging and micro/nano resonators lays foundation for productization of several MEMS devices that impact all aspects of our lives including modern communication, transport, national security and quality of life. Our research on human-computer modality aims to improve understanding of human senses and to enhance interactions with computers.

Shankar Kumar Selvaraja

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Research Interests

- Silicon Photonic Integrated circuit
- Photonics assisted exascale computing
- Microwave Photonics
- Mid-IR photonics for sensing application
- Visible-to-Mid-IR photonic circuit platform

Publications and Collaborations

- Ultra-compact low-loss broadband waveguide taper in silicon-on-insulator, Purnima Sethi, Anubhav Haldar, **Shankar Kumar Selvaraja,** *Optics Express* 25 (9), 10196-10203, 2017 (Top download)
- Tunable coupling-induced resonance splitting in self-coupled Silicon ring cavity with robust spectral characteristics, Awanish Pandey and **Shankar Kumar Selvaraja,** *Optics Letters,* vol. 42, no. 14, 2017
- All-optical wavelength multicasting in quadruple resonance-split coupled Silicon microring cavity, Awanish Pandey and **Shankar Kumar Selvaraja,** *arXiv preprint* arXiv:1711.09820, 2017
- Efficient and Tunable Strip-to-Slot Fundamental Mode Coupling, Viphretuo Mere, Rakshitha Kallega, **Shankar Kumar Selvaraja,** *arXiv preprint* arXiv:1711.09819, 2017
- High precision measurement of intensity peak shifts in tunable cascaded microring intensity sensors, Prashanth Ragavandra Prasad, **Shankar Kumar Selvaraja,** Manoj Varma, *Optics letters* 41 (14), 3153-3156, 2016

Research Vision

Our focus is to leverage the characteristics of light confinement in waveguides for high-speed communication, computing and sensing applications. On-chip integration of multiple optical functionalities; light source, detection, filters, polarizers, attenuator and power splitter could bring a paradigm shift in photonic circuits. Miniaturization of bulk optical functions can help us to realise energy efficient and highly-sensitive systems.

Srinivasan Raghavan

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Research Interests

- Growth of thin films and nanostructures
- In-situ stress-defect measurement and control
- Microstructure-electronic property correlations
- GaN, oxides and 2-D materials

Publications and Collaborations

- KVLV Narayanachari, Hareesh Chandrasekar, Amiya Banerjee, KBR Varma, Rajeev Ranjan, Navakanta Bhat and **Srinivasan Raghavan,** "Growth Stress Induced Tunability of Dielectric Permittivity in Thin Films," *J. Appl. Phys.,* 119, 014106, 2016

- Shishir Kumar, R Pratap and **Srinivasan Raghavan,** "Graphene on paper: A Simple, Low-cost Chemical Sensing Platform" *ACS Appl. Mat. Interfaces,* v. 7, p. 2189, 2015

- KK James, Tanushree Choudhury, S Dhar, SA Shivashankar and Srinivasan Raghavan, "Predictive Approach to CVD of Crystalline Layers of TMDs: The Case of MoS_2," *Nanoscale,* 7, 7802, 2015

- Dhayalan Sakthivel and **Srinivasan Raghavan,** "Si Nanowire Growth on Sapphire: Classical Incubation, Reverse Reaction and Steady State Supersaturation," *J. Appl. Phys.,* 117, 164302, 2015

- **Srinivasan Raghavan,** "Kinetic Approach to Dislocation Bending in Low Mobility Films," *Phys. Rev. B,* 83, 052102, 2011

Research Vision

Control of material chemistry, stoichiometry, microstructure and stress affects the entire spectrum from tuning fundamental physical properties to ensuring reliability in device applications. In our group, we strive to achieve this control by designing the physico-chemical aspects of thin film deposition and nanostructure synthesis.

Supradeepa V R

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Research Interests

- High Power Fiber Lasers
- Nonlinear Optical Frequency Conversion
- Integrated Photonics
- Optical Frequency Combs and Metrology
- High Bandwidth Optical Communications

Publications and Collaborations

- **Supradeepa, VR,** and Jeffrey W Nicholson. "Cascaded Raman Fiber Lasers." In Raman Fiber Lasers, pp. 35-66. *Springer, Cham,* 2017. (Invited)

- Aparanji, S, Balaswamy, V, Arun, S, & **Supradeepa, VR** (2017, October). Simultaneous Power Combining and Wavelength Conversion of High Power Fiber Lasers. *In Advanced Solid State Lasers* (pp. ATu3A-4). Optical Society of America

- Arun, S., Vishal Choudhury, V. Balaswamy, and **Supradeepa, VR.** "High Power, High Efficiency, Continuous-Wave Supercontinuum Generation using Standard Telecom Fibers." In Laser Applications Conference, pp. JM5A-31. *Optical Society of America,* 2017

- Arun, S, V Balaswamy, Santosh Aparanji, and **Supradeepa, VR.** "High power, grating-free, cascaded Raman fiber lasers." *CLEO/Europe-EQEC, 2017 Conference, IEEE,* 2017

- **Supradeepa, VR,** Yan Feng, and Jeffrey W. Nicholson. "Raman fiber lasers." *Journal of Optics 19,* no. 2 (2017): 023001 (Invited) (Selected as Paper of the week)

Research Vision

High power lasers are ubiquitous with a multitude of industry, consumer and defense applications. However, a fundamental limitation exists in the technology with regard to wavelengths (colors) of emission. Despite being a mature technology, only a few wavelengths of emission are available, limiting its adaptation to a small fraction of potential applications. Our work is on overcoming this problem and advancing a new, disruptive laser technology referred to as Cascaded Raman lasers to develop scalable, powerful lasers at all wavelengths.

Sushobhan Avasthi

Assistant Professor
PhD (Princeton University)

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www.cense.iisc.ac.in/savasthi

Research Interests

- High-efficiency perovskite thin-film solar cells
- Integration of semiconducting oxides to silicon, forming oxide/silicon heterojunction devices
- Functional oxide devices for applications such as photovoltaics, sensing, and memory
- Integration of solar cell on novel substrates such as steel

Publications and Collaborations

- AS Chouhan, N Prathibha J, S Hadke, S Raghavan, **S Avasthi,** "Large grained and high charge carrier lifetime $CH_3NH_3PbI_3$ thin-films: Implications for perovskite solar cells," *Current Applied Physics 17,* 1335, 2017

- P Ravindra, R Mukherjee, **S Avasthi,** "Hole-Selective Electron-Blocking Copper Oxide Contact for Silicon Solar Cells," *IEEE Journal of Photovoltaics 7,* 1278, 2017

- KA Nagamatsu, **S Avasthi,** G Sahasrabudhe, G Man, J Jhaveri, A Berg, J Schwartz, A Kahn, S Wagner, JC Sturm, "Titanium dioxide/silicon hole-blocking selective contact to enable double-heterojunction crystalline silicon-based solar cell," *Applied Physics Letters 106,* 123906, 2015

- KA Nagamatsu, **S Avasthi,** J Jhaveri, JC Sturm, "A 12% Efficient Silicon/PEDOT:PSS Heterojunction Solar Cell Fabricated at <100 C," *IEEE Journal of Photovoltaics,* 4, 260, 2014

- **S Avasthi,** W. McClain, G Man, A Kahn, J Schwartz, and JC Sturm, "Hole-Blocking Titanium-Oxide/Silicon Heterojunction and its Application to Photovoltaics," *Applied Physics Letters 102,* 203901, 2013

Research Vision

To solve societal challenges in energy and sensing, we need to look beyond conventional silicon electronics. In our group we fabricate electronic devices with unusual architectures, materials and fabrication techniques. In one project we are trying to make solar cells on steel sheets and flexible glass. We work on both materials science and engineering challenges, with the goal of realizing an actual product.

KN Bhat

Emeritus Professor
PhD (IIT Madras)

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www.cense.iisc.ac.in/knbhat

Research Interests

- Double Gate SOI MOSFETs modelling and technology
- AlGaN/GaN hetrojunction FETs and Normally OFF Devices
- MEMS Pressure Sensors and industry interaction on MEMS Sensors Design and Technology
- Carbon Nanotube Field-Effect Transistors
- Focussed Ion Beam (FIB) Implantation for Nano structured device doping applications

Publications and Collaborations

- Graphene Electrodes as Barrier-Free Contacts for Carbon Nanotube Field-Effect Transistors, PR Yasasvi Gangavarapu, Punith C Lokesh, **KN Bhat,** and AK Naik, *IEEE Transactions on Electron Devices,* VOL. 64, NO. 10, 1335-1339, 2017.

- Gallium-Doped Piezoresistive Sensor With Optimized Focused Ion Beam Implantation Akshdeep Sharma, Suma BN, **KN Bhat,** and AK Naik, *IEEE Journal of Microelectromechanical Systems,* No3. March 2017

- Surface modification of textured Silicon and its wetting Behavior" *Journal of Adhesion Science and Technology (UK),* Vijay Kumar, **KN Bhat,** NN Sharma Vol.132, (Dec, 2014)

- Analysis of size quantization and temperature effects on the threshold voltage of thin silicon film Double-Gate MOSFET, A Medury, **KN Bhat,** and Navakanta Bhat, *J. Appl. Phys.,* Vol 114, pp 014507-18. (2013)

- Technology Transfer to (i) Bharat Electronics Ltd and (ii) SITAR for Pressure sensor chip Design and fabrication of Pressure sensors for operation in the pressure range 0-150mbar, 0-600mbar, 0-1.2 bar, 0-200 bar and 0-400 bar

Research Vision

Integration of Electronics and MEMS on a single chip.

MM Nayak

Emeritus Professor
PhD (IISc)

mmnayak@iisc.ac.in
www.cense.iisc.ac.in/m-m-nayak

Research Interests

- MEMS Packaging
- Pressure Transducers – Conventional and Advanced
- Graphene/RGO/GO based Temperature Sensors
- System Integration, Testing, Calibration etc.

Publications and Collaborations

- Scalable fabrication of highly sensitive flexible temperature sensors based on silver nanoparticles coated reduced graphene oxide nanocomposite thin films, Nagarjuna Neella, V Gaddam, **MM Nayak,** Dinesh NS and K Rajanna, Sensors & Actuators: *A. Physical,* 2017, Accepted (In Press)

- Morphology controlled synthesis of Al doped ZnO nanosheets on Al alloy substrate by low-temperature solution growth method, V Gaddam, RR Kumar, M Parmar, GRK Yaddanapudi, **MM Nayak,** and K Rajanna, *RSC Advances,* 5 (18), 13519-13524, 2015

- Synthesis of ZnO nanorods on flexible Phynox alloy substrate: Influence of growth temperature on their properties, V Gaddam, RR Kumar, M Parmar, **MM Nayak,** and K Rajanna, *RSC Advances,* 5 (109), 89985-89992, 2015

- Graphene-Nickel Composite Films on Flexible PCB for Temperature Monitoring, Vaishakh Kedambaimoole, Nagarjuna Neella, V Gaddam, **MM Nayak,** and Konandur Rajanna, *Proceedings of the 12th IEEE International Conference on Nano/Micro Engineered and Molecular Systems,* PP: 173-176, April 9-12, Los Angeles, USA, 2017

Research Vision

At present, in India, most of the Sensors/Transducers required for Aerospace and Biomedical Applications are being imported from other countries, at huge costs. Our aim is to develop low-cost, high-performance, indigenous technology and package these systems for the required application, in-house. This, we believe, will make India more self-sufficient and help in catapulting India to one of the leading positions in technology.

SA Shivashankar

Emeritus Professor
PhD (Purdue)

shivu@iisc.ac.in
www.cense.iisc.ac.in/s-shivashankar

Research Interests

- Chemical synthesis of nanomaterials, nanostructured thin films by vapour and solution-based methods: CVD, ALD, Pyrolysis, sol-gel
- Development of chemical precursors; exploring applications of these materials
- Lead role in INUP, extending CeNSE facilities to researchers from around Indian and beyond

Publications and Collaborations

- An integrated X-band inductor with nanoferrite-film core, R Sai, Suresh DK, M Yamaguchi, N Bhat, **SA Shivashankar,** *IEEE Magnetics Letters,* 8, 2017

- Predictive approach to CVD of crystalline layers of TMDs: The case of MoS_2, Kranthi Kumar V, Dhar S, Choudhury TH, **SA Shivashankar,** Raghavan S. *Nanoscale,* 7(17), 2015

- Conformal cytocompatible ferrite coatings facilitate the realization of a nanovoyager in human blood, Pooyath Lekshmy Venugopalan, Ranajit Sai, Yashoda Chandorkar, Bikramjit Basu, **SA Shivashankar,** Ambarish Ghosh, et al. *Nano Letters,* 14(4), 2014

- A composition-dependent "re-entrant" crystallographic transition in the substitutional metal acetylacetonate complex ($Cr_{1-x}Gax$)(acac)3, M Srinidhi Raghavana, Piyush Jaiswal, B Nalini, G Sundarama, **SA Shivashankar.** ca *Polyhedron,* 70, 2014

- Microwave-assisted, surfactant-free, synthesis of air-stable copper nanostructures and their SERS study, M I Dar, S Sampath, **SA Shivashankar,** *J. Materials Chemistry,* 22, 2012

Research Vision

Abrading/shaping metals is a big industry that uses (a) tools made by energy-intensive processes (b) large volumes of eco-unfriendly lubricants. Based on lab-scale results, we want to fabricate, at low temperatures, abrading/shaping tools which are self-lubricating, greatly reducing the eco-footprint of a huge industry.

S Mohan

Emeritus Professor
PhD (S.V. University, Tirupathi)

smohan@iisc.ac.in
http://www.cense.iisc.ac.in/s-mohan

Research Interests

- High-K dielectric thin films for next generation electronic devices
- MEMS Gas Sensors
- Shape Memory Micro Actuators
- Multilayer dielectric stacks for laser gyros
- Faculty-In-Charge for Industry Affiliate Program and Strategic Sector Interaction

Publications and Collaborations

- Optimization of HfO_2 films for high transconductance back gated graphene transistors, Kolla Lakshmi Ganapathi, Navakanta Bhat, and **Sangeneni Mohan,** *Applied Physics Letters* 103, 073105, 2013

- Development of bi-axial preferred orientation in epitaxial NiMnGa thin films and its consequence on magnetic properties, Amit Sharma, **Sangeneni Mohan,** Satyam Suwas, *Acta Materialia* Vol. 113, Pages 259-271, 2016

- Super Defect Inside Photonic Crystal Ring Resonator to Enhance Q Factor, Srinivasulu T, V R Kolli, T Badrinarayana, Gopalkrishna Hegde, **Sangeneni Mohan,** T Srinivas, *Optical Engineering* - 55(3), 035103, 2016

- Performance and Reliability of Gd2O3 and Stacked Gd2O3-Eu2O3 Metal-Insulator-Metal Capacitors, Revathy Padmanabhan, Navakanta Bhat, and **Sangeneni Mohan,** *IEEE Transactions on Electron Devices,* Vol. 60, No. 5, pp. 1523-1528, 2013

- Effect of contact stresses on shape recovery of NiTiCu thin films, NVR Vikram Gelli, MS Bobji, **Sangeneni Mohan,** *Thin Solid Films,* Volume 564, Pages 306-313, ISSN 0040-6090, 2014

Research Vision

Development of MEMS and Nano sensors for Strategic Sector.

R Muralidharan

Emeritus Professor
PhD (IISc)

rmuralidharan@iisc.ac.in
www.cense.iisc.ac.in/r-muralidharan

Research Interests

- III-Nitrides
- High power RF devices
- Gallium oxide based devices

Publications and Collaborations

On the origin of kink effect in current-voltage characteristics of AlGaN/GaN High Electron Mobility Transistors, Janesh K Kaushik, V Raman Balakrishnan, Brishbhan Singh Panwar, and **Rangarajan Muralidharan,** *IEEE Transactions on Electron Devices,* VOL. 60, NO. 10, p3351(2013)

"Thickness Dependent Parasitic Channel Formation at AlN/Si Interfaces", Hareesh Chandrasekar, KN Bhat, **Rangarajan Muralidharan,** Srinivasan Raghavan & Navakanta Bhat, *Scientific Reports 7,* Article number: 15749(2017)

UV Detector based on InAlN/GaN-on-Si HEMT Stack with Photo-to-Dark Current Ratio > 107, Sandeep Kumar, Anamika Singh Pratiyush, Surani B Dolmanan, Sudhiranjan Tripathy, **Rangarajan Muralidharan,** and Digbijoy N Nath, *Appl. Phys. Lett. 111,* 251103 (2017)

Research Vision

Develop wide band gap based UV Focal plane arrays (UV FPA).
Establish a platform for research and pilot production of wide band gap devices for high power applications.

Technology Managers

Better Management for Better Research

Nanotechnology research needs advanced equipment, electronics, and software. CeNSE offers state-of-the-art laboratories and technical facilities that are open to users to further their nano research goals. These facilities are managed by a dedicated group of highly qualified and skilled Technology Managers, with help from technical staff. The Technology Managers work closely with the research groups on various projects. Together they optimize the experimental setup and the technical infrastructure for each new experiment.

Vijay Mishra

Chief Technology Officer

PhD (BARC)
vijaymishra@iisc.ac.in

Responsibilities

MNCF (Micro and Nano Characterization Facility) and Systems Engineering Facility.

Monitoring new technologies at CeNSE and assessing their market potential to become new start-up products or services.

Industrial interactions and initiating related research projects from industries.

Delivering quality services/training around CeNSE centralized facilities to industries, external academic communities.

Savitha P

Chief Operating Officer

PhD (IISc)
savithap@iisc.ac.in

Responsibilities

Responsible for NNFC fab operation including all the process bays, utilities and fab management.

Vijayaraghavan Madakasira

Chief Technologist

PhD (IISc)
vijayaraghav@iisc.ac.in

Responsibilities

Process development and integration. Project management and execution. Product Development, Technology Transfer and Business Development. Nodal contact person for project and technology services and industry interaction.

Sanjeev Kumar Shrivastava

National Coordinator
Indian Science Technology and Engineering facilities Map (I-STEM)
PhD (IIT Delhi)
sanjeevs@iisc.ac.in

Responsibilities

National Coordinator of Indian Science, Technology and Engineering facilities Map (I-STEM) initiative. Coordinator of Indian Nanoelectronics Users Program (INUP), a unique program initiated in 2008 to open up the sophisticated facilities at CeNSE for use by researchers from around the country. Coordinating Project Management Office.

Arun Kumar KA

Technology Manager
BTech (Manav Bharathi University)
arunkumar@iisc.ac.in

Responsibilities

Responsible for all the utilities and maintenance at NNFC, MNCF and CeNSE building.

Raghupathy N

Technology Manager
DECE (VET BVL)
raghupathyn@iisc.ac.in

Responsibilities

Incharge of personnel, equipment and processes at Wet etch, Diffusion, Thin films and Inline characterization bay, Breakdown and Periodic maintenance of cleanroom equipments.

Siva Prasad Raju Penmetsa

Technology Manager
BTech MS (Louisiana Tech University)
sivapenmetsa@iisc.ac.in

Responsibilities
Process Development and Integration

Smitha Nair

Technology Manager
MSc Electronics (Bharathiar University)
smithanair@iisc.ac.in

Responsibilities
Managing complete operations of Lithography and dry etch bays.

Suma BN

Technology Manager
B.E. (VTU)
sumabn@iisc.ac.in

Responsibilities
Managing and executing INUP projects (Indian Nanoelectronics Users Program). Providing technical service to other academic and industrial projects.

Suresha SJ

Technology Manager
PhD (IISc)
sureshasj@iisc.ac.in

Responsibilities

Managing MNCF (Micro and Nano Characterization Facility) operations.

Coordinate and interact with wide user community of MNCF, including students and researchers from all over India and industry users.

Varadharaja Perumal S

Technology Manager
M.Tech. (Sastra Univ.)
vardhu@iisc.ac.in

Responsibilities

Major responsibilities include oversight of the technical activities of MNCF and its staff, streamlining of MNCF operations through making policies, interacting with IISc users and IISc Faculty.

Academics

Exceptional Education

As part of its focus to deliver exceptional education and pursue cutting edge research, the centre offers MTech and PhD degree programs in the area of nanoscience and engineering to students.

MTech Degree Program

The MTech program is focused equally on coursework and research projects. The coursework prepares the students by providing training in interdisciplinary areas such as Solid State Physics, Nanomaterials, Nanoelectronics, MEMS and NEMS, Nanophotonics, Biosensors, Micro/Nano Fluidics, with hands-on experiments on Nanofabrication and Nano Characterization techniques. The MTech program is also unique in its emphasis of entrepreneurship and social impact of technology in its curriculum.

PhD Degree Program

The Centre offers a Direct Admission (NE stream) doctoral degree program conducted by its core faculty. Recognizing the need for interdisciplinary research, the Centre also conducts an Interdisciplinary PhD program (NA stream), jointly with several other departments across IISc.

