PressCeNSE

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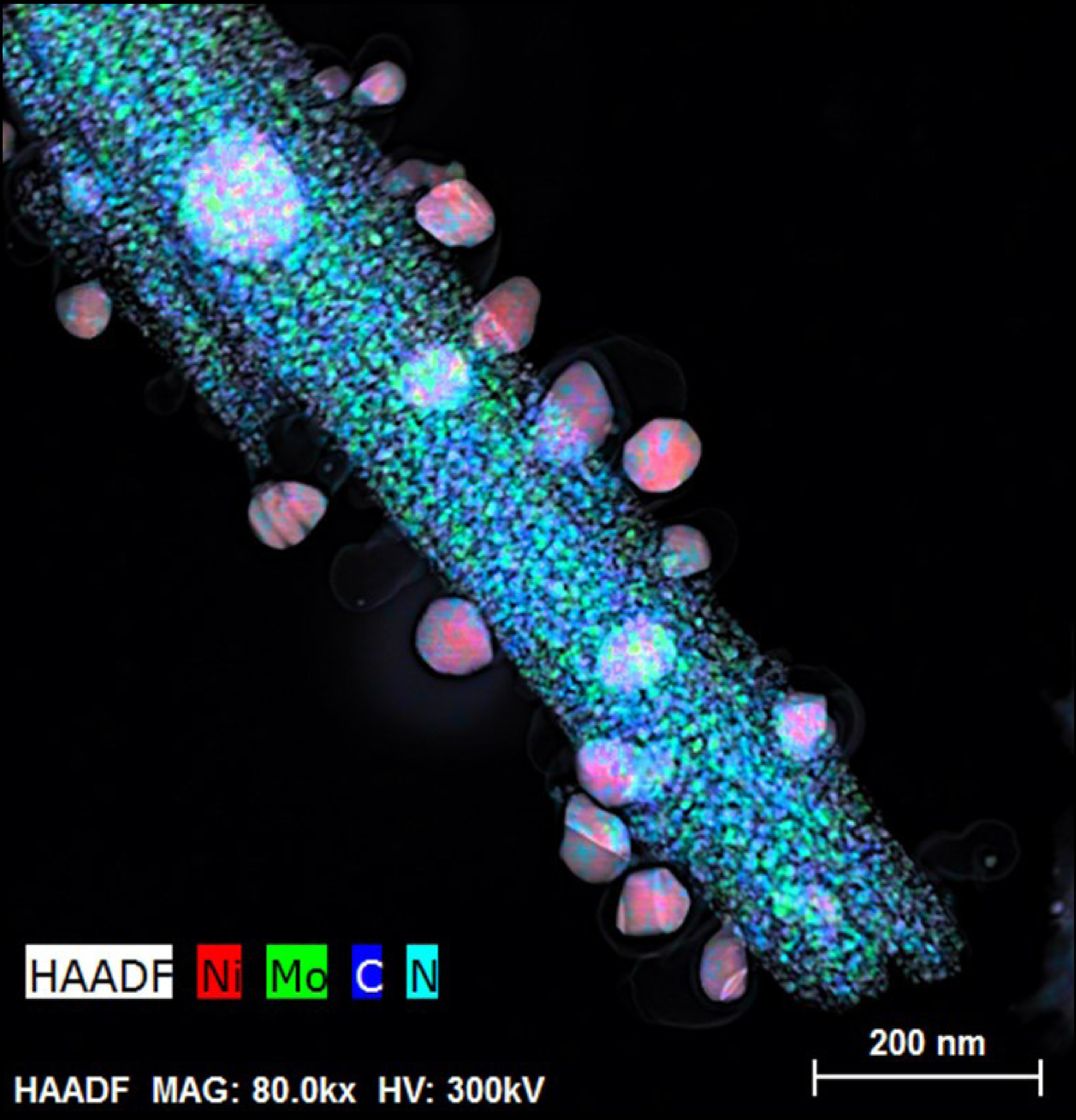


Centre for Nano Science and Engineering (CeNSE)

Indian Institute of Science

CONTENTS

Cover photo: Nano Climber Plant; EDS mapping in STEM by Ambresh M. Sample Courtesy: Debanjan Das, MRC.

MESSAGE FROM THE CHAIR

I take this opportunity to wish you all a very happy new year 2020. This year is special for us, as it marks a very important milestone in our journey. CeNSE is completing one decade since its inception in the year 2010. Over the last decade, we have come a long way in terms of establishing CeNSE as one of the premier centres for Nanoscience and Nanotechnology in all aspects including research, technology development, outreach and incubation of start-ups. This is also an occasion for us to retreat and plan for the vision for the next decade. With the backdrop of learning and experience gained over the last decade, we aim to position ourselves to meet the challenges ahead and convert the future opportunities into tangible outcomes. We also seek your inputs and suggestions to shape our future for the next decade.

During the last quarter we started an important initiative called "CeNSE DBT Nanobiotechnology Alliance (CDNA)", funded by the Department of Biotechnology, Government of India. This is a 5 year program with an objective of fostering nanotechnology education and collaborative projects, with a focus on researchers in biological sciences and clinicians. You will see more details in this issue, about the inaugural workshop conducted under this initiative.

The I-STEM portal developed by CeNSE in consultation and close collaboration with the Office of the Principal Scientific Adviser to the Government of India, was formally launched by the honourable prime minister Shri Narendra Modi, during the 107th Indian Science Congress. This will be a transformational initiative to enable many to many mapping between researchers and resources, in the context of science and technology education and research in the country.

We had an interaction with our alumni, during the annual alumni meet of the Institute held on 14th December, 2019. It was heartening to note that our alumni have been performing extremely well in various organizations. We plan to have continuous engagement with our alumni in the years to come.

-Navakanta Bhat

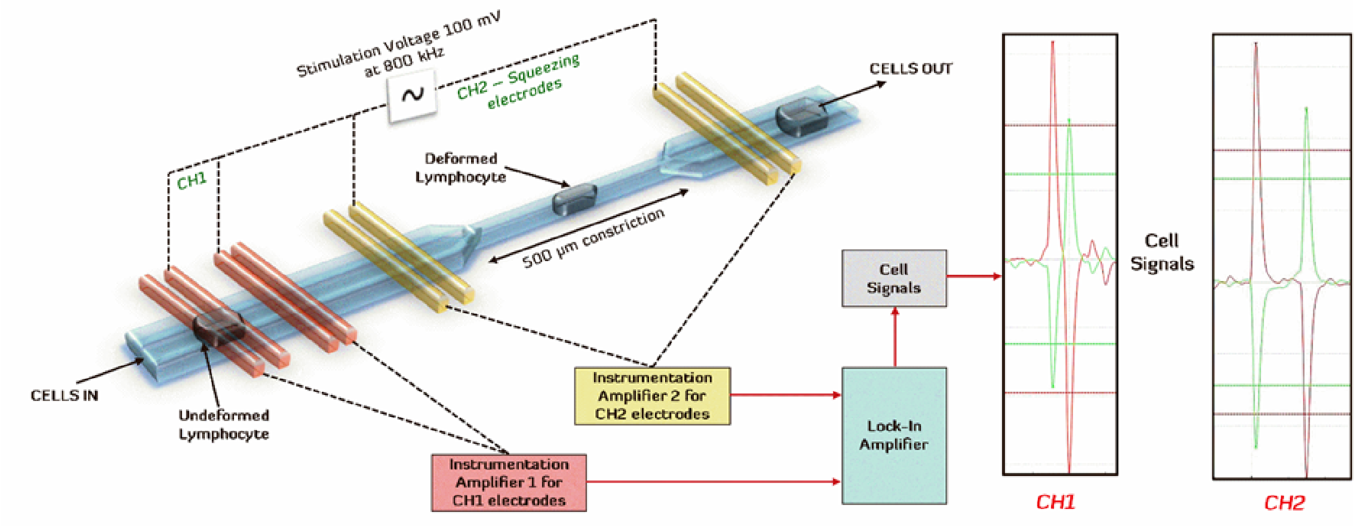
What's new in research at CeNSE?

