PressCeNSE

ISSUE: SEPT 2021

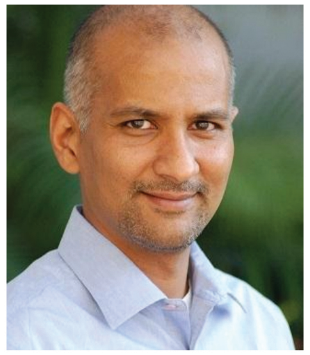
Message from the Chair

Welcome to the new avatar of PressCense. It is new in that we have made a conscious effort to create content that is more readable. We have engaged writers who have strived to understand the exciting scientific output at CeNSE from an external point of view.

The articles written by them then don't have the many gaps that are present when the scientist himself is writing it. In doing so the scientist assumes an understanding on the part of the reader that may not always exist, which then also make it difficult to read and enjoy.

If your antennas were raised by a particular aspect of the previous paragraph, then it is a good sign. You must have noticed my use of the word "himself". I left it in there intentionally to draw attention to the fact that even in this day and age, such errors are unintentionally made and even in letters written by women themselves. Let me use this opportunity to focus on the fact that CeNSE welcomed its first woman faculty member Gayathri Pillai who works on

fact that even in this day and age, such errors are unintentionally made and even in letters written by women themselves. Let me use this opportunity to focus on the fact that CeNSE welcomed its first woman faculty member Gayathri Pillai who works on Piezo MEMS. It is a start, but it is not a record we are proud about. We have a long way to go. You will see a profile on Gayathri and this emerging area in the next News Letter. You will notice at the end of the news letter that our students have made us proud by winning many awards, but what stands out is that all the recipients feature in this edition are women. Congratulations to Jagriti, Sushmita and Nishta. Applied Materials came on board as an Industry Affiliate Member. At a time when the world semiconductor industry is in a churn and it is becoming increasingly obvious that India needs to catch up, we hope this partnership will be a synergistic one for the two of us and the Nation. Welcome AMAT, glad to have you on board.
I don't want to kill the suspense, but I invite you to dig in. You will find exciting write ups on nano-scale ferroelectricity, piezo MEMS and Ge - yes the same germanium that Bardeen, Brattain and Shockley demonstrated their transistor on - becoming fashionable once again. Speaking of this Nobel prize, did you know that the MOSFET transistor we now use was actually proposed long before by Lilienfeld in 1926 and realized long after by Kahng and Atalla in 1959! Have fun reading.



- Srinivasan Raghavan
Chair, CeNSE

Collaborations

From Left: Mr. Peter Manoj* (IAP Program Coordinator), Dr. VijayRaghavan* (CTO NNfC), Prof. Rudra Pratap* (IAP Faculty-In-Charge), Prof. Srinivasan Raghavan* (Chairperson), Dr. Suraj Rengarajan# (CTO), Dr. Gopi Chandran# (DD R&D) and Dr. Suresha* (Technology Manager)

*CeNSE, IISc #Applied Materials India

Centre for Nanoscience and Engineering (CeNSE), IISc Bengaluru advances nanoscience research with semiconductor giant Applied Materials India as newest partner via the Industry Affiliate Program (IAP)

Media Contact
Anuroopa Pereira
Applied Materials India
E: Anuroopa_Pereira@amat.com
T: +91-9513399630

Media Contact
Peter Manoj
CeNSE, IISc
E: petermanoj@iisc.ac.in
T: +91-7760055428

Applied Materials India, the Indian arm of US semiconductor and materials engineering giant Applied Materials Inc. announced its partnership with the Centre for Nanoscience and Engineering (CeNSE), IISc Bengaluru via its renowned Industry Affiliate Program (IAP). The materials engineering giant is working closely with CeNSE in the field of advanced materials to explore new application and solutions leveraging their materials engineering expertise.

Applied Materials India, with its domain expertise of over fifty years, has forged an alliance with the Institute of Eminence having world-class infrastructure, to take solutions from 'Lab to Fab' and provide a much-needed impetus to semiconductor technology & manufacturing in this country. The main goal of CeNSE is to carry out cutting-edge research and technological innovations and translate them with appropriate partners into successful commercial products and services.

Talking about this valuable partnership, **Srinivas Satya, Country President, Applied Materials India,** said, *"We are delighted to partner with IISc Bengaluru's Centre for the IAP program. We intend to bring our expertise in Nano engineering to scale the level of commercial viability for all R&D initiatives. Our domain expertise in micro and Nano electronics will create a platform that will accelerate advanced research and charter growth in whitespace areas. We are also looking forward to the positive impact this partnership could bring, especially in the areas of joint research projects, student internships and student-faculty interactions".*

"We welcome Applied Materials India on board as an Industry affiliate. It is a win-win relationship given the emphasis of both parties on electronics manufacturing and futuristic technologies", added **Prof. Srinivasan Raghavan, Chairperson, CeNSE**.

Talking about the impact of this partnership on both the entities, **Dr Suraj Rengarajan,** CTO, said, *"Applied Materials works with leading global institutions to spur innovation in our core semiconductor and display areas and new and adjacent markets. The wide portfolio of technologies and infrastructure that CeNSE brings makes it an ideal partner for us".*