Both these programs involve rigorous course work followed by thesis research in various fields, including Nanomaterials and Nanostructures, Electronics, Nanofluidics, Nanophotonics, Nanobiotechnology, Plasmonics, Sensor Systems, Computational Modeling etc.

Direct Admission (denoted as NE stream)

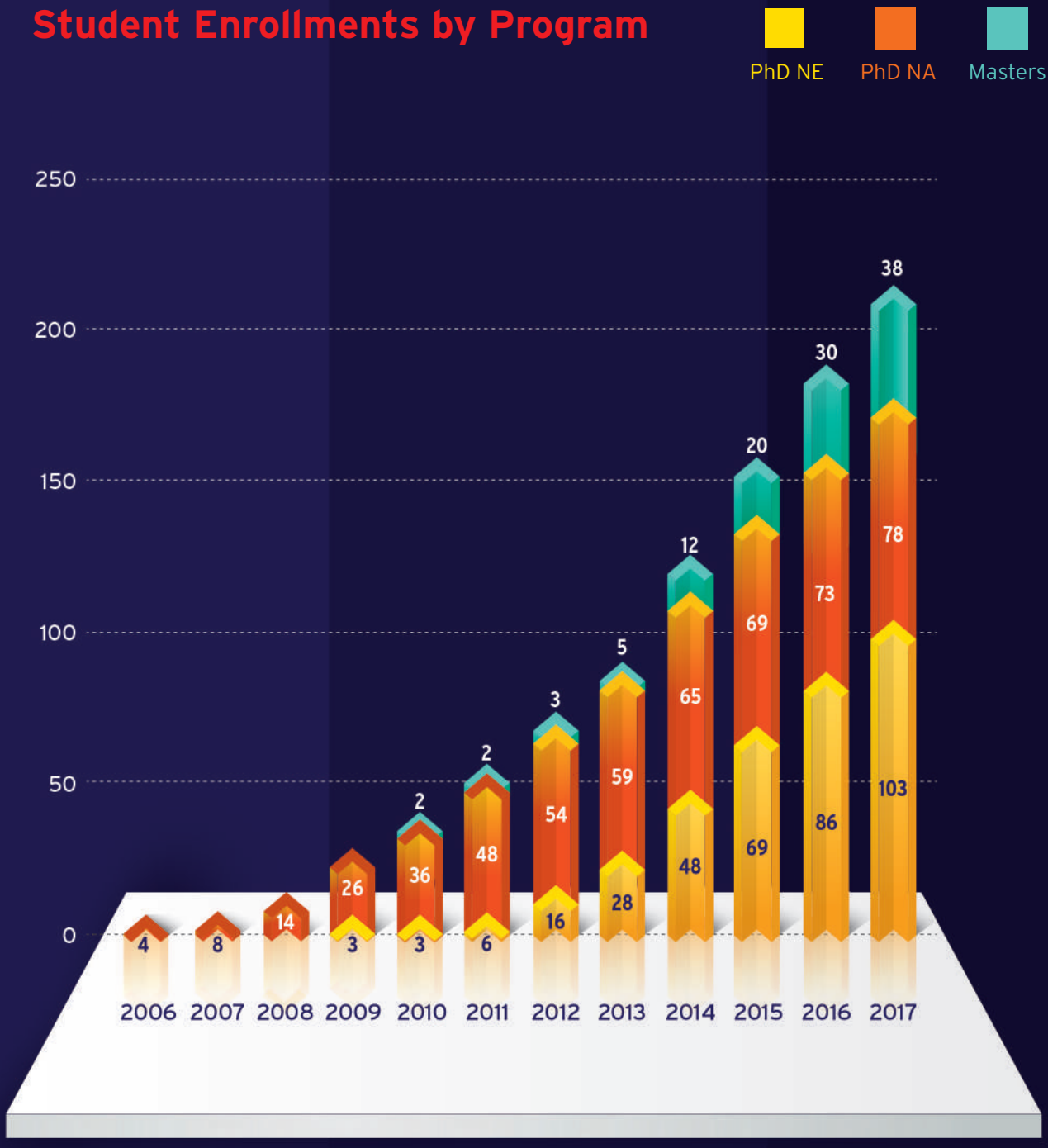
The NE stream provides direct admission to the PhD program of the Centre run by its faculty.

Interdisciplinary Program (denoted as NA stream)

The second stream is an interdisciplinary program conducted by the Centre in conjunction with several other departments across the Institute. A student admitted under this program has two advisors from two different departments. The admission into this program is offered against a specified research project proposed by the two advisors. A list of all projects is made available to admission seekers before the interview.

For more details, please visit: http://www.cense.iisc.ac.in/content/degree-programs

Student Enrollments by Program



Summer Program

Starting from 2013, the centre conducts a training program every summer, for promising Undergraduate and Masters students from India and abroad, selected through a rigorous and competitive process. The training is of 8 -10 weeks duration and covers a variety of research topics under the broad umbrella of Nanoscience and Engineering.

Research

Interdisciplinary Synergy

NanoBiotechnology

NAVAKANTA BHAT

RUDRA PRATAP

SRINIVASAN RAGHAVAN

Electronics

DIGBIJOY NATH

SUPRADEEPA VR

S MOHAN

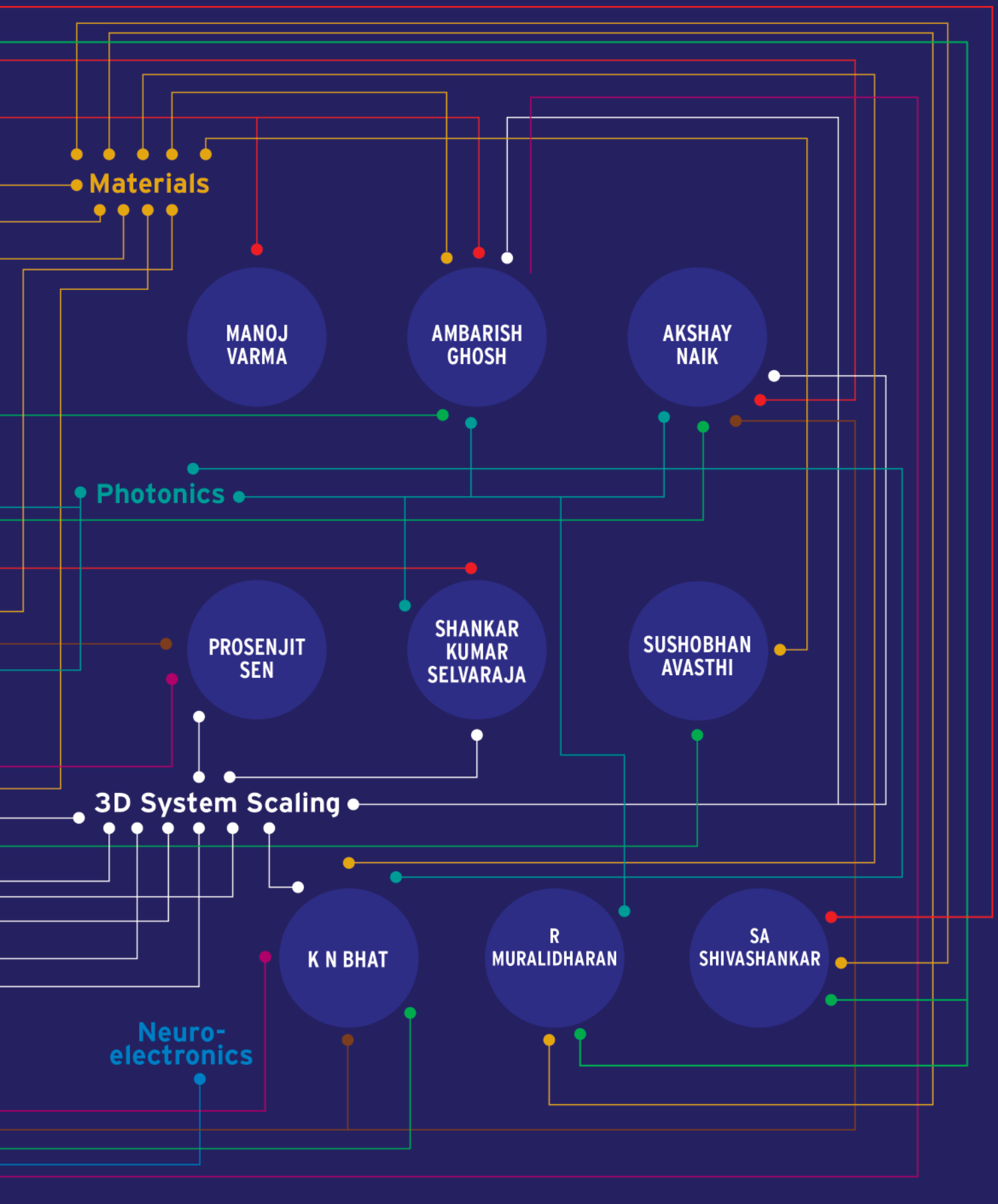
Microfluidics

SAURABH CHANDORKAR

M M NAYAK

MEMS/NEMS

The most striking feature of the Centre is its interdisciplinary research culture. Being housed within the IISc campus gives the Centre further access to world-class academic expertise in many disciplines – from Mathematics and Computer Science to Chemistry, Physics and many others. The researchers benefit from this unusually high degree of interdisciplinary synergy.



Research Focus Areas

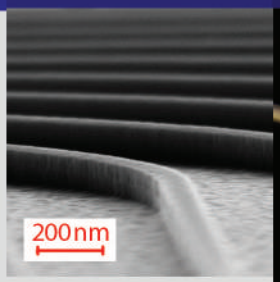
Research at CeNSE covers both – fundamental questions in the basic sciences and the development of technologies and devices for direct societal impact. With the involvement of almost 50 faculty members across 14 departments, the thrust is on interdisciplinary research, with particular focus on the following areas:

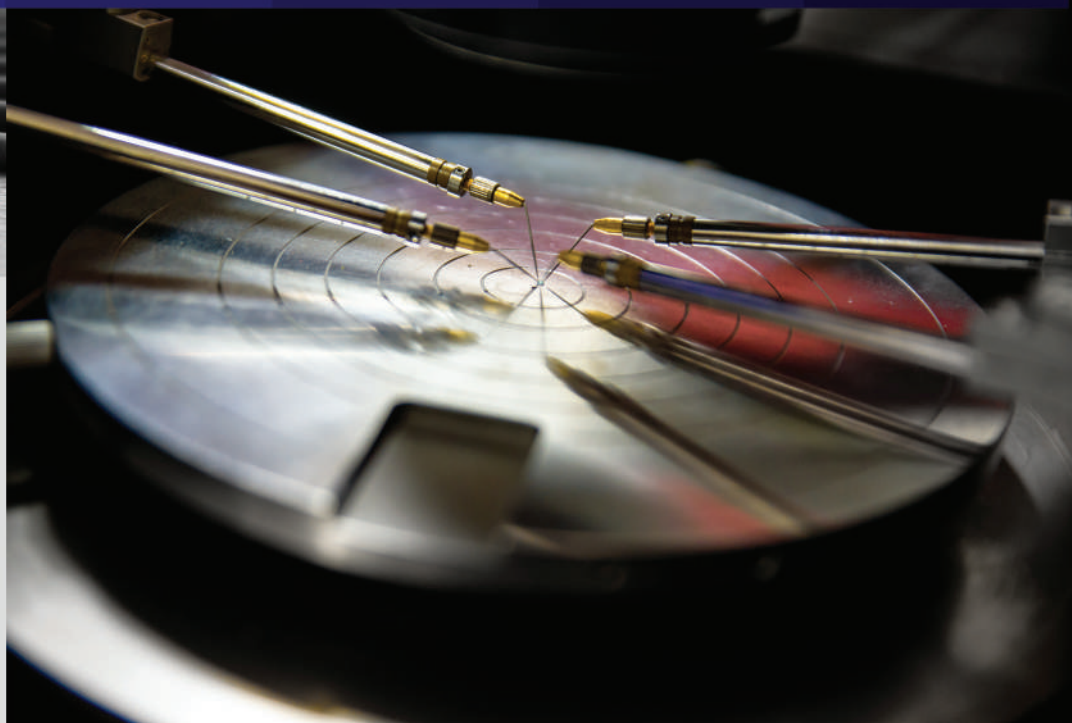
Electronics

Nanoelectronics pertains to the investigation of transport and behavior of electrons (and holes) at the nanoscale, which leads to realization of technologically critical devices besides presenting an excellent platform for exploring exciting physics.

Teaching electrons new tricks – as Nobel Laureate H Kroemer put it, has enabled applications such as power amplification using transistors, digital switch, CMOS technology, sensing, light emitting diodes, etc. Current research efforts at CeNSE in nanoelectronics & optoelectronics are directed along the following major themes:

- GaN Technology
- Post-silicon Options
- Solar Cells
- Gas-sensing, Bio-sensing
- Device Modeling and Simulation
- Devices on 2D Materials
- Gallium oxide electronics

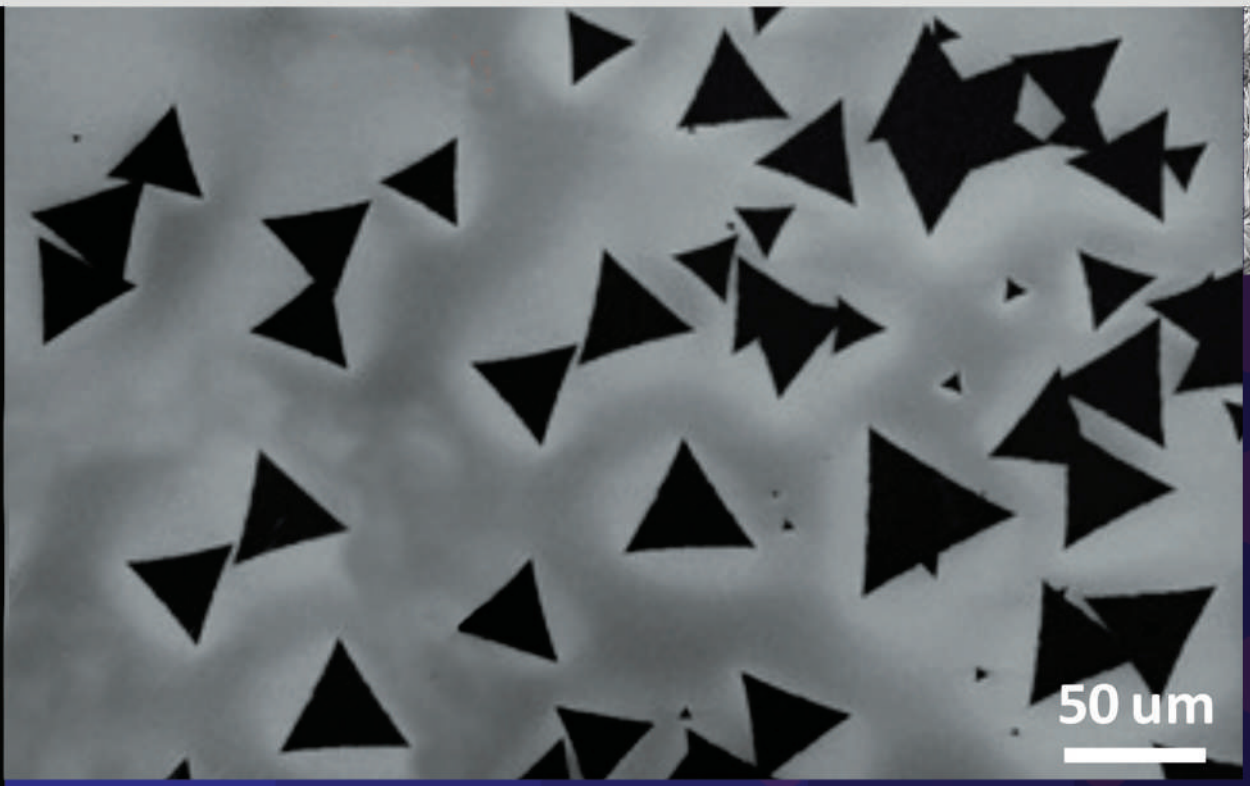


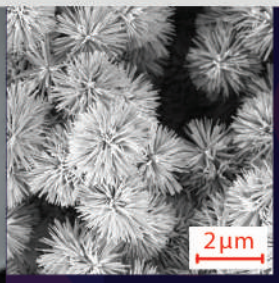


Materials

Development of novel technologies for depositing silicon, gallium nitride, oxide and organic semiconductors. Study and engineering of the interface between different semiconductors. Specifically,

- Design/construction of an in-house chemical vapour deposition (CVD) reactor for gallium oxide
- Stress engineered epitaxial and non-epitaxial oxide films on Si
- Electrochemical synthesis of nanoporous oxide membranes
- Synthesis of nanopowders and nanostructures using combustion, co-precipitation, controlled pyrolisis sonication, and microwave irradiation
- Metal-organic CVD for oxides





MEMS/NEMS

Micro-Electro-Mechanical Systems (MEMS) and its nano-scale counterpart, Nano-Electro-Mechanical Systems (NEMS), refer to the entire technology of design, fabrication, and deployment of micro and nano-scale mechanical structures tightly coupled with, and many a times co-fabricated with, the required electronics for sensing and actuation applications. These devices are not only important for practical applications but are also of immense importance in fundamental research. MEMS business worldwide is currently estimated to be close to Rs 5 lakh crores. These include sensors, accelerometers, actuators which form critical components in a range of products including cars, cell phones and inkjet printers. Current research efforts at CeNSE in the area of NEMS/MEMS include:

- MEMS and NEMS Sensors
- Vibratory Mechanobiology
- Materials for MEMS/NEMS
- Fundamental research in NEMS/MEMS

NanoBiotechnology

The central theme of NanoBiotechnology research at CeNSE is to use nanoscale devices, systems and technologies for understanding complex biological phenomena, and to develop novel diagnostic and therapeutic solutions for biomedical applications.

- Biosensors
- Nanoswimmers for targeted delivery and microsurgery
- Biomolecular interactions

Microfluidics

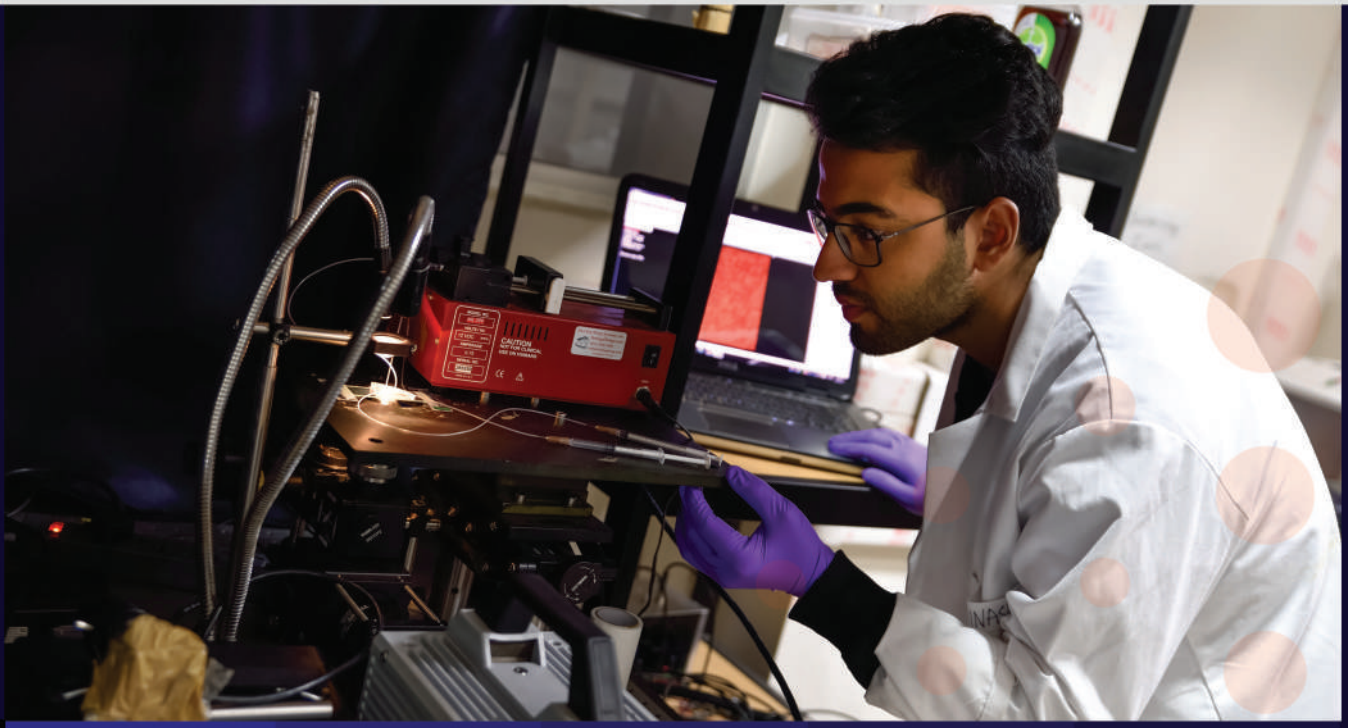
In Micro-Nanofluidics various phenomena related to fluids, their interfaces and their complex interactions with other soft / hard matter at micro-nanoscale is investigated. Behavior of a fluid in such a tiny volume is quite different from that of the bulk. For example, tiny volumes of liquid have higher pressure than in bulk. Many of these differences arise from the increasing influence of the fluid surface and surface forces at these scales. Dominance of these surface forces at tiny scales enables some insects to walk on water. The research in this area is focused on multiple interesting scientific problems including interfacial dynamics, nano-swimmers, DNA sequencing & bio-sensing, liquid-solid interfaces, probing cells in microfluidic devices, etc. These fundamental explorations are leading to technology solutions in the fields of healthcare, water conservation, industrial / scientific metrology, etc. Current research efforts at CeNSE in Micro-Nanofluidics are directed along the following major themes.