Complex Systems and Molecular Sensing Lab
Micro and Nano Fluidics Lab

Rapid Electromechanical Diagnosis of Single Cells

Karthik Mahesh, Manoj Varma and Prosenjit Sen

The Complex Systems and Molecular Sensing (CoSMoS) Lab and the Micro and Nano Fluidics Lab (MNFL) have jointly developed a novel microfluidic platform capable of probing the electrical and mechanical properties of individual cells at a rapid throughput. Historically, the diagnosis of human diseases has always relied on the quantification of certain biochemical parameters to determine the extent of disease progression. Although these biochemical parameters are widely accepted in the diagnostic field, there is little to no understanding of what is actually happening at the cellular level. The present study answers two important questions – a) does the progression of diseases correlate to biophysical changes at single-cell level? b) how does one quantify these changes so that they can be used in rapid and efficient diagnosis?



The platform developed by CoSMoS lab and MNFL was used to understand the changes in the biophysical and rheological properties of lymphocytes in diabetes-affected individuals. Thousands of individual lymphocytes were allowed to flow through a microchannel having a narrow constriction at the centre to mechanically squeeze the cells. This constriction was placed between two pairs of co-planar microelectrodes. As the lymphocytes traversed over each electrode pair, the impedance measured by the system was altered, enabling one to measure the electrical properties of the cell. A differential measurement principle was employed in which there were two peaks – positive and negative – in the measurement signal, corresponding to the relative impedance change of the entire system. Analyzing the time difference between the generated electrical signals gives an estimate of the time required by the cell to squeeze through the constriction (termed "transit time"). This time of transit is an effective way of comparing the mechanical properties of cells with varying degrees of deformability or stiffness. Thus, the platform enables the independent and simultaneous measurement of electrical and mechanical properties of cells, at a high throughput.

A longer transit time was recorded for diabetic lymphocytes than for healthy lymphocytes, correlating to a reduction in deformability. Additionally, larger electrical signal amplitudes were observed for diabetic lymphocytes, indicating significant changes in electrical behavior. The data from both these parameters were combined to visually identify the differences between normal and diabetic lymphocytes and develop a simple diagnostic model that can predict whether a random lymphocyte from an individual is healthy or diabetic. In the near future, this kind of technology may assist in the development of a "pre-diagnostic" tool that supports healthcare professionals in assessing whether a patient has the chance of developing a disease even before the onset of disease symptoms, using just a single drop of blood.

[The detailed research-findings have appeared in the Journal of Micromechanics and Microengineering volume 29, (August 2019) [https://iopscience.iop.org/article/10.1088/1361-6439/ab38fc]]

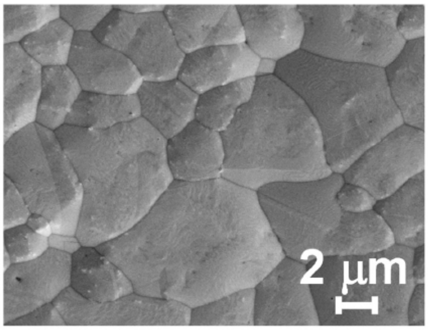
HETERO-JUNCTION LAB

Wafer-scale two-step liquid phase crystallization of Ge-on-Si for near-infrared photodetector applications

Sandeep Kumar and Sushobhan Avasthi

Germanium, a group-IV material like Si, has the first direct band gap minimum at ~140 meV above its indirect bandgap of 0.66 eV. This property leads to a significant optical absorption in the near-infrared (NIR) range, hence making it a potential candidate for NIR photodetector applications. It is compatible with the complementary metal-oxide-semiconductor (CMOS) process, unlike the other III-V semiconductors. Further, the growth of Ge over Si provides a low-cost and mechanically stable path, together with its ease to CMOS process integration for various circuits. However, the ~4% lattice mismatch between Ge and Si introduces high surface roughness, as well as threading dislocations that act as recombination centres, and degrades the device performance. Therefore, growth of epitaxial Ge-on-Si with low surface roughness and fewer threading dislocation densities is highly desirable.

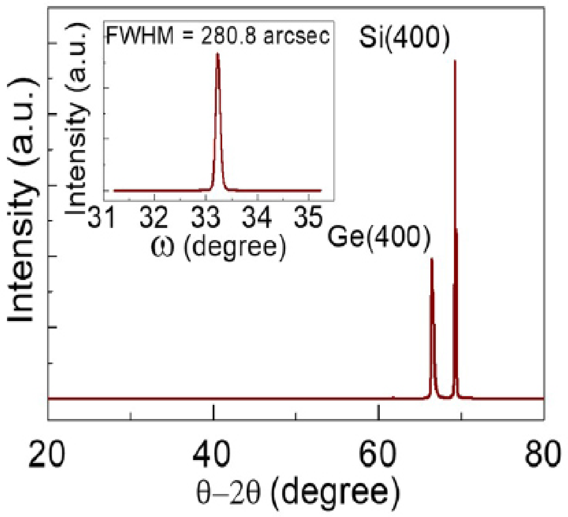
The Hetero-junction Lab proposes a novel two-step liquid phase crystallization (LPC) process of Ge-on-Si. The LPC process is motivated by the well-known Czochralski (CZ) process, widely used in the microelectronics industry. This process does not require any complex equipment, like molecular beam epitaxy or ultra-high vacuum chemical vapour deposition (CVD), or a complex recipe like reduced



Scanning electron microscope image of crystallized Ge-on-Si

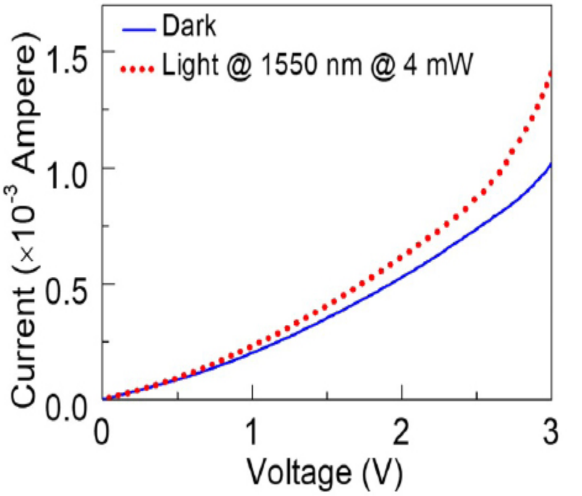
Liquid phase crystallized Ge-on-Si 2"-wafer.

pressure CVD. With the use of a simple furnace, Ge with a Hall mobility of >500 cm^2/Vs was obtained. The amorphous Ge was grown using plasma-enhanced chemical vapour deposition. In the first step of the LPC process, the samples are heated at 950°C for 5 minutes. The melted Ge is cooled at ~4°C/minute to 930°C (a temperature just below the melting point of Ge). In the second step, the samples are kept at 930°C for 2 hours to provide sufficient thermal budget for the grain growth. The choice of temperatures – 950°C and 930°C - results in reduced nucleation while maintaining high rate of grain-growth.

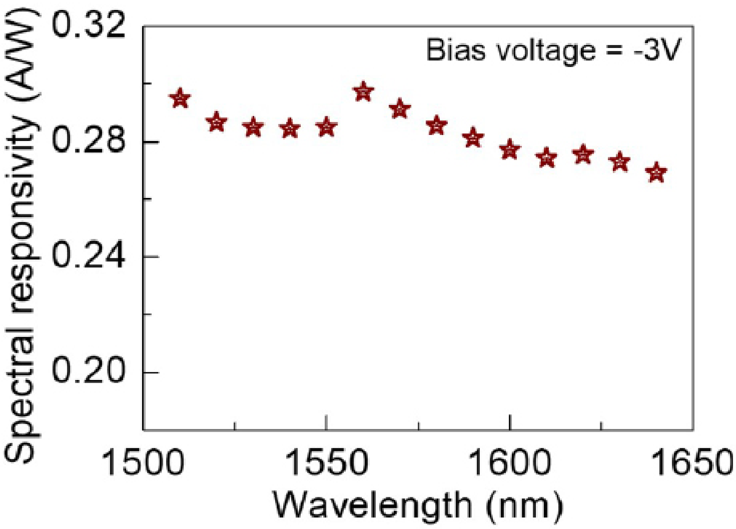


X-ray diffraction measurement of crystallized Ge-on-Si

Scanning electron microscopy confirms formation of grains of size up to 12 μm. The normal incidence θ-2θ X-ray diffraction (XRD) scan confirms growth of Ge along the 400 plane. Rocking curve XRD shows that the growth Ge is epitaxial. The full-width half-maximum of 280.8 arcsec quantifies the misorientation of grains along the normal. A dislocation density of 108 cm^{-2} is obtained by assuming that the rocking curve broadening is caused only by the angular rotation. Metal-semiconductor-metal (MSM) devices sensitive to 1500-1550 nm NIR illumination show an average spectral responsivity of 0.50±0.16 A/W at 1550 nm at -3V, comparable to the state-of-the-art MSM Ge photodiodes on Si-wafers.