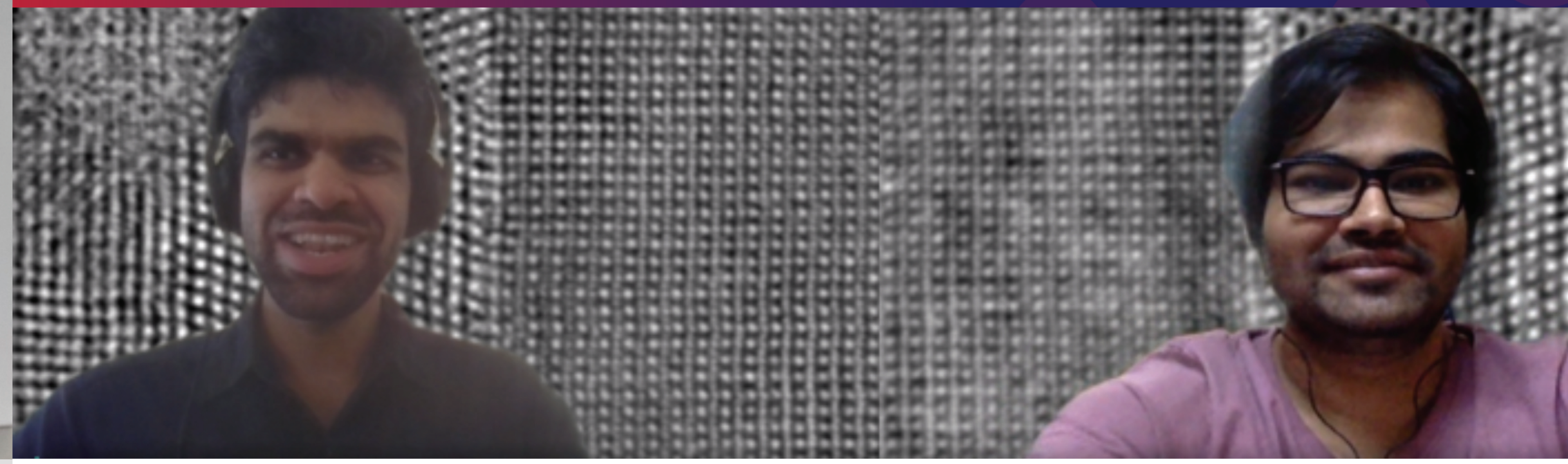
As one of the foremost companies working at the Nano level, Applied Materials continues to deepen its engagement with India's premier engineering and technology institutes via industry-academia partnerships. Last year, it celebrated 15-years of collaboration with IIT Bombay in the field of Nano electronics and energy. Applied Materials is also a leading proponent of the Indian Nano electronics User Program (INUP), a program jointly run by IIT Bombay and IISc Bengaluru. This government-backed program has made Nano electronics research facilities accessible to the socially and economically disadvantaged communities of India. In 2018, it collaborated with IIT Madras to boost research in artificial intelligence, machine learning and data science with applications in semiconductors and pharmaceuticals.

Research News

UNRAVELING THE MYSTERY BEHIND NANOSCALE FERROELECTRICITY

Dr. PAVAN NUKALA

From Left: Dr. Pavan Nukala and Tuhin Chakrabortty



In a path breaking research carried out by Dr. Pavan Nukala, Assistant Professor at the Centre for Nano Science and Engineering (CeNSE), IISc, Bangalore along with his colleagues from the University of Groningen, Netherlands, using state-of-the-art atomic resolution microscopy, it is shown experimentally, for the first time, how an unusual form of ferroelectricity arises in certain nano-sized materials. The insights offered by the study open up new avenues for designing oxygen-conducting ferroelectric materials that could eventually be used for miniature memory and logic devices.

In 2011, it was reported that silicon compatible hafnia-based oxides could exhibit ferroelectricity at nanoscale dimensions and this unconventional ferroelectricity becomes robust upon making the material smaller. **This turned out to be a magic material that the microelectronics community was looking for.** The interest in this materials and technology they can offer shot up exponentially ever since. However, there was no real understanding of what the magic in these materials is, how they are different from normal ferroelectrics, and how they switch unconventionally.

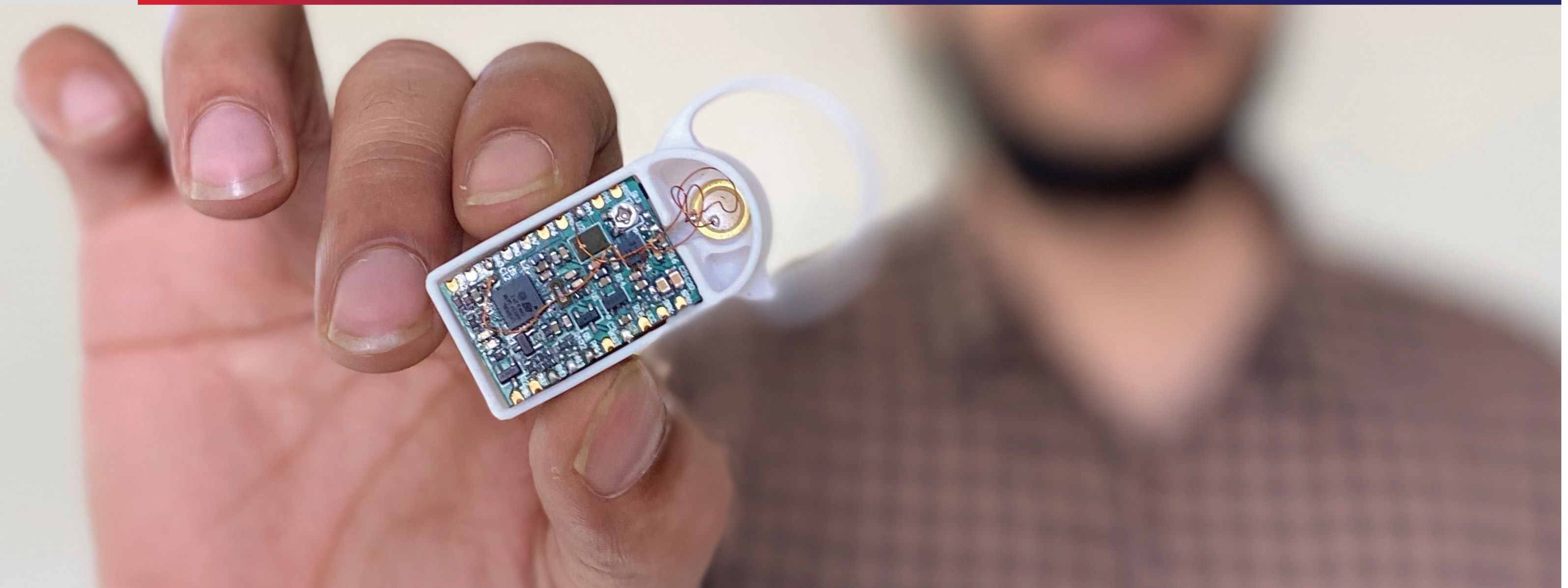
Dr.Pavan Nukala said, "Hafnia-based ferroelectric memory devices are already in production, even though the mechanism behind their behavior is not known." With a background in electron microscopy and materials science, especially in ferroelectric hafnia systems, Dr. Pavan Nukala who was then working with Beatriz Noheda, Professor of Functional Nanomaterials at the University of Groningen, teamed up with experts in microscopy Dr. Majid Ahmadi and for the first time imaged the atomic lattice of hafnium-zirconium oxide in between two electrodes, including oxygen atoms (the light atoms) and followed its evolution with applied voltage.

