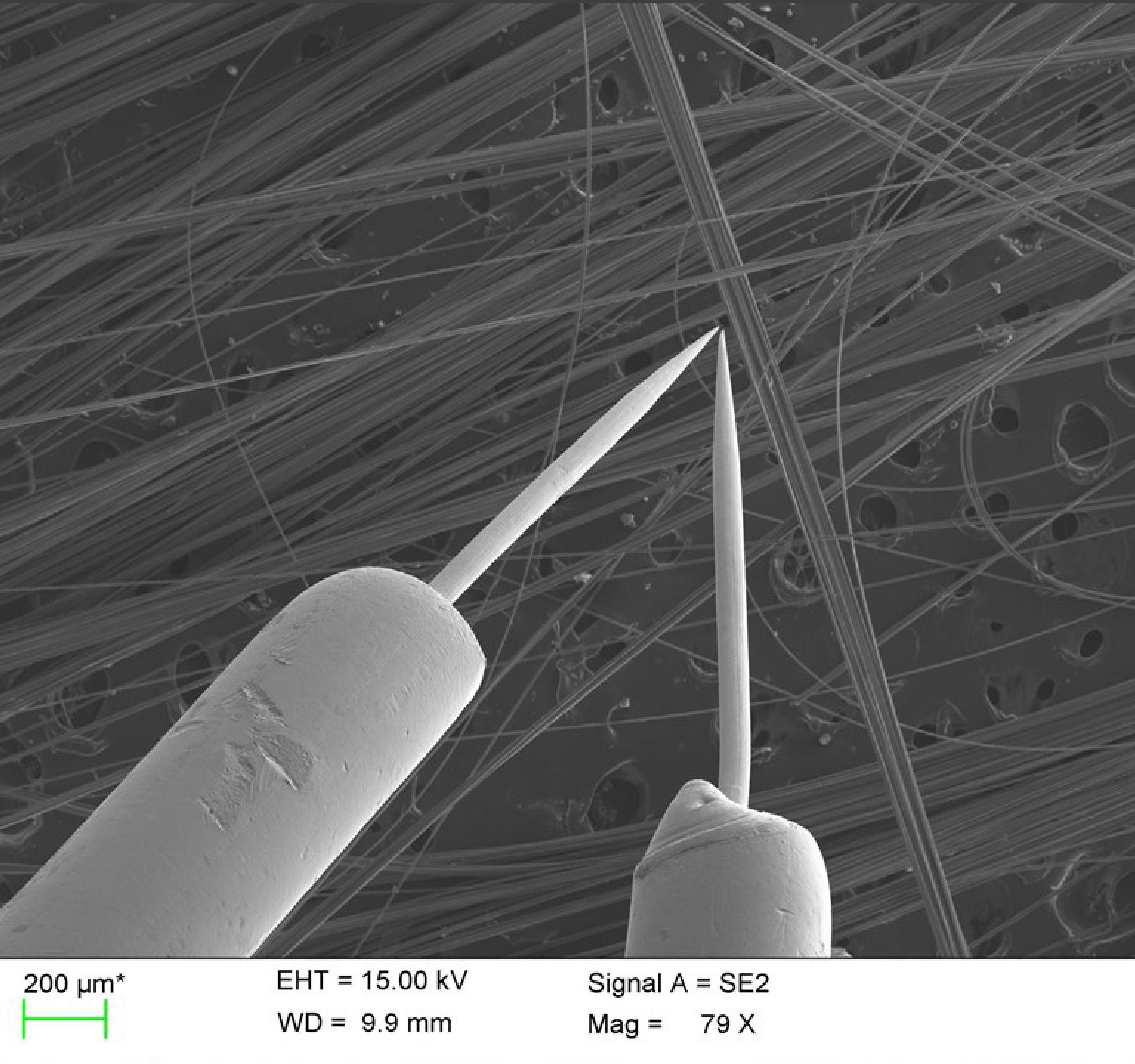
PressCeNSE

Newsletter | Issues 2 & 3, 2020



Centre for Nano Science and Engineering (CeNSE)
Indian Institute of Science

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Cover photo: Microgripper by Varadharaja Perumal.

MESSAGE FROM THE CHAIR

This issue of PressCeNSE is coming to you under very challenging times. We are going through an unprecedented worldwide crisis due to COVID-19 pandemic. There is a lot of anxiety and uncertainty around us, and this situation is likely to continue for some more time. Hence it is imperative that we need to recalibrate ourselves to the "new normal". In our centre, we have initiated the gradual resumption of our research activities, although our teaching activities are likely to continue online for another semester. Over the next couple of months, we hope to have most of our research students returning to campus and actively resuming their research work, while adhering to strict COVID protocols.

In this issue, I am very pleased to present to you a special feature article on CeNSE response to COVID-19, elaborating a variety of COVID specific technologies developed in the last few months, despite the very challenging constraints during lockdown. I congratulate all the faculty, students and staff who were able to unleash their creativity and stand tall under testing times to make this possible. This is another illustration of the ethos that CeNSE represents : "science for society". These achievements will truly inspire the generation of students, who will come into the portals of CeNSE in future.

In January this year, we had the honour of hosting Shri Amit Khare, Secretary, MHRD, to visit our centre. The faculty had an excellent interaction with Shri Khare during this visit. MHRD has been a pillar of support for CeNSE, and we shall continue to work closely with MHRD officials, to realize the dream of "Atmanirbhar Bharat", in the years to come.

During the IISc open day on February 29, we had more than 8,000 visitors at CeNSE, and we have included a brief report on the open day, in this issue. The other major events that we conducted before the lockdown, include training in Nanotechnology for scientists from ITEC countries, a special Science Policy workshop for senior academicians and administrators from Ecuador, residential training program for clinicians from Rajiv Gandhi University of Health Sciences, and Indo-Japanese workshop on Nanomagnetics.

Finally, you will also see a special feature on CeNSE decennary, with images of the past illustrating the inception and evolution of CeNSE. This is also an appropriate time for change of guard at CeNSE. My colleague Prof. Srinivasan Raghavan (Vasu) will now be taking over as the new Chair of CeNSE, to steer us through the exciting journey through the next decade. I take this opportunity to thank you all for your support over the last 4 years.

Stay safe and take care.

-Navakanta Bhat

COVID-19: CeNSE Response

During the COVID-19 pandemic Science and Technology are playing a crucial role in keeping our society functional. As part of incident management and response, CeNSE mustered all its resources and initiated multiple projects to address the issues arising out of the current global public health crisis. The results of these innovations will have a long-lasting impact, even beyond COVID-19, on building a resilient society.

Sanitizer for use across the Institute

Just as the whole Institute was going into a lockdown around mid-March, a team of researchers prepared and supplied sanitizer to the entire campus. These bottles have been primarily issued to security personnel at all the entrances to the campus, and to service providers at critical places that have been kept open to serve the needs of campus residents, and students who couldn't go back to their homes.

Team: Savitha P and BMS staff.

N95 mask characterization

In the event of a shortfall of N95 masks, one needs to decontaminate and re-use the same mask. To this end, the team of researchers in collaboration with KAS Technologies Pvt Ltd devised a procedure to clean N95 masks without affecting their specifications. The team has assembled a setup and measured pressure drop across the mask as well as the particle count across it. One of the companies that the team helped with testing of masks, passed the BIS test for N95 masks. The company intends to donate these N95 masks to a hospital.

Team:

Faculty members: Akshay Naik, Srinivasan Raghavan.

Students: Ankit Rao, Harshvardhan Gupta.

Research Staff: Veera Pandi N, Thyaganand.

Industry partners: KAS Technologies Pvt Ltd.

3D printed valves for split use of ventilators

In the wake of the COVID-19 crisis that has resulted in widespread ventilator shortages, this device was designed to enable multiple patients to be ventilated with one intensive care ventilator. The first of these splitter valves fabricated at CeNSE has been delivered to Manipal Hospitals and tested there with simulation lungs (video of the same can be found here: https://covid19.iisc.ac.in/3-d-printed-valves-for-splitting-of-ventilators-for-servingmultiple-patients/

<u>Team:</u>

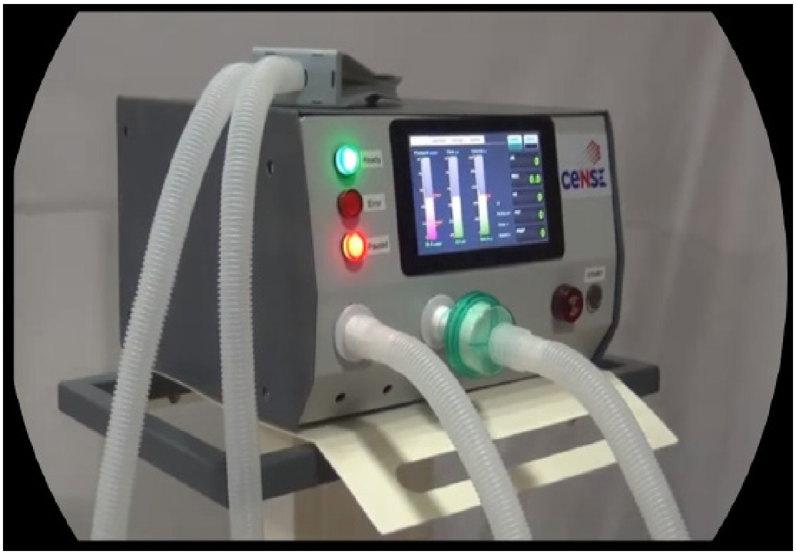
Faculty members: Akshay Naik, Prosenjit Sen, Srinivasan Raghavan.

Students: Harshvardhan Gupta, Swapnil More, Prajval Prabhu.

Medical consultant: Dr. Justin Gopaldas, Manipal Hospitals.

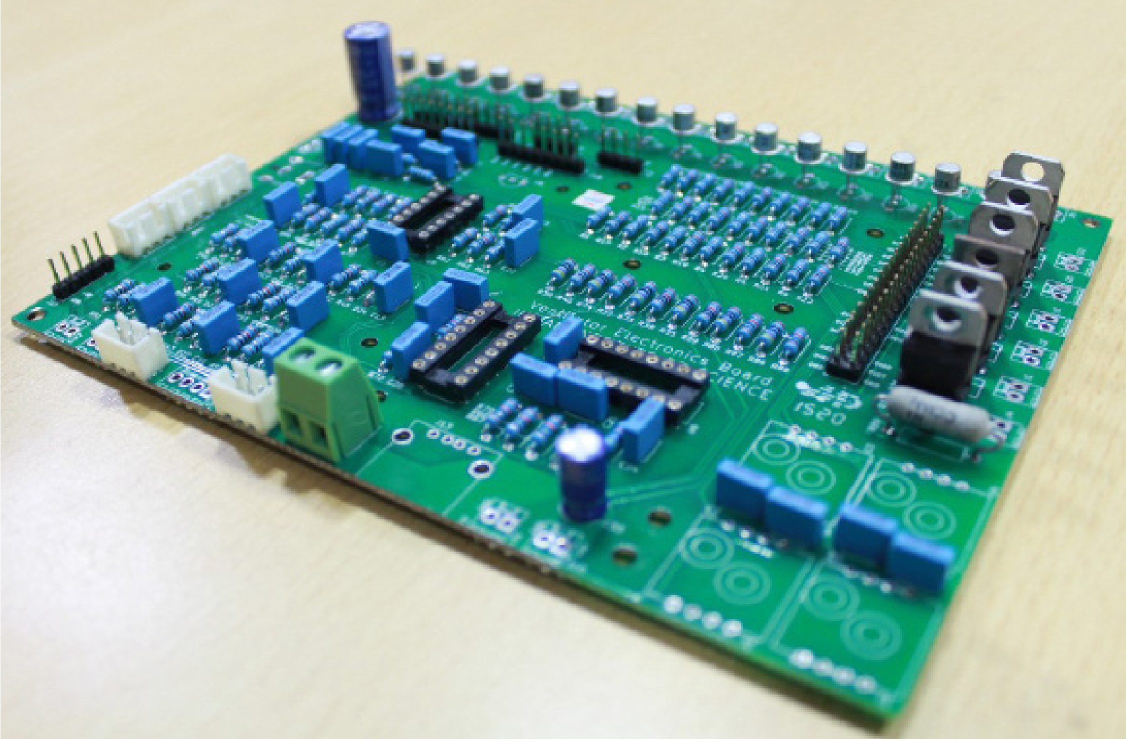
“Sub INR 50,000 Ventilator

The aim was to create a ventilator or a ventilation mechanism, with minimal electronics, that can easily interface with existing hospital infrastructure, and costs less than INR 50,000. After having been almost shelved and much deliberation about the design and capability of the end product - a simple ventilation mechanism or a full-fledged medical ventilator - the project took off after the team decided to work on a “ventilation solution” as opposed to a ventilator. The idea was to set up an industrial scale ventilation system along the lines of the CeNSE clean room gas supply system, but to supply air and oxygen mixtures. Once the problem was defined, the team of researchers started working on the initial designs (D1) for a ventilation solution which later evolved into a complete ventilator (D3).