Current-voltage characteristics of metal-semiconductor-metal photodetector



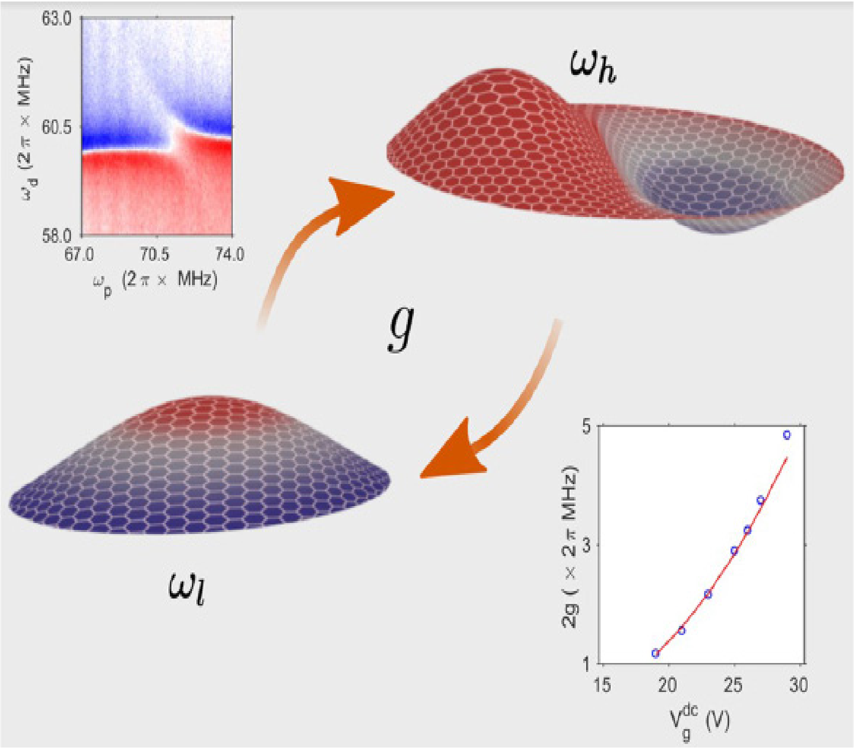
Spectral responsivity of metal-semiconductor-metal photodetector

MEMS/NEMS Lab

Gate-tunable Cooperativity between Vibrational Modes

Parmeshwar Prasad, Nishta Arora and Akshay Naik

Christiaan Huygens's "Horologium Oscillatorium"(1673) is considered as one of the foundations of modern mechanics. Huygens the inventor of pendulum clock described the synchronization of pendulum clocks in the book. Pendula in these clocks hung on the wall used to get synchronized over time no matter how their clocks began. This synchronization is



the result of the coupling between the pendula: dynamics of the pendula are affected by each other's motion through the exchange of energy between them. Such coupling phenomena are ubiquitous in nature from synchronized flashing of fireflies in biology to Raman scattering and quantum computing in physics. This concept is used in coupling radiation with mechanics known as optomechanics, which plays a crucial role in one of the most precise experimental set-up on earth, LIGO (Laser Interferometer Gravitational-Wave Observatory).

In a recently published paper in *Nano Letters*, Parmeshwar Prasad and colleagues, from Prof. Akshay Naik's group, studied strong coupling mechanism between two modes of a nanoscale resonator. Strong coupling between nanoresonators have previously been used to demonstrate novel effects such as cooling and electromagnetically induced transparency. The nanoscale resonator in this work is a drum shaped resonator made of a membrane with the thickness of a few atomic layers, and the modes are accommodated in this single nano drum resonator. The two different mechanical vibration modes have frequencies in the range of 100 MHz, the same frequency range where FM radio works. The modes interact with each other via tension in the membrane which can be controlled electrically. In their experiment, the researchers manipulated this coupling to enhance or reduce the energy exchange between the vibrational modes. The coupling can be increased to such an extent that the energy between the modes is exchanged more than 500 times back and forth before the information is lost to the environment. This is more than an order of magnitude improvement in coupling compared to previous demonstrations. This demonstration of strong tunable coupling between high-frequency vibrational modes at nanoscale could lead to improvements in sensitivity of nano-mechanical sensors and has major implications for mechanical logic circuits and quantum limited measurement.

[The detailed research-findings have appeared in Nano Letters in 2019 and can be accessed at https://pubs.acs.org/doi/10.1021/acs.nanolett.9b01219]

FACILITY UPDATES

MICRO AND NANO CHARACTERIZATION FACILITY

Suresha SJ

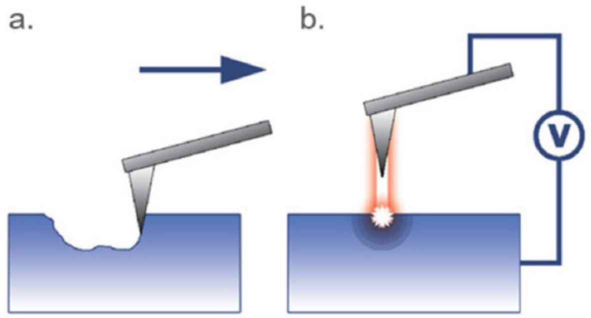
The Micro and Nano Characterization Facility (MNCF) is a fully equipped national research facility that offers researchers convenient access to a wide range of state-of-the-art analytical instrumentation and services needed for the development of micro- and nano-scale materials and devices with novel properties. This facility supports the research and educational objectives of CeNSE, IISc and offers advanced characterization facilities. To support technology and process development, which is a major thrust area for the Center, new processes and capabilities are constantly developed and implemented at MNCF. The following provides an overview of the new characterization processes, capabilities and features recently added to MNCF's portfolio.

AFM Nano Lithography

Atomic force microscopy (AFM) is a very-high-resolution type of scanning probe microscopy (SPM), which can demonstrate spatial resolution of the order of tens of nanometers and vertical resolution of the order of fractions of a nanometer.

Normally, AFM is used to image a surface to get information such as topography. However, AFM can also be used to modify a surface. One such modification technique where the surface is modified atom by atom is known as Nanolithography.

Using Nanolithography, patterns can be created on the sample surface by two methods as shown in figure 1. The first method uses a hard AFM probe where the sample surface is scratched, thereby mechanically deforming the sample surface. This is called Scratch Lithography. The second method is to apply a bias between the tip and the sample surface thereby inducing a change of the surface's chemical properties. This is called Oxidation Lithography. Raster Nanolithography is common where the entire image is scanned, whereas another more advanced technique is Vector scanning nanolithography.



Pattern created on the surface by plowing the surface with the tip (a) and by changing the surface with applied bias (b).

Figure 1: Image from parksystems.com

Oxidation Lithography

By applying voltage pulses between the tip and sample in contact mode, local oxidation experiments are performed with an atomic force microscope. The local oxidation process is mediated by the formation of a water meniscus.