Nukala explains. 'In hafnia, people believed that oxygen atom displacement gives rise to polarization. Therefore, any microscopy will make sense only if oxygen can be imaged and followed, and we had the exact tool for that. Then we applied external voltage to the capacitor and watched the atomic changes in real time.' Such an experiment by directly imaging oxygen atoms inside the electron microscope had never been done.' A significant feature that we observed, explains Nukala: 'is that the oxygen atoms move. They are charged and reversibly migrate with electric field between the electrodes through the hafnia layer. Such a reversible charge transport enables ferroelectricity'.' Confirmation of this mechanism also came simultaneously from the x-ray diffraction experiments that Dr. Nukala and his colleagues performed at the Max IV synchrotron at Sweden.
'Now, we have opened up the road towards a new generation of oxygen conducting, Si compatible ferroelectric materials', says Nukala.

The collaboration has resulted in the development of suitable protocols for future generation of researchers to perform similar kind of niche experiments using, the *in situ* electron microscopy at atomic resolution.

Tuhin Chakrabortty, PhD student at CeNSE used image-processing tools and statistical analysis to further prove that 'reversible oxygen migration' as visualized, is the cause of ferroelectricity in these materials.
The authors have published their research findings in the April issue of the Journal Science.

MEMS-BASED PIEZOELECTRIC TRANSDUCER: DATA THROUGH ACOUSTICS



Harshvardhan Gupta, Bibhas Nayak, Rudra Pratap

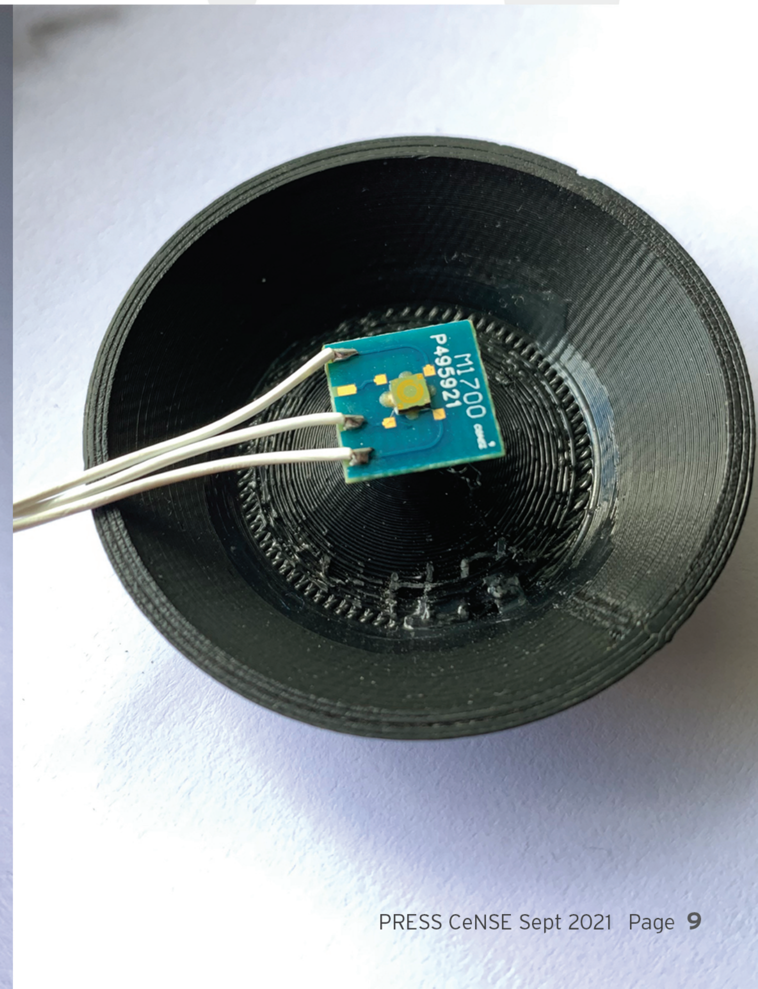
Do we communicate through sounds? Of course! We speak and hear, and it's the dominant form of communication among us all through human civilization. But can we use sound waves to transmit and receive data for more sophisticated applications like, transaction authentication, indoor positioning and proximity detection? Yes, but it would be better if such sound waves are just above the range of human hearing so that this mode of acoustic communication doesn't create a background noise for our ears!

Data-over-sound (DoS) is precisely that thing: an emerging and highly promising technology that relies on audible and inaudible sound waves to send and receive digital data. The microphones used in our smartphones, for instance, can detect such sound signals if configured appropriately. However, DoS devices should be preferably battery-powered for their ubiquitous proliferation and should consume as low power as possible (obviously!). And herein lies a technological challenge: *the micro-speakers for DoS devices usually consume 0.2 to 1 W of power, which is too high to make them more mainstream.*

The MEMS lab at CeNSE under Prof. Rudra Pratap has achieved a major breakthrough in this direction by developing transducers called PMUT (piezoelectric micromachined ultrasound transducer), designed to operate in the near ultrasound range. These are diaphragm-like multi-layered structures made on a structural device layer by deposition and patterning of electrode and piezoelectric films. (Piezoelectric materials convert mechanical stress to electricity, and vice versa). The diaphragm is then released by backside etching of the silicon wafer. The electrodes are patterned such that when a voltage is applied, the strain in the film produces a deflection in the diaphragm which can be used for both transmitting and receiving sound waves.

"The fabrication of PMUTs with natural frequencies required for DoS had been a challenge due to the high tensile stresses present in the piezoelectric thin films. This can have a pronounced effect on increasing the natural frequencies of the transducers, something like tightening the skin of a drum or a string on a guitar", said Harshvardhan Gupta, the lead PhD student with Prof. Rudra Pratap working on this project.

The team used theory, modelling and simulation, and characterization to understand the behaviour of the piezo films, and subsequently developed D4500, an indigenous DoS device which was tested as a transmitter. Its diaphragm radius of 4.5 mm is much smaller than that of 20 mm x 30 mm sized conventional micro-speakers in vogue. More impressive is the fact that this PMUT consumes less than 4% of the corresponding electrical power! For instance, it could communicate up to a distance of 50 m by consuming just 20 mW of power. The day is probably not far away when DoS enabled by PMUTs would be embedded into wireless and underwater sensors for data transmission.