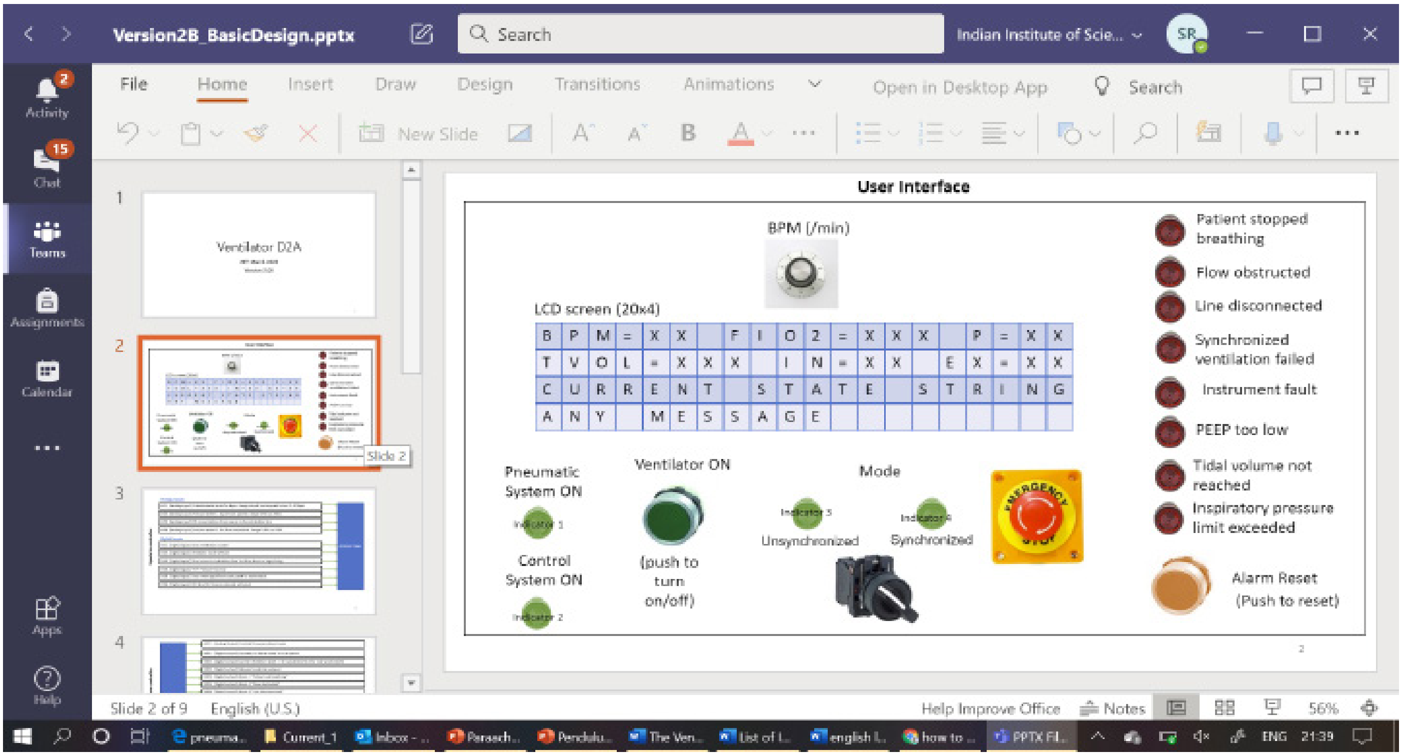
D1 is a simple pressure pulse ventilation system. It uses a single solenoid to pulse, a regulator to control pressure and two rotameters to control flow. With minimal electronics, the prototype was put together within 12 hours. It was interfaced with existing equipment in the lab at CeNSE to supply gases and measure parameters. The team connected D1 to a data acquisition unit (DAQ) to monitor pressure profiles and tested it on a lung obtained from Manipal hospitals. While evaluating D1 for the original intent -- a cost-effective Continuous Positive Airway Pressure (CPAP) or Bilevel Positive Airway Pressure (BiPAP) instrument – the team was not satisfied with the degree of control observed. Being engineers who could not keep quiet, one thing lead to another and soon D2 was born.

D2 works on a proportional valve which needs a feedback from a sensor for pressure and flow rate control. Pressure sensors developed by the packaging lab at CeNSE for other applications were initially adapted to put the pneumatics together. However, due to the COVID lockdown, flow sensors could not be procured. The team then used the age-old Bernoulli principle to convert pressure drops into flow. This was easier said than done. Ventilators required that flows of 30-90 Standard Litre Per Minute (SLPM) be supplied for breathing without introducing big resistances, or large pressure drops, in the flow path. On the other hand, not introducing a big enough resistance would not cause a large enough pressure drop that that is needed for accurate measurement. Using a combination of getting back to the basics of chemical engineering, various Venturi designs that are 3D-printed and an external calibrated flow rate instrument, the team eventually got to a flow sensor system they were satisfied with. To test the D2 concept, the team printed out a plastic Venturi, and connected a differential pressure sensor across the Venturi for flow and another sensor for pressure to provide feedback for coding and automation. Testing, calibration, and design changes were iterated until



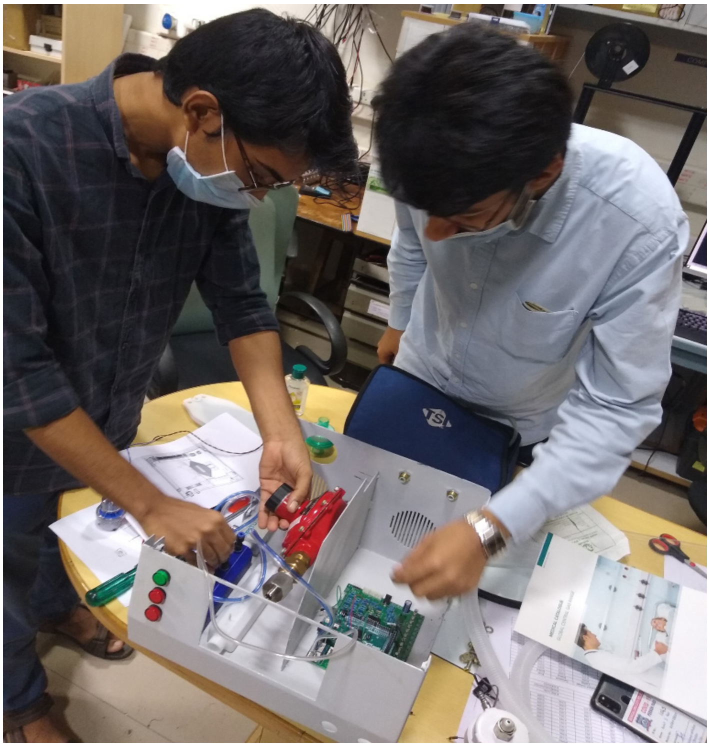
The electronics board designed for D2

a reliable feedback was achieved, because it is important for closed loop control to work properly. PEEP valves were sourced from Manipal Hospitals. D2 was then packaged in an external chassis and, tested. It has completed 100 hours of continuous working without failure. The process of converting D2-the prototype to D2-a reliable product threw up flaws that the team hopes to address in D3. Ultimately, three prototypes will be made and will undergo certification. Further, there will be animal tests and short-term human tests before either D2 or D3 can be released as a full-fledged ventilator.



The User Interface for D2

The team could have released D2 as it meets the requirements set out in the beginning of the COVID situation for emergency ventilators. However, given the current scenario, in which it is being suggested that high oxygen flows through a nasal canula are the first round of therapy, followed by CPAP, the team has decided to ensure that the ventilator it puts out is a well certified and properly tested instrument. How would these be different from existing ventilators? It would be a lower cost solution. The control code developed at IISc, that is going to go in free of cost, would be the primary enabler.



Ankit and Harsh assembling the components of D2

Details on each design and more on the project can be found here: http://www.cense.iisc.ac.in/ventilator/

Team:

Faculty members: Sushobhan Avasthi, Saurabh Chandorkar, Prosenjit Sen, Akshay Naik and Srinivasan Raghavan.

Students: Ankit Rao, Harshvardhan Gupta, Kapil Upamanyu (Electrical Engineering) and Vikrant Kumar Singh (Instrumentation and Applied Physics).

Industry Partners: Manjunath Jyothinagar (KAS Technologies) and Anoop Varghese (VASMED).

Medical consultancy: Dr. Justin Gopaldas (Manipal Hospitals)

and many more… (see website).