In order to perform Local Oxidation Nanolithography, the relative humidity in the AFM chamber is kept between 30% and 60%. Humidity presents the necessary water layer formation on the sample. A voltage is applied between a conductive AFM probe and the sample. The applied voltage induces the formation of a water bridge between the tip and sample. When the water meniscus is created, the applied voltage pulse causes an oxidation reaction by breaking the covalent bonds in the water molecules. The liquid bridge provides the oxyanions (OH^- and O^-) needed to form the oxide, and confines the lateral extension of the region to be oxidized.

The chemical reactions that govern local oxidation in a metallic substrate (M) are the following:

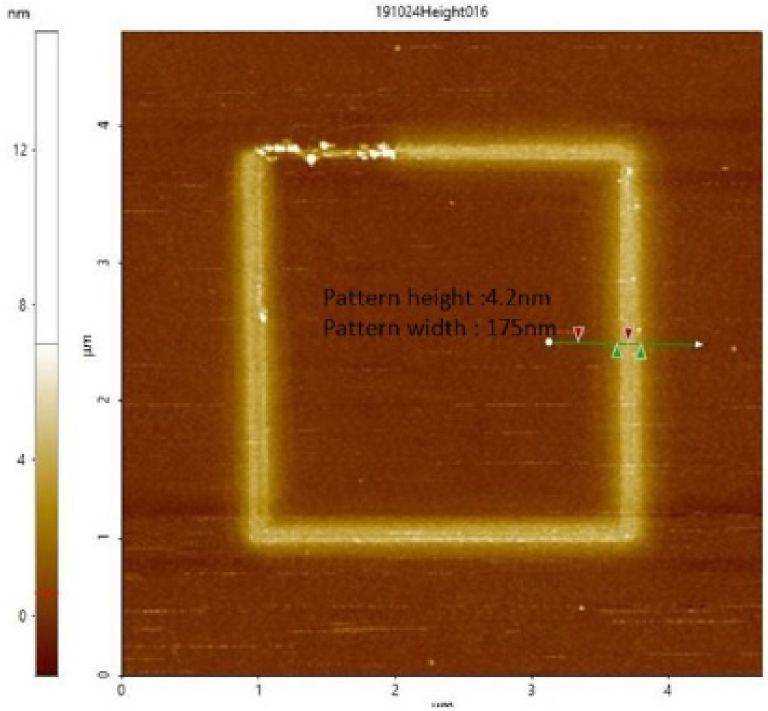
$$\mathrm{M} + n\mathrm{H_2O} \longrightarrow \mathrm{MO}_n + 2n\mathrm{H}^+ + 2ne^-$$

$$\mathrm{M}^n + 2n\mathrm{H_2O} + 2ne^- \longrightarrow n\mathrm{H_2} + 2n\mathrm{OH}^- + \mathrm{M}$$

while hydrogen gas is liberated at the AFM tip through the reduction reaction.

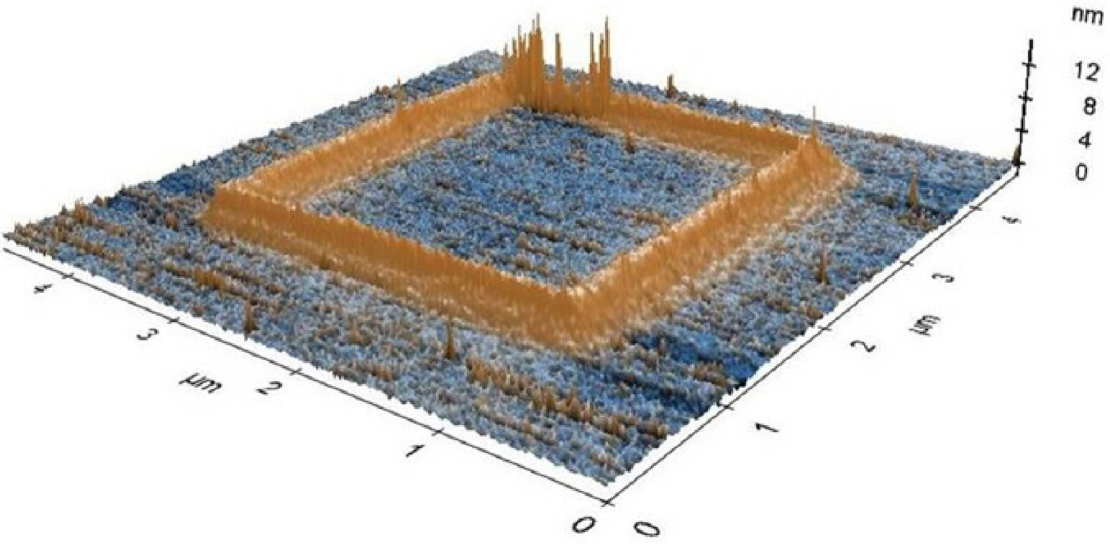
$$2\,\mathrm{H}^+ + 2\,\mathrm{e}^- \longrightarrow \mathrm{H_2}$$

Courtesy: Wikipedia



When the voltage is OFF, the AFM feedback forces the cantilever to revert to its original oscillation amplitude, withdrawing the tip from the sample and breaking the water meniscus. The AFM continues to scan the sample thus allowing one to image MO_n nanostructure fabricated by using the local oxidation process with the very same tip used for its fabrication.

The method to form liquid bridges is so precise that water meniscus diameters of 20 nm or below are easily obtained. This has led to the reproducible fabrication of sub-10 nm structures on silicon and on metallic surfaces.



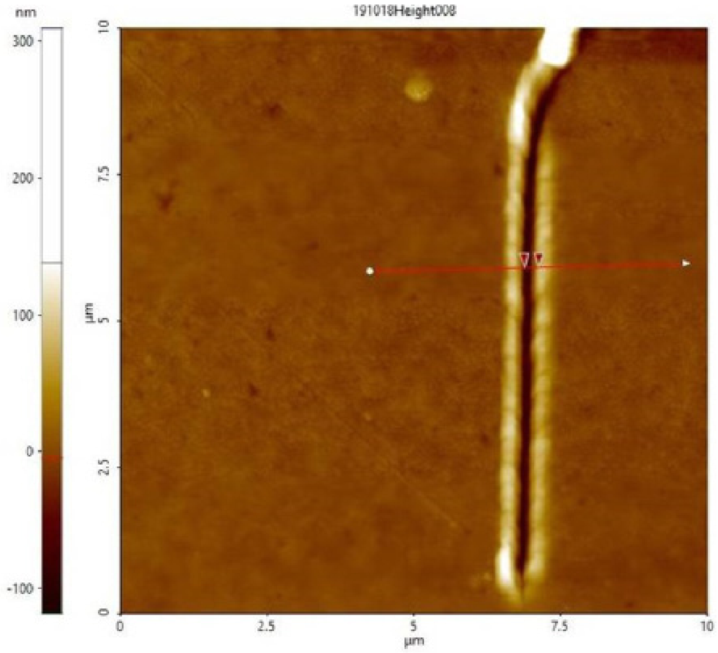
3D representation

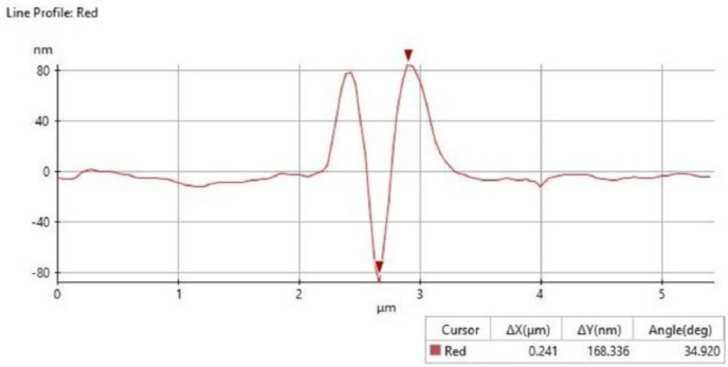
A square pattern made using oxidation lithography method