VORTEX CHIP INCORPORATING AN ORTHOGONAL TURN FOR SIZE-BASED ISOLATION OF CIRCULATING CELLS

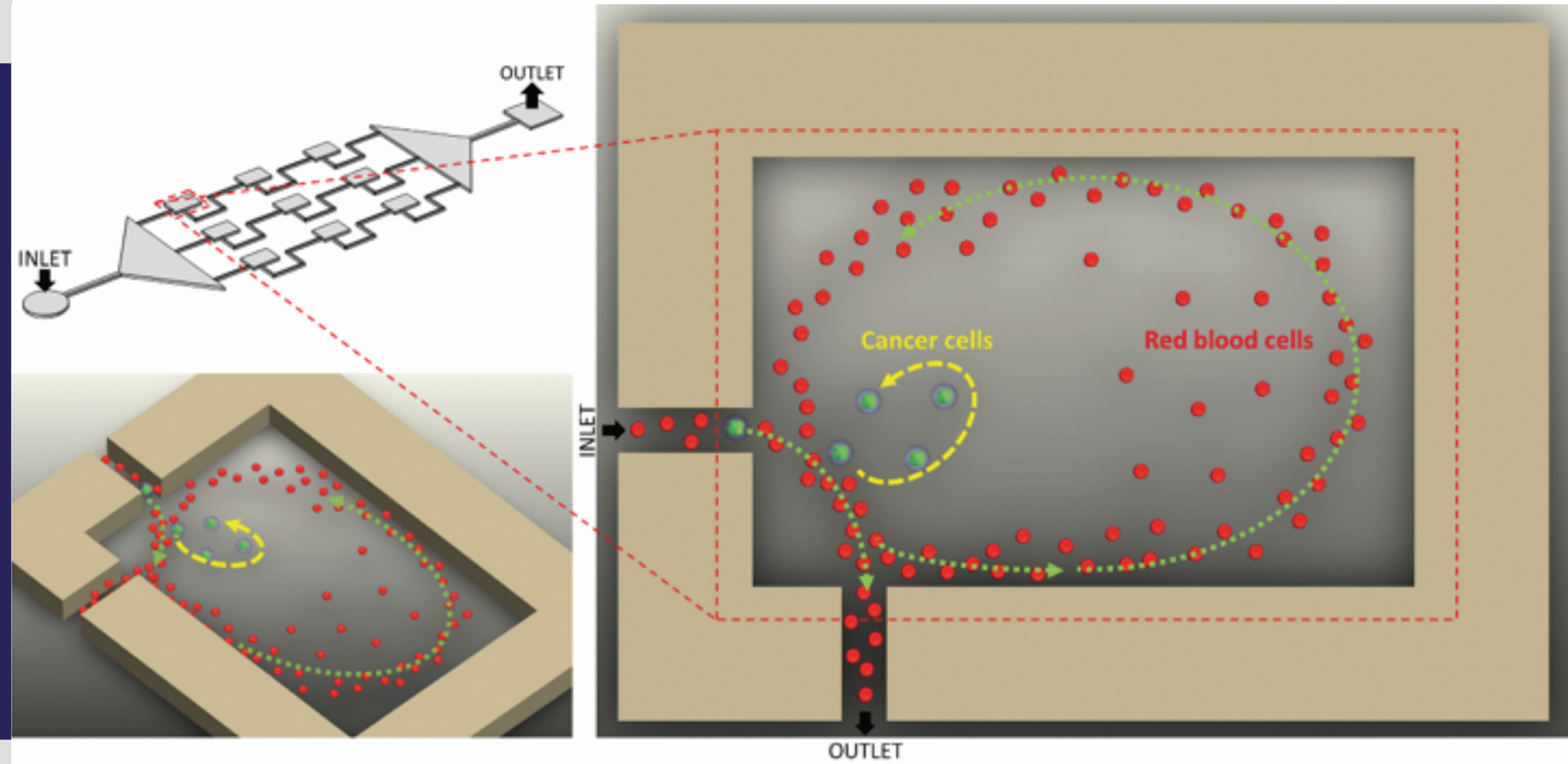
Over the past fifteen years, medical researchers have been developing methods for 'liquid biopsy' where a few ml of peripheral blood, as obtained for routine blood tests, can be used for cancer diagnosis.

Navya Rastogi, Pranjal Seth, Ramray Bhat, Prosenjit Sen

Interestingly, an Indian medical-diagnostics company – Datar Cancer Genetics, based in Nashik – has been attracting considerable attention recently in the international research efforts to bring 'liquid biopsy' into clinical practice!

These 'liquid biopsy' techniques are expected to enable the avoidance/augmentation of the more surgically invasive techniques of 'tissue biopsy' used for cancer diagnosis. Biomarkers in the peripheral blood can potentially be used not only for the primary diagnosis of cancer, but also for finer molecular characterization (for classifying the sub-type), evaluating the response of the patient to treatment and to identify secondary metastasis. Circulating tumor cells (CTCs) and circulating tumor-associated cells (C-TACs) in the peripheral blood have to be separated (sorted) for subsequent studies (assays, immuno-staining, cell-culturing, genomics). This is quite a challenging task, as these CTCs and C-TACs are present in very minute quantities (between 5 to 100 per ml). Given the difficulty of isolating circulating tumor cells from blood, several research groups around the world are engaged in developing innovative methods for such extremely selective cell-sorting.

Led by Professor Prosenjit Sen of CeNSE in collaboration with Professor Ramray Bhat of the Department of Molecular Reproduction, Development and Genetics at IISc, a novel microfluidic device has been developed to isolate



circulating tumour cells (CTCs) from peripheral blood by vortex-trapping in a series of chambers. Unlike earlier designs explored by other research groups, the CeNSE team has designed and evaluated several variants where the inlet and outlet to the chambers in the microfluidic chip are located perpendicular (orthogonal) to each other, and a few of these variants have been found to be very effective in trapping the larger CTC cells (approximately 20 μm diameter) at critical velocities that are low enough to prevent any damage to these cells. Further, unlike other methods for isolating CTCs, the technique developed at CeNSE is label-free, i.e. it does not use any bio-molecular labels or fluorescent markers that could interfere with subsequent bio-analytical processes.

The device design and fabrication has been entirely done in CeNSE using the National Nanofabrication Centre.