- Interfacial Microfluids
- Artificial nano-swimmers
- Droplet based devices
- Lab-on-a-Chip
- Electron bubbles in liquid helium

Neuro-electronics

Neuro-electronics or Neurotechnology is a rather new research discipline that broadly relates to interfacing the neurons of the nervous system with electronic devices. We have been successful in interfacing live cultured neurons with planar multi-electrode arrays to understand neuronal network topology. This research has now expanded and become inclusive in its scope, involving faculty from diverse science and engineering disciplines like Neuroelectrophysiology, Neuro-optics, Microfabrication, Electronics, Signal Processing and Machine Learning.

- Neuronal networks
- Interfaces to neuronal networks
- Neuroelectronic hybrid systems



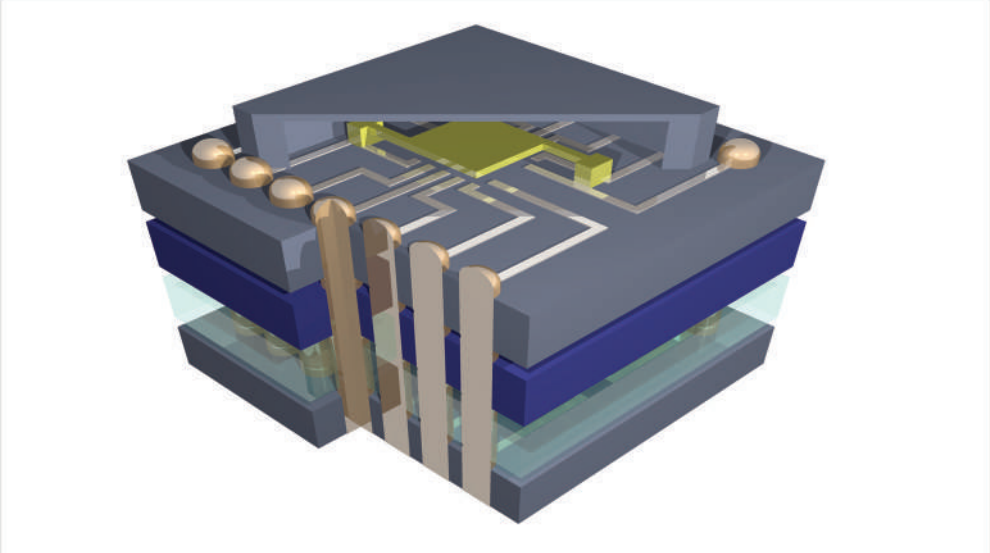
Photonics

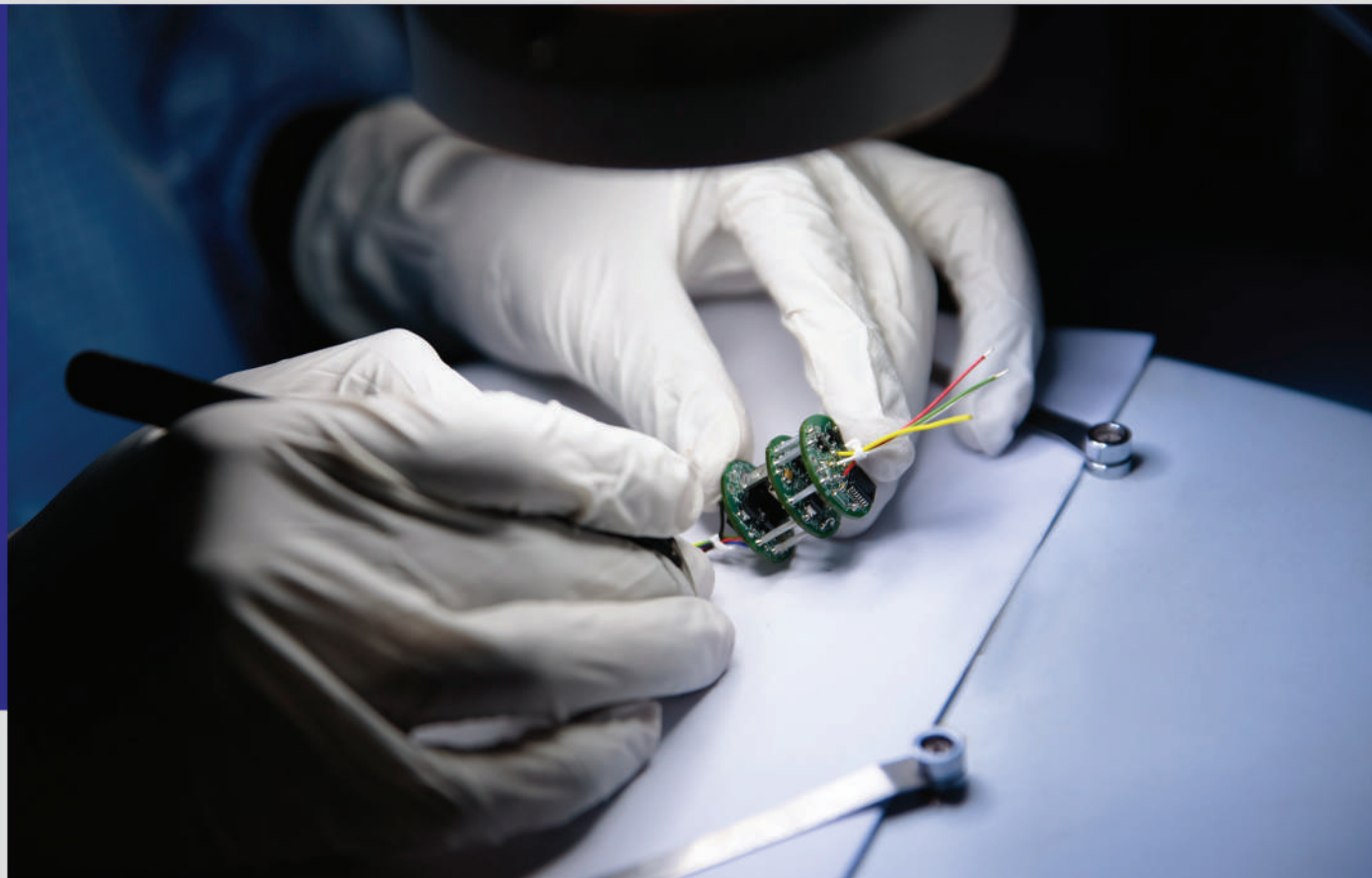
Photonics is a field concerned with the science of light and developing applications for it. It encompasses all aspects related to the generation, processing, transmission and detection of light and its interaction with matter at various length scales. Several scientifically interesting and technologically important phenomena arise and application areas are extensive. Current research efforts at CeNSE in Photonics are directed along the following major themes:

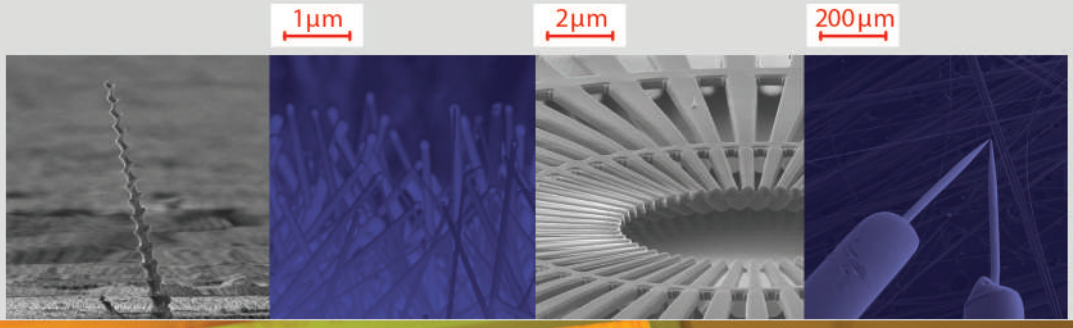
- Optical Sensing
- Integrated Optics
- Lasers
- Plasmonics and Metamaterials
- Optical Data/Tele-Communications

3D System Scaling

In near future Internet of Things (IOT) will be a key enabler in realizing better healthcare, improved structural monitoring, better resource management, automated industries/home, smart city, etc. IOT requires pervasive use of smart sensor systems. Such systems need to have small form-factor, use negligible power and perform in a severely resource challenged environment. These stringent requirements will be satisfied by integrating various transducers, controllers, communication devices and energy solutions on a single chip in a tiny volume. CeNSE is developing technologies to solve several fundamental challenges in order to enable 3D integration of heterogeneous devices in a single platform.






1µm
2µm
200µm


WATER

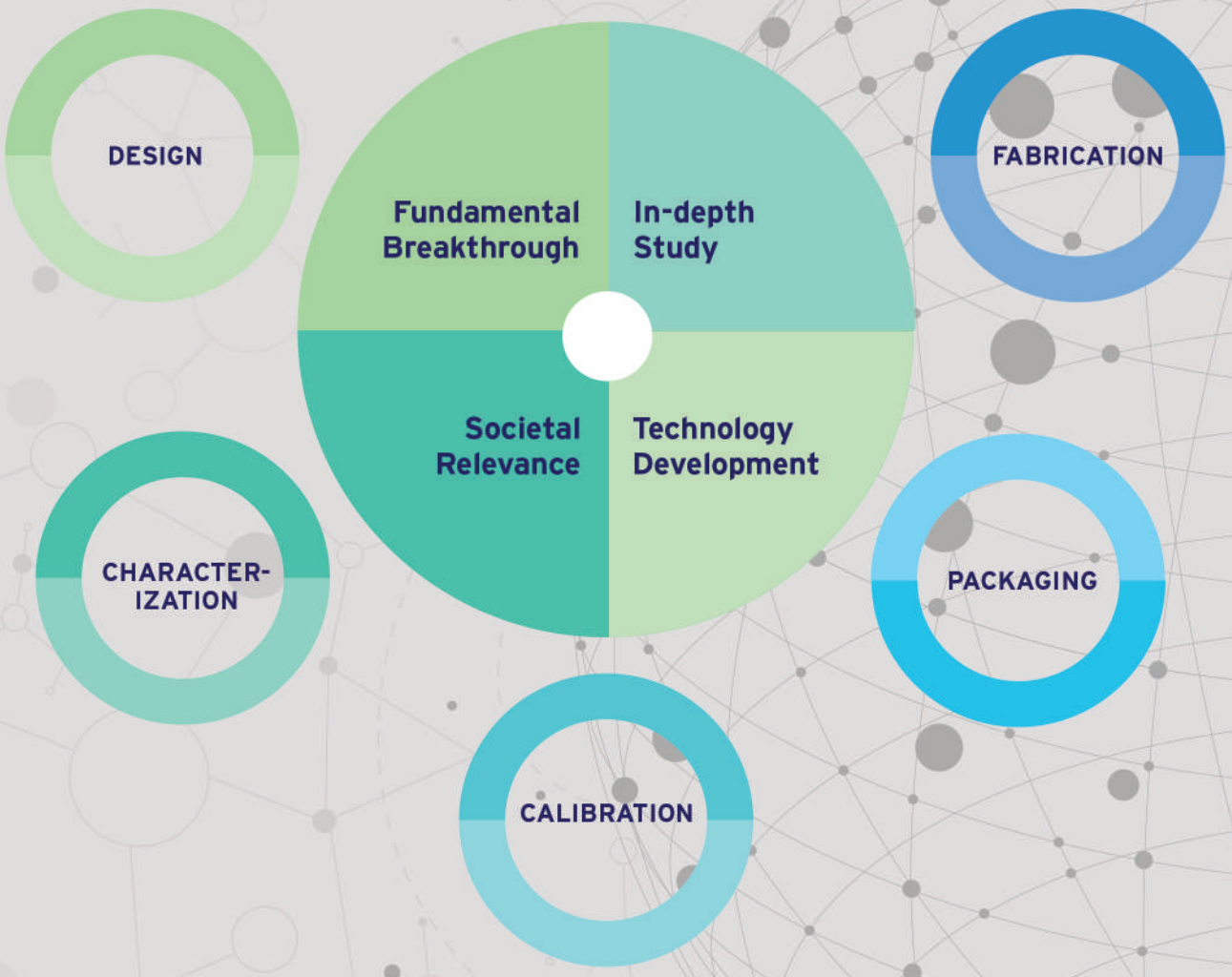
Research

State-of-the-art Facilities

- Biophotonics and Bioengineering
- Bio Sensors Lab
- Functional Thin Films Lab
- Gas Sensors Lab
- Heterojunction Lab
- MEMS/MOEMS Lab
- NEMS
- Neuro-electronics Lab
- Non-linear Photonics and High Power Lasers Lab
- Optics, Nanostructures and Quantum Fluids
- Photonics
- Polymer Process Lab
- Photovoltaics and Energy Lab

The Centre has been built around two state-of-the-art central facilities – The National Nano Fabrication Centre (NNFC) and the Micro and Nano Characterization Facility (MNCF). Both are national user facilities, i.e. they are accessible to outside academic and industrial users.

Supporting the central facilities are the MEMS and IC Packaging lab, Systems Lab, and 13 other functionally distinct laboratories managed by various research groups. In keeping with the Centre's collaborative and open atmosphere, access to these laboratories can also be provided after appropriate permissions.



NNFC

National Nano Fabrication Centre

The National Nano Fabrication Centre (NNFC) is a CMOS/MEMS/NEMS capable research facility. This Centre houses state-of-the-art research equipment for both fabrication and in-line characterization of the devices in a comprehensive 14,000 sq. ft. clean-room facility with capability for:

Lithography

Optical and e-beam lithography with resolution of 1 µm and 10 nm, respectively.

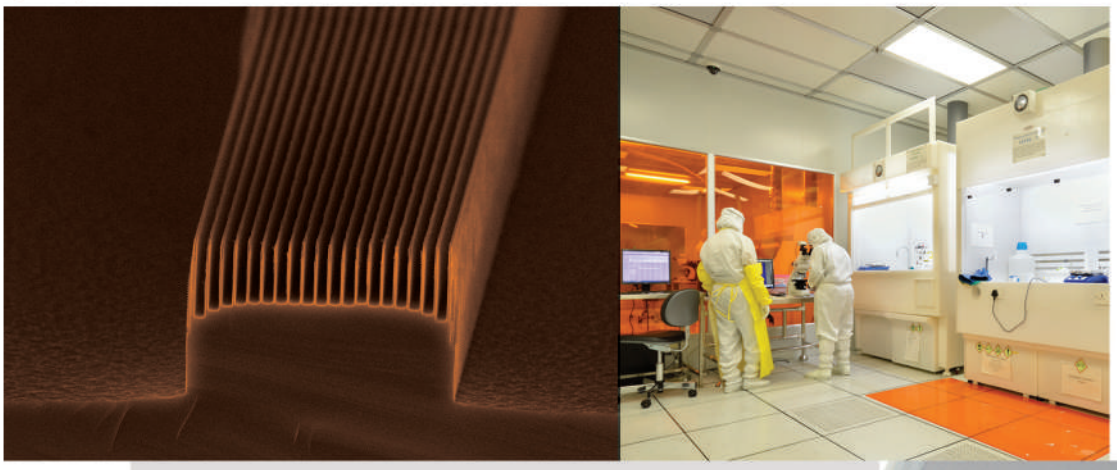
Deposition

Developing unit processes for chemical and physical vapour deposition (CVD & PVD) of most commonly used semiconductors and dielectrics, such as Si, SiGe, Ge, SiO_2, SiN_x, Al_2O_3, TiO_2, etc.

Etching

Developing unit processes for wet and dry etching of most commonly used semiconductors and dielectrics.


FILMS
WET ETCH
LITHOGRAPHY



Packaging

Fabricating complete MEMS sensors, gas sensors, GaN HEMTs, Si solar cells, novel 1D and 2D devices including graphene and MoS_2, and photonic circuits.

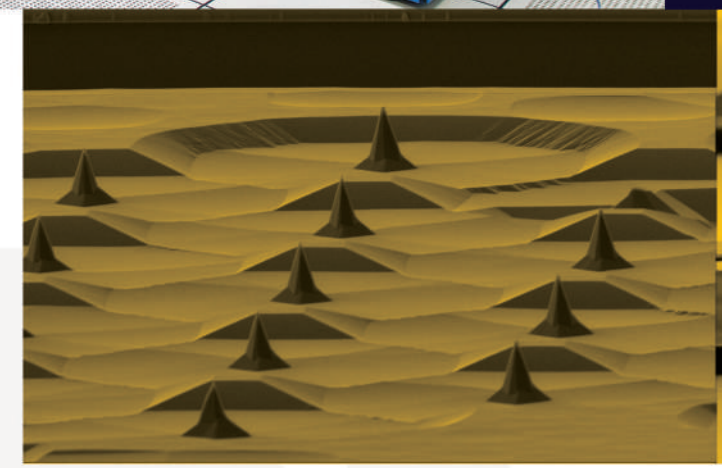
Process Development and Integration

Developing new and customized processes for MEMS/NEMS devices, microfluidic structures, and semiconductor devices for industries and other laboratories.

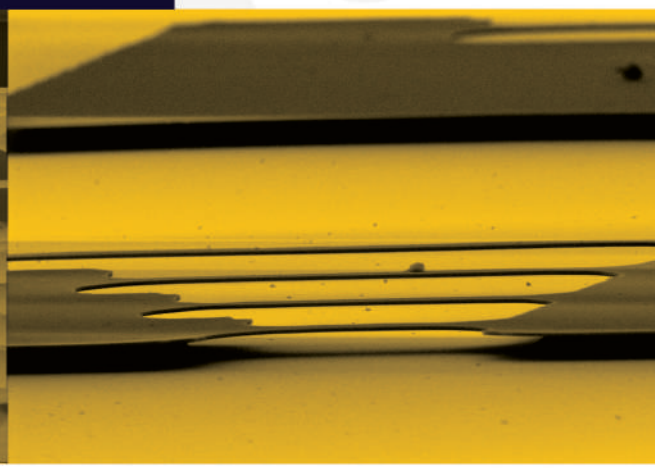
In-line Characterization

In-line characterization, using various metrology tools.