Scratch Lithography

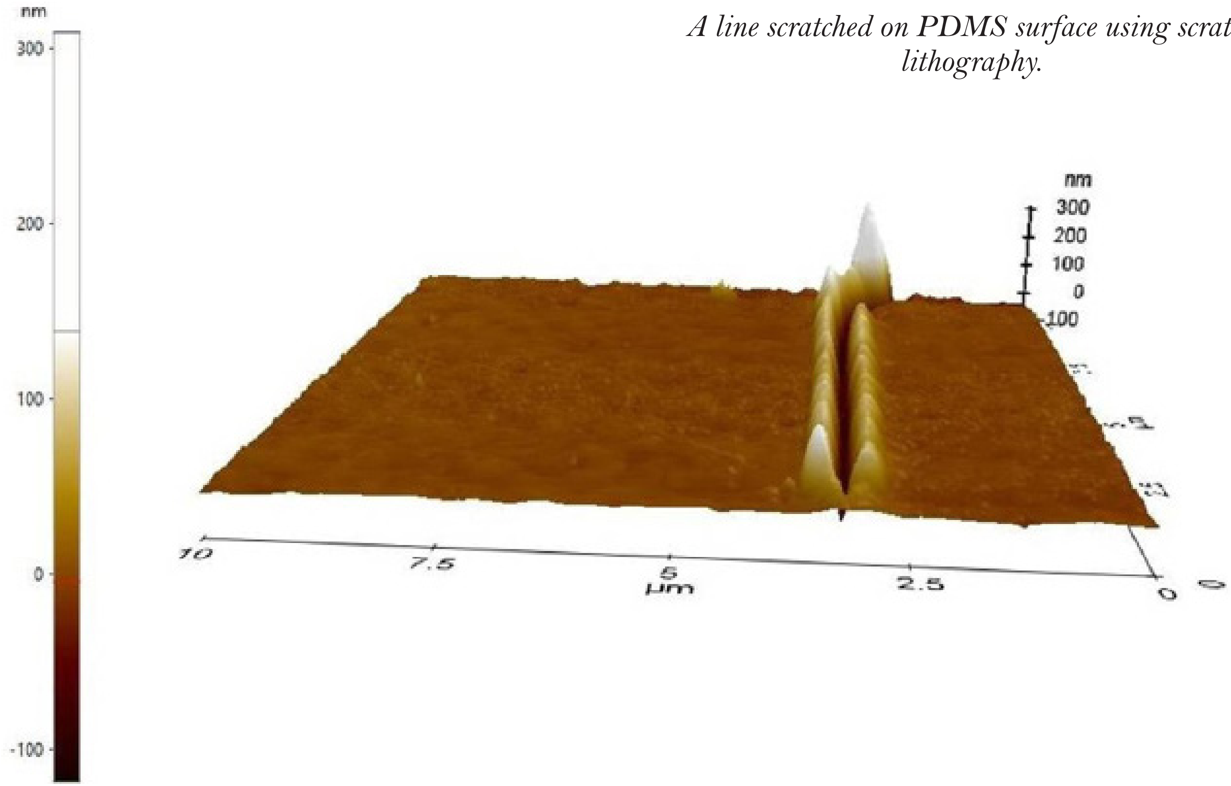
An AFM probe with stiffness compatible with that of the target sample is chosen.

A strong loading force known as deflection setpoint (in AFM terms) is applied on the probe cantilever to scratch the sample in a manner similar to the ploughing technique used in traditional agricultural methods. Depending on the shapes of the probe used, one can have precisely made trenches at the nanoscale level.





A line scratched on PDMS surface using scratch lithography.



Nanolithography presents users a wider window of possibilities with the Atomic Force Microscope, making the microscope not only a viewing instrument but also one which can be used to manipulate surfaces at nano level.

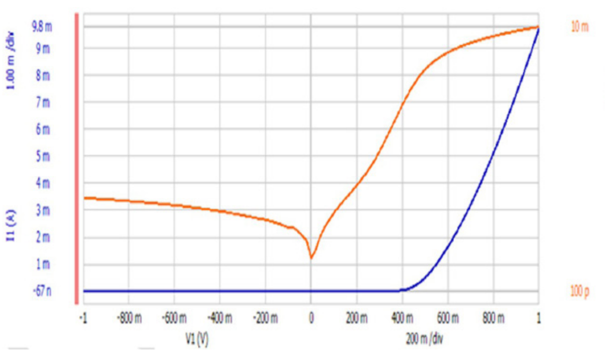
Reverse Diode Recovery

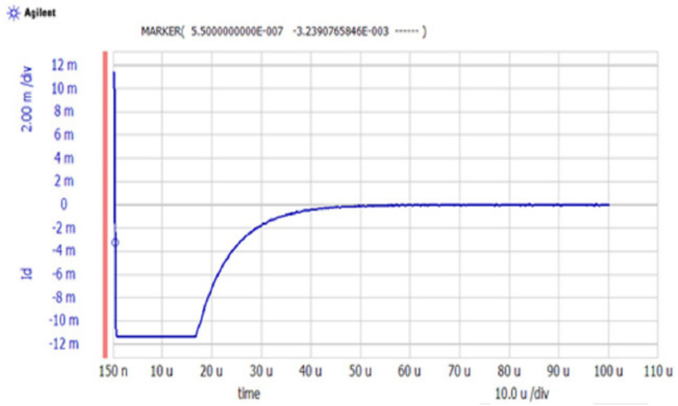
Improved Reverse Recovery Measurements for The Extraction of Recombination Lifetime in Solar Cells

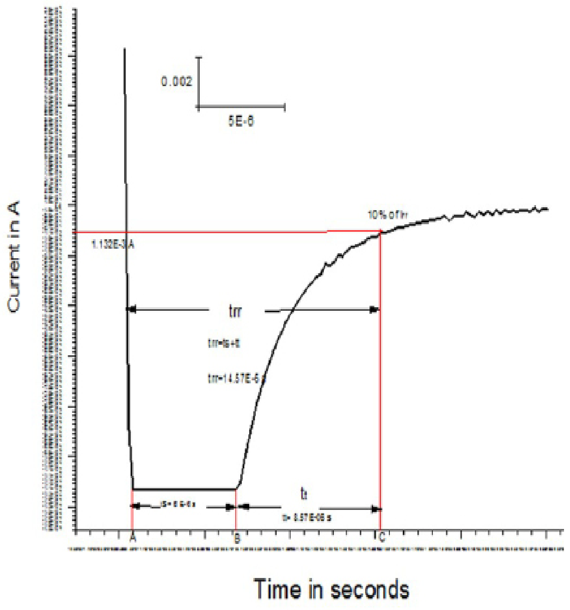
The measurement of the minority carrier recombination lifetime is a crucial issue for the characterization of solar cells. Recombination lifetime is the major factor responsible for performance of solar cells, but its value is strongly dependent on technological processes. As a matter of fact, the monitoring of the lifetime during device fabrication gives quantitative information on the "quality" of technological processes. Numerous techniques exist in the literature, but one of the measurement methods used commonly is the reverse recovery method.

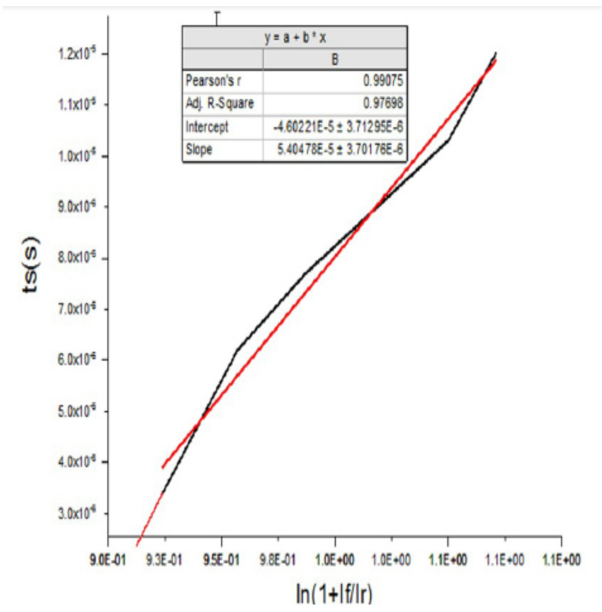
In this method, when the diode is switched from the ON to the OFF state, the diode conducts in a reverse condition for a short time, as the forward voltage leaks and as it takes some time to recover the diode in the OFF state. The current through the diode will be fairly large in a reverse direction during this brief recovery time. After the carriers have been flushed and the diode is acting as a normal blocking device in the reversed condition, the current flow should drop to leakage levels.