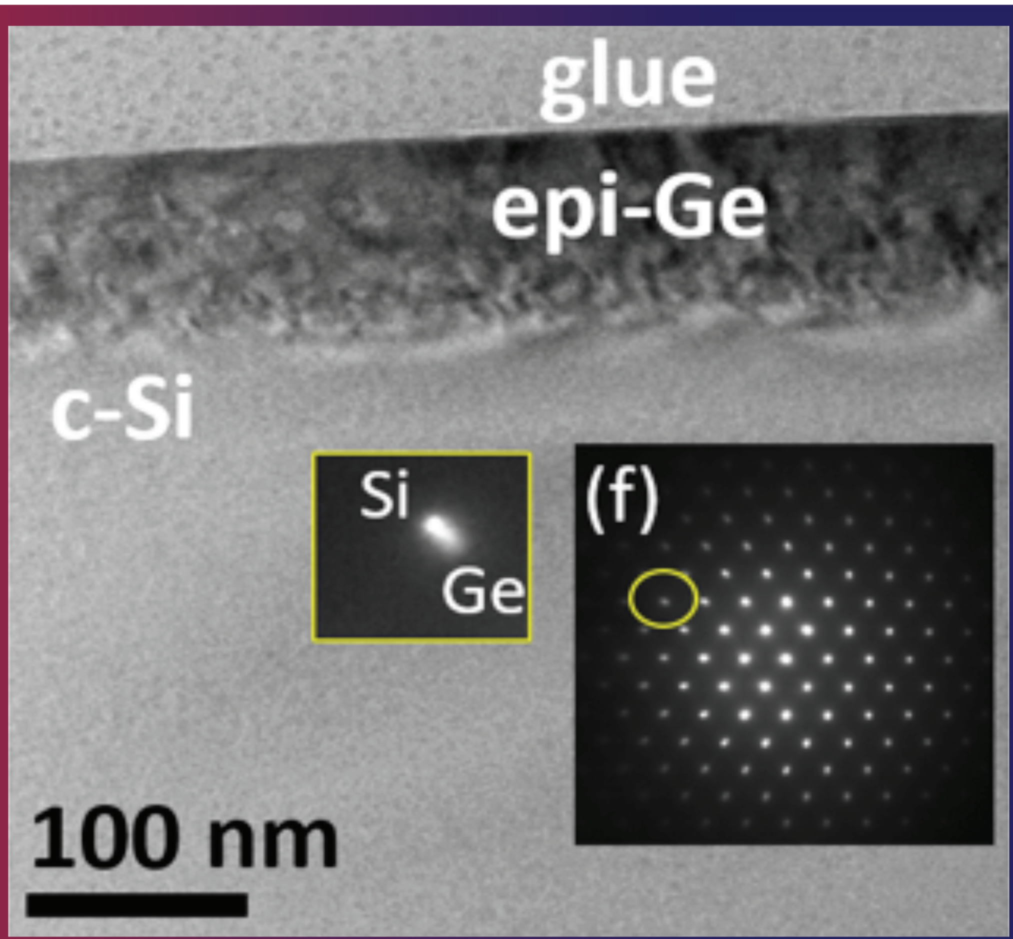
'Microfluidics' involves the use of very minute (micro) channels, valves and other structures (eg. heating elements, electrodes, membranes) on solid substrates to control the flow of tiny amount of fluid. This can enable faster chemical or bio-molecular analysis with very little sample, while also enabling substantial reduction of size and cost. The solid-substrates can range from silicon and glass to polymeric materials and even coated-paper!

The research article from CeNSE has been published in the journal ***'Analytica Chimica Acta',*** with the online version available to readers since 22-March-2021. The lead author of the first research publication based on this work is Navya Rastogi, who hopes to defend her doctoral dissertation next year (2022). Professor Sen's team is continuing with the further development and evaluation of the Vortex-Chip, in collaboration with clinical partners.

CRYSTALLINE GERMANIUM ON SILICON: A LOW-COST SOLUTION

Germanium (Ge) was what Shockley, Bardeen and Brattain used, to demonstrate the first point-contact transistor in 1948 that eventually ushered in the electronics era, and on the other hand, silicon (Si) is the most dominant and widely used semiconductor today.

Khushboo Kumari, Sandeep Vura, Srinivasan Raghavan and Sushobhan Avasthi



Yet, integrating Ge on Si is not trivial, especially when the former has to be crystalline and epitaxial on Si. ('Epitaxial' loosely means that the deposited layer mimics the structure of the substrate below while 'crystalline' means there is a periodic and definite arrangement of atoms in a solid.)

Epitaxial Ge on Si can enable novel infrared sensors, high-efficiency solar cells, high-performance transistors, etc. And the reason why Ge integration with Si is non-trivial is because of a large mismatch (4.2%) in their lattice constant i.e. mismatch in the spacing and arrangement between adjacent atoms. Still, people have achieved the same by adopting fairly costly and complicated approaches such as ultrahigh-vacuum chemical vapor deposition (CVD), metalorganic CVD, reduced-pressure CVD, and molecular beam epitaxy. All of these methods require expensive tools, ultrahigh vacuum and extremely careful surface preparation, putting a constraint on the application space.

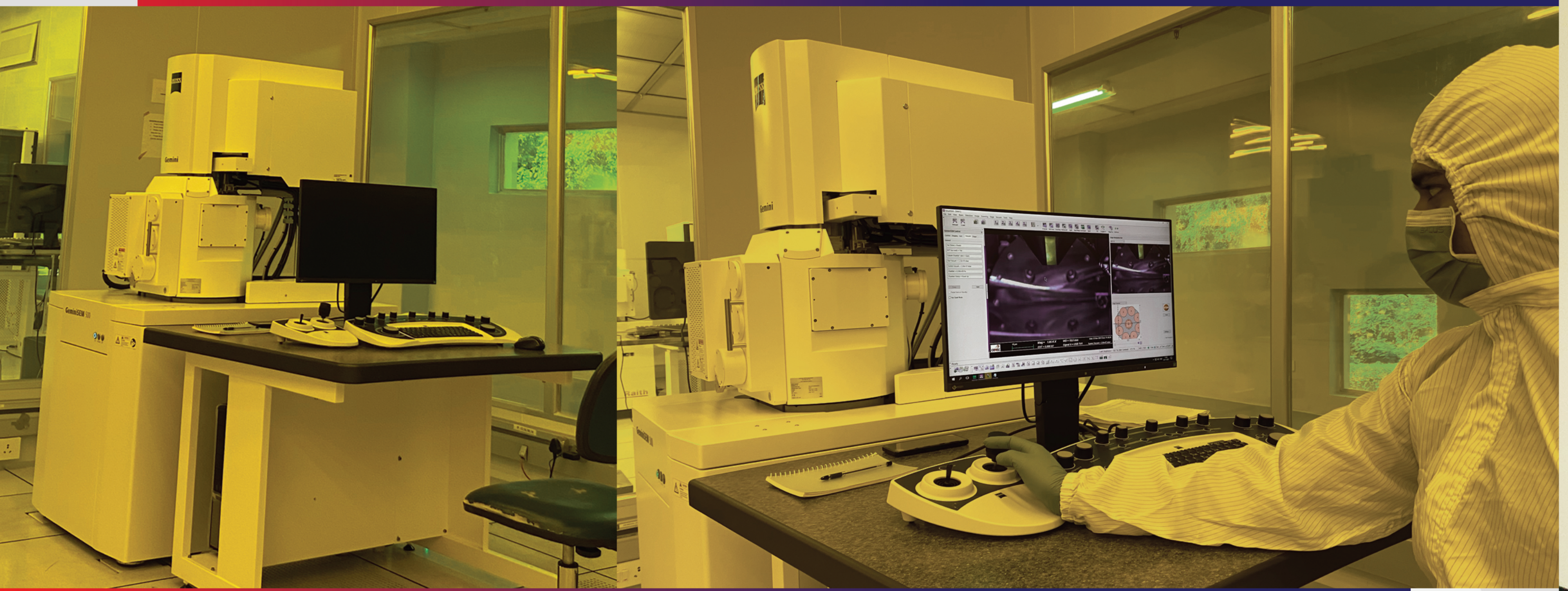
In an interesting development, a group led by Prof. Sushobhan Avasthi at CeNSE has achieved epitaxial Ge on Si using a cost-effective and simple method called LIC i.e., Laser Induced Crystallization. It is a fast, scalable and low thermal budge process than furnace-based approaches. LIC in itself isn't a new technique: it was extensively used in the past to anneal damage in Si and Ge, to electrically activate dopants in Si (to make it conducting for instance) and to crystallize amorphous Si.