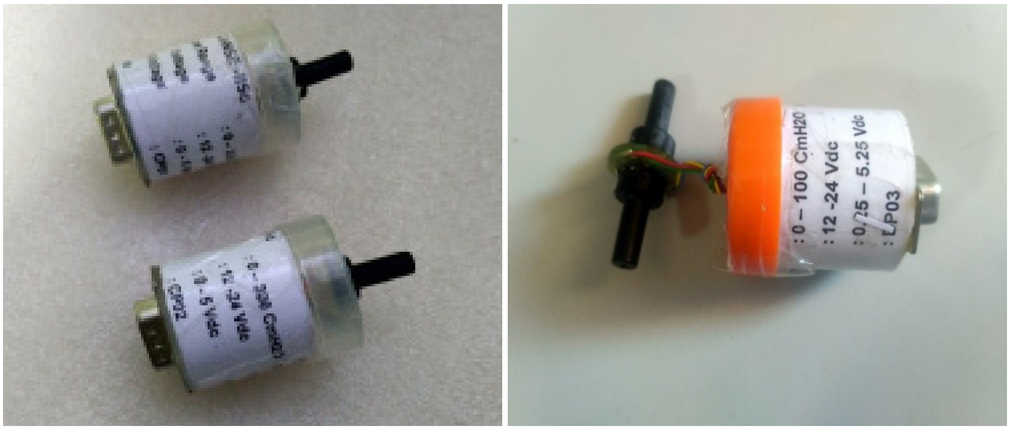
CeNSE's contribution to Project Praana

Pressure sensors

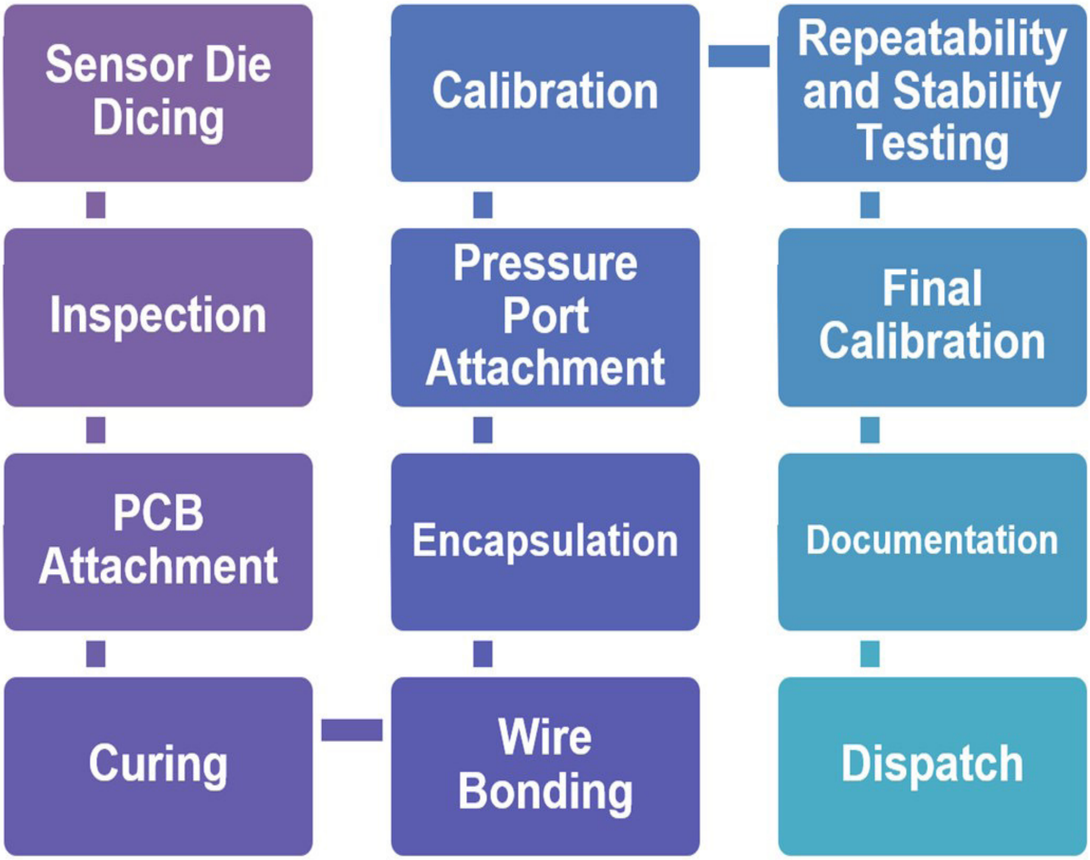
The Packaging Lab at CeNSE has worked on MEMS Pressure Sensor Technology for almost 10 years now. The Packaging Lab has worked on a plethora of pressure sensors catering to the Aerospace sector; specifically the ones fabricated and supplied to HAL for their helicopters' altitude and wind pressure measurements. But, when researchers from Project Praana (https://covid19.iisc.ac.in/project-pranaa-voluntary-ventilator-prototype-design-effort/#) approached CeNSE with a requirement for pressure sensors, it was for sensors of very low ranges (0 - 100 cm H_2O): a very low-pressure sensor that can measure pressure below 100 cm of water. This presented an exciting challenge to the researchers in the Packaging Lab and they got on board.

A Pressure Sensor is the heart of the ventilator as it constantly provides feedback on how the person is responding to the support, which decides how the support is adjusted. After going through their inventory and reassigning parts which were initially dedicated to other projects, the team embarked on this project on an emergency basis. It was decided that the very low-pressure aerospace-grade MEMS pressure sensors would be reconfigured to cater to the requirements of Project Praana. These sensors were initially designed and fabricated at the National Nano Fabrication Facility, CeNSE by Prof. K. N. Bhat and his team. The same were reconfigured with electronics, and tested, calibrated, and packaged for 2 different pressure ranges in consultation with the Project Praana team. Ultimately, 3 numbers of these pressure sensor prototypes were given to Project Praana.

Specifications	Gauge (2Nos)	Differential (1 No)
Pressure Range (cm H_2O)	0 – 300	0 – 100
Proof Pressure (cm H_2O)	0 – 600	0 – 200
Input Supply (V_{dc})	12 – 24	12 – 24
Output Voltage (V_{dc})	0 – 5	0.25 – 5.25
Accuracy (% FSO)	±0.2	±0.2
Temp. Range (°C)	10 – 50	10 – 50



The MEMS Pressure Sensor Prototypes provided to Project Praana



Packaging Steps for Project Praana's MEMS Pressure Sensors

Specifications	Gauge (2Nos)	Differential (1 No)
Sensitivity (mV/cm H_2O)	16 ± 1	50 ± 1

To say that achieving this feat of designing and fabricating parts for a medical device from scratch in record time with limited resources - human and material - in the midst of a pandemic was challenging, would be an understatement. The team worked relentlessly to produce the best possible pressure sensing system in a very short time at CeNSE. CeNSE is now planning to improve the specification of these very low pressure sensors, and launch a prototype with an advanced packaging scheme.

Team: M M Nayak, Veera Pandi N.

Oxygen sensors

The two different groups (one led by Prof. Gaurab Banerjee and the other led by Prof. Srinivasan Raghavan) that initiated major efforts for the development of a medical grade ventilator, though had completely different approaches, both required a crucial sensor to be integrated – the Oxygen sensor. This sensor would enable exact measurement of Oxygen concentration in the mixture of 100% Oxygen gas and air, which needs to be carefully mixed in the ventilator, depending on the patient's condition. Both these groups approached the gas sensors team at CeNSE to see if such a sensor can be provided.

The gas sensors team at CeNSE had been working on a range of chemi-resistive gas sensors over the last decade, including Oxygen sensor for monitoring oxygen depletion. However, the oxygen depletion sensor was calibrated and developed to measure Oxygen concentrations in the range of 0 to 25%. In contrast, for ventilator application, the requirement was to measure Oxygen in the range

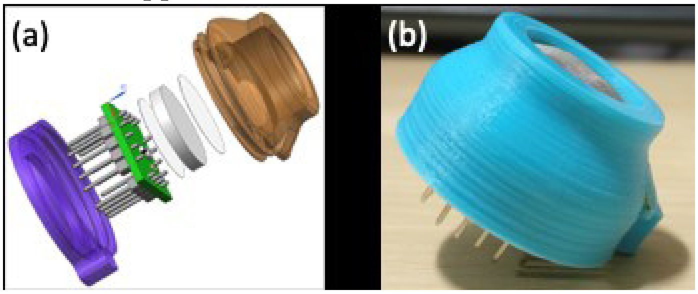


Fig 1. (a) 3D rendering of package (b) Final packaged oxygen sensor

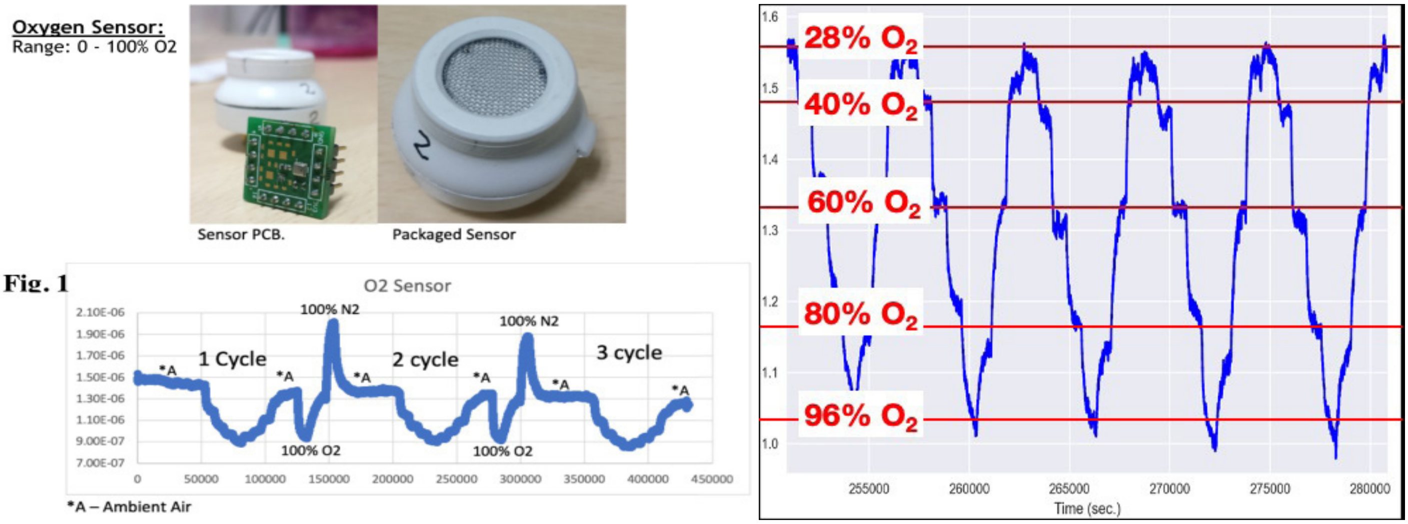


Fig 2. Calibration curves for Oxygen sensor

of 20% to 100%. In reality this required the development of a completely new sensor to serve the purpose. However, all the labs at CeNSE, in particular the Nanofab and Nanocharacterization labs, were closed and hence it was impossible to initiate the fabrication of new sensors. Hence the team took up the challenge of re-purposing Oxygen depletion sensor and re-calibrating it for ventilator application. Through custom packaging of chips using a 3D printer, and extensive characterization of sensor dice, they were able to deliver a few prototypes of Oxygen sensors in record time.

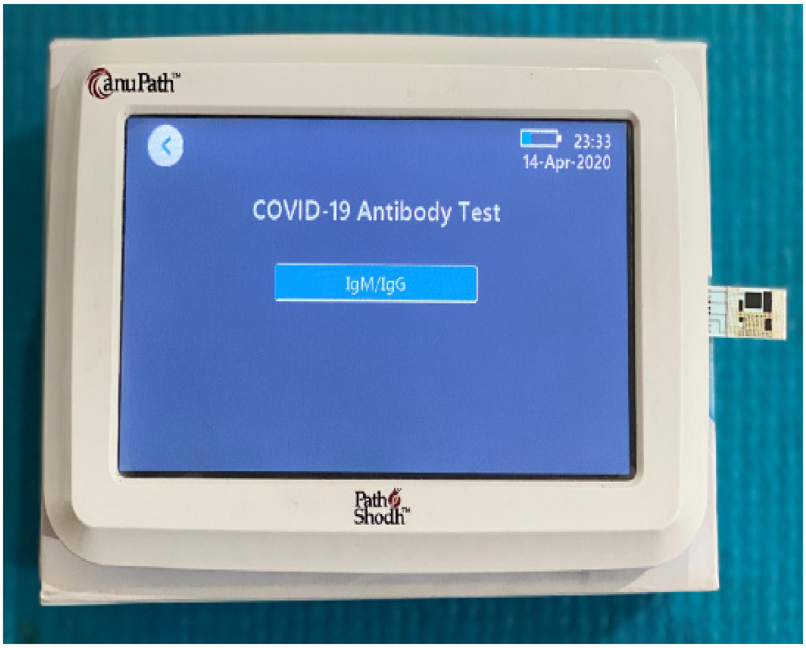
With the successful development of Oxygen sensor for ventilators, several ventilator manufacturers have shown interest in sourcing these sensors, based on the technology developed at CeNSE. At present, efforts have been initiated to spin-off a start-up from CeNSE to commercialize this technology and scale-up the production of these sensors. There is a need for seed funding of this start-up in a fast track process to ensure local supply of Oxygen sensors for all ventilator products developed in the country.

Team: Chandrashekhar Prajapati, Thejas and Navakanta Bhat.

Rapid antibody and antigen tests for COVID

PathShodh Healthcare, the start-up from CeNSE founded by Prof. Navakanta Bhat and Dr Vinay Kumar, is currently developing a unique diagnostics solution for COVID-19. In particular, PathShodh's lab-on-palm device anuPath is being re-purposed for both rapid antibody test and rapid antigen test, using electrochemical sensing technology.

The commercially available rapid antibody tests, are based on lateral flow ELISA technique, analogous to pregnancy testing kits. In contrast, PathShodh's solution will leverage disposable screen-printed



anuPath: PathShodh's lab-on-palm device.

electrodes, for rapid and accurate results. PathShodh has received funding from CAWACH, a DST program, to develop and deploy this product in the market, after due validation and certification over the next few months. Simultaneously, PathShodh is also developing a rapid antigen test, for nasal/oral swab samples, using the same platform. The company has received funding from BIRAC to validate and scale-up production for the rapid antigen testing technology.

In summary, PathShodh plans to offer a very unique diagnostics solution for COVID-19, for both rapid antibody and rapid antigen test on a single platform.

Team: PathShodh Healthcare Pvt Ltd (http://pathshodh.com/)

What's new in research at CeNSE?