This measurement method uses a B1500A Semiconductor Device Analyzer and WGFMU (Wave Form Generation and Fast Measurement Unit) connected to a probe station. Such Analyzers and pulsing units are ideal for wafer-level devices, low current measurements, and fast pulsing measurements.









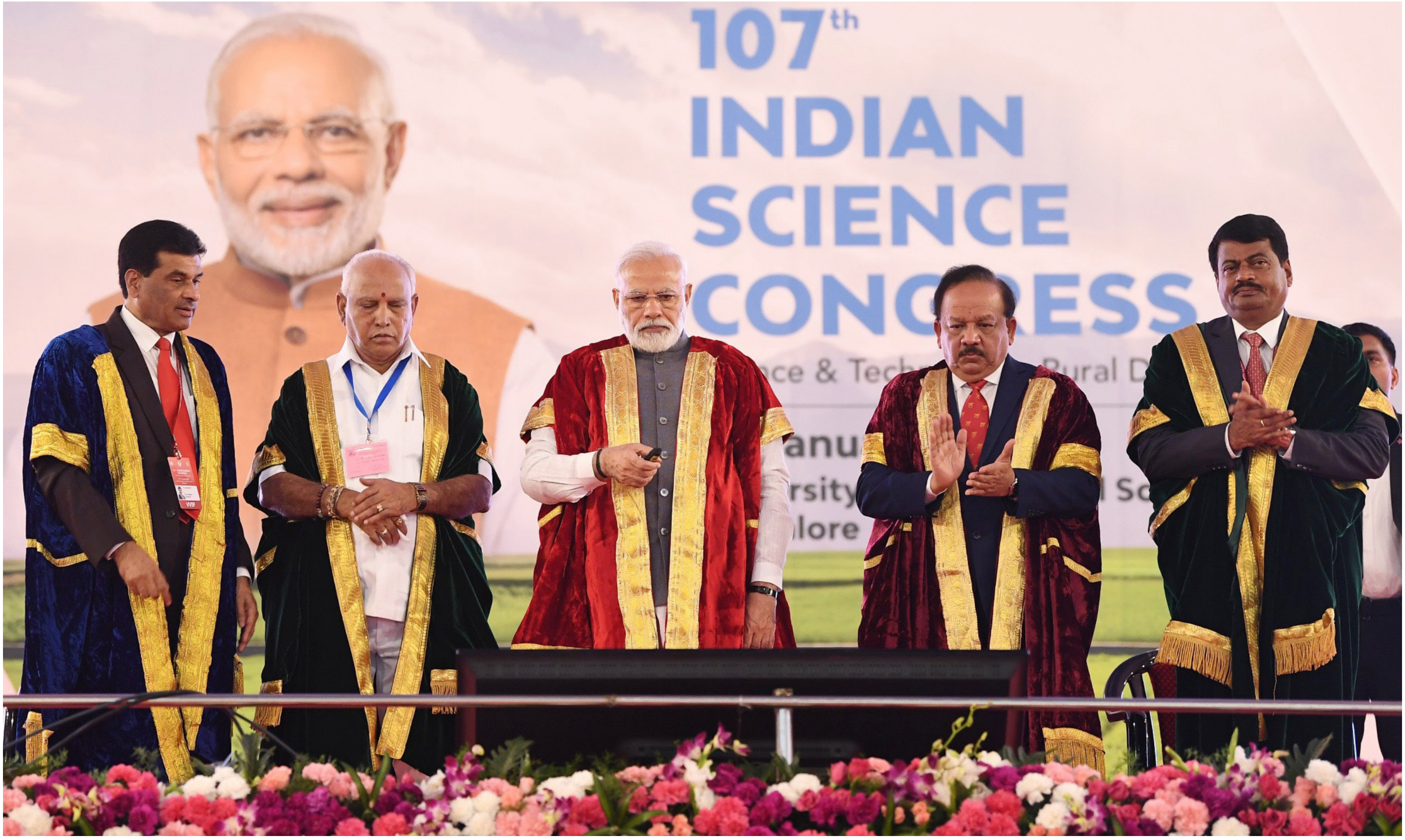
OUTREACH

CeNSE IN THE NEWS

Indian Science, Technology and Engineering facilities Map (I-STEM): Back in August 2019, I-STEM and its initiatives were featured in *Nature Asia*, with the endorsements of Prof. K. VijayRaghavan, the PSA to the Govt.of India, Prof. R. Mashelkar, former DG-CSIR, and Prof. Ashutosh Sharma, Secretary, DST. The complete article titled "Equipped for a collaborative future" can be accessed here:

https://www.natureasia.com/en/nindia/article/10.1038/nindia.2019.105?WT.mc_id=FBK_NPG

The I-STEM web portal was officially launched by Shri Narendra Modi, honourable Prime Minister of India, on January 3, 2020, during 107th session of the Indian Science Congress. The event, held at the GKVK campus from 3rd to 7th January, 2020, was organized by the University of Agricultural Sciences, Bengaluru. The theme for this session was **Science and Technology: Rural Development**. The I-STEM portal was lauded as a great platform that would "link researchers and resources, hold database of all the R&D facilities established in institutions all around the country, and enable their sharing in a transparent manner".



Prime Minister Shri Narendra Modi inaugurating the 107th session of the Indian Science Congress

Dr. Sanjeev Shrivastava is the National Coordinator for I-STEM, with Prof. S.A. Shivashankar serving as the Adviser and Prof. Navakanta Bhat as the PI of the I-STEM Project sponsored at CeNSE by the Office of the Principal Scientific Adviser to the Govt. of India.

FEATURE

CeNSE DBT NANO-BIOTECHNOLOGY ALLIANCE

The CeNSE DBT Nano-Biotechnology Alliance (CDNA) is a training program aimed at researchers with biology and medical background, interested in pursuing interdisciplinary research in nano-biotechnology. The program aims to catalyze research and education in nano-biotechnology across India, with a focus on the nanoengineering and nanotechnology aspects of this interdisciplinary field. CDNA is a five-year initiative conceived and recommended by the nanobiotechnology task force of DBT. The inaugural workshop was held at our Center on 4th and 5th November, 2019, and CeNSE hosted several eminent speakers from around the country, who are working at the intersection of biological science, clinical, and translational research, and nanotechnology. The program was inaugurated by Prof. Padmanabhan Balaram, who spoke about the various discerning aspects of the CDNA initiative. Prof. Ambarish Ghosh convened this program with the assistance of Ms. Grace Mathew Abraham, Coordinator, CDNA.

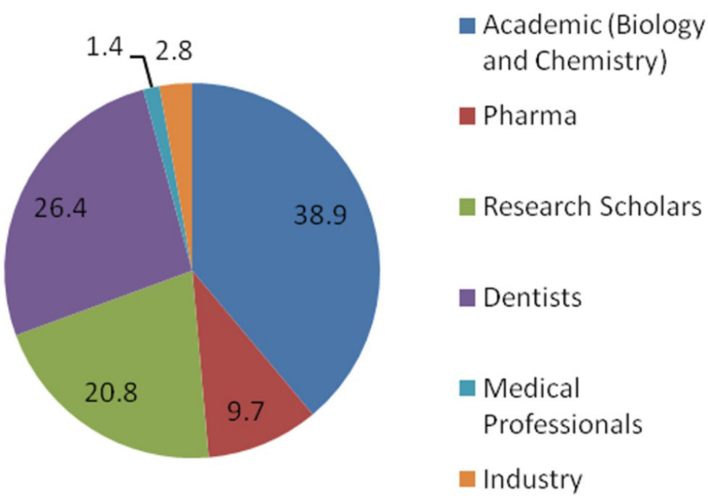
Profs. Bhat, Balaram and KN Ganesh

The workshop was structured around theoretical lectures by faculty members, who explained the fundamental principles behind the standard nanotechnology techniques, and lectures from experienced faculty members from other institutions, government officials, medical doctors, and healthcare industry professionals, aimed at creating awareness about Intellectual Property (IP) creation and policy issues (bio-ethics) pertaining to nanobiotechnology research. Panel discussion conducted on the first day of this workshop had given the participants an opportunity to interact with the panellists Profs. K N Ganesh, Navakanta Bhat, Dr. Satya Dash and Dr. P R Krishnaswamy, and discuss interdisciplinary approaches in Nano-biotechnology Research and Development. Further, tours of MNCF and NNfC were organized for all the participants by our technical staff.