However, Prof. Avasthi's group has now used LIC to demonstrate epitaxial Ge on Si and studied the effect of film thickness and laser fluence (sort of intensity) in doing the same.

The anneal step just includes the laser and the sample stage. "Despite being processed at room temperature and in ambient atmosphere, our samples exhibit excellent crystallinity. We confirm this from the structural quality assessed using high-resolution X-ray diffraction scans", says Ms. Khushboo, the PhD student who leads this work. Moreover, the laser spot was rastered across a 2-inch wafer to achieve wafer-scale process. This demonstration is likely to spur a new paradigm on integrating two most commonly used semiconductors for a plethora of applications.

New tools & capabilities at CeNSE cleanroom (NNfC)

GEMINISEM 500 FIELD EMISSION SCANNING ELECTRON MICROSCOPE



GeminiSEM 500, Field Emission Scanning Electron Microscope from Carl Zeiss, is currently available at the NNFC cleanroom for use. This tool is designed for maximum surface analysis on a broad range of sample materials, with high image contrast and outstanding resolution even at ultra-low beam voltages. "This tool will be dedicated for quick inspection of samples processed inside the cleanroom. It is expected to drastically reduce or even avoid sample contamination incurred from carrying out the SEM inspection in a non-cleanroom environment", said Dr. Savitha, COO of NNfC.

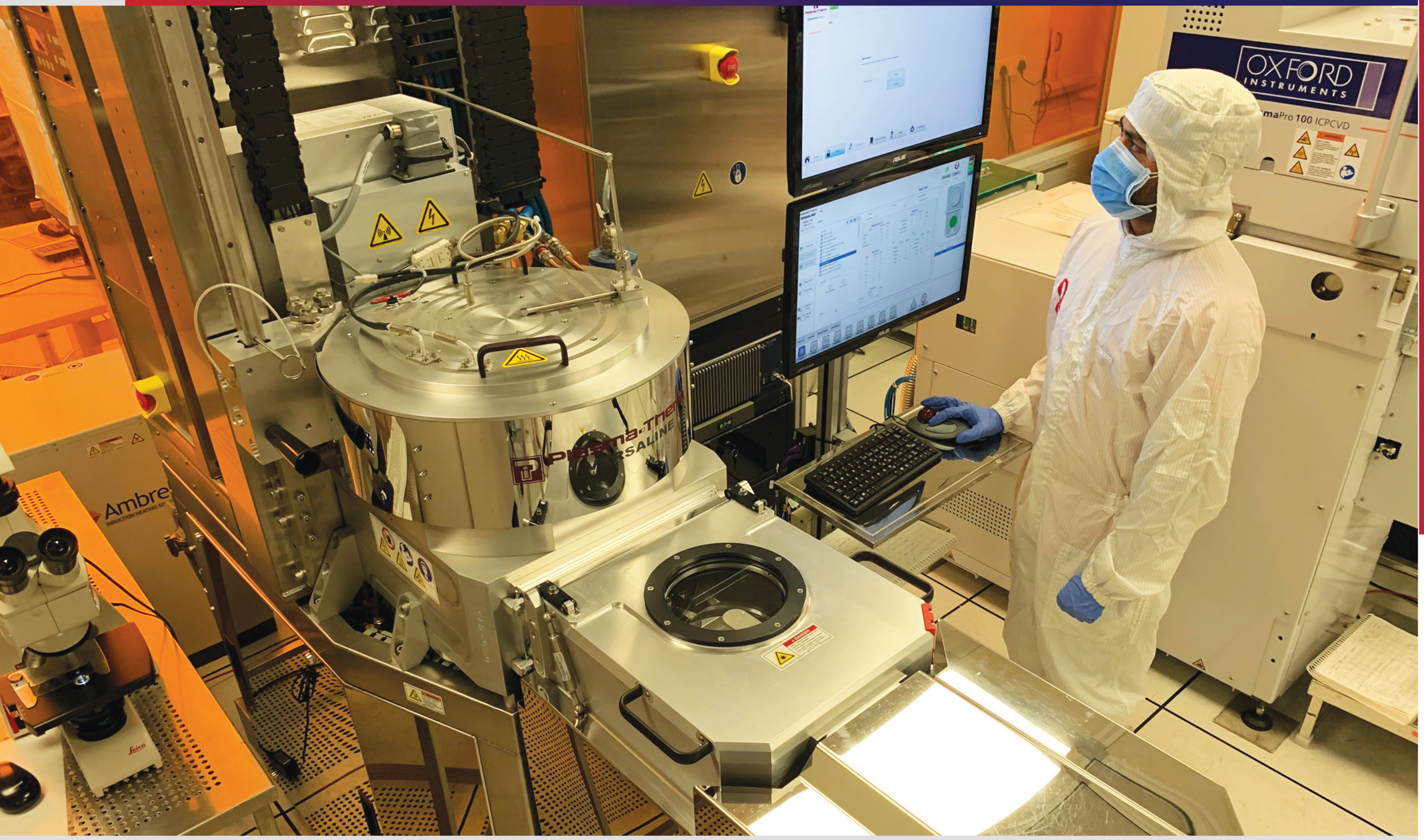
The tool will considerably decrease the turnaround time required between process steps where meticulous inspection is needed. It has a motorized stage which can accommodate sample up to 4 inch in diameter. "This FESEM can provide a resolution as low as 0.5 nm which is at the limit of an atomic layer, and can provide a magnification up to 2 million," added Mr.Balasubrahmaniyam, the tool owner.