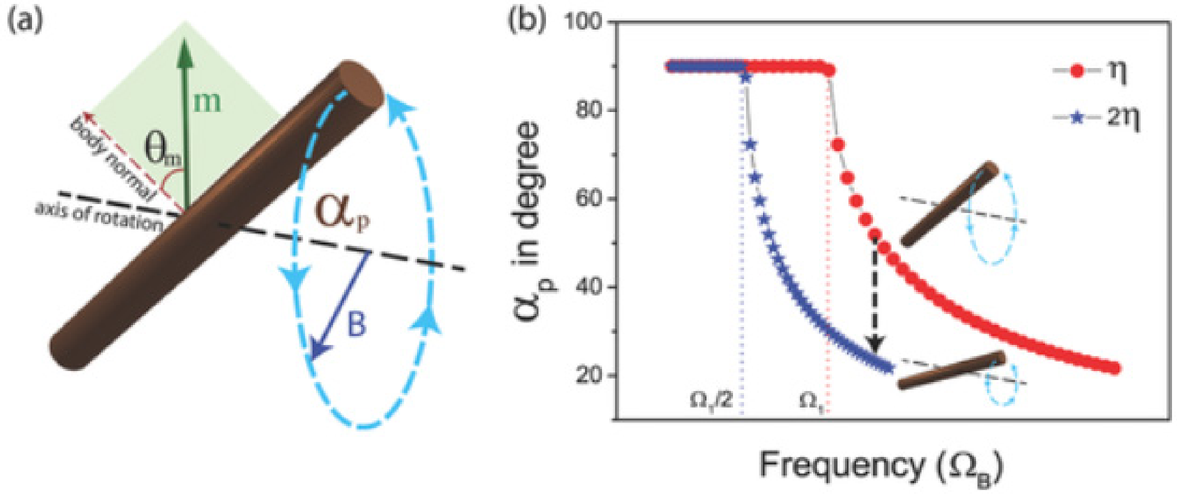
Optics, Nanostructures and Quantum Fluids Lab

Multifunctionality of helical nanobots

Gouri Patil and Ambarish Ghosh

Erwin Schrodinger's book, "What is life?", heralded the popularity of an interdisciplinary field, biophysics, in which physical laws and methodology are applied to explain biological phenomena. The ideas of biological machines such as ribosomes, kinesin or myosin have served as an inspiration to physicists and engineers alike for artificial nano or micro machines. The system of helical nano-swimmers driven by magnetic field is one such technological tool which can be used as the probe for biological environments and it deserves attention because of an important property, i.e., being minimally invasive, which is pertinent to any biological medium.

Biological media are very heterogenous in nature with living cells having complex environment, including dynamic protein networks, extra-cellular matrices and fluids. In probing such local environment, measuring a variable like viscosity becomes difficult yet important to understand the micro-rheological properties of the complex fluids. One part of the study focuses on using the helical swimmer as an active rheological tool for demonstrating

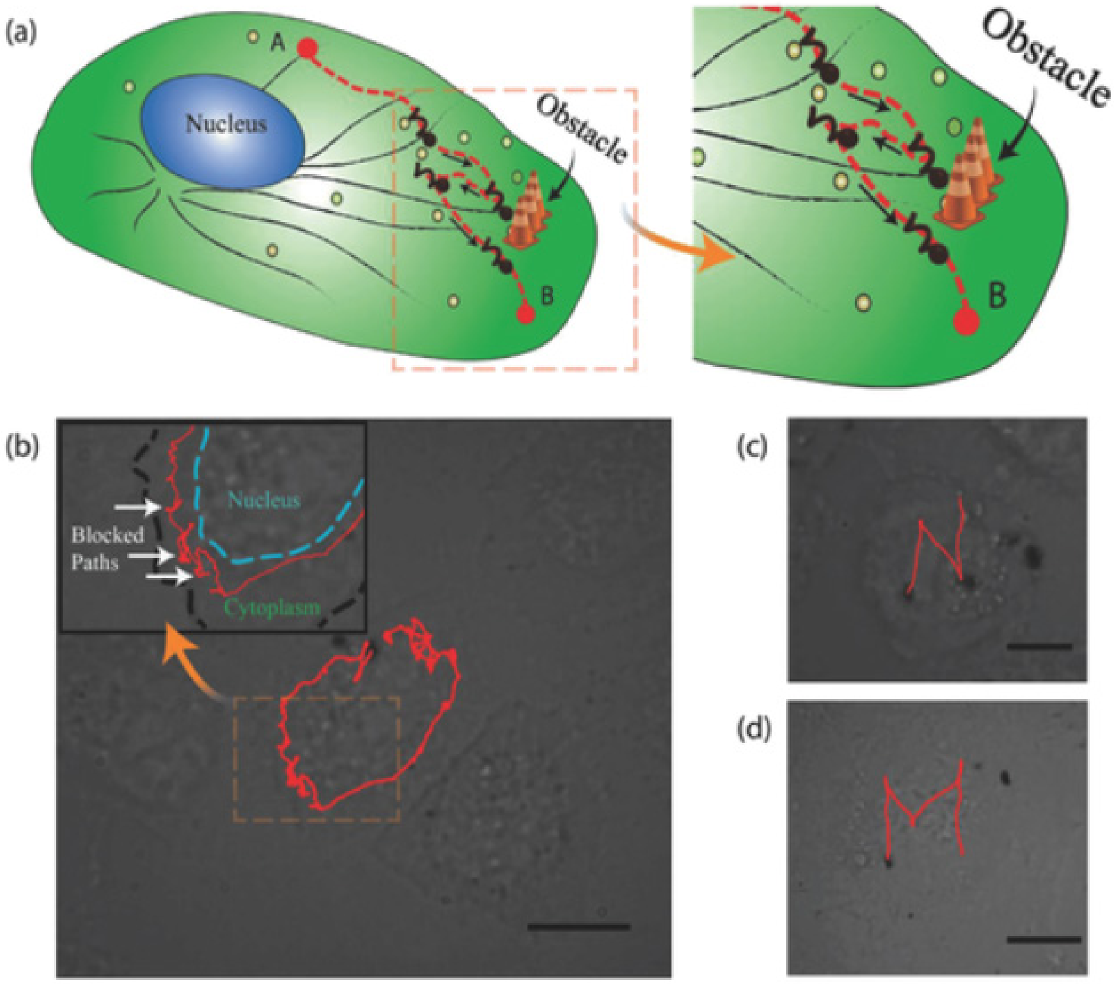


Schematic: magnetized rod under rotating magnetic field. a) a rod with permanent magnetization *m* at an angle θ_m to the short axis. Applied field is of strength *B* rotating at frequency Ω_B. The precision angle measured with reference to the axis of rotation is α_p. b) Precision angle as a function of Ω_B. Two curves denote the dynamics within media of two different viscosities, η and 2η. Change in viscosity, induced by external perturbation such as temperature, or by physically moving the rod to a location of different viscosity will result in a different precision angle.

the methodology of quantifying the viscosity of both Newtonian and shear-thinning fluids in real-time. The dynamics of these helical swimmers is such that the tumbling-to-wobbling transition of the helices is a function of the applied magnetic field and its frequency. And the frequency of this transition is directly linked to the viscosity of the medium, thereby giving an estimate of the viscosity by just observing the dynamics in different kinds of fluids.

With a convenient tool like the one described above, one can extend the same technique to biological media. So the second part of the study deals with accessing the cellular regions using swimmers. The authors demonstrate the manoeuvrability of helical swimmers in a precisely controllable manner inside the cell using rotating magnetic fields. Another important highlight of the study is that, even after the movement of these nano-bots in a complex medium like a cell, there are no adverse effects seen in cell viability.

Combining these two powerful techniques can result in exquisite control of motors inside the cell for delivery of payload to cytoplasm and also use the motors as mobile viscometers to sense the local environement. Currently, they have enabled rheological measurements in extra-cellular fluids like the reconstituted basement membrane matrix, and the hope for the future is to do similar active real-time sensing in the live cells.



Demonstration of controlled manipulation. a) Schematic showing a strategy to get good maneuverability. b) Trajectory of motion around the cell (inet) showing zoomed image of trajectory where the motor follows the strategy described in the main text (scale bar 15µm). c,d) Trajectory of nanomotors inside cells that navigate a track depicting the letter "N" and "M", corresponding to the word "Nano Motor"(scale 10 and 15µm, respectively).

References:

1. Helical nanomachines as mobile viscometers. A.Ghosh, D.Dasgupta, M.Pal, K Morozov, A Leshansky, A Ghosh, *Advanced Functional Materials*, 2018.

2. Manoeuvrability of magnetic nanomotors inside the living cells. M Pal, N Somalwar, R Bhat, S Ishwarappa, D Saini, A Ghosh, *Advanced Materials*, 2018.

3. Helical nanobots as mechanical probes forintra and extra-cellular environments. M Pal, D Dasgupta, N Somalwar, R Reshma, ,.......A Ghosh, *Journal of Physics-Condensed Matter*, 2020.

Investigating photoresponsivity of graphene-silver hybrid nanomaterials in the ultraviolet

Preeti Deshpande, Priyanka Suri, Hyeon-Ho Jeong, Peer Fischer, Arindam Ghosh, and Ambarish Ghosh

There are a number of ways through which light matter interaction of graphene can be enhanced. One of these strategies is using plasmonic structures. These hybrid structures have high photodetection efficiencies in the visible, IR, but not in UV. In an earlier study published in Nanoscale (2018), Debadrita Paria and Ambarish Ghosh showed strong photo-response enhancement in the UV region in a silver nanoparticle- graphene stacked device.

In this paper published in JCP, the underlying mechanism for the strong photo-response is considered. The graphene -plasmonic nanoparticle hybrid devices are fabricated using either gold or silver nanoparticles. The role of the underlying plasmonic layer is investigated by using these nanoparticles and testing the hybrid devices independently under the same conditions. The graphene-silver device displays an unusually large responsivity of 13A/W at 270nm, which