For more details on nanofabrication facilities, please visit http://nnfc.cense.iisc.ac.in/



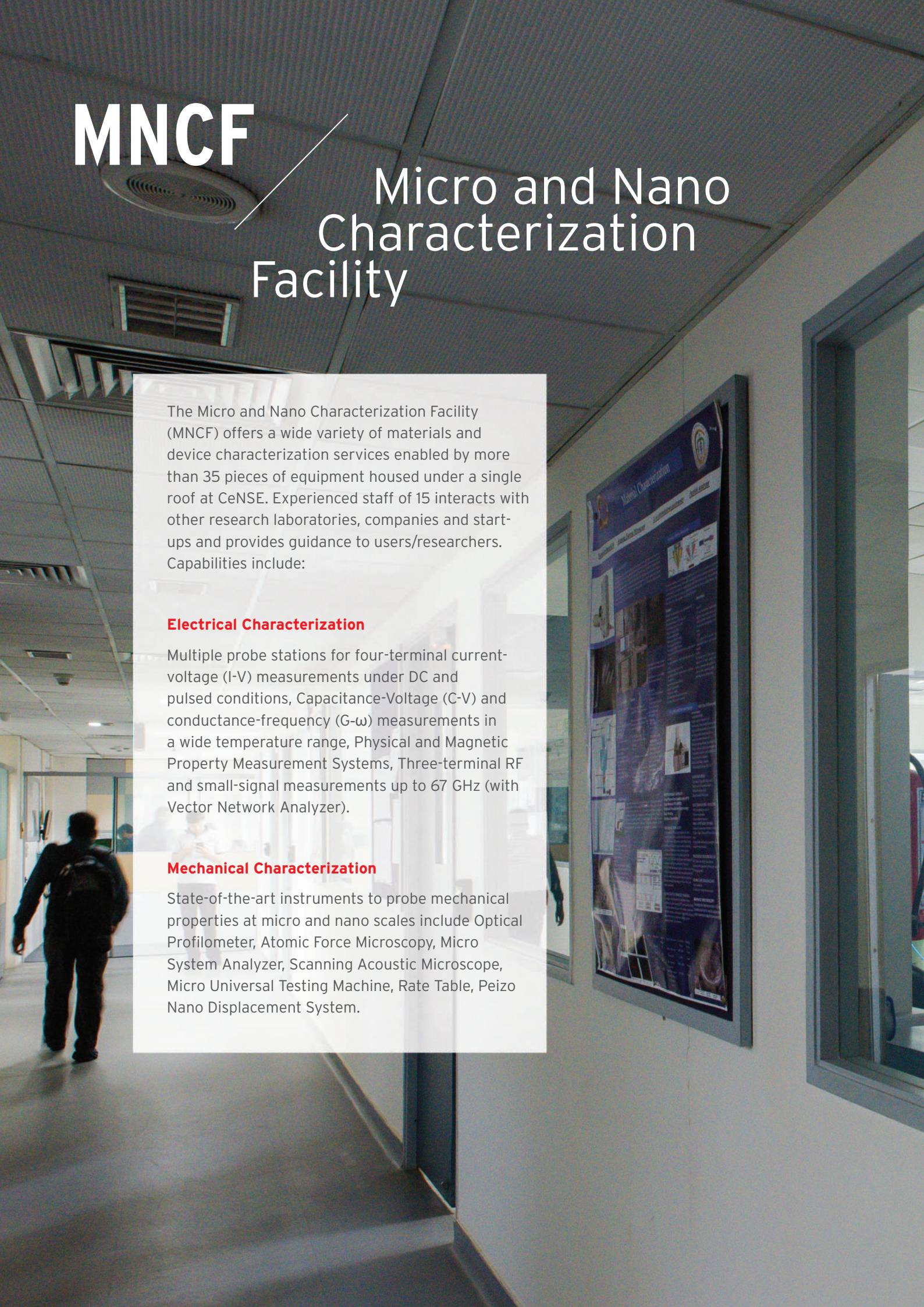
2µm



2µm

MNCF

Micro and Nano Characterization Facility



The Micro and Nano Characterization Facility (MNCF) offers a wide variety of materials and device characterization services enabled by more than 35 pieces of equipment housed under a single roof at CeNSE. Experienced staff of 15 interacts with other research laboratories, companies and start-ups and provides guidance to users/researchers. Capabilities include:

Electrical Characterization

Multiple probe stations for four-terminal current-voltage (I-V) measurements under DC and pulsed conditions, Capacitance-Voltage (C-V) and conductance-frequency (G-ω) measurements in a wide temperature range, Physical and Magnetic Property Measurement Systems, Three-terminal RF and small-signal measurements up to 67 GHz (with Vector Network Analyzer).

Mechanical Characterization

State-of-the-art instruments to probe mechanical properties at micro and nano scales include Optical Profilometer, Atomic Force Microscopy, Micro System Analyzer, Scanning Acoustic Microscope, Micro Universal Testing Machine, Rate Table, Peizo Nano Displacement System.


AXIS

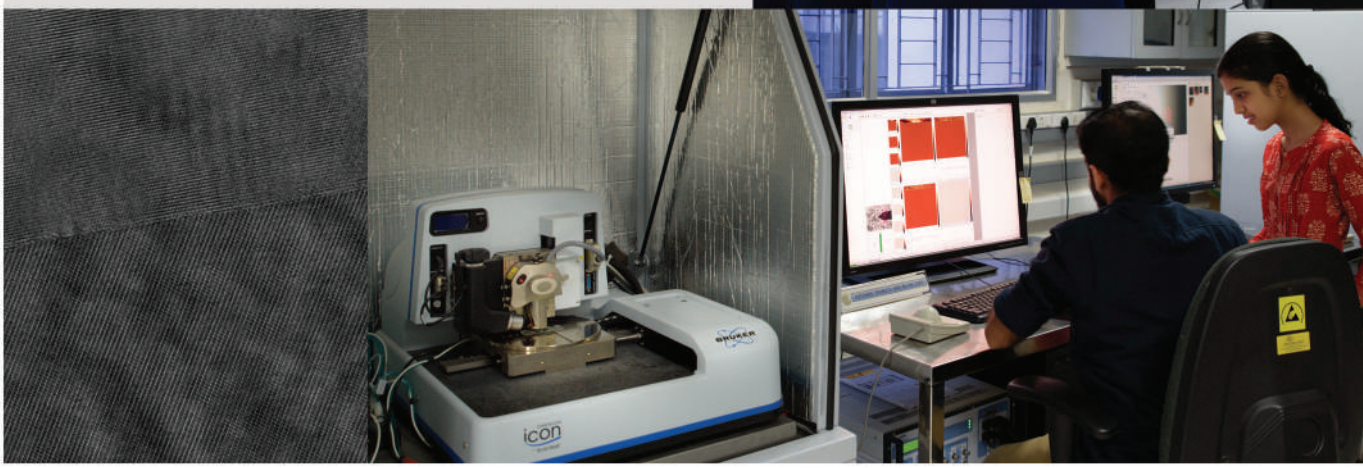
Material Characterization

In-depth analysis of micro and nano structure and chemistry of materials using Field Emission Scanning Electron Microscope (FESEM) with Energy Dispersive Spectroscopy (EDS) and Cathodoluminescence (CL), Dual Beam Focussed Ion Beam (FIB), X-Ray Photoelectron Spectroscopy (XPS), Transmission Electron Microscope with multi-mode capabilities.

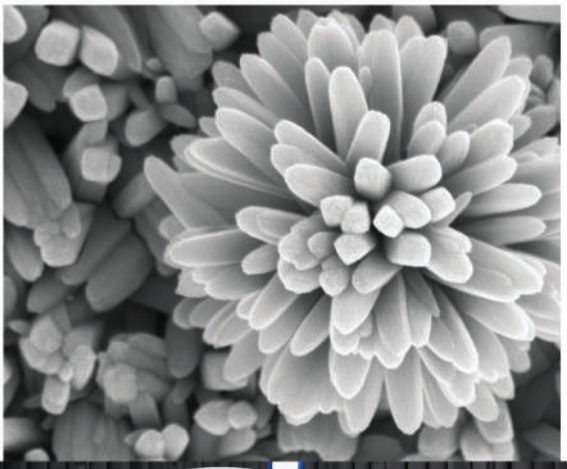
Optical Characterization

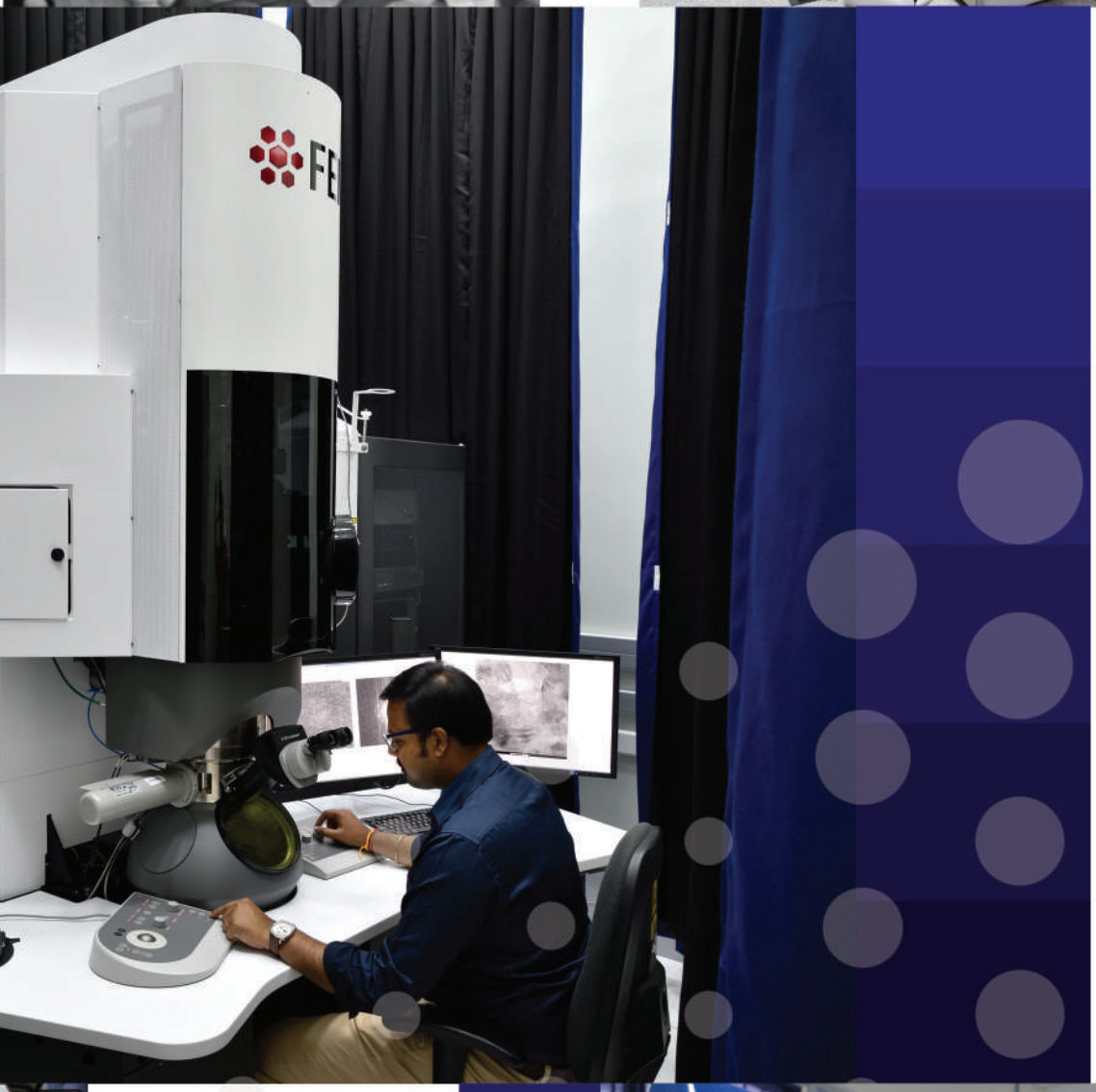
Comprehensive characterization of bulk materials and thin films using Raman Spectroscopy, Photoluminescence, Fourier Transform InfraRed Spectroscopy (FTIR), Simultaneous Thermal Analyzer, X-Ray Diffraction (XRD), X-Ray Reflection (XRR), Phase Analysis Light Scattering (Zeta PALS), UV-Vis-NIR spectrometer, Solar Simulator and Quantum Efficiency. MNCF also houses optical microscope for material analysis, stereo microscope and fluorescence microscope.

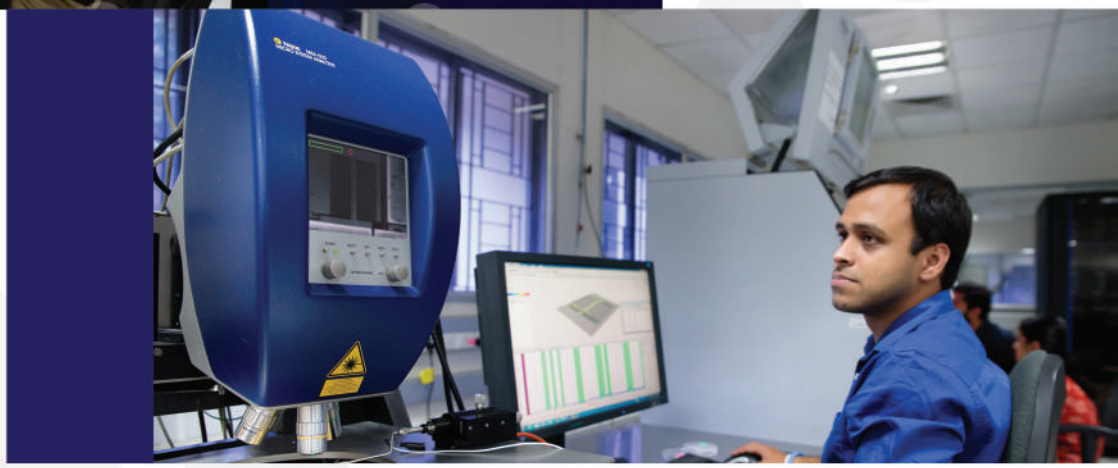
For more details: http://mncf.cense.iisc.ac.in



5nm



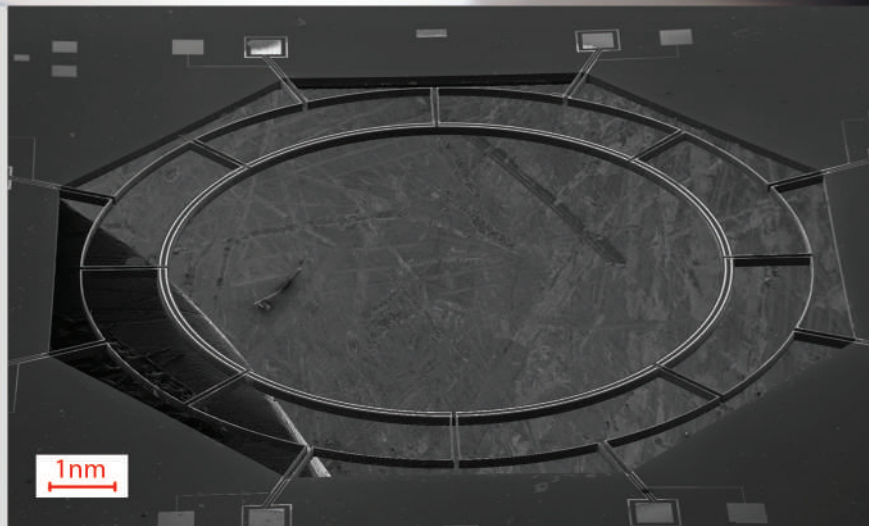


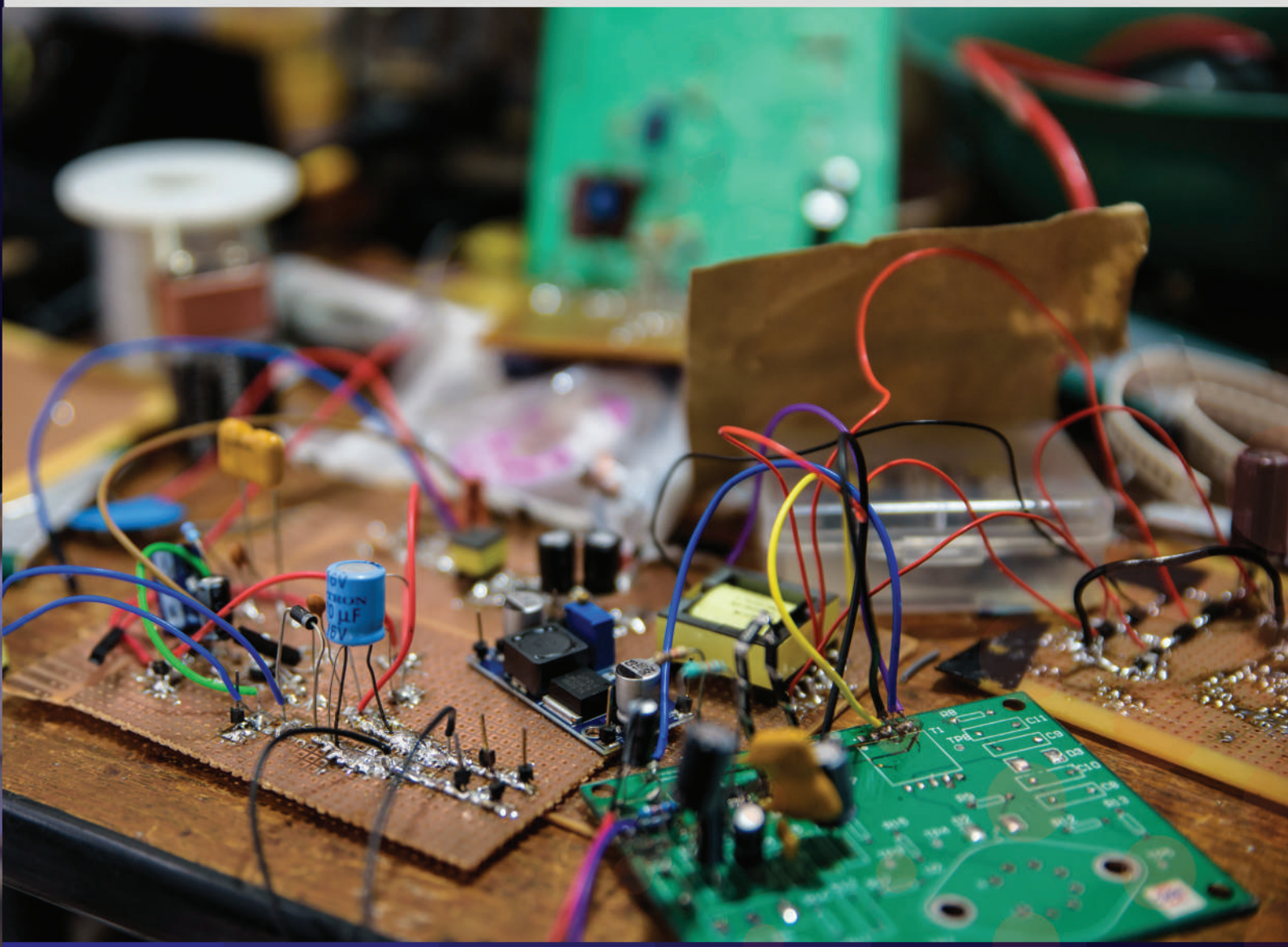


MEMS & IC Packaging Facility

IMEMS and IC Packaging facility has the complete capability to convert a wafer into a packaged device – from wafer sawing to wire bonding to precision welding. In addition, there are dedicated setups for pneumatic/hydraulic pressure calibration for pressure sensors and acoustic calibration for acoustic sensors.

For more details on Packaging facilities, please visit
www.cense.iisc.ac.in/infrastructure/mems-packaging-lab





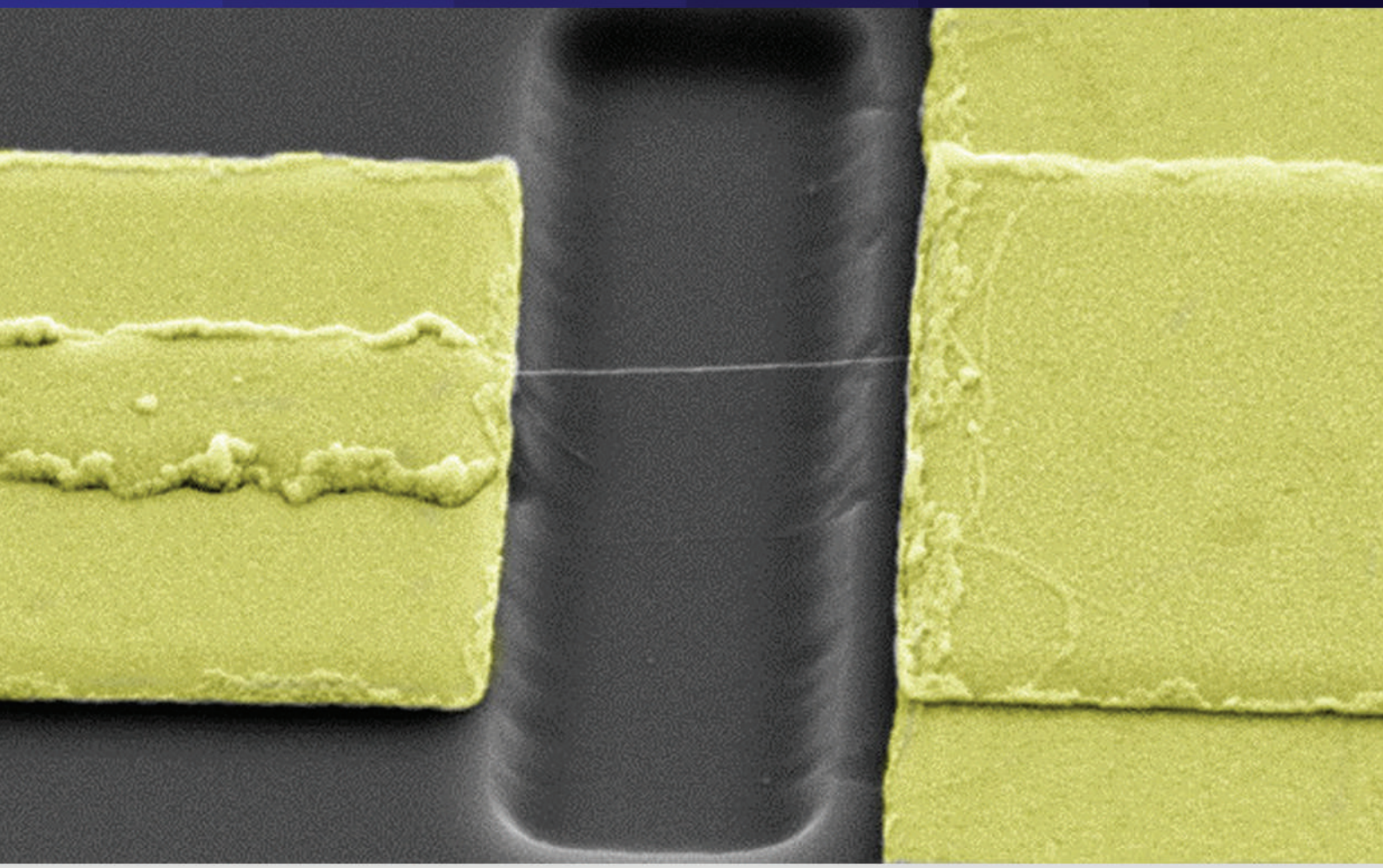
System Engineering Facility (SysEF)

SysEF focuses on building product prototypes around nanotechnology based sensors ideas. SysEF has built product prototypes around gas sensor technology for urban air quality monitoring and strategic sectors. SysEF is an ESD safe workspace which houses various electronic test & measurement equipment, ESD work stations, soldering and desoldering stations, two-layer PCB making machine, 3D scanner, 3D printer, PCB design tool, embedded and software design tools, pressure sensor calibration setup, various gas & pressure sensors, electronic modules & components and processor based evaluation kits.