DIENER: PLASMA ASHER

Diener Plasma asher is a new addition to the list of tools at the NNfC cleanroom which is available for use. It is useful for ashing of electron-beam resist and optical photoresists, which provides a cleaner sample surface after lithography. It will also provide descum process to remove any undeveloped regions or residues from the patterned region before dry etching. The tool owner Mr.Nawaz said "The tool can handle samples up to 6 inch in diameter and will also allow for O_2 plasma treatment for activating surface." The gases available include O_2, Ar, N_2 and CF_4.

New tools & capabilities at CeNSE cleanroom (NNfC)

PLASMA THERM ICP RIE



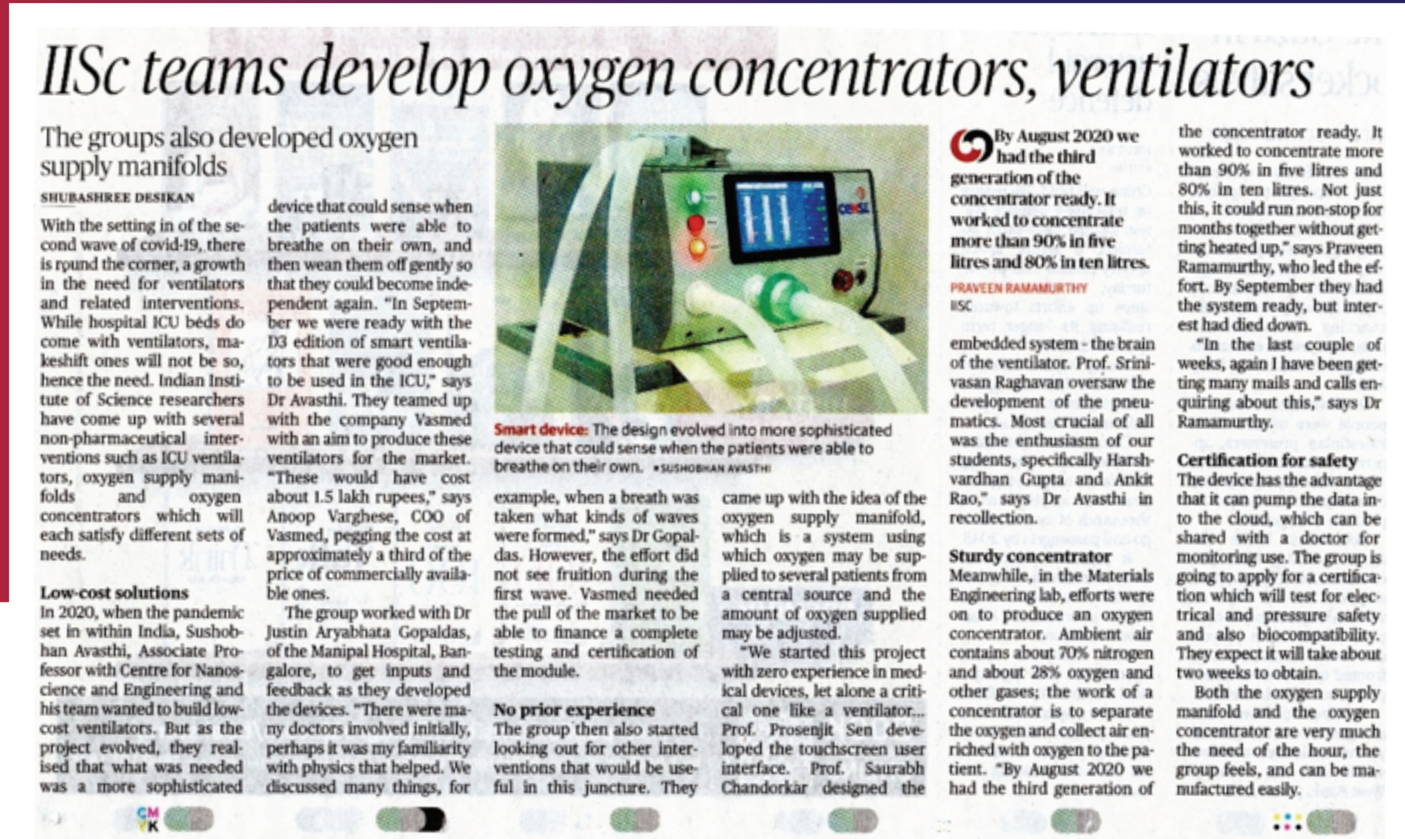
A new Inductively Coupled Plasma Reaction Ion Etch (ICP RIE) system from Plasma Therm has been installed at the NNfC cleanroom and is now available for use in dry etching. The tool can etch up to 1 micrometer of material such as PZT and aluminium nitride with a non-uniformity of less than 5% on 6 inch wafer. It offers less than 3% of wafer-to-wafer variability and nano meter level surface roughness after etching.

"We can etch features which are less than 100 nm in size, and also use both fluorine as well as chlorine-based chemistries in the same chamber," said Mr. Arjun, the tool owner. "We can also use argon to do sputter etching", he added.

(More details on the technical specifications of any of these tools can be accessed at National Nanofabrication Centre | CeNSE, IISc)

From print media

THE HINDU, BANGALORE, 25/04/2021



IISc teams develop oxygen concentrators, ventilators

The groups also developed oxygen supply manifolds

SHUBASHREE DESIKAN

With the setting in of the second wave of covid-19, there is rpund the corner, a growth in the need for ventilators and related interventions. While hospital ICU beds do come with ventilators, makeshift ones will not be so, hence the need. Indian Institute of Science researchers have come up with several non-pharmaceutical interventions such as ICU ventilators, oxygen supply manifolds and oxygen concentrators which will each satisfy different sets of needs.

Low-cost solutions

In 2020, when the pandemic set in within India, Sushobhan Avasthi, Associate Professor with Centre for Nanoscience and Engineering and his team wanted to build low-cost ventilators. But as the project evolved, they realised that what was needed was a more sophisticated device that could sense when the patients were able to breathe on their own, and then wean them off gently so that they could become independent again. "In September we were ready with the D3 edition of smart ventilators that were good enough to be used in the ICU," says Dr Avasthi. They teamed up with the company Vasmed with an aim to produce these ventilators for the market. "These would have cost about 1.5 lakh rupees," says Anoop Varghese, COO of Vasmed, pegging the cost at approximately a third of the price of commercially available ones.