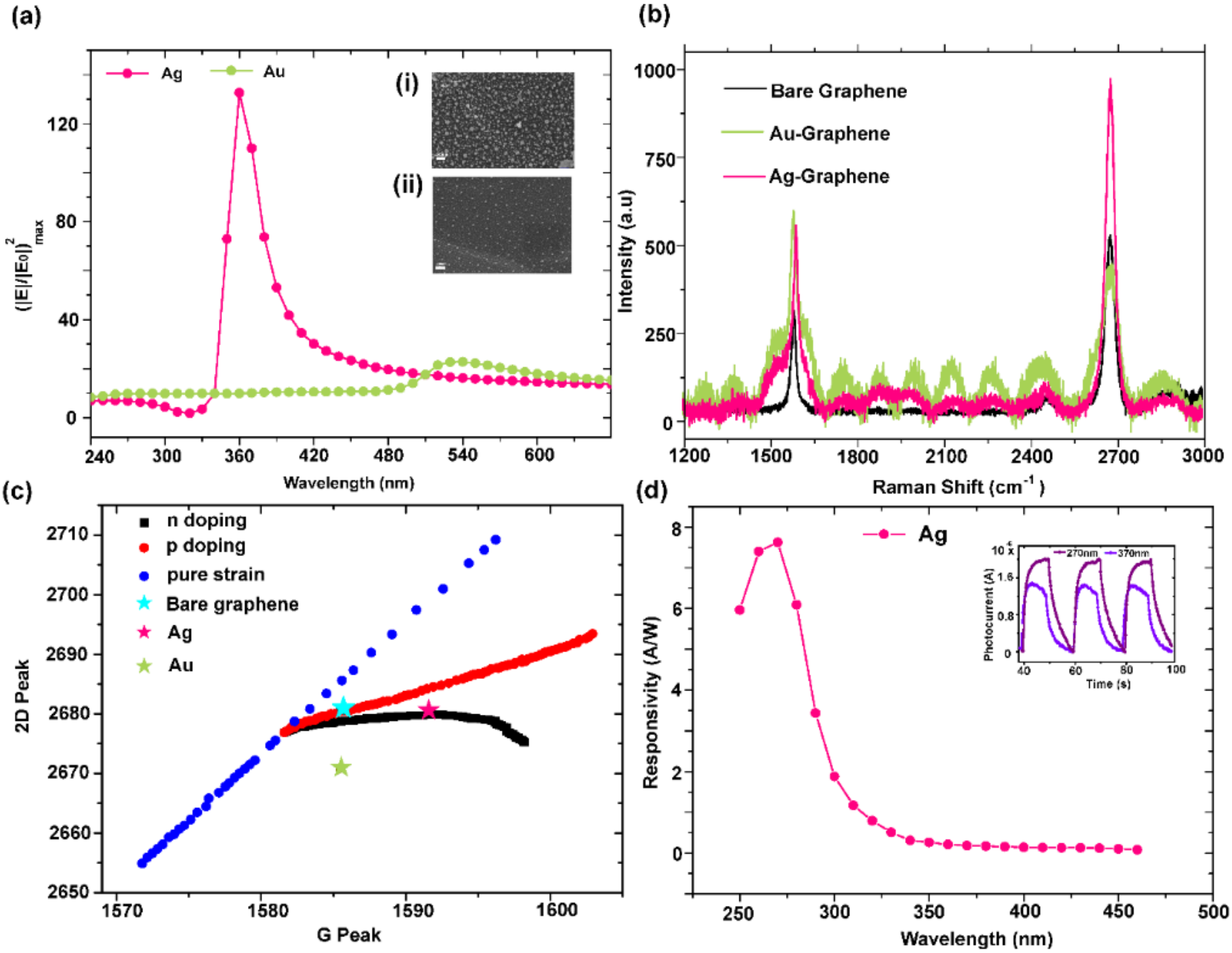


Figure: (a) Total near field enhancement in gold and silver nanoparticles of 50nm diameter; inset: Scanning Electron Micrograph of (i) graphene-silver hybrid, (ii) graphene-gold hybrid. (b) Comparison of Raman spectra of bare graphene, graphene-silver, graphene-gold. (c) Peak positions for G and 2D peaks indicating pure strain, electron doping (E doping) and hole doping (H doping) taken from the literature. Mean peak positions of the 3 nanoparticles used in this study are indicated by star symbols. (d) Responsivity graph of graphene-silver hybrid at Vsd of 0.35V; inset: ON-OFF response at 270nm, 370nm.

corresponds to the van Hove singularity in the graphene band structure. We explore the role of plasmonic particles by studying the effect of gold and silver nanoparticles by further characterizing them using Raman spectroscopy.

The doping and strain contribution in the Raman spectra reveals that silver nanoparticles induce electron doping, whereas gold nanoparticles induce p doping to the graphene, the strain induced by gold being much higher than by silver. The local doping in graphene-silver coupled with high optical absorption, enables efficient extraction of photogenerated carriers, leading to high responsivity.

References:

1. Deshpande, P., Suri, P., Jeong, H. H., Fischer, P., Ghosh, A., and Ghosh, A. (2020). Investigating photoresponsivity of graphene-silver hybrid nanomaterials in the ultraviolet. T*he Journal of Chemical Physics*, 152(4), 044709.

MEMS Lab

An ultra-portable Vis-NIR spectrometer with an integrated light source for quality analysis of food and agricultural produce

Amruta Ranjan Behera, Hasika Suresh, Avinash Kumar,
Shankar Kumar Selvaraja and Rudra Pratap

A growing demand for on-site quality analysis of food and agricultural produce has forced us to look beyond the time consuming traditional laboratory measurement techniques such as HPLC, GCMS and FTIR for quality assessment and control. Recent developments in miniaturised optical-sensors have enabled the realization of ultra-portable devices that can incorporate chemometrics-based models for chemical identification and quantification without the hassle of bulky instruments and usage of other undesirable chemicals. Chemometrics captures the signature of the chemical moieties of a compound through their reflectance spectrum, and together with the miniature optical sensors provides a potent platform for a rapid, non-destructive, and a fairly accurate method for analysing a wide variety of substances with portable point-of-use spectrometers. We have designed and fabricated one such handheld Vis-NIR spectrometer. The device (6.5cm x 2.5cm x 6.5cm) consists of a spectral sensor and an LED light source (wavelength 400-1000 nm) encased in a thermoplastic holder 3D-printed in-house (Figure 1).

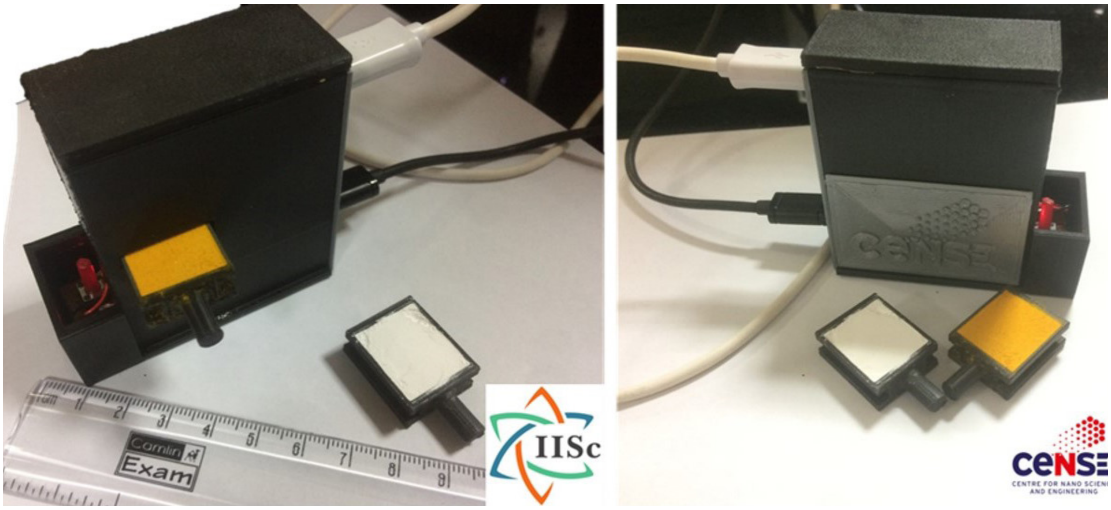


Figure 1: Image of the spectrometer from two iews, along with the sample holders containing Barium Sulphate (white) and Turmeric powder (yellow).

Spectral data can be acquired from the device through either wired or wireless communication. Each spectrum can be viewed as a graphical image and can be exported in text format for further data processing. The device performance is highlighted with two widely used classes of chemometric techniques: classification and prediction.

Identification and classification of similar compounds is a key element in quality control. To demonstrate this, we analysed the reflectance spectra captured by our device of four chemically different but optically similar culinary organic powders, namely, corn starch, calcium propionate ($C_6H_{10}CaO_4$), icing sugar ($C_{12}H_{22}O_{11}$) and white flour. With multivariate analysis, we were able to successfully distinguish one substance from the other by their distinct cluster formation using the Principal Component Analysis (PCA) algorithm. (Figure 2a). Having achieved this, we turned our attention to detection and quantification of curcumin in turmeric powders as a complete test case. For the prediction task, we have built a regression model to estimate the amount of pharmacologically active curcumin present in turmeric powders. Quantifying the active ingredient in medicinal plants is a direct way of analyzing their quality. The curcumin content was first accurately quantified by high performance liquid chromatography (HPLC), which served as the reference data. Reflectance spectra of five different varieties of turmeric powders (1-7% curcumin) were collected using the device. The initial model gave a high correlation coefficient (r2) of 0.99 and a standard error of 0.17. This model was cross-validated with test samples and the plot for the predicted *versus* actual values of curcumin content is shown in Figure 2b.

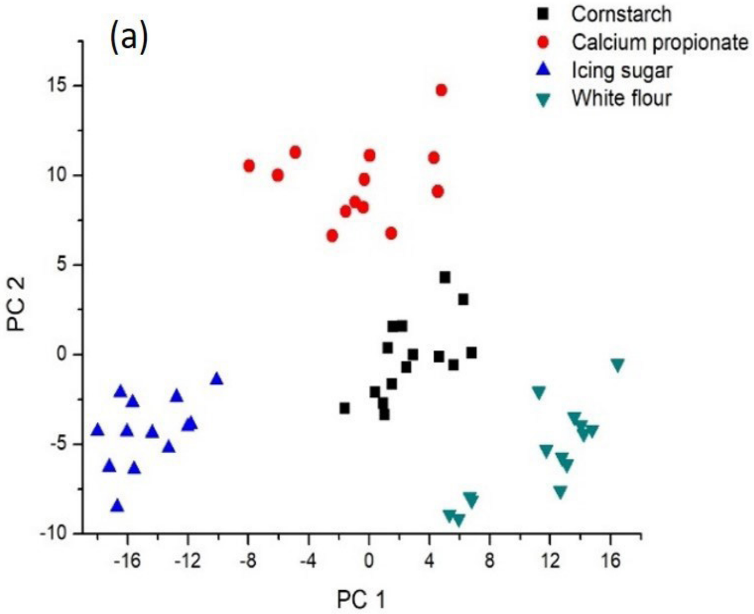


Figure 2a) Scores plots of PCA showing the reflectance spectra of the four powders represented by different colors in distinct clusters.

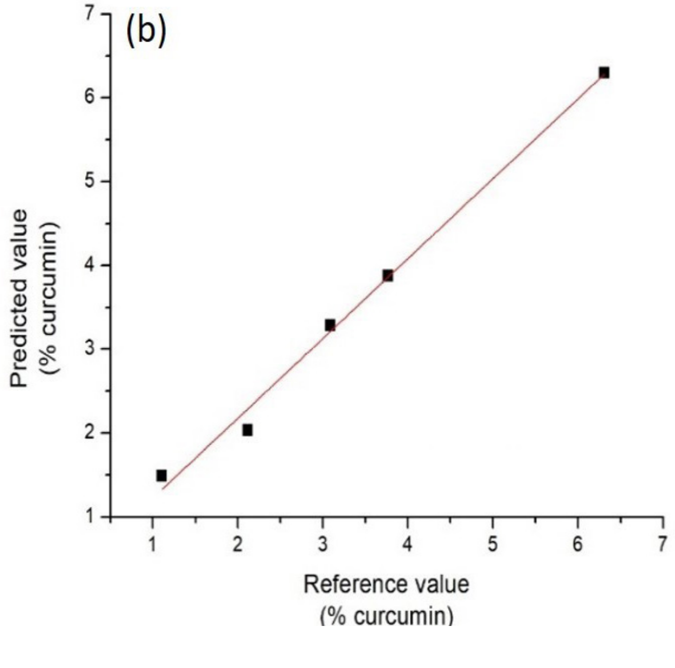


Figure 2b) Plot of actual v/s redicted values of curcumin content.

Optimization for one medicinal/agricultural analyte will set up momentum for the development of a platform technology for on-site quality analysis of other valuable agricultural products that play an important role in the economic development of the country. An ultra-portable spectrometer with an integrated light source for the acquisition of reflectance spectra and its subsequent analysis for one such active ingredient (curcumin in turmeric) is thus demonstrated.

Model building for any particular parameter lies at the heart of this process, and is also the most challenging aspect that needs to be optimized at multiple fronts and hence needs special mention. Before we started making models with our proposed device, we used a well calibrated spectrometer (Jaz, Ocean Optics, Germany), to understand chemometrics at a deeper level. Extensive data was acquired, where reflectance spectra of 66 samples having 15 scans each (total – 990 spectra), were used as the training data. The correlation between the processed spectra and the curcumin content was examined by the partial least squared regression (PLSR) algorithm. Owing to the diversity in the range of values and the need for accuracy in quantifying the total curcuminoids through their spectrum, two sets of finer models were constructed. The result of the coarse model's prediction, along with the error ($x \pm \Delta x$) for a test sample, determined which of the finer models was best suited to give the final predicted value of curcumin.

Figure 3 illustrates the range division along with the results of two model parameters. Our final goal is to provide a portable system that will help the user in taking faster and better decisions with on-site measurements, considering multiple parameters.