Dr. Suchita Ninawe speaking during the inaugural session

The inaugural workshop brought together 72 participants from various institutions across the country, who represented academic, medical and industrial organizations and a range of disciplines in biology, chemistry, materials science, physics, and engineering. The participants said this two-day workshop was a unique opportunity for them to gain an understanding of the entire spectrum of nano-biotechnology research -- from materials to devices and systems. Participants who intend to pursue research focussed on the translation of nano-biotechnology from concept to product found the lectures on IP creation and policy issues particularly useful. A proposal to organize an international conference on nanobiotechnology every two years was made, which would involve participants of the training program as well as world-renowned researchers in the field of nano-biotechnology.

Panel discussion on day one of the CDNA workshop



Distribution of the participants of CDNA workshop in percentage

Participants of the CDNA workshop

Prof. A K Dinda, Dept. of Pathology, AIIMS, speaking about the "Application of Nanotechnology in Medicine: Understanding the safety guidelines for product development "

Dr. Taslimarif Saiyed, Center for Cellular and Molecular Platforms, DBT, delivering his lecture on "Critical Ingredients for Catalysing Life Science Innovations"

Future workshops under the CDNA program aim to include hands-on training on nanofabrication and characterization tools by technical staff, which would be arranged in training modules designed to mimic an entire nanobio-research project -- from synthesis and characterization of a system of nanoparticles to applying the system for therapeutics and sensing applications. These modules will expose participants to various characterization tools such as electrical, mechanical, materials, and optical characterization.

The next event under this initiative, C-DNA familiarization workshop, is going to be held at our Center from 18th to 20th March, 2020. All information and regular updates on CDNA events can be found here: http://cdna.cense.iisc.ac.in/

https://www.facebook.com/C-DNA-101255361392924/?modal=admin_todo_tour

https://www.linkedin.com/in/c-dna-cense-0a072719a/

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AWARDS

STUDENTS

The Materials Research Society's (MRC) fall meeting was held from 1st to 6th December, 2019, in Boston, Massachusetts, USA. Ms. Neha Sakhuja, graduate student in Prof. Navakanta Bhat's research group, won the Best Poster award for her poster presentation titled "Iron Oxide Anchored Tungsten Diselenide Nanosheets for Ultrasensitive Detection of Ammonia".

Ms. Anisha Kalra, graduate student jointly advised by Profs. Digbijoy Nath and Srinivasan Raghavan, won the Best Presentation award for her presentation titled "Record High Zero-Bias External Quantum Efficiency of 92% for $Al_{0.40}Ga_{0.60}N$-Based p-i-n UV Detectors", at the Electronic Materials Conference held from 26th to 28th June, 2019 at the University of Michigan, Ann Arbor, Mihcigan.

Dr. Namrata Singh won the IIT Bombay Metrohm Young Chemist award for 'Innovation in Research' at IIT Bombay for her work on "uncovering the role of an antioxidant nanozyme that provides cytoprotection in Parkinson's Disease model".

Ms. Preeti Deshpande won the Best Poster award at the Gordon Research Conference on Plasmonically Powered Processes held in Hong Kong in August 2019. She received the award for her poster titled "Plasmonic Dimer Array with sub-Nanometer Gap using MoS_2 Space Layer: Application in Hot Electron Generation and Localized Heating".

FACULTY

Prof. V R Supradeepa received the Indian National Academy of Engineering's Young Engineer award and the Indian National Science Academy's Young Scientist award, in 2019.

Picture credit: Ayush Ranka

Prof. Navakanta Bhat has been elected the Vice President, Education, IEEE Electron Devices Society.

DEPARTMENTAL AWARDS

The inter-departmental sports competition at IISc saw team CeNSE emerge as the winner in the volleyball tournament - 2019.

EVENTS

ITEC COURSE ON SCIENCE, TECHNOLOGY, AND INNOVATION POLICY

27 November – 03 December

The Course on STIP was started by CeNSE in 2018. This program is funded by the Ministry of External Affairs (MEA) through its Indian Technical and Economic Cooperation (ITEC) program and provides a forum for discussion and development of public policy to promote Science, Technology, and Innovation. The second session of this course focussed on the following themes:

1) Healthcare

2) Climate Change and the Environment

3) Agriculture and Food Security

4) Energy Security

5) Innovation/Translational Research/Start-up Policy/Intellectual Property.

Lectures and presentations were delivered by eminent speakers from Government, academia, and industry, addressing topics such as History and evolution of science policy, Role of government in promoting, financing, and directing R&D in science and technology, Science, technology, and IPR, Promoting entrepreneurship to deal with national/regional concerns, Science Policy, Education, and Culture, Professional organizations and science/engineering societies, and Regional/cross-regional collaboration.

- Dr. A S Kiran Kumar, Former Chairman, ISRO delivered a lecture titled “Harnessing Space Technology”.
- Shri M N Vidyashankar, Former Additional Chief Secretary, Govt. of Karnataka delivered a lecture on “E-governance: Policy aspects and benefits”.
- Dr. R. Chidambaram, Former Principal Scientific Adviser to the GoI and Former Chairman, Dept. of Atomic Energy delivered a lecture on “Technology Foresight”.
- Prof. Sundar Sarukkai, Former Professor of Philosophy, National Institute of Advanced Studies (IISc campus) spoke about “The Ethics of Science, Technology and Development”.
- Prof. J. Srinivasan, Distinguished scientist at the Divecha Centre for Climate Change, IISc, spoke about his work on climate modelling and satellite meteorology, shared insights on “What can Developing Countries do about Climate Change?”

The ITEC-STIP program was organised by Dr. Sanjeev Shrivastava and Prof. S A Shivashankar. The course had 25 participants from thirteen countries.

ADVANCED TRAINING PROGRAM ON NANOFABRICATION AND CHARACTERIZATION TECHNIQUES

03 - 13 December

This INUP event saw 23 participants from over 20 organizaions. The course modules included MEMS Cantilever, MOS Capacitor, Photovoltaic Cell and Gas Sensors.

ALUMNI MEET

14 - 15 December

As part of IISc's annual alumni reunion, CeNSE welcomed back its alumni. Talks by noted alumni on entrepreneurship opportunities and industry requirements were followed by networking sessions with current students.

VISITORS TO CeNSE

During the last quarter, we at CeNSE received encouraging feedback from many distinguished visitors.

Dr. Ahmed Al-Shoaibi, Senior Vice President of Research and Development, Dr. Ashraf Al-Najdawi, Chief of Staff and Director of International Cooperation and a delegation from Khalifa University of Science and Technology, Abu Dhabi, UAE, visited CeNSE in September, 2019. The visit was aimed at exploring the opportunities for cooperation on exchange of faculty and students, collaborative research/academic programs and joint supervision for graduate students.