The group worked with Dr Justin Aryabhata Gopaldas, of the Manipal Hospital, Bangalore, to get inputs and feedback as they developed the devices. "There were many doctors involved initially, perhaps it was my familiarity with physics that helped. We discussed many things, for example, when a breath was taken what kinds of waves were formed," says Dr Gopaldas. However, the effort did not see fruition during the first wave. Vasmed needed the pull of the market to be able to finance a complete testing and certification of the module.

Smart device: The design evolved into more sophisticated device that could sense when the patients were able to breathe on their own. •SUSHOBHAN AVASTHI

No prior experience

The group then also started looking out for other interventions that would be useful in this juncture. They came up with the idea of the oxygen supply manifold, which is a system using which oxygen may be supplied to several patients from a central source and the amount of oxygen supplied may be adjusted.

"We started this project with zero experience in medical devices, let alone a critical one like a ventilator... Prof. Prosenjit Sen developed the touchscreen user interface. Prof. Saurabh Chandorkar designed the embedded system - the brain of the ventilator. Prof. Srinivasan Raghavan oversaw the development of the pneumatics. Most crucial of all was the enthusiasm of our students, specifically Harshvardhan Gupta and Ankit Rao," says Dr Avasthi in recollection.

By August 2020 we had the third generation of the concentrator ready. It worked to concentrate more than 90% in five litres and 80% in ten litres.

PRAVEEN RAMAMURTHY
IISC

Sturdy concentrator

Meanwhile, in the Materials Engineering lab, efforts were on to produce an oxygen concentrator. Ambient air contains about 70% nitrogen and about 28% oxygen and other gases; the work of a concentrator is to separate the oxygen and collect air enriched with oxygen to the patient. "By August 2020 we had the third generation of the concentrator ready. It worked to concentrate more than 90% in five litres and 80% in ten litres. Not just this, it could run non-stop for months together without getting heated up," says Praveen Ramamurthy, who led the effort. By September they had the system ready, but interest had died down.

"In the last couple of weeks, again I have been getting many mails and calls enquiring about this," says Dr Ramamurthy.

Certification for safety

The device has the advantage that it can pump the data into the cloud, which can be shared with a doctor for monitoring use. The group is going to apply for a certification which will test for electrical and pressure safety and also biocompatibility. They expect it will take about two weeks to obtain.

Both the oxygen supply manifold and the oxygen concentrator are very much the need of the hour, the group feels, and can be manufactured easily.

Awards

1. Ms. Jagriti Singh, PhD student, CeNSE

As part of Golden Jubilee Celebrations of Department of Science and Technology (DST), Government of India, **Science, Technology and Innovation Talks (STIN 2021)** by **Young Research Fellows** was being organized on **National Science Day** by International Advanced Research Centre for Powder Metallurgy & New Materials (ARCI), Hyderabad during February 25-26, 2021 on virtual platform. **Young Research Fellows** carrying out research in the field of **Materials Science and Engineering** participated in the national level competition and presented their work in the form of a presentation on their project/research work. Best presentation award was facilitated to Ms. Jagriti Singh, CeNSE, IISc, along with 2 other scholars. Her talk was entitled "The optical Wrestle: Why is black Silica better than black Si"

Best Presentation Award, National Science Day (DST/STIN, Young Research Fellow)

2. Ms. Kumari Sushmita

DST organizes AWSAR (Augmenting Writing Skills for Articulating Research) to popularize and unleash the spirit of science communication among young scientists and take the research happening within the laboratories to the general people.
Ms. Kumari Sushmita's popular science story, ***Polymer-based-hybrid Material as 'Electromagnetic Kawach',*** was selected as one of the best stories under the Ph.D. category. It is based on her Ph.D. research work at CeNSE, Indian Institute of Science, Bengaluru.
The recent surge in electronics usage has led to a new kind of problem, electromagnetic interference (EMI), which necessitates finding alternate materials that offer ease of processing, design flexibility, lightweight, and ease of embedding/integrating with existing systems. This story talks about mitigating EMI by developing robust shields (electromagnetic absorbers) using polycarbonate-based hybrid materials and its current challenges.

DST AWSAR "Awardees of Best Stories" under Ph.D. Category

2. Ms. Nishta Arora

AROP is a funding program that offers travel grants and scholarships to support research stays of doctoral candidates and postdocs from strategically relevant international universities or research institutions at RWTH Aachen University. The goal of AROP is to develop or strengthen bilateral relations with international partner institutions.

Ms. Nishta Arora will join the Chair of Electronic Devices working on 2D heterostructures for optoelectronics and NEMS applications under the guidance of Prof. Max Lemme. Her research work at IISc focuses on fabrication and characterization of resonators based on 2D materials.

Advanced Research Opportunities Program (AROP) fellowship by RWTH Aachen University, February - July 2021

PressCeNSE

ISSUE: SEPT 2021

CENSE ACKNOWLEDGES FUNDING FROM MEITY, MHRD, DST, DRDO AND ISRO FOR SUPPORTING THE FACILITIES AND FUNDING PROJECTS AT THE CENTER

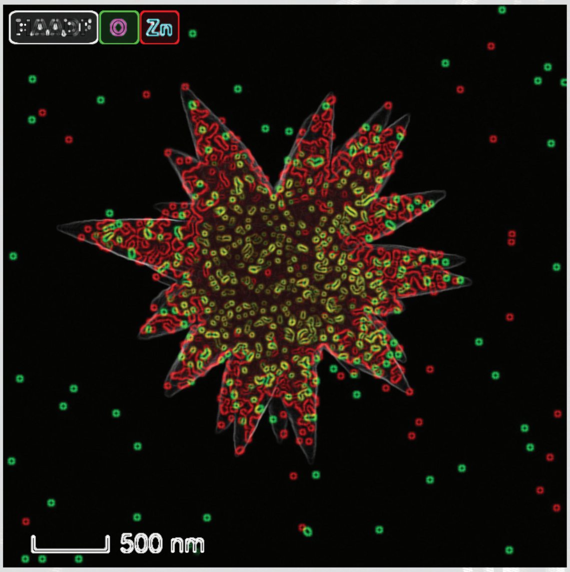


Image caption: Zinc Oxide nano-flower
Image credit: Ambresh M.

EDITORIAL TEAM:
Venkatesh Ranganathan
Digbijoy Nath
Aditya Sadhanala

***Sharath Ahuja and Karthik Mahesh also contributed to this issue**

Design: TheFool.in