Thematic Research Laboratories

NEMS Lab / Micro and Nano Sensors Lab

The Micro and Nano Sensors Lab focuses on physics and applications of Nanoelectromechanical Systems (NEMS). Activities of this lab include fabrication of resonant NEMS devices with frequencies in VHF and UHF ranges, novel actuation and detection schemes at these frequencies and nano-dimensions, study of noise processes that govern the frequency stability of these ultra-sensitive devices and their utility in various applications including NEMS mass spectrometery and gas sensing. Facilities include a NEMS-based mass spectrometery system, two closed cycle cryostats capable of reaching below 10K, an ultra-high vacuum system to probe frequency noise in NEMS devices and electrical characterization equipment including spectrum analyzers and microwave signal sources.

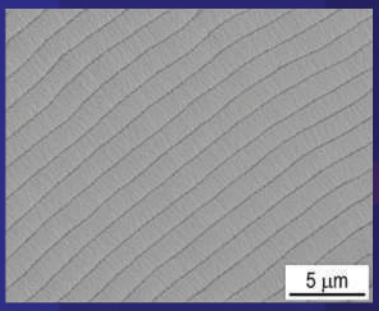


Bio Sensors Lab

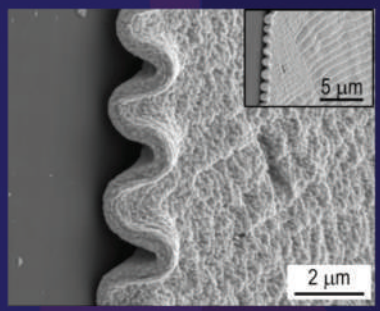
Focuses on developing low-cost biosensors for various bioanalytes of interest. Involves study of various surface modification methodologies. Facilities include electrochemical workstation, chemical synthesis equipment, equipment for processing biomolecules.

MEMS/MOEMS Lab

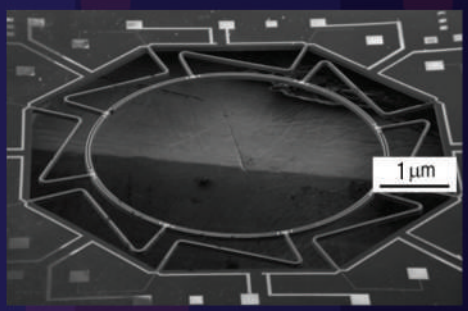
Design and development of MEMS inertial sensors, MEMS microphones, capacitive and peizoelectric ultrasound transducers (CMUTs and PMUTs), suspended gate FET-coupled MEMS sensors, all-optical actuation and sensing MEMS, study of energy dissipation in micro and nanoscale structural vibrations, study of microscale biosensors in insects, haltere dynamics, and cell dynamics. Facilities include experimental measurement tools for sub-nanoscale vibrations, angular rate measurements, ultrasound transmitters and receivers, and optical imaging, including high speed videography.



Ripple pattern with nanoscale gaps produced by liquid electromigration of gallium



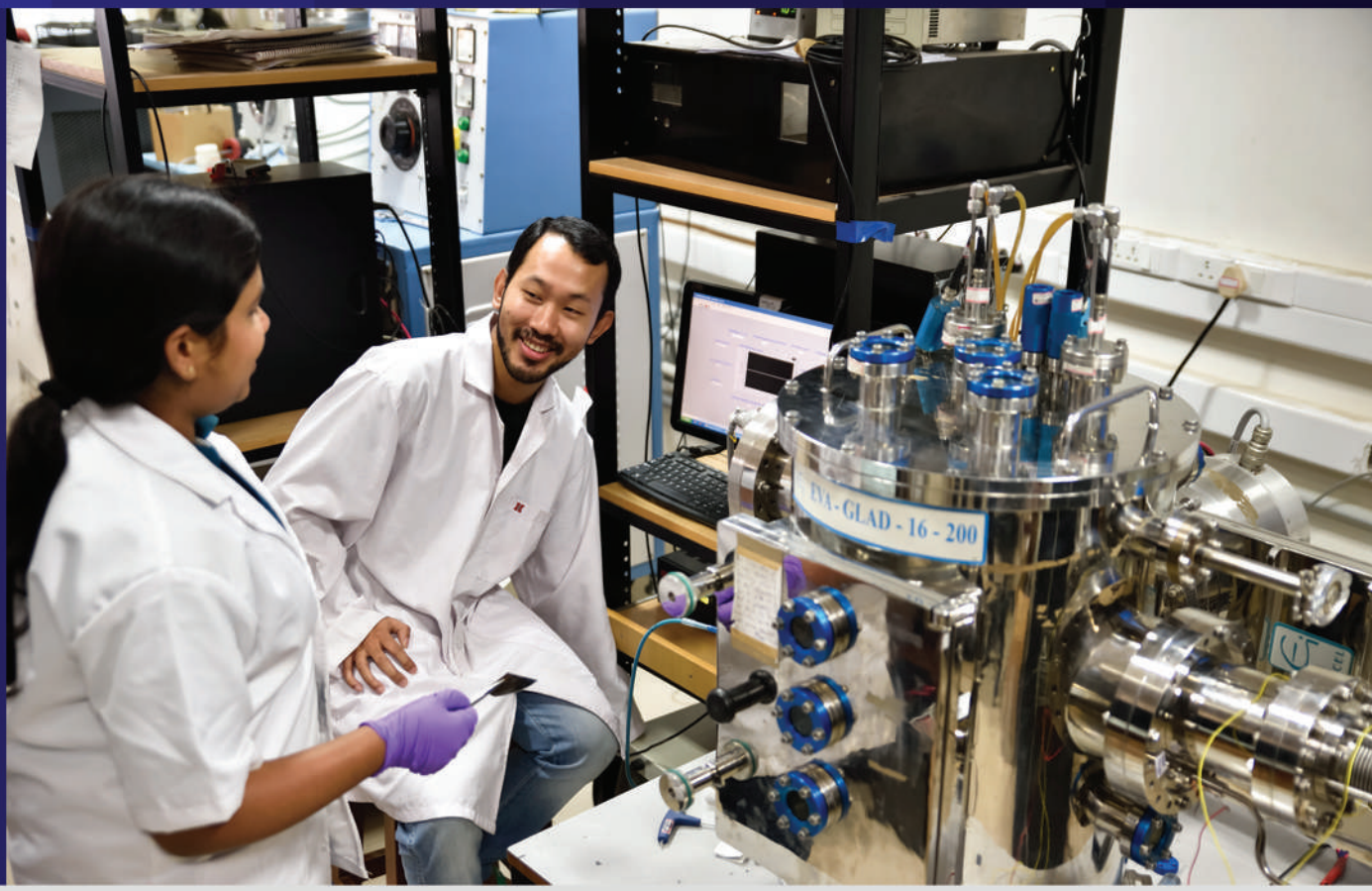
Micro-channels formed by electromigration driven liquid gallium flow



A ring resonator MEMS gyroscope

Biophotonics and Bioengineering

Our work follows two themes. One is the development of sensors to sense various molecules (molecular sensors) for bio/chemical applications and the other is to understand the molecular sensing process in terms of robustness to interference or perturbation. The robustness often emerges as a consequence of complexity in sensor design and/or in sensory signal processing. Examples of complexity in sensor design could be our olfactory receptors which enable our sense of smell or the signalling cascades employed by immune cells in our body to identify infective pathogens. We are interested in understanding the performance limits of molecular sensing, i.e. limits of sensitivity, accuracy, tolerance to interference and so on.



Optics, Nanostructures and Quantum Fluids

Study of optical and hydrodynamic properties of nanostructured particles and films, with emphasis on developing nanoscale drug delivery vehicles and nanoplasmonic sensors for biological applications. Facilities include nanostructured thin film fabrication system, optical microscope, and various optical characterization tools.

Gas Sensors Lab

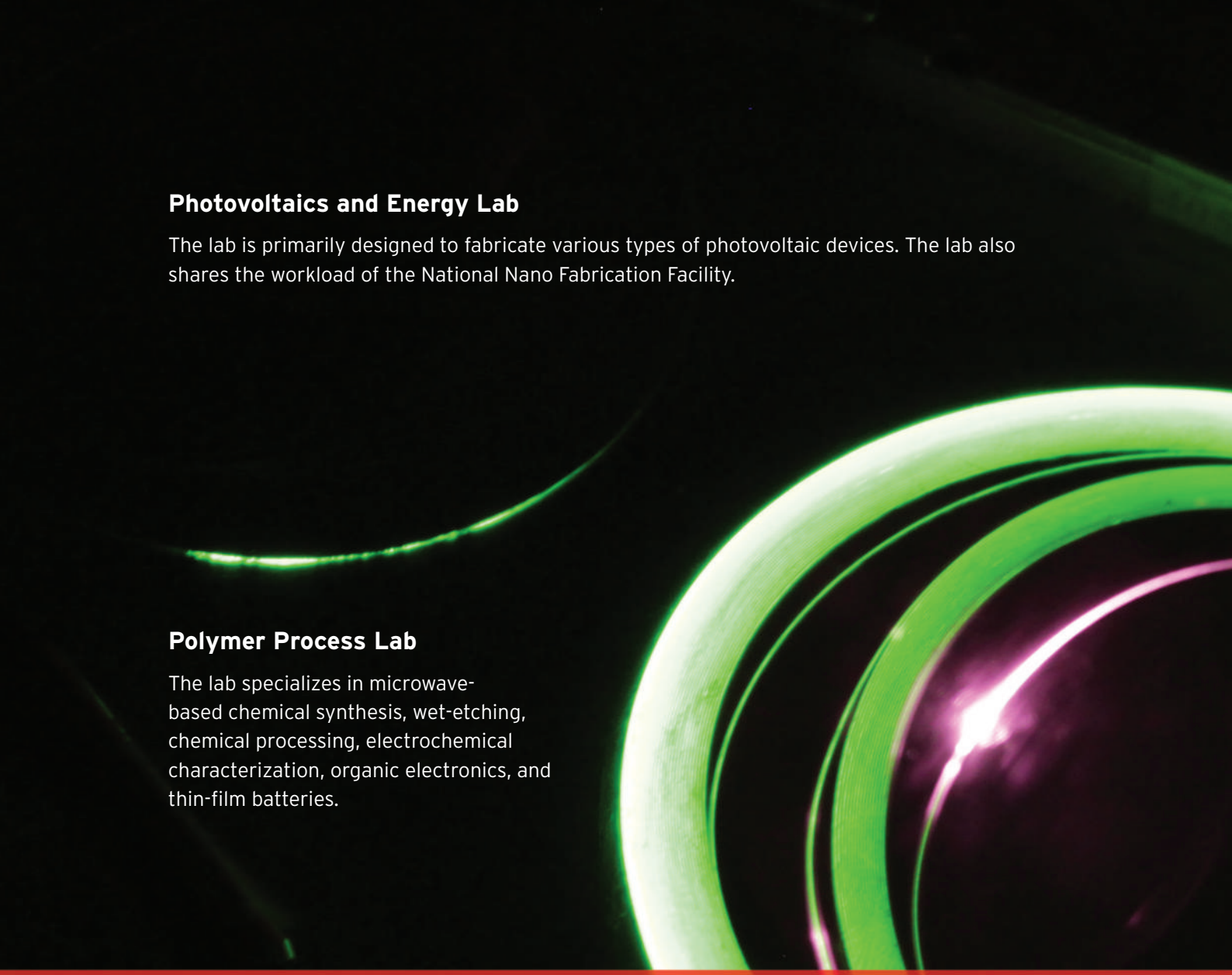
The Lab has facilities to characterize sensors employing different concentrations of gases – both inorganic and volatile organics – from ppb (~1) to ppm (>10,000); an IR camera to study the thermal morphology of microheaters; a microdispenser to dispense a desired amount of an analyte (solution) with a 20 µm spatial resolution. The lab also has the facility to fabricate sputtering targets of sensor materials.

Functional Thin Films Lab

The lab conducts investigations on influence of process parameters on the structure and properties of functional thin films, leading to the development of micro and nano sensors and actuators. Faciltiies include evaporation, sputtering and ion beam systems, designed and fabricated for specific requirements.

Photovoltaics and Energy Lab

The lab is primarily designed to fabricate various types of photovoltaic devices. The lab also shares the workload of the National Nano Fabrication Facility.



Polymer Process Lab

The lab specializes in microwave-based chemical synthesis, wet-etching, chemical processing, electrochemical characterization, organic electronics, and thin-film batteries.

Non-linear Photonics and High Power Lasers Lab

This laboratory focuses on development of novel optical sources and processing technologies for varied applications from optical communications, sensing and biomedical imaging to high power industrial and defense lasers. Fundamental research on non-linear optics in guided-wave devices, an enabler for many of the novel laser technologies, is also undertaken.

Neuro-Electronics Lab

The research emphasis is on interfacing neurons of the brain with electronic devices. The broad aim is to understand how learning takes place in biological neuronal networks using electrical and optical recording and stimulation, and to utilize it for robotic control. Facilities available are: nanofabrication of multi-electrode arrays, tissue culture laboratory for neuronal culture, electrophysiology rigs for multi-electrode array recording with feedback control, an electronics lab bench, high-end microscopes with fast fluorescence imaging and optical stimulation of neurons using a femto-second laser.

Heterojunction Lab

This laboratory conducts research in design, fabrication and characterization of novel electronic devices. The focus is on integrating different semiconductor materials with each other, e.g. silicon with metal-oxides or germanium to silicon. Such heterogenous integration introduces novel functionality and improves performance for the next generation of electronic devices.

Photonics

Photonics Research Laboratory is a dedicated characterization facility for integrated photonic devices and circuits. The primary focus of the lab is to develop high-speed integrated photonic devices for next-generation computing and communication. The lab houses a comprehensive high-speed electro-optic testbed for characterizing bandwidth of discrete devices such as Wavelength filters, light modulators, photodetectors, and amplifiers in the O, C, and L bands. The device and circuits developed are tested using a custom developed vertical and horizontal optical probe station. Research in the lab is also aimed at exploiting the photonic circuit for on-chip gas and bio-sensors. Spectrometers spanning from visible to Near-IR are used to develop such on-chip sensors.

Technology Development

Transfering Production-ready Technology

The primary goal of CeNSE is to translate cutting-edge research and technological innovation into the development of products, services and to help commercialize them successfully. CeNSE works with industry and government labs to develop new technology and is able to transfer production-ready technology. Even though a young department, CeNSE has already developed and transferred several technologies. We list a few of them below:

Envirobat

Envirobat is an IoT device that was conceived, designed and developed at CeNSE. It provides low cost solution for measurement of urban air quality at granular urban locations to create air quality index map for an urban city. This product and its variants are available to industries for commercialization.

Envirobat - An urban air pollution monitoring device

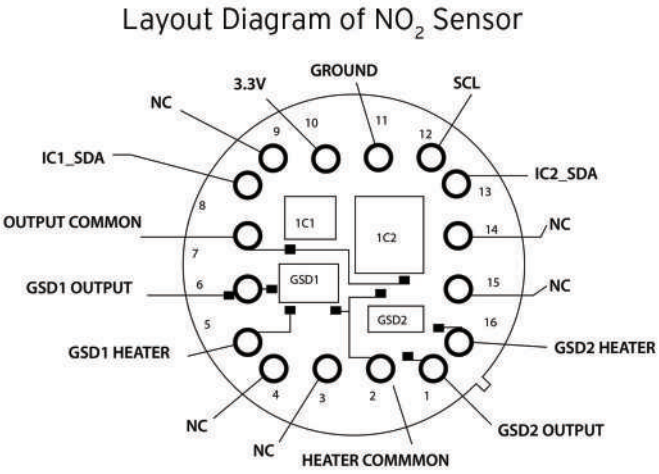
Low power, low cost wireless urban air quality monitoring device
Design based on ATmega - 2560 microcontroller
Data communication using GSM and GPS
Onboard CO, CO_2, NO_2 and pressure sensors
Integrated temperature and humidity sensors
LCD and button interface
SD card Interface

Ocean

Named 'Ocean', a lab prototype system at CeNSE was transformed into a world class CVD reactor tool jointly with an industrial partner. It is a chemical vapour depositor that can produce various two-dimensional materials including graphene. This technology is transferred to industry and ready to hit nano manufacturing industry.

Nitrogen dioxide air pollution sensor and transmitter

CeNSE has successfully delivered prototype sensors for sensing NO_2 pollution levels at satellite launch site of ISRO (SDSC, SHAR). The sensors are qualified for meeting their expected specifications and are being tested at site for their reliability and ruggedness.



Technology Development

Transfering Production-ready Technology

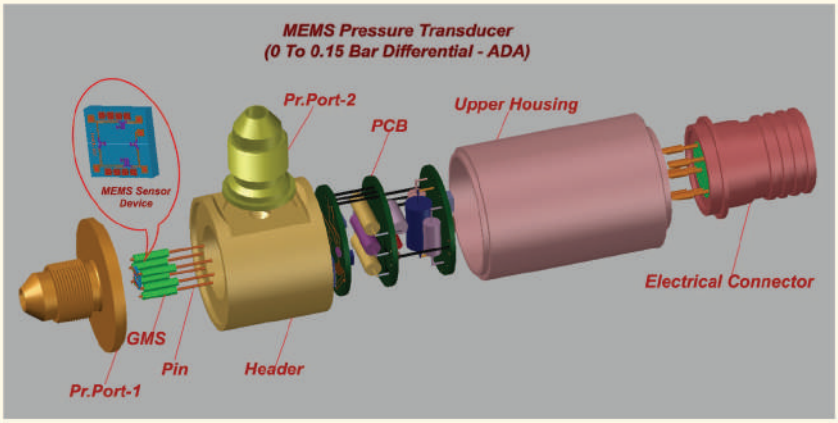
MEMS Pressure Transducers - requirement from DRDO and HAL - Helicopters

Indigenously Designed, Developed, Fabricated and Tested at CeNSE, IISc and already delivered 20 Nos to HAL-HD.

- 140mBar Differential and 1Bar Absolute Flight tested
- In-house packaging and calibration
- In-house testing for five million pressure cycles
- EMI/EMC, ESD, Lightning test-qualified
- User required interfaces
- Typical overall accuracy better than 1% FSO
- Adequately temperature compensated (from -40° to 65°C) at CeNSE

CeNSE-MEMS Pressure Transducers are miniature piezoresistive based sensors fabricated using silicon micromachining technique which enables great precision for realizing the diaphragm. The diaphragm acts as the sensing element and the piezoresistors serve as transducers. MEMS pressure sensors are popular because of low cost, simple to fabricate, small in size, low weight, higher accuracy, higher sensitivity, excellent repeatability and ability for mass production, along with ability to build redundancy in same size and lesser power. Low pressure device can be scaled up to any pressure levels without changing overall dimension of the Pressure Transducer.