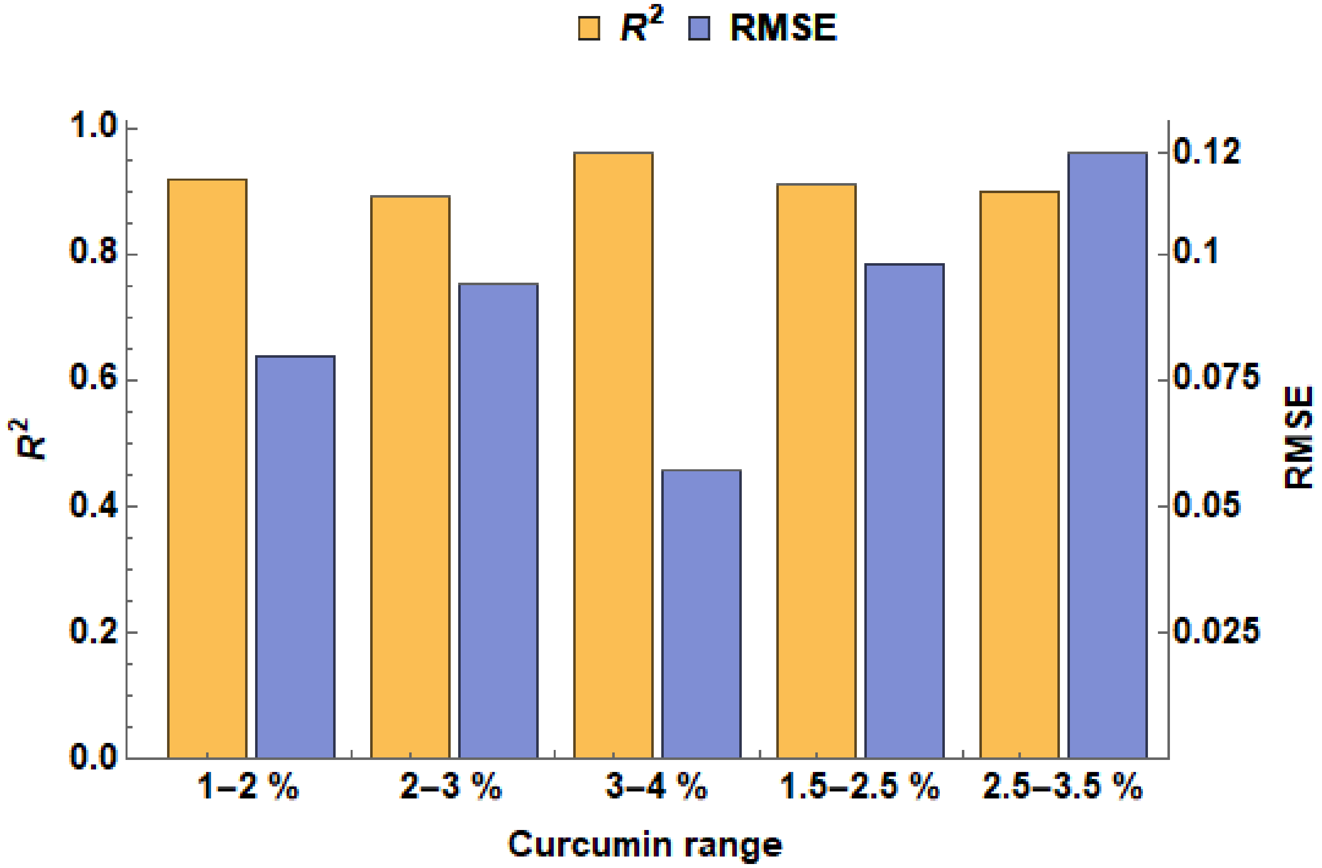
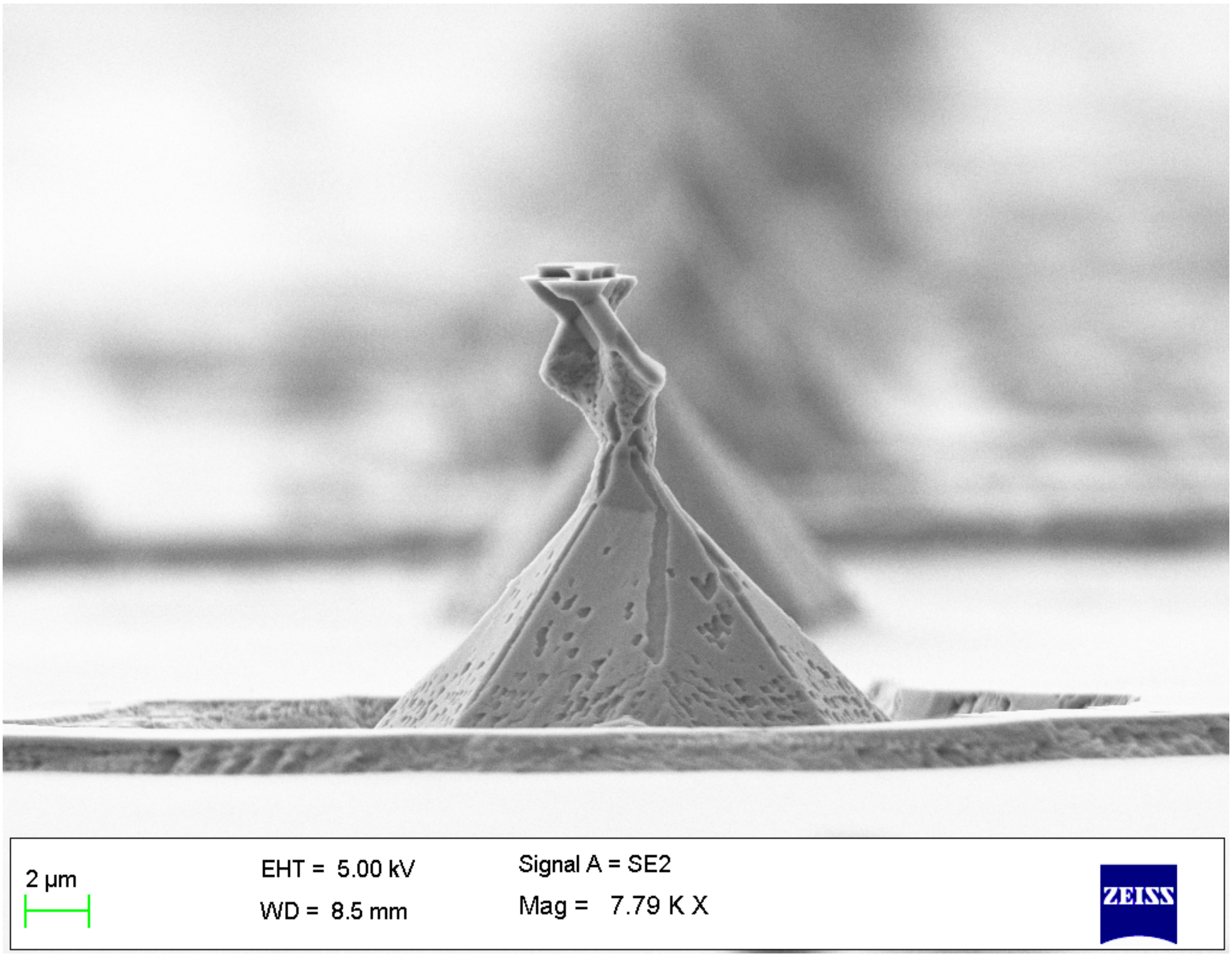


Figure 3: Bar charts illustrating two model parameters for each of the fine models: coefficient of determination (R^2) and Root Mean Squared Error (RMSE)

Research in Pictures



Dancing nano-sculpture

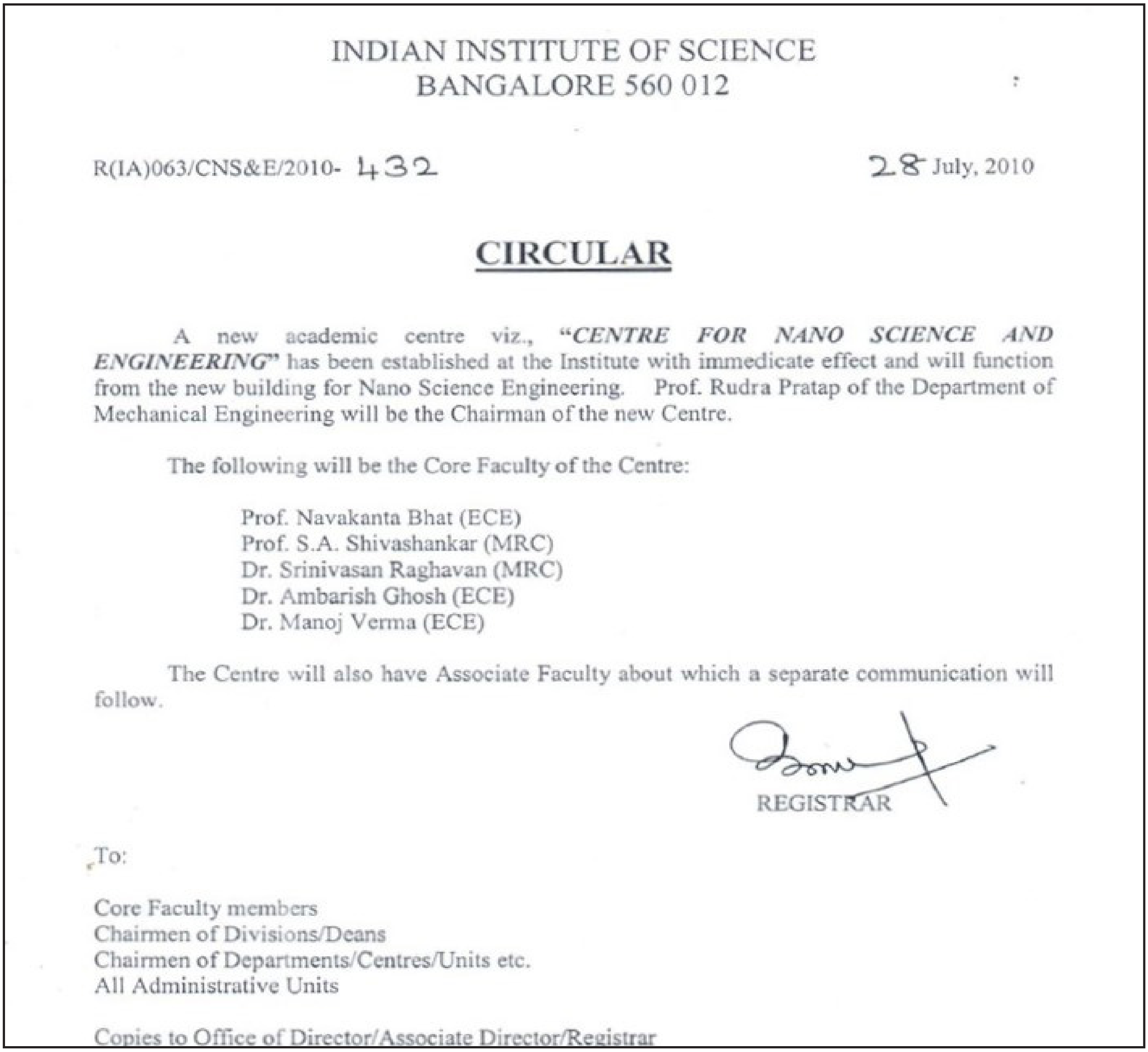
An intermediate step during Si tip formation by KOH etch

Authors: Deepu B R and Savitha P.

Leading the way in nanoscience and technology research since inception, CeNSE ushers in it's decennial year in 2020!

FEATURE

The Centre for Nano Science and Engineering was born as a department on 28th July 2010, but it was conceptualized much earlier, way back in the year 2000. It was a result of the realization that a world-class nano fabrication facility needed to be established in our country because designing our devices here and getting them fabricated in other countries, wouldn't take us too far. This huge challenge -- in terms of raising money, expertise and infrastructure -- was undertaken by Profs. Rudra Pratap and Navakanta Bhat, who collaborated with people who shared their ideas and came together to form what is CeNSE today. This photo article chronicles 10 years of CeNSE.



INDIAN INSTITUTE OF SCIENCE
BANGALORE 560 012

R(IA)063/CNS&E/2010- 432 | 28 July, 2010

CIRCULAR

A new academic centre viz., ***"CENTRE FOR NANO SCIENCE AND ENGINEERING"*** has been established at the Institute with immedicate effect and will function from the new building for Nano Science Engineering. Prof. Rudra Pratap of the Department of Mechanical Engineering will be the Chairman of the new Centre.