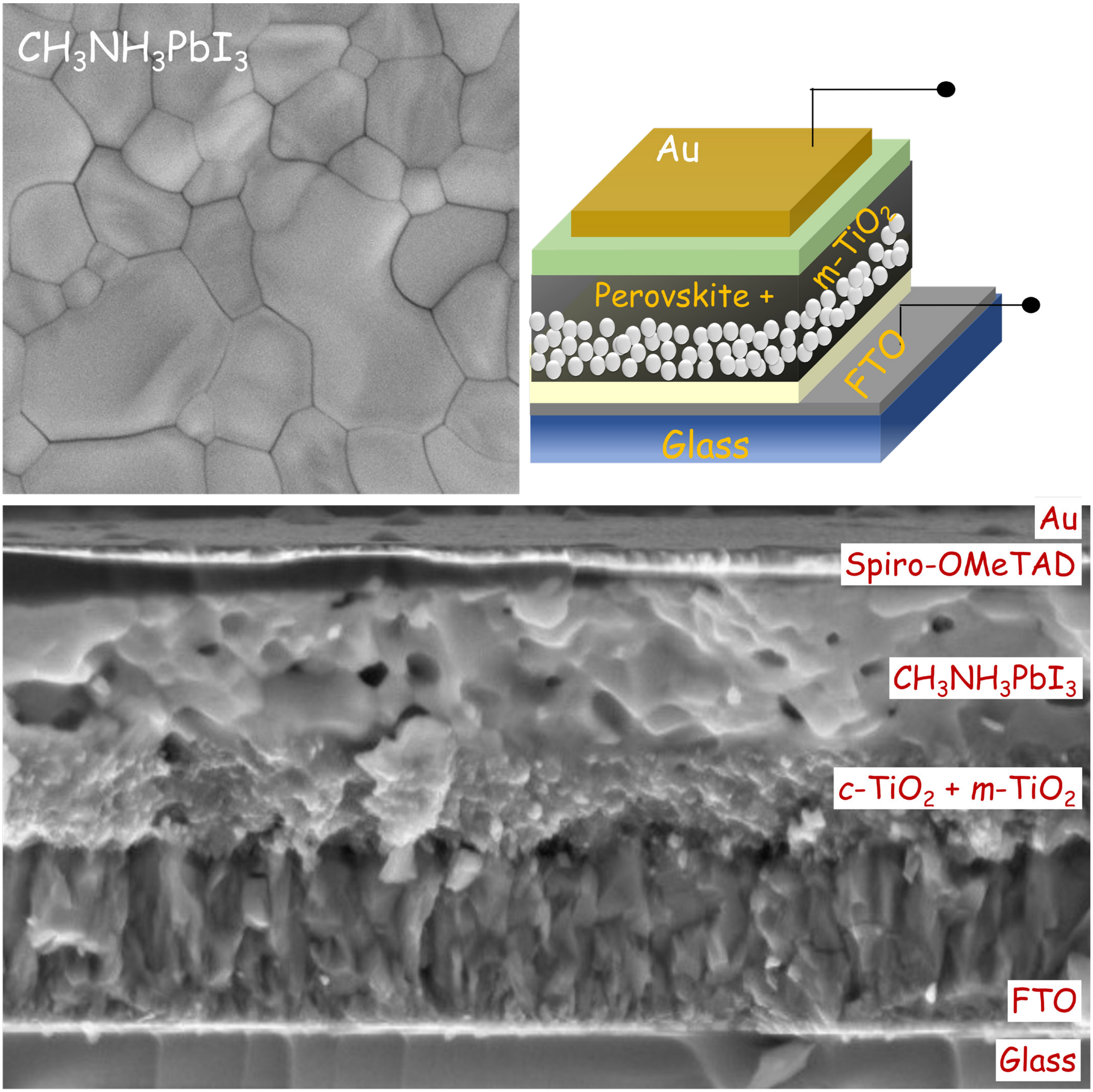
Rear Admiral V Bhel CSO (trg) and his team visited CeNSE as part of their effort to orient towards futuristic technologies proposed for induction into the Indian Navy.

Sir Dominic Asquith, the British High Commissioner to India, and his delegation visited CeNSE in November, 2019.

Prof. David Leebron, the President, Rice University, Houston, Texas, USA, and his delegation said that CeNSE is "a magnificent centre in a leading research institute. We look forward to building an exemplary collaboration".

Prof. Yoichiro Matsumoto, President, Tokyo University of Science, and his delegation at CeNSE in October, 2019.

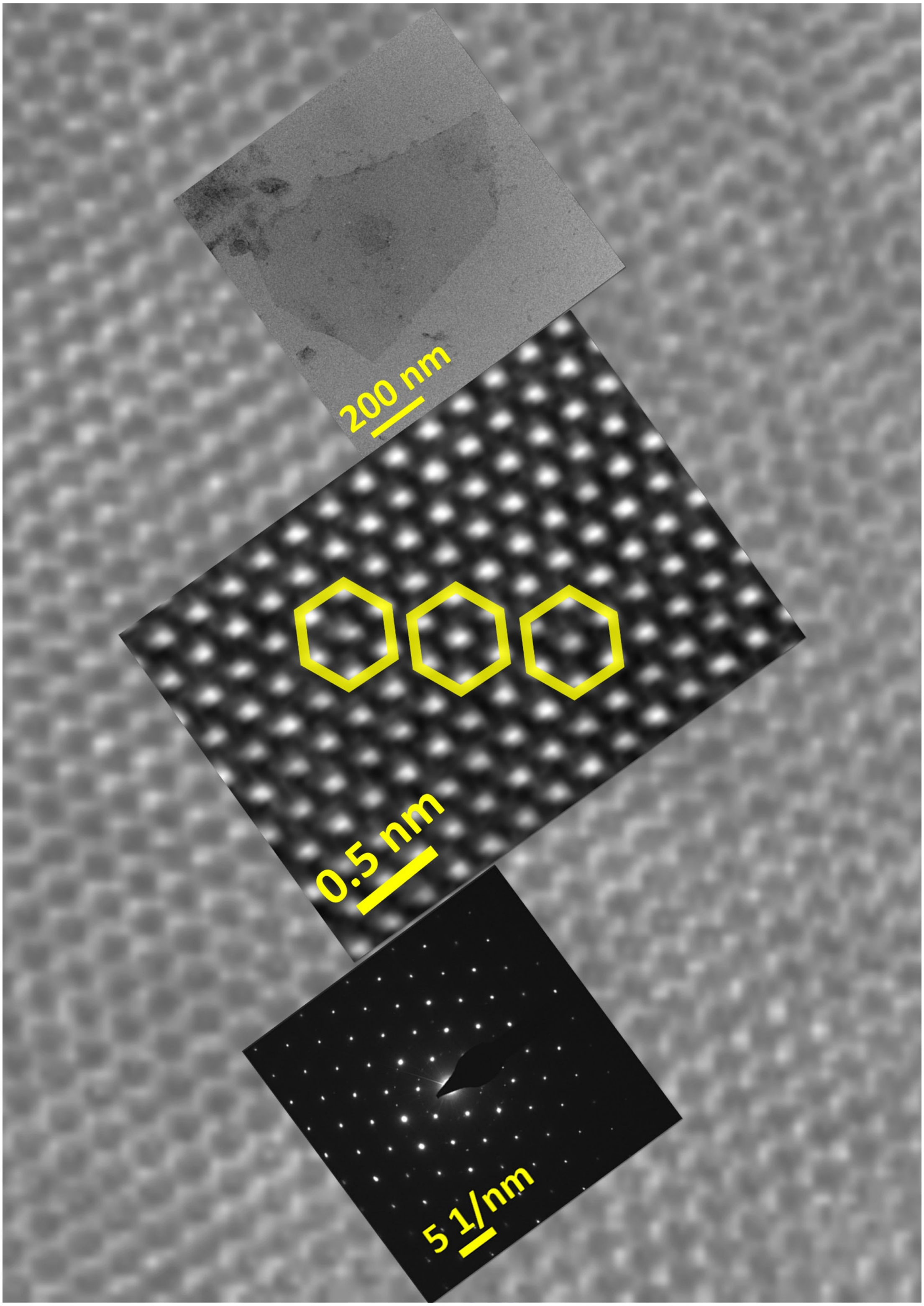
Research in Pictures



Sunlight to Electricity

$CH_3NH_3PbI_3$ based Perovskite Solar Cell: an emerging energy harvesting technology

Authors: Pallavi Singh, Rudra Mukherjee
Advisor: Sushobhan Avasthi



Atoms in a honeycomb

Side-by-side 2D flatland of Tungsten Disulphide

Authors: Neha Sakhuja, Ravindra Jha
Advisor: Navakanta Bhat

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