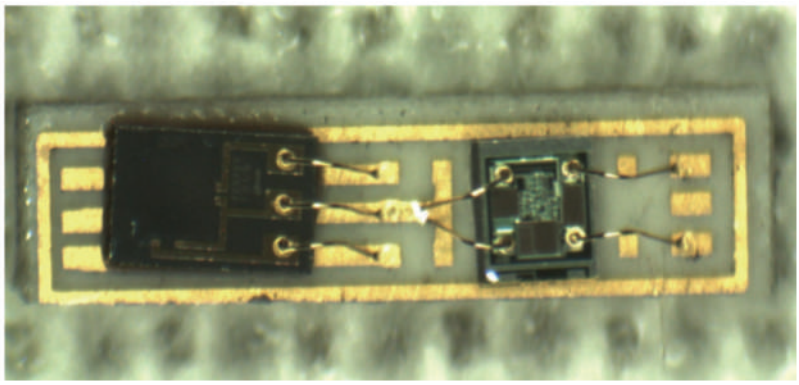
All the finer aspects of design, fabrication, packaging, characterization and calibration of silicon micro machined piezo-resistive pressure sensors for pressure ranging from 140mbar to 600bar were fabricated at the National Nano Fabrication Centre (NNFC) and packaged at MEMS Packaging facility at CeNSE.

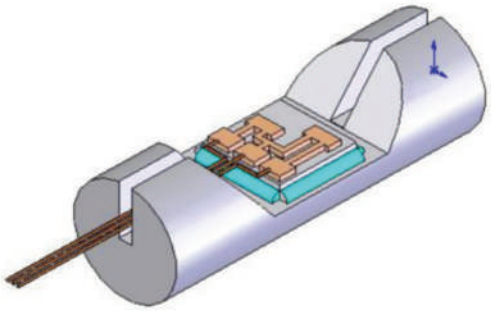


DEPLOYED IN

Intracranial Pressure Sensor

CeNSE has developed pressure sensor and biocompatible advanced packaging to build solution for intracranial pressure monitoring for bio medical applications related to head injuries.

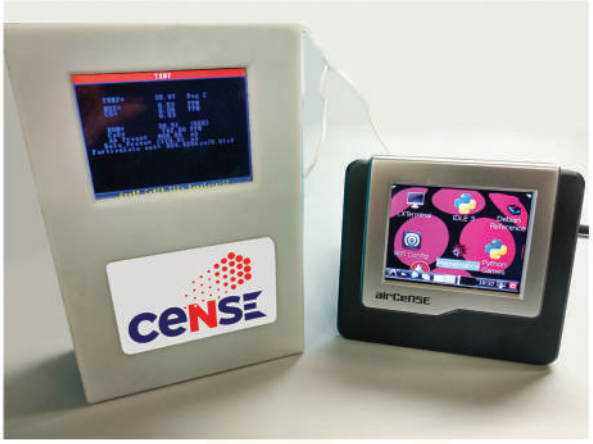




- Material: Gold plated Ceramic substrate with 0.6mm thickness.
- Dimension:
  - > Single sided: 0.8mm x 4.0mm
  - > Double sided: 0.8mm x 3.5mm
- Die-attach: GE P161 and ADTMP36 should be die-attached using H74 Non-conductive epoxy
- Wire bonding: 1mil ball to wedge bonding.
- Sensor output connection:
- 0.8mm O.D PTFE, Enamelled copper wire with five different colours as follows; clear, blue, red, black, green
- Cut to length: 1.5m

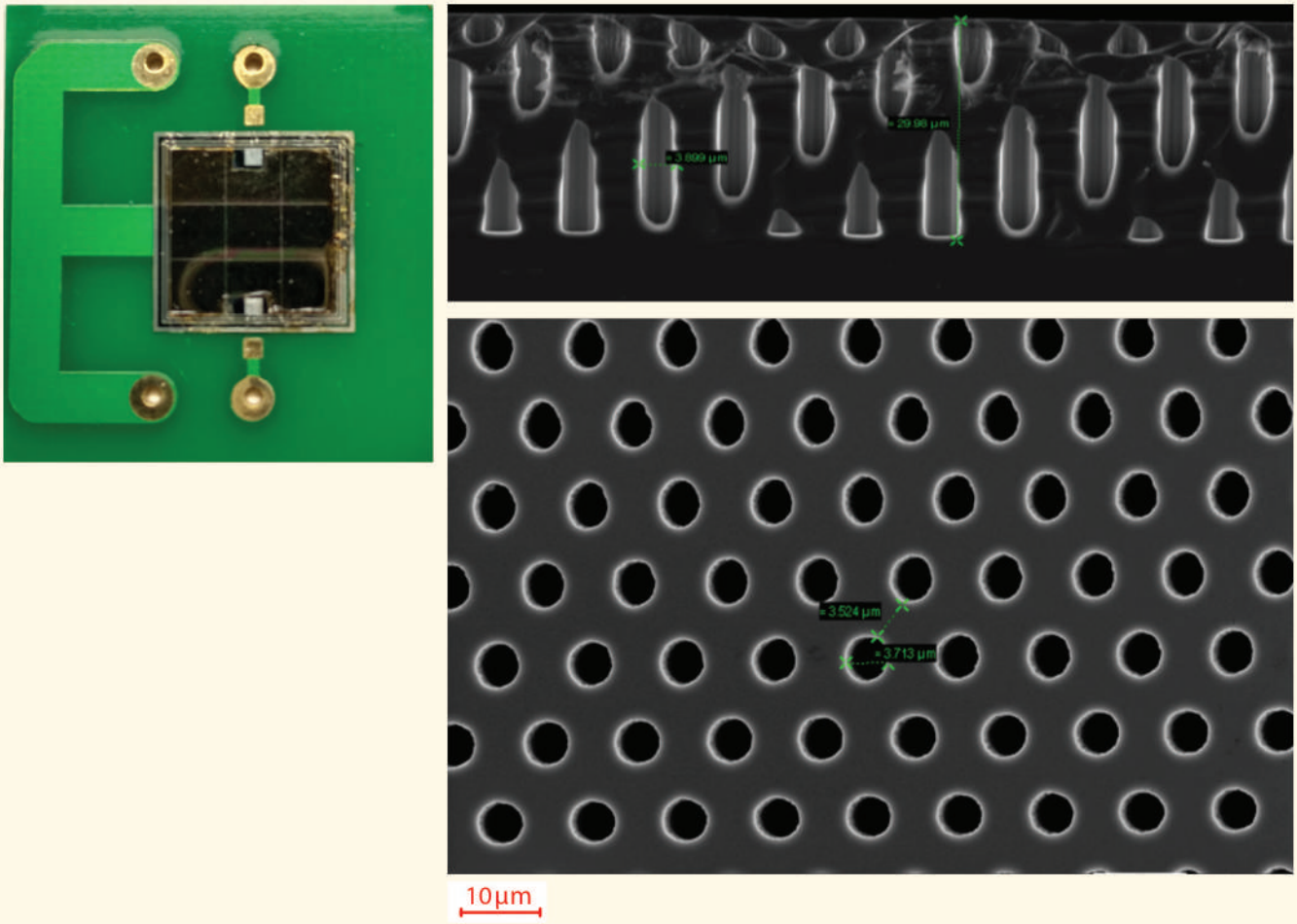
airCeNSE

Air quality monitoring devices with metal oxide sensors developed at CeNSE with corrections for humidity and temperature effects. Particulate matter sensor is included as part of sensors besides temperature, humidity and pressure. Another variant of airCeNSE is for calibration of metal oxide sensors at laboratory.



Neutron Sensors for strategic applications

CeNSE has manufactured neutron sensors for applications in nuclear security. These sensors are solid state batch processed silicon technology based and utilize novel converter material growth using nanotechnology.

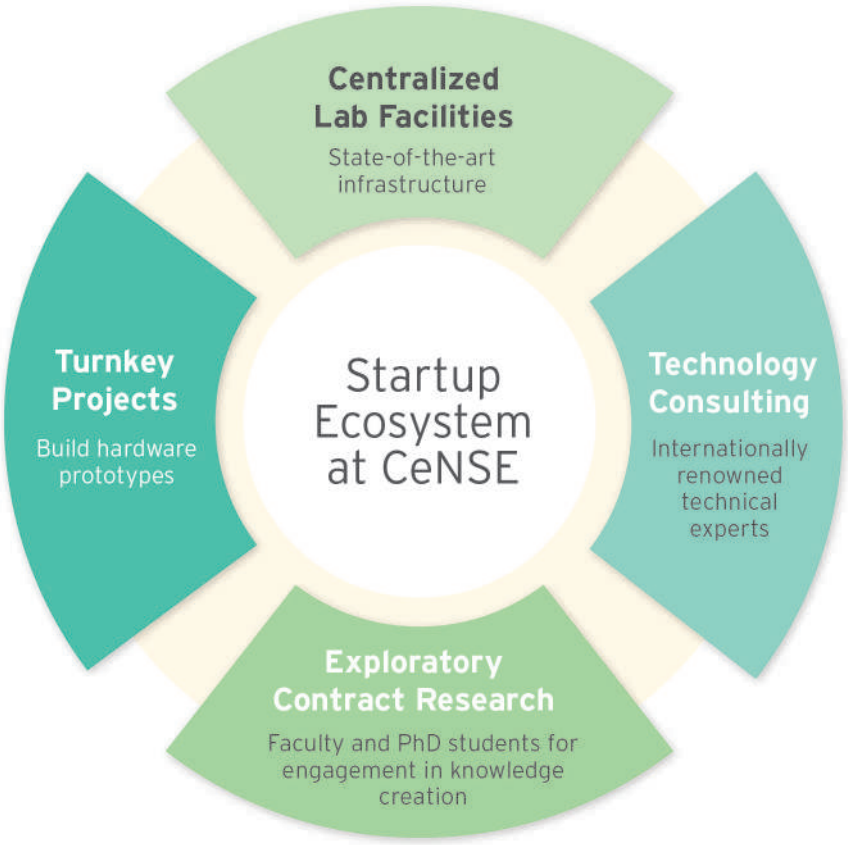


H_2, O_2 and N_2H_4 leakage sensors and transmitters for ISRO

CeNSE has initiated indigenous development of H_2, O_2 and N_2H_4 sensors along with data transmitters for SDSC, SHAR using facilities at CeNSE. This indigenous development is expected to meet annual consumption of these devices of SHAR through prototype productization and commercialization.

Nurturing Startups

Make in India



The founding leadership team envisioned CeNSE to be not just continuum of academic excellence but also an innovation engine in nanoscience and engineering that could seed startups originating on Indian soil. The centralized facilities viz. NNFC, MNCF, SysEF and Packaging labs, with world-class technical expertise and well-aligned academic research groups are right ingredients to form an ideal ecosystem for germinating startups using nanotechnology.

This Centre itself is driven and grown like a startup in terms of its pace of growth, aggressive initiatives and astounding team work. Aligning with the national mission of Startup India, CeNSE has been consciously translating nanotechnology IPs into products for societal impact.

#startupindia

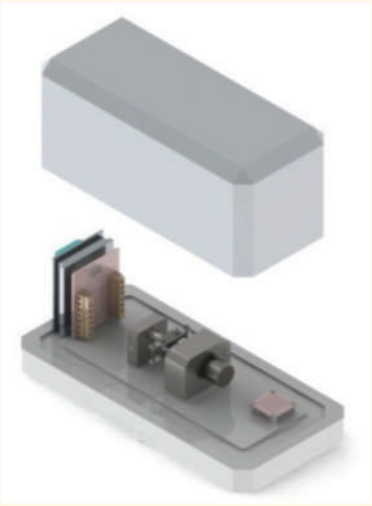
Technology Business Incubation (TBI@CeNSE) is a new initiative at CeNSE to enable nanotechnology based startups under the Government of Karnataka's program. This initiative will strive to ideate and incubate more than 15 startups focussing around technologies in the domain of nanoscience and nanotechnology.

There are several examples of startups sprouting out of CeNSE intellectual properties, initiating a CeNSE transformational culture to conceive and implement lab ideas to commercial market. This is just a beginning!

i2N Technologies Pvt Ltd

"Lot of excitement about nanotechnology in the country when CeNSE was being conceived, many courses around nanoscience and engineering all being taught as sociology courses without any hands-on. We had a dream of building simplest equipment to enable college students to feel intuitively nano dimensions and quantum phenomena like tunnelling of electrons or experience van der Waals forces. We built desktop affordable STMs and AFM, made in India in its true sense, machines that are deployed at colleges and is available in the market now. Critical technology challenges like measuring very small signals, mastery over nano dimensional displacement control and complete product lifecycle was done indigenously."

- Prof Rudra Pratap, CeNSE



Prof Rudra Pratap, CeNSE
Founder i2N Technologies

i2N develops products, designs nanotech trainings, provides services on characterization and consultancy to set up NanoLabs. i2N's long term vision is to build systems around nano sensors and actuators for process monitoring in machining and gas industries. They are building multiple sensor systems around pressure transducers developed at CeNSE as well for aerospace industries and defence market.

PathShodh Healthcare Pvt Ltd

"My research group at CeNSE ventured into electrochemical biosensors, a decade ago, with a focus on diabetes and its complications. After two generations of PhD scholars working on this topic, we could invent novel sensing technologies, resulting in number of international IPs. I started my entrepreneurial journey together with Dr Vinay Kumar, member of my research group, cofounding PathShodh Healthcare Pvt Ltd in 2015. PathShodh has commercialized world's first multi-analyte point of care diagnostic device for multiple chronic diseases including diabetes, anaemia and malnutrition, kidney and liver diseases."

- Prof Navakanta Bhat, CeNSE

PathShodh Healthcare Pvt Ltd is a medical device research and development company incubated at CeNSE, IISc. Driven by a social mission of making healthcare diagnosis affordable and available to all, the company is built on a very strong foundation of innovative research in physiology inspired biosensors. The motto of PathShodh is to revolutionize medical diagnostics and bridge healthcare divide, through deep science and cutting-edge technology.

Prof Navakanta Bhat, CeNSE
Co-founder PathShodh

Dr Vinay Kumar
Co-founder, PathShodh

GT Silicon Pvt Ltd

"While working at CeNSE, I experienced how to conceive and design a product with end consumer application in mind even when my prior experience was primarily in niche domain of digital chip design. I learnt a lot about complete hardware ecosystem at CeNSE. CeNSE leadership gave me enough free hand in conceiving and formulating my entrepreneurial journey ahead."

– Amit Gupta, Formerly CeNSE Technology Manager

Amit Gupta, Founder of GT Silicon
Formerly CeNSE Technology Manager

GT Silicon is sensor systems company and supplies sensors systems customized to specific requirements from industries.

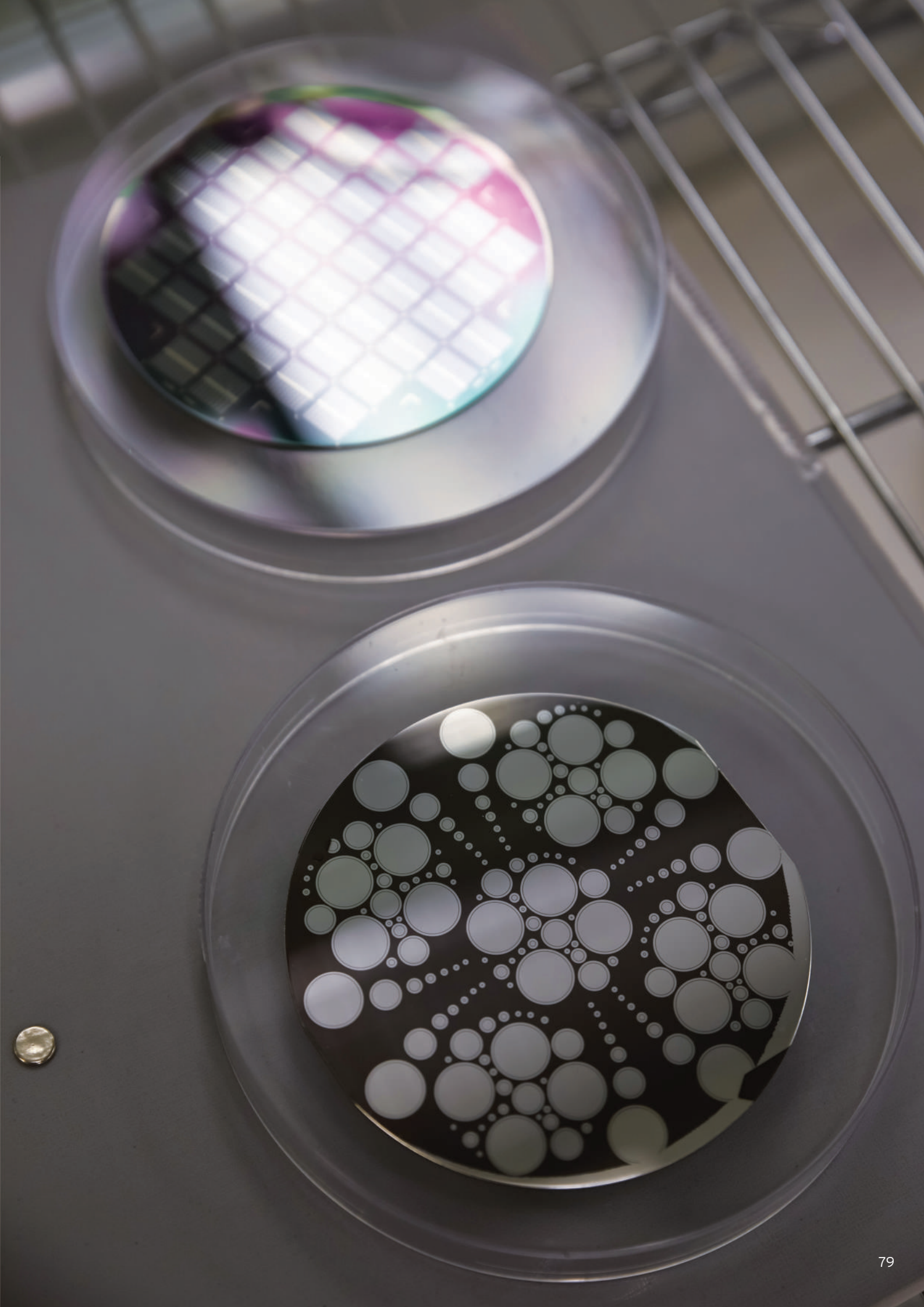
Qrera Technologies Pvt Ltd

"Prof Rudra Pratap and Prof Navakanta Bhat encouraged us to build new products around our own innovative ideas when I was student at CeNSE, 3 years ago. Looking at whatever systems we built at CeNSE, the professors encouraged us to transform them into business and enterprise entities. I could transform myself into an entrepreneur because of CeNSE open culture of trust and freedom and support of faculty members."

– Amod Hulge, Founder of Qrera, Formerly CeNSE Student

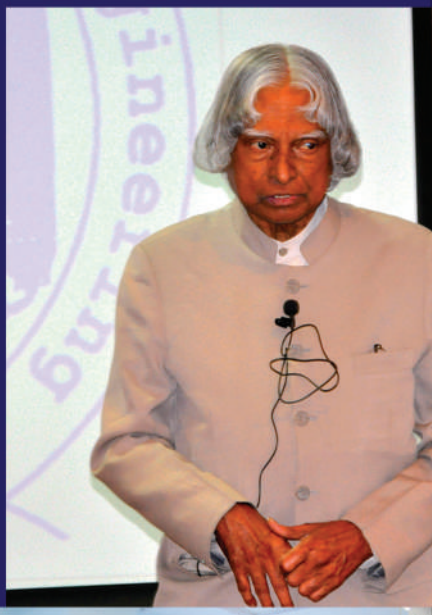
Amod Hulge, Founder of Qrera
Formerly CeNSE Student

Qrera focuses on three core verticals. First, IoT and Industry 4.0 – where it wants to convert dumb machines into smart machines. Second, continue its core expertise in 3D printer technologies in metal, plastic and other polymers. Third, Qrera wants to build desktop versions of machine tools and micro/nano fabrication technologies.



Visitors

Over the years at CeNSE



It is an honour to have visited the Indian Institute of Science. From its very inception, it has been dedicated to the cause of science and the cause of India. Please keep up your exciting and meaningful work.

Shri Ram Nath Kovind
Honorable President of India
24th October, 2017

Salutation to our scientists, great work being done. All the Best.

Sri M Venkaiah Naidu
Honorable Vice President of India | 27th September, 2017

Delighted and inspired to visit IISc Nano Centre and its state-of-art facility. Nice to see large number of young research groups.

Late Dr APJ Abdul Kalam
Honorable Past President of India | 31st March 2012

The journey of progress inspired by Swami Vivekananda and commenced by Jamshedji 100 years ago has been doing an amazing job helping improve human life. Best wishes/ Congratulations to the scientists who are dedicated to science.

Shri Narendra Modi
Honorable Prime Minister of India
18th February, 2015

Shri Ratan Tata
Indian industrialist, investor, philanthropist, former Chairman of Tata Sons and Former President of IISc Court

Visitors

Over the years at CeNSE

What a fine laboratory we have here! It is neat as neat can be, clean as clean can be, beautiful as beautiful can be. I am impressed. I congratulate those involved in building and organising it. I hope and pray that results of high quality emerge from this laboratory in our institute.