The following will be the Core Faculty of the Centre:

Prof. Navakanta Bhat (ECE)
Prof. S.A. Shivashankar (MRC)
Dr. Srinivasan Raghavan (MRC)
Dr. Ambarish Ghosh (ECE)
Dr. Manoj Verma (ECE)

The Centre will also have Associate Faculty about which a separate communication will follow.

REGISTRAR

To:

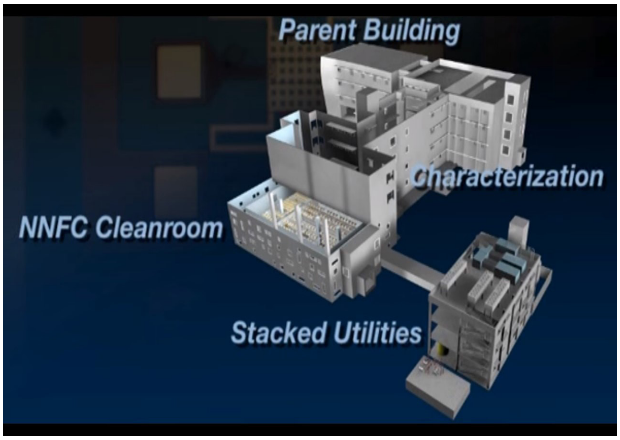
Core Faculty members
Chairmen of Divisions/Deans
Chairmen of Departments/Centres/Units etc.
All Administrative Units

Copies to Office of Director/Associate Director/Registrar

Circular announcing the establishment of CeNSE.

Land allotted for the construction of a new building for Nano Science and Engineering; September 2006.

Clearing the site for construction; 2007.



A rendering of the building plan; 2008.

A flurry of construction activity; September 2009.

Construction completed in September 2011.

Today, upon entering the NNfC, one can see on the wall a timeline of the chronology of events that took place during the construction of the Nano fab and rest of the facilities at CeNSE.

A myriad of educational videos about the design, construction, and function of the fabrication and characterization facilities at CeNSE can be found on our department's YouTube channel.

https://www.youtube.com/user/censeiisc/videos

CeNSE has been dedicated to the Nation by Prime Minister *Shri* Narenda Modi in 2015.

Ten years on and thanks to inspired leadership, infrastructure investment, world-leading academics and various outreach programs, CeNSE is determined to continue being at the very forefront of nanoscience research and education.

Recent PhD Thesis Colloquia

On-Chip Optical Sensing Platforms

Viphretuo Mere

Sensing has become an important field of research because of its wide variety of applications, such as chemical sensing, biomedical diagnostics, environmental gas monitoring (NO_x and CO_x), and oil quality monitoring. This has spurred researchers across various fields to develop new sensing techniques. These new techniques need to be both sensitive and selective to give direct evidence of the presence of the target analyte/molecule. Compared to the traditional electronic and mechanical-based sensing techniques, optical sensing offers superior sensitivity and selectivity. However, to sense low concentrations, meter-long interaction path between the target molecules and light is required, thus making it bulky and unsuitable for portable applications.

On-chip photonic sensors based on waveguides could address the challenges in conventional optical sensing systems by taking advantages of the reduction in system footprint by orders of magnitude. Additionally, compatibility with micro- and nano-fabrication technologies reduces the cost of production. For small-scale production, electron beam lithography-based fixed-beam-moving-stage (FBMS) technique is widely used for writing stitch-error-free structures. However, the writing is limited to primitive patterns such as circles, squares and rectangles. To write smoothly varying polygons, a combination of FBMS and area mode is used, which often results in misalignment between the two writing processes (Fig. 1a). To mitigate this, a method that offers smooth and alignment-error-free tapering (Fig. 1b and 1c) has been proposed and experimental demonstration of a stitch-error- and misalignment-free patterning of different photonic circuit components such

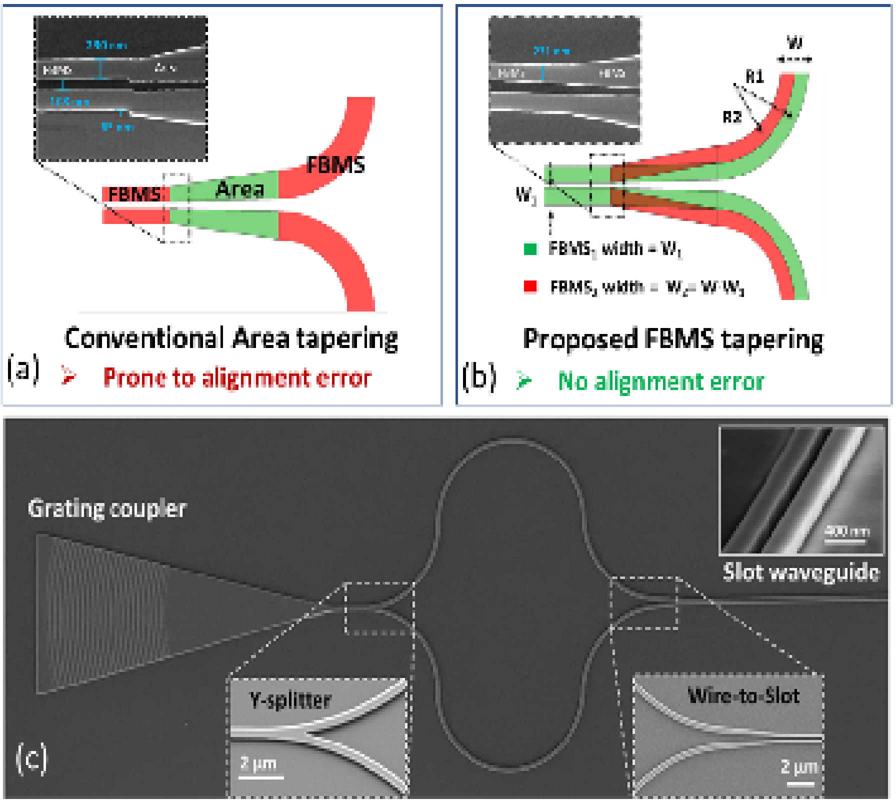
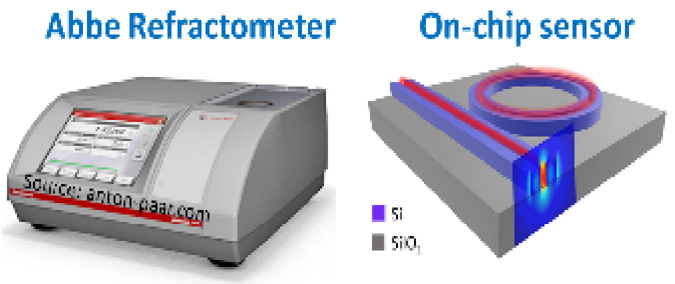


Figure 1: Comparison of tapering based on: (a) conventional area mode and (b) the proposed FBMS mode. (c) Scanning electron micrograph of the fabricated photonic circuit consisting of Y-splitter (left inset), bend waveguides, wire-to-slot coupler (right bottom inset) and slot waveguide (right top inset).

as power splitter, interferometer and resonator [1] was done.

In waveguide-based sensing, sensitivity is a combination of the strength of interaction and the underlying waveguide/resonator's sensitivity to the change in refractive index or absorbance. This thesis presents a slot waveguide-based high field interaction waveguide system, which can confine light in a low-index medium for increased sensitivity. The problem of coupling from a wire to a slot has been addressed through a novel coupling scheme. This work also experimentally demonstrates in silicon-on-insulator platform, slot-mode excitation with the proposed coupling design with high efficiency (99%), and shows athermal behavior of a PMMA-filled slotted ring resonator [2]. A detailed simulation was performed to optimize the slot-waveguide geometry for maximum sensitivity. A 37% improvement in the sensitivity compared to existing slot waveguide-based ring resonators has been reported [3]. Using the sensor, the dynamic refractive index on-chip measurement of different liquids was evaluated in comparison with a commercial Abbe refractometer (Fig. 2).



Liquids	Slope: [Δ refractive index (RIU) /ΔConc. (%)]	
	Abbe	On-chip
Glycerin	$0.00106 \pm 2.48*10^{-5}$	$0.00095 \pm 8.09*10^{-5}$
KCL	$0.00288 \pm 2.90*10^{-4}$	$0.00286 \pm 1.62*10^{-4}$
$KHCO_3$	$0.00201 \pm 7.11*10^{-5}$	$0.00200 \pm 1.17*10^{-4}$

Figure 2: Comparison of refractive index measured using slotted ring resonator and Abbe refractometer.

Furthermore, the feasibility of cross-modal sensing was studied to improve sensitivity and selectivity using an on-chip optical readout scheme. This thesis presents a highly compact (**16x smaller**) interrogation grating design that enables probing of smaller vibrating structures (Fig. 3), and experimentally demonstrates a resonant displacement sensitivity of 10 μW/nm which is 100 times better than static displacement sensitivity. Based on this, the researchers demonstrate resonant sensing of

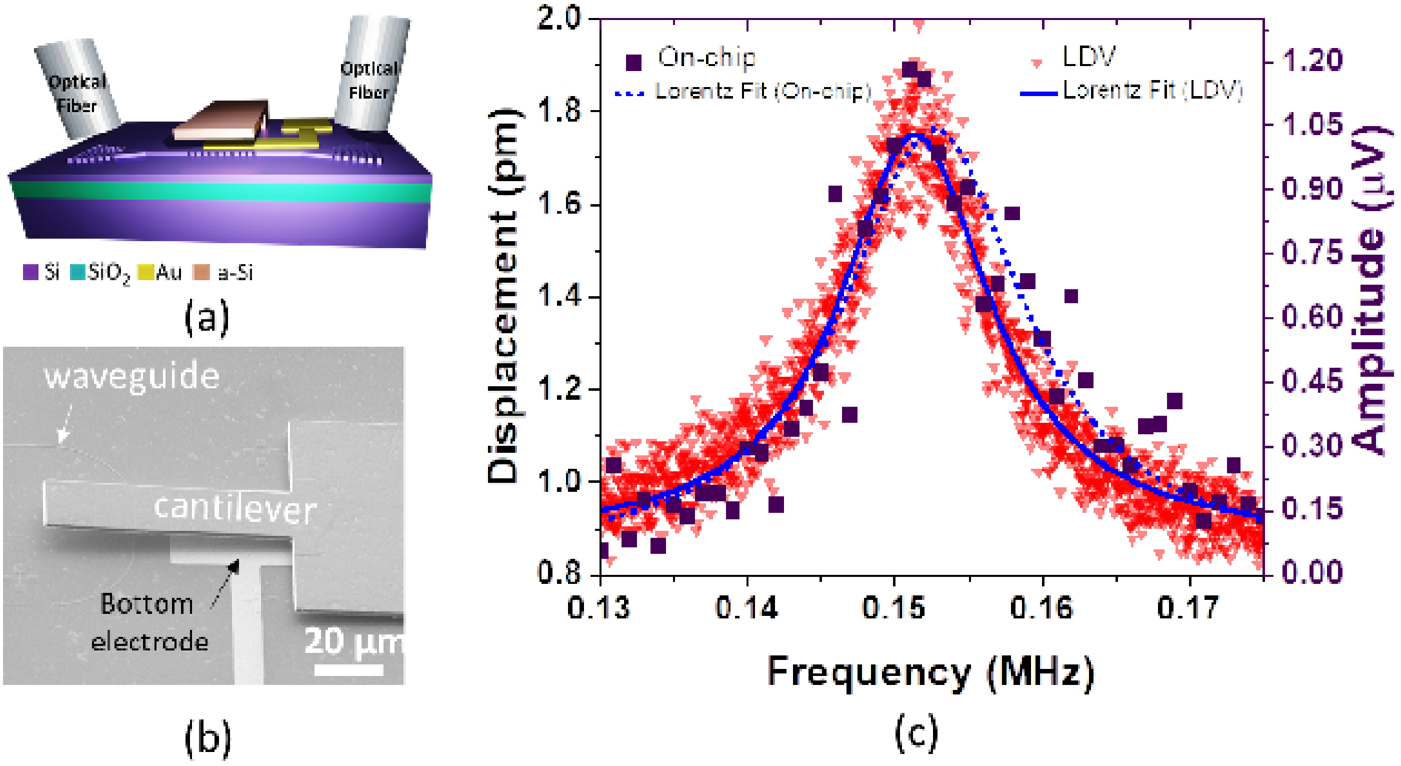


Figure 3: (a) Schematic of the On-chip grating-based vibration sensor. (b) Scanning electron microscope image of the fabricated device. (c) Comparison of the displacement measured using a commercial Laser Doppler Vibrometer (LDV) and on-chip grating sensor.

temperature via Joule heating and photothermal excitation. Experimentally, a thermal sensitivity of 3.1 nm/K was measured and a minimum detectable temperature difference of 129 mK was estimated. A bonding approach for fixing vibrating structure on top of the interrogation grating was also demonstrated experimentally.

Further reading:

1. V. Mere and S. K. Selvaraja, "Method to fabricate taper waveguide using fixed-beam moving stage electron-beam lithography," *J. Micro/Nanolithography, MEMS, MOEMS* (2019).

2. V. Mere, R. Kallega, and S. K. Selvaraja, "Efficient and tunable strip-to-slot fundamental mode coupling," *Opt. Express 26*(1), (2018).

3. V. Mere, H. Muthuganesan, Y. Kar, C. Van Kruijsdijk, and S. K. Selvaraja, "On-chip Chemical Sensing using Slot-waveguide based Ring Resonator," *IEEE Sens. J. 20*(11), (2020).

Ultra-wide band-gap semiconductor heterostructures for UV opto-electronics and power electronics

Anisha Kalra

A host of strategic, astronomical, healthcare and commercial applications require efficient detection of ultra-violet (UV) signals. Photodetectors utilizing wide bandgap semiconducting absorber layers such as Aluminium Gallium Nitride (AlGaN) and Gallium Oxide (Ga_2O_3) offer multiple advantages over the commercially-used Silicon photodetectors. These include intrinsic solar-blindness, room temperature operation, improved External Quantum Efficiencies (EQE), and radiation hardness. Vertical detector architectures such as p-i-n and Schottky are especially interesting since they allow UV sensing without the application of an external bias, and benefit from a vertical topology that enables integration into focal plane arrays.

The first part of this thesis focuses on the development of vertical, self-powered, deep-UV (sub-290 nm) AlGaN detectors on c-plane sapphire. The presence of a high density of defects in the hetero-epitaxially grown AlGaN epi-layers and the inability to realize low resistance contacts impedes the performance of these detectors. The work aims to develop growth strategies to address these challenges, establish a microstructure-defect-detector performance correlation and utilize this understanding for the development of record performance Schottky and p-i-n UV detectors on sapphire. The second part of the thesis aims at exploring novel device designs for the realization of broadband UV detectors, whose response can be tuned in any application-specific wavelength range. Energy band engineering at epitaxial heterojunctions of AlGaN and β-Ga_2O_3 has been explored as a less complicated, scalable approach for demonstration of UV-A/C and UV-C broadband detectors.

The impact of dislocation density variation on electrical characteristics of p- and n-doped $Al_{0.50}Ga_{0.50}N$ epi-layers was studied first. The growth of AlGaN on sapphire initiates with an AlN nucleation layer, and thus, a crystalline quality variation was achieved by tuning the nucleation density in this low temperature nucleation layer. Hall measurements, in conjunction with *in-situ* stress monitoring and cathodoluminescence studies suggested the importance of a low edge dislocation density buffer for the growth of crack-free, low resistive, Si-doped n-$Al_{0.50}Ga_{0.50}N$ epi-layers. The electrical characteristics of the Mg-doped p-$Al_{0.50}Ga_{0.50}N$ epi-layers weren't found to have a significant dependence on dislocation density. A substantial improvement in the electrical characteristics of the p-contact layers could however be achieved by utilizing the built-in polarization field in compositionally graded AlGaN-epi-layers for acceptor dopant ionization.

Next, a crystalline quality-to-detector performance correlation was established for AlGaN-based Schottky and p-i-n detectors. The dark (or reverse leakage) current was found to be sensitive to the density of screw dislocations, with a 350-fold dislocation reduction resulting in a billion-fold reduction in the dark current. An eight-fold reduction in the edge dislocation density was in-turn associated with a 5000-fold (20-fold) enhancement in the zero-bias EQE, from 0.01% to 49.23% (3.5% to 67.3%) for Schottky (p-i-n) detectors, when measured under front illumination. p-i-n detectors were subjected to constant UV stress for up to 3 hours and a defect-diffusion-mediated degradation in the device performance was observed for the high dislocation density samples. Schottky (p-i-n) detector stacks, realized using the optimized AlN nucleation conditions, yielded state-of-the-art zero-bias EQE of 54 % (74 %) under 280 nm (289 nm) back illumination, a dark current density below 0.6 nA/cm^2, a UV-to-visible rejection ratio exceeding 106, a thermal-noise limited detectivity (D*) of 3.3×10^{14} (4.1×10^{14}) $cmHz^{1/2}W^{-1}$, a linear response with optical power over three decades and stable operation under 1 mW/cm^2 UV stress for upto 3 hours.

p-i-n epi-stacks utilizing AlN/AlGaN superlattices along with the optimized AlN as the buffer, and polarization-graded Mg-doped AlGaN as the p-contact layer, were grown next. This helped realize record performance parameters for $Al_{0.40}Ga_{0.60}N$ p-i-n diodes with a near-theoretical breakdown field of 6.2 MV/cm, a low on-resistance of 6.25 $m\Omega.cm^2$, a rectification exceeding 10^{11}, a zero-bias EQE of 92%, a detectivity of 6.1×10^{14} $cmHz^{1/2}W^{-1}$ and a UV-to-visible rejection ratio exceeding 107. A 6 x 1 linear array of the diodes was realized, and the performance parameters were found to compare well before and after wire bonding.

In the last part of the work, novel vertical device architectures based on epitaxial integration of β-Ga_2O_3/GaN and β-Ga_2O_3/$Al_{0.45}Ga_{0.55}N$ are explored for the realization of tunable spectral response, broadband UV detectors. Firstly, a small conduction band offset at the heterojunction of β-Ga_2O_3 and GaN- and a small lattice mismatch between the two semiconductors was exploited to realize a detector epi-stack with both β-Ga_2O_3 and GaN as the absorber layers. This helped achieve a broadband photo response between 256 nm and 365 nm, with responsivity measuring 3.7 A/W at 5 V, a UV-to-visible rejection ratio exceeding 10^3 and a near-zero-bias dark-current-limited detectivity of 4.7×10^{10} cm $Hz^{1/2}W^{-1}$. Finally, epitaxial β-Ga_2O_3/$Al_{0.45}Ga_{0.55}N$ Schottky barrier photodiodes were explored to achieve a self-powered broadband response measuring 4 mA/W at both 254 nm and 284 nm, with a UV-to-visible rejection ratio > 10^3. Carrier transport studies were performed to identify the conduction mechanisms contributing to the observed performance under dark as well as UV illumination.

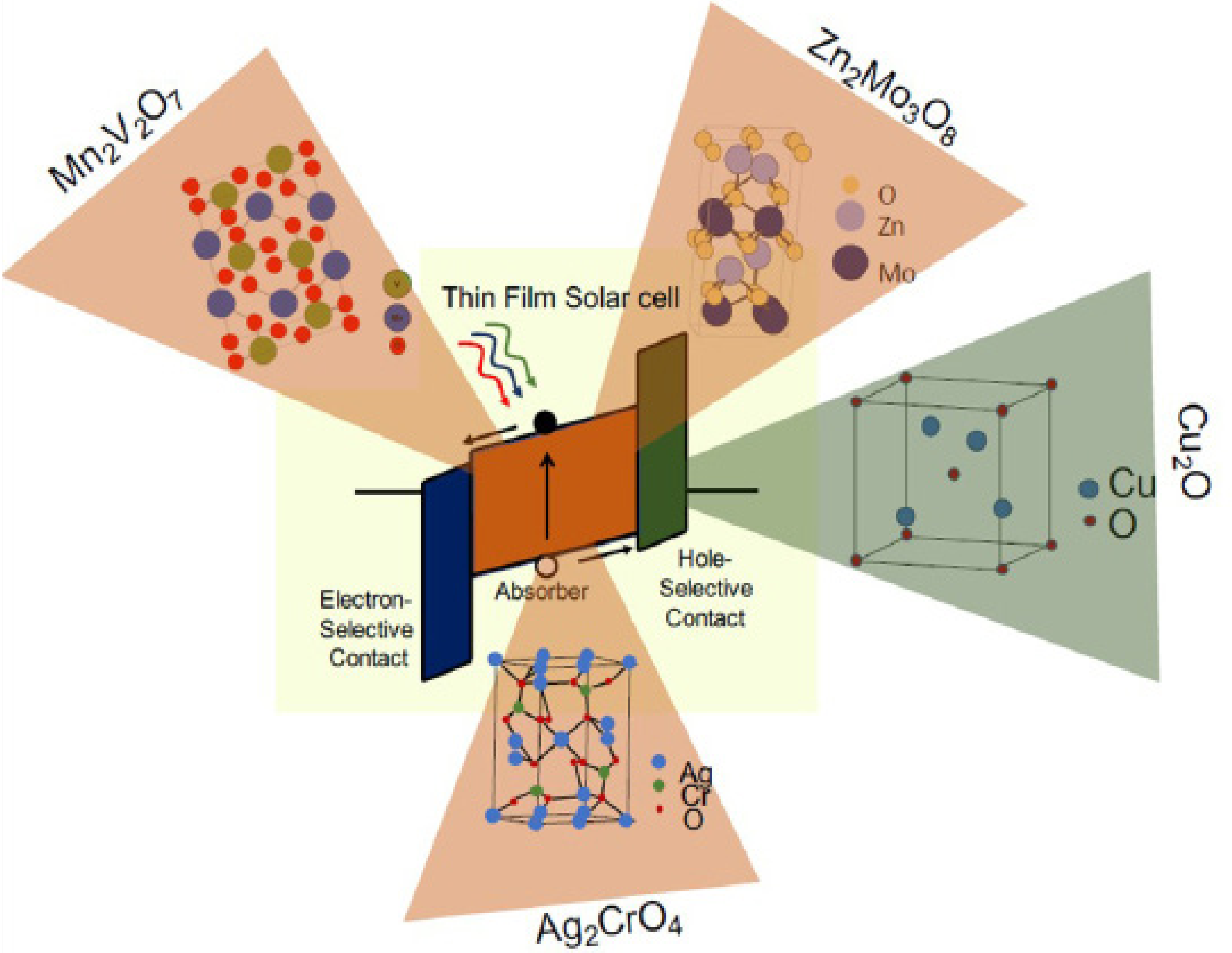
The work done as part of this thesis is expected to enhance the understanding and aid the development of wide band gap semiconductors-based, high-performance vertical diodes for UV detection and high power electronics using template and mask free, scalable, less complicated, relatively low temperature and inexpensive growth techniques.

Transition Metal Oxide Absorbers for Photovoltaics

Pramod Ravindra

Oxides are ubiquitous in photovoltaic devices. Most commonly as transparent electrodes (SnO_2: F. In2O_3: SnO, etc.), but also as carrier-selective contacts (TiO_2, MoO_x, etc.). However, oxides are rarely used as light-absorbers, mostly because most oxides have large bandgap, low carrier mobility and low carrier diffusion lengths. There is a compelling case for new materials that overcome these issues, as most oxides are non-toxic, stable and can be deposited using inexpensive techniques on a variety of substrates. Referred to as "all-oxide photovoltaics", such devices have long been a research area. Though, despite effort, few oxides have been demonstrated as efficient solar absorbers, either in theory or practice. One class of oxides, still poorly investigated, are the multi-cation transition oxides. This is a very large library, so it is conceivable that good solar absorbers are waiting to be discovered. This work presents a comprehensive study of three multi-cation transition metal oxides for their application in solar cells: $Zn_2Mo_3O_8$, Ag_2CrO_4, and $Mn_2V_2O_7$.

$Zn_2Mo_3O_8$ is a low