Prof CNR Rao
Head of Scientific Advisory Council to the Prime Minister of India | 18th January, 2013

A cutting-edge fortune of placing judice as first amongst equals. Proud to see what we can do.

Smt Renuka Chaudhary leading the Parliamentary delegation
MP, GOI | 30th August 2016

We Indians are very grateful to you for your mega aspiration in the nano area.

Shri Narayan Murthy
Indian IT industrialist and the co-founder of Infosys | 11th October, 2012

Absolutely phenomenal and truly inspiring to see so much of progress in emerging technologies. Congratulation to the great team at CeNSE. Stay inspired.

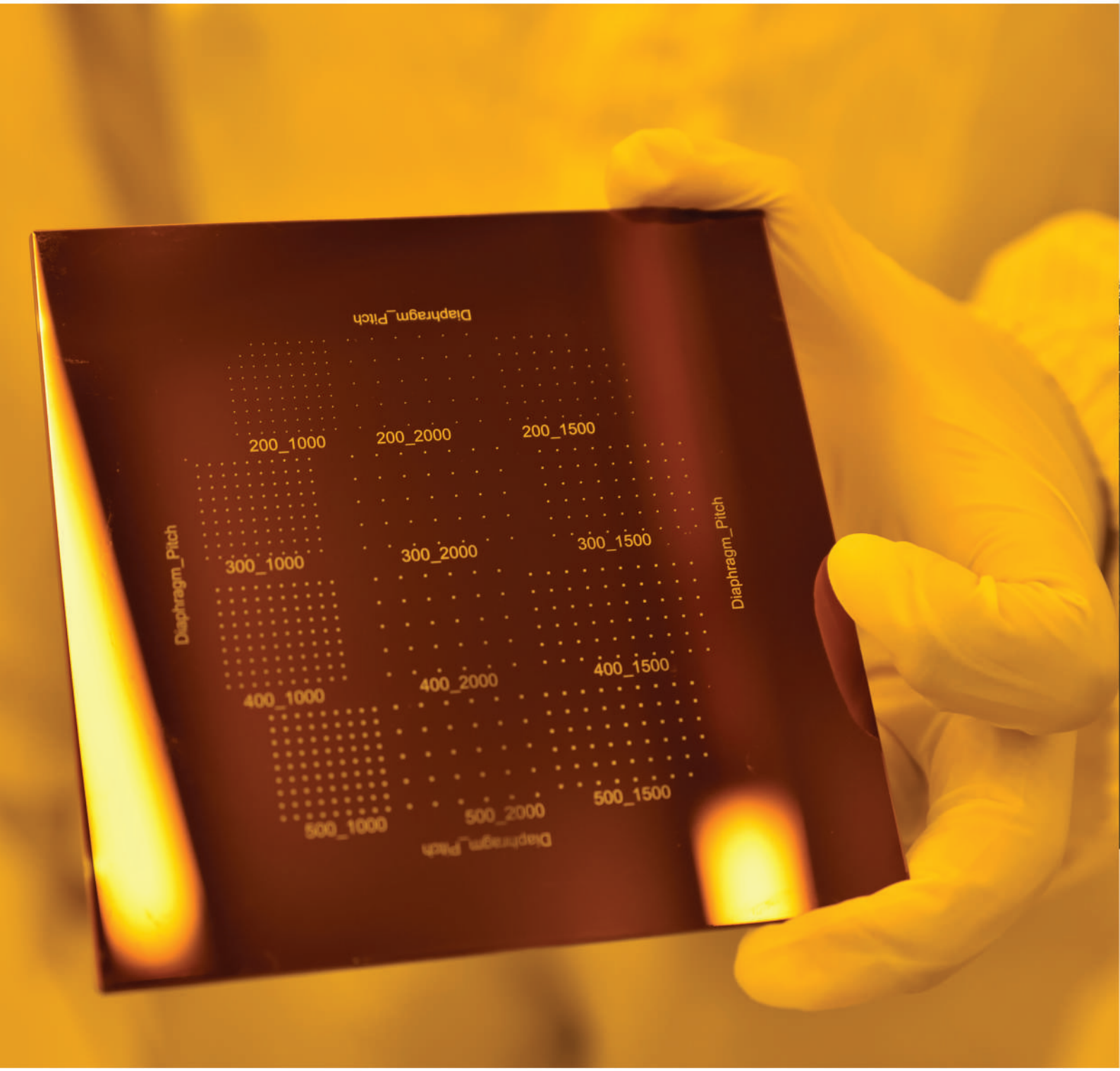
Shri Priyank Kharge
Honorable ITBT Minister, Government of Karnataka | 3rd July, 2017

Always very happy to visit IISc. I am sure it will lead in research and innovation efforts to make India a great power and economy.

Shri Prakash Javadekar
Honorable Minister of Human Resource Development, Government of India
1st July, 2017

Research is generating new knowledge and innovation is deriving economic and societal benefit from that knowledge... So what will happen here, is that some of the people working here may start their own start up companies, and this centre is likely to become an incubation centre for large industries across India, and perhaps across the globe.

Dr R Chidambaram
PSA, Govt. of India | 5th January, 2011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Outreach

Building Collaborations

CeNSE orchestrates various outreach initiatives to create tangible outcomes for societal impact. The outreach programs at the Centre provide access to MEMS foundry services, advanced material and device characterization services, 3D systems scaling and packaging services and mentorship to industry and academia through its state-of-the-art facilities and experienced technical team.

IAP: Industry Affiliate Program

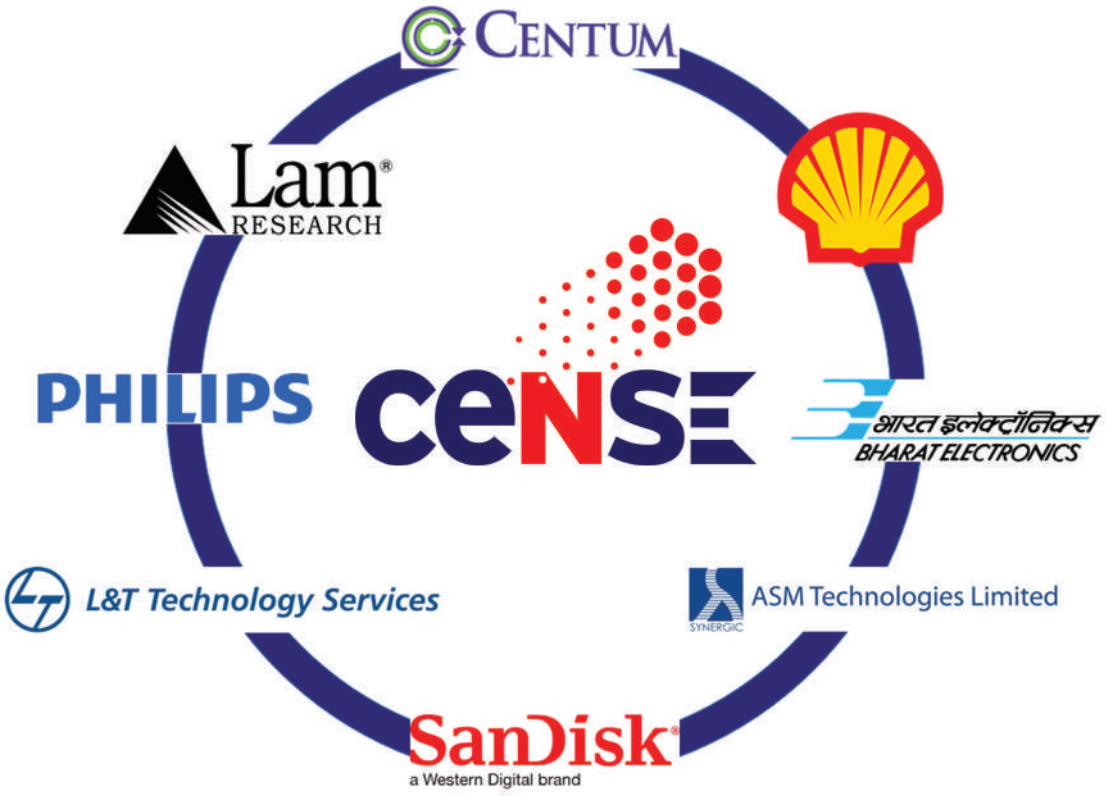
This program is engineered to bring industry on board at CeNSE and work with them as extended teams. This initiative has increasingly become a critical component of our innovation system with multiple high-tech industries joining hands with us. Besides other benefits, IAP members at CeNSE get privileges like:

IAP FEATURES

CeNSE also offers another program called Startup Industry Affiliate Program, specially designed for Indian region startups. The benefits of this membership are that these new enterprises get access to centralized facilities and opportunity to rapidly create new product prototypes.

IAP MEMBERS

Through the Industry Affiliate Program, leading industry players sponsor and participate in R&D projects at CeNSE. The present affiliate members are:



Outreach

Building Collaborations

In response to the growing need from startups, CeNSE promotes utilization of its world-class research and prototyping facilities. Large number of industrial users use centralized facilities at CeNSE to meet their characterization needs and short-term fabrication demands. Most of these industries are fabless design houses at Bangalore and R&D centres of MNCs located in India. Some of these users are:

Corporate Sector

- **3M India**
- **AkzoNobel India**
- **Marico**
- **Unilever**
- **CavinKare Research**
- **Siemens**
- **Applied Materials**
- **HPCL (Hindustan Petroleum Corporation Limited)**

Strategic Sector

- **BEL**
- **DRDO Labs**
- **ISRO**
- **CPRI (Materials Division, Central Power Research Institute)**


KAS

INUP

Indian Nanoelectronics Users Program

Indian Nanoelectronics Users Program (INUP) is a joint program run by CeNSE, IISc and IIT Bombay to accelerate research and development activities in the area of nanoelectronics in India. The program, funded by the Ministry of Electronics and Information Technology (MeitY), Government of India (GoI), was launched in 2008 and is now in its second five-year phase.

The program provides hands-on training to qualified and motivated scientists and engineers from around the country in nanotechnology and subsequently, allows them to carry out their research projects at CeNSE. Easy access to the state-of-the-art equipment and technical expertise of scientists and engineers resident at the Centre makes it possible for aspirants, even from the remote corners of India, to get exposed and be engaged in cutting-edge R&D. INUP has expanded its footprint across India with a network of over 700 educational institutes.

INUP has grown rapidly over the years and now routinely conducts training workshops throughout the year. At any given time, more than fifty INUP projects are active at CeNSE. Since launch of the program, more than 6000 scientists from around the country have been trained and more than 600 research projects have been carried out. Based on the research work done under this program, more than 300 PhD scholars, registered in universities across India, have graduated. Users under this program have authored more than 400 publications and more impressively, have applied for more than a dozen patent applications. The unprecedented outreach of the program and its success has been consistently recognized by Government of India. INUP was a featured program at the "National Good Governance Day" in 2014.

Levels of training offered under INUP

1. The Familiarization Workshop
2. Hands-on Training Workshop
3. Execution of Research Projects

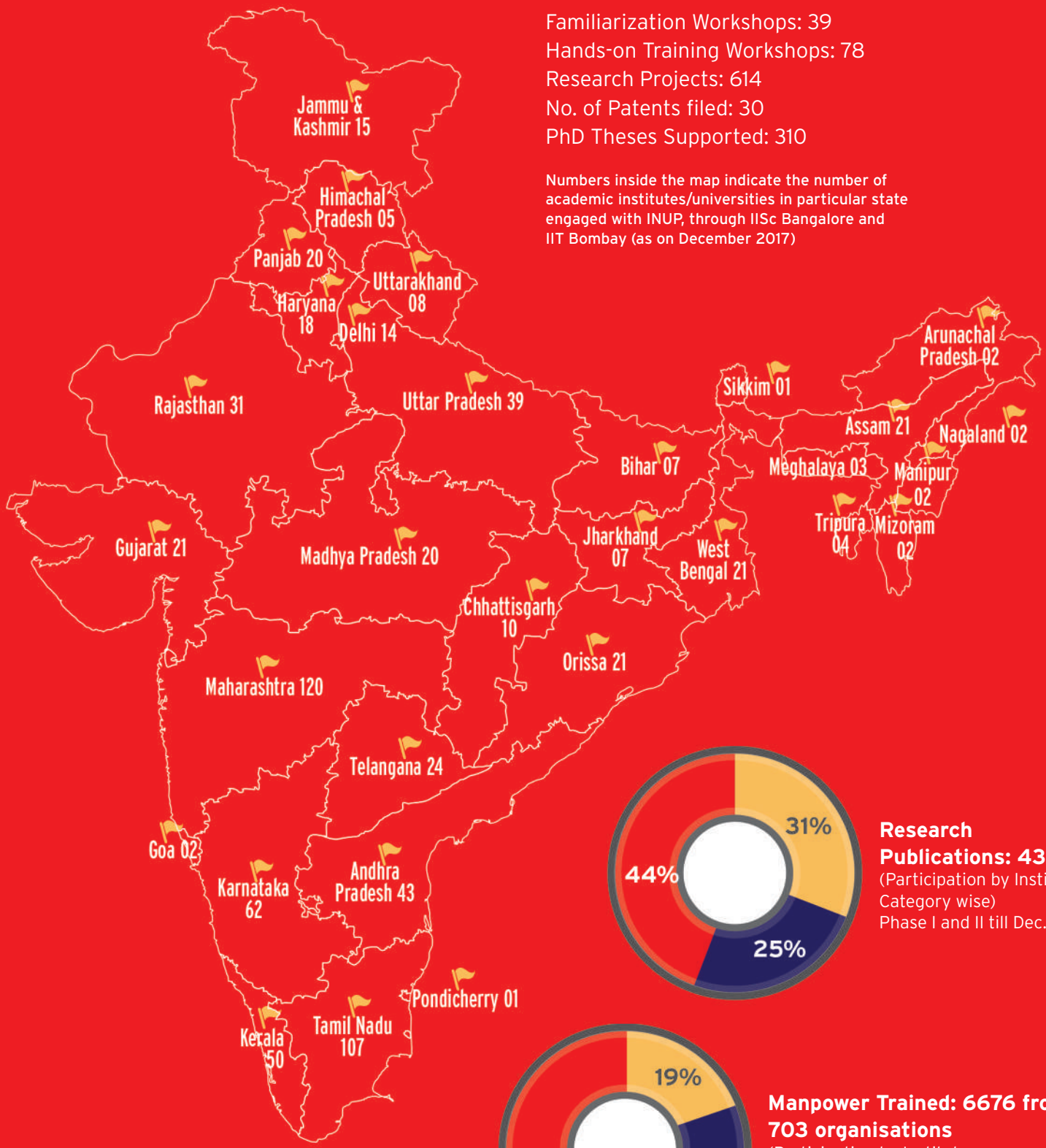
Special training for scientists from neighboring countries

Over the past few years, India's role in promoting and assisting development in neighboring countries has increased substantially. Encouraged by the success of INUP, CeNSE has now embarked on providing INUP-type training to scientists from neighboring countries. The program is supported by the Ministry of External Affairs (MEA), GoI. First of such workshops was conducted on 3rd February 2016, which was attended by 26 scientists from Sri Lanka, Bangladesh, Myanmar and Maldives. The initiative has generated interested from many more countries seeking opportunities to participate in similar programs and access to nanofabrication facilities available at CeNSE. MEA is eager to expand the program, enabling India to become an international hub and destination for nanotechnology R&D.

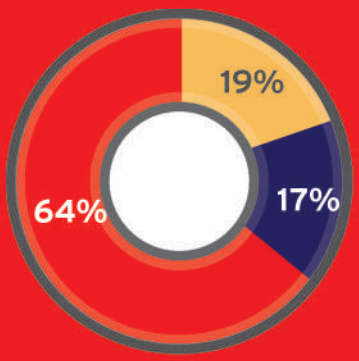
INUP
Indian Nanoelectronics Users Program

Familiarization Workshops: 39
Hands-on Training Workshops: 78
Research Projects: 614
No. of Patents filed: 30
PhD Theses Supported: 310

Numbers inside the map indicate the number of academic institutes/universities in particular state engaged with INUP, through IISc Bangalore and IIT Bombay (as on December 2017)



Research Publications: 436
(Participation by Institutes – Category wise)
Phase I and II till Dec. 2017



Manpower Trained: 6676 from 703 organisations
(Participation by Institutes – Category wise)
Phase I and II till Dec. 2017
Cumulative Data for IISc and IITB

IITs, National Labs & Central Universities
New IITs & NITs, IISER, NISER
Private Engineering Colleges

INDIAN SCIENCE, TECHNOLOGY AND ENGINEERING FACILITIES MAP (I-STEM)

The What and the Why

It has always been the basic tenet of Government of India, in generously funding R&D efforts at academic institutions over the years, that facilities established through such support be made available to those needing them and qualified to make use of them for their own research work. Thanks to the internet, it is much easier today to have a national and regional 'inventory of resources', so as to match users with the resources they need, in an efficient and transparent manner. This will lead to a leap in R&D productivity and greatly enhance the effectiveness of public investment. This is the motivation behind I-STEM.

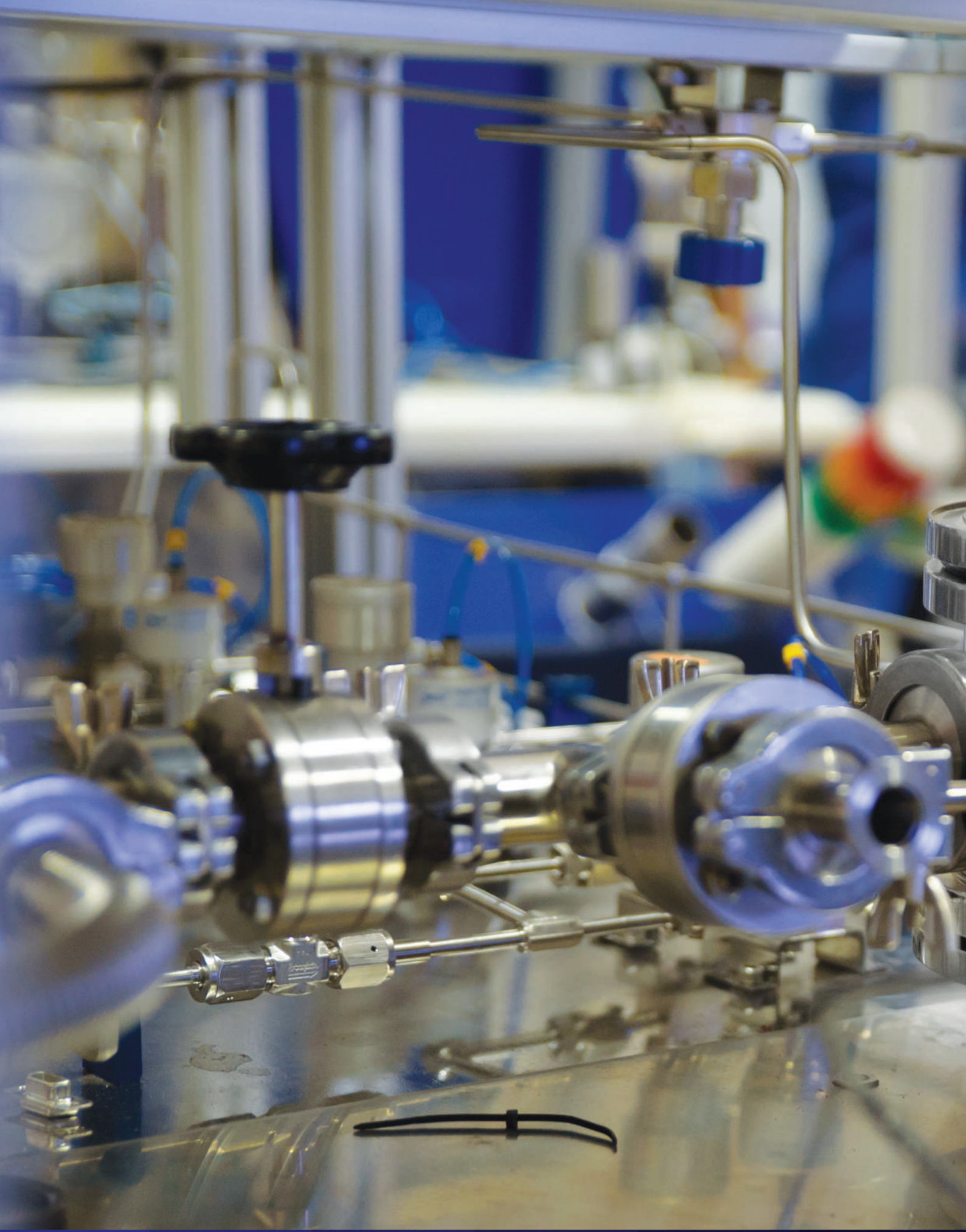
The genesis of I-STEM is the very successful Indian Nanoelectronics Users Program (INUP), supported by Ministry of Electronics and Information Technology (MeitY), GoI. Now in its tenth year, INUP has been providing access to state-of-the-art facilities at CeNSE to academic researchers from all corners of the country. Under the program, these researchers receive hands-on training and carry out sophisticated R&D projects at the Centre. The trained INUP participants, shared information on public-funded facilities in their respective institutions, providing the initial, unofficial database that led to the genesis of I-STEM national portal.

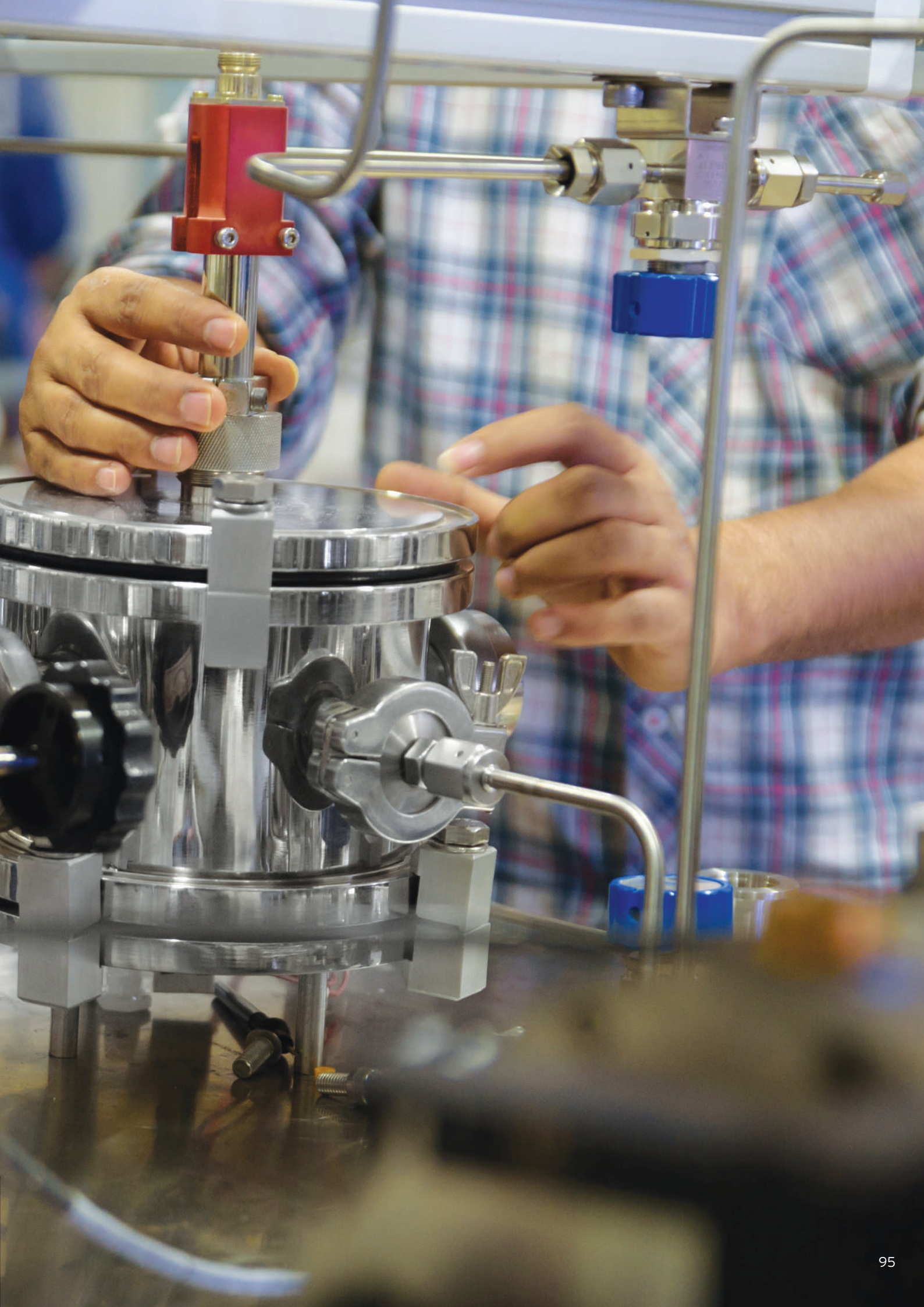
The How

The I-STEM Web Portal allows users to locate specific facilities they need for their R&D work and identify which are closest to them or available soonest. Institutions that have procured and installed R&D facilities with funding from GoI (or its agencies) are now required to list them on the I-STEM Portal (which is regularly updated and can also be accessed via a Mobile App). Through I-STEM, a user can make a reservation for using the desired facility, at the prescribed user fee, which depends on whether the user is from the academia (and whether s/he has a research grant), a public institution, or from industry. A panel of experts will be formed over time to help users (via the Web) to make the most informed use of resources made available through I-STEM.

For more details, please visit www.i-stem.ac.in or download the app (i-stem) from Google Play Store.

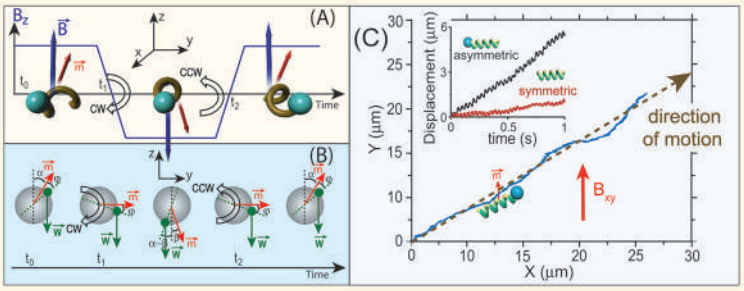
The project on National Web portal is supported by the Office of the Principal Scientific Adviser, GoI.



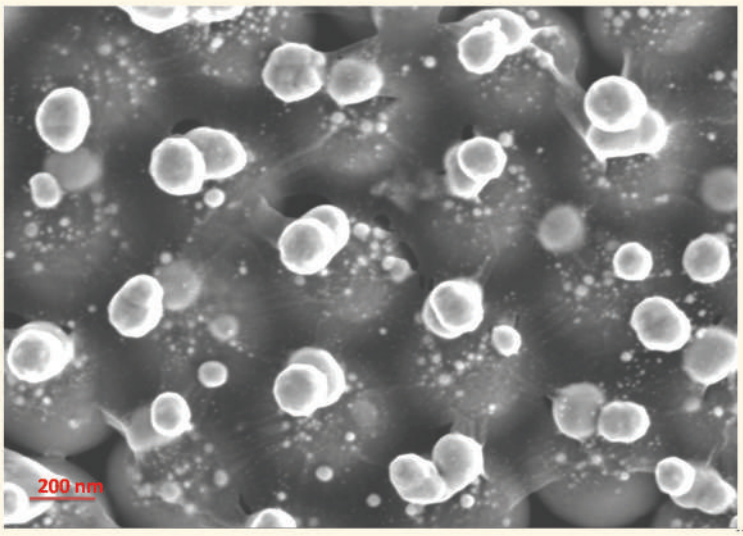


Research Breakthroughs

Demonstration of autonomous motion of magnetic nanoswimmers, which can also be positioned independently of each other. [Phys Rev Letters 2013, ACS Nano 2015].



Integration of Graphene sandwiched between plasmonic nanoparticles to obtain record near field enhancement and photoresponsivity [Advanced Materials 2015].



Development of Bright-field Nanoscopy: technique to visualize nanostructures using a conventional microscope [Scientific Reports 2016]

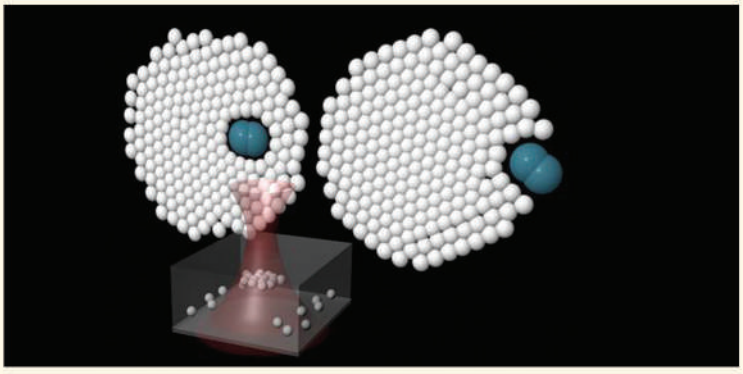
Demonstration of an artificial cyto-compatible "nano-voyager" manoeuvred in undiluted human blood [Nano Letters 2014].

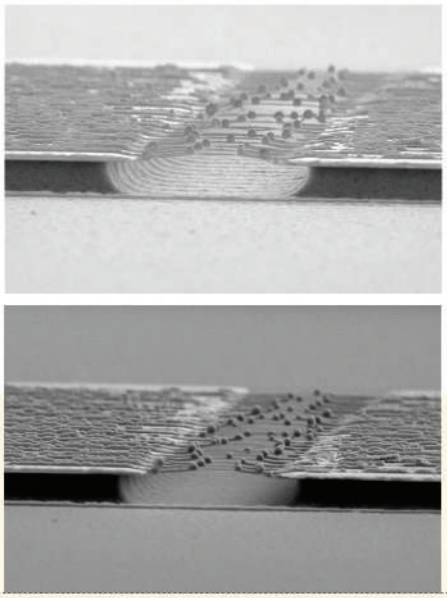
Elucidating the roles of wrinkles and ripples on mechanical properties of graphene-based nanoelectromechanical devices [submitted].

Development of low cost RGO-coated fabrics as disposable electro thermal wearable body warmer [patent filed].

Demonstration of a n-Si/Cu_2O hole-selective heterojunction with a highly improved open-circuit voltage compared to state-of-the-art, by reducing the defect density at the Si/Cu_2O interface by 1000 times [IEEE Journal of Photovoltaics 2017].

Discovery of self-purification of dopants in confined colloidal crystallites [Phys Rev Letters 2016, Editors suggestion].





Core-shell suspended metal-metal oxide gas sensor array for high sensitivity [Sensors and Actuators B: Chemical, 2018]

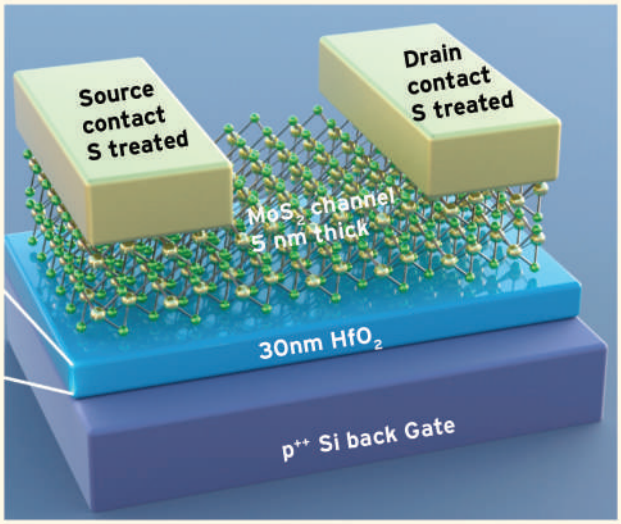
Development of a novel vapor-annealing process to consistently and reliably get high-performance perovskite solar cells [Current Applied Physics, 2017].

Demonstration of trapping of multielectron bubbles in liquid helium which allows the study of interacting electrons in curved geometries [Nature Communications 2014].

Demonstration of a simple and low-cost liquid phase epitaxy (LPE) technique to grow high quality epitaxial films of germanium on silicon (100) [IEEE Photovoltaic Specialists Conference 2017].

Invention of biosensors for multiple chronic diseases such as anaemia, malnutrition, diabetes, kidney and liver disease. The electrochemical sensing technology utilizing novel receptors has resulted in world's first multi-analyte diagnostic device – a mobile Laboratory. PathShodh Healthcare, a start-up at IISc has now commercialized this product.

Development of an ultralow power switch with record mobility on 2D MoS_2 channel, by integrating high-k Hafnium dioxide (HfO_2) gate dielectric, along with sulphur treated nickel contacts [IEEE Electron Device Lett 2015, IEEE Transactions on Electron Devices 2016]

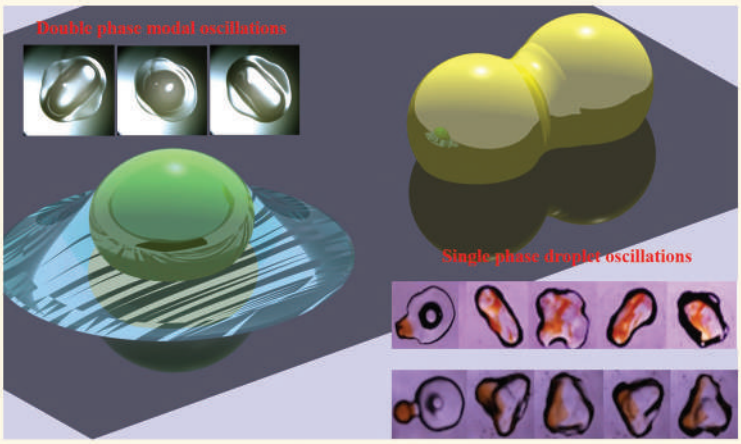


Observation of strongly nonlinear mode coupling and internal resonances in NEMS devices based on 2D materials [Applied Physics Letters 2015]

IDevelopment of low cost temperature and pressure sensors using graphene/GO/RGO/metal nanocomposites [several patents filed].

Research Breakthroughs

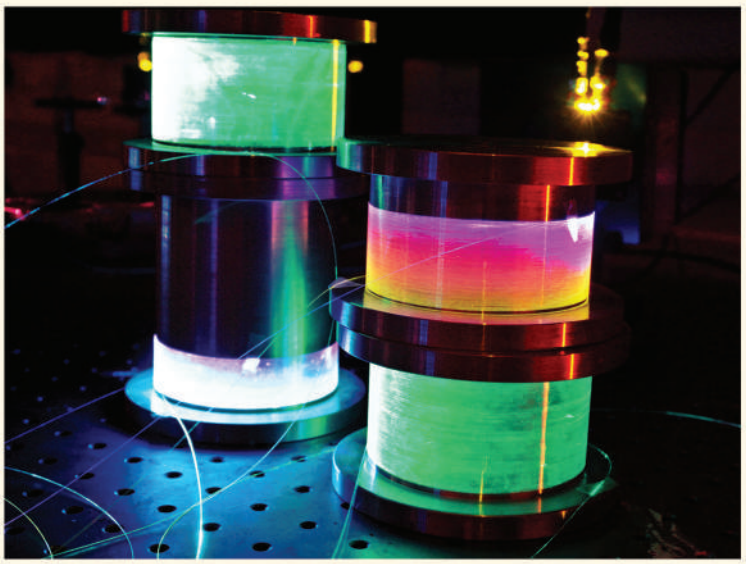
Demonstrated non-axisymmetric droplet oscillations to achieve one of the fastest mixing times in microfluidics [Sensors and Actuators, 2016].



Development of a family of metalorganic precursors, which are crucial to the development of low-temperature processes for oxide electronics, the fabrication of flexible electronics, and the fabrication of sensors [to be commercialized].

Development of a low-temperature, solution-based process for thin films and coatings of nanostructured spinel ferrites for a CMOS-compatible process and material for inductor cores in GHz CMOS ICs [patented, IEEE Transactions on Magnetics 2013].

Advancing the technology referred to as Cascaded Raman lasers to develop high power lasers across the optical spectrum [review in Journal of Optics, 2017].

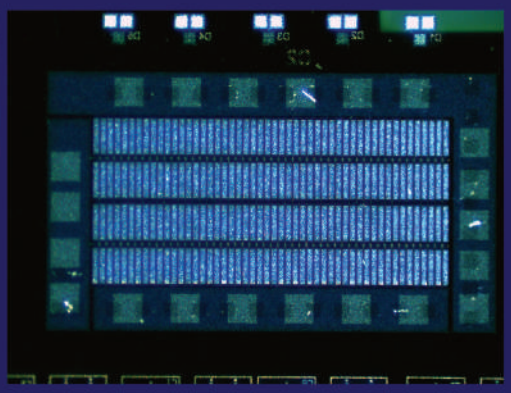


Modelling the bioacoustics of field crickets, which led toward the design of MEMs speakers with ten-fold improved efficiency compared to conventional designs [patented, manuscript in preparation]

Technology developed to probe and manipulate cells by using the liquid-air interface as a mechanical element [patent filed, MicroTAS Conference 2017].

CeNSE heads a multi-disciplinary effort on GaN power electronics that spans materials growth, device design/fabrication, testing & measurement, packaging and systems integration. A team of 21 people including 9 faculty members have enabled the demonstration of a 5Amp/40V GaN power transistor, the first of its kind in India, towards integrating into a DC-DC converter. With an ongoing effort towards 600V GaN technology, various properties of HEMTs (eg: breakdown, leakage) are investigated in parallel which is feeding into an expanding scientific base. In addition, CeNSE is leading a GaN-based optoelectronics initiative where state-of-art responsivity and photo-to-dark current ratio are demonstrated for deep-UV photodetectors [5 patents filed, 16th International Conference on Embedded Systems - VLSID 2017, Journal of Applied Physics 2017, Solid-State Electronics 2017].

Packaged power transistors that can carry 5Amp of current, ready to be shipped to CDAC, Trivandrum for making DC-DC converters



A single power transistor with 50mm periphery, just after dicing

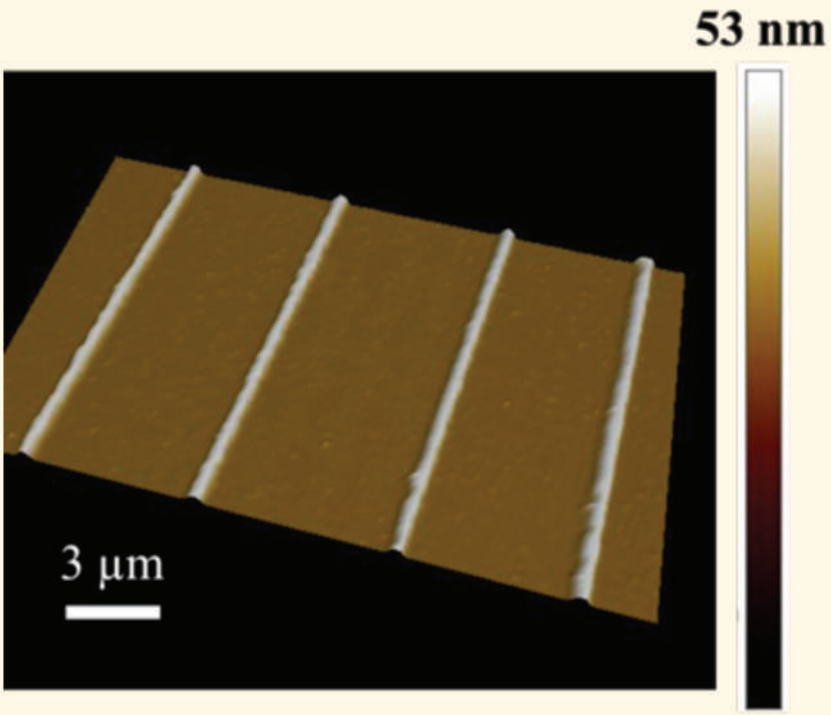
Demonstrated a non-adiabatic shot waveguide taper of length just 15microns to couple light efficiently between a 10micron and 450nm waveguide. [patented, Optics Express 2017].

Technology developed for high throughput measurement of cells mechanical properties using electrical signals only [IEEE MEMS Conferene 2017].

Investigation on Boron-linked polymers (BLP) as technologically simpler and cheaper way to fabricate solid-state neutron sensors, to eventually meet the needs of the Indian strategic sector.

Development of a kinetic model for dislocation bending in III-nitrides that is being used in commercial software [Phys Rev B 2011, J. Crystal Growth 2012].

Research Breakthroughs



100nm wide metal lines patterned through electrolithography

Development of 'Electrolithography': a new technology for nanoscale lithography based on understanding of nanoscale percolation network formation in thin metal films and subsequent discovery of liquid electromigration in chromium thin films. This technology is currently being productized to develop a table top nanolithography tool, that works at room temperature and pressure [patented, Scientific Reports 2015, Applied Physics Letters 2014, Journal of Applied Physics, 2012].

Development of graphene impregnated impermeable plastics [ACS Nano 2016, productization in progress].

Life at CeNSE


NANO
SCIENCE
&
ENGINEERIN

Administrative officer Dr RN Narahari, with his team

Design: Thefool.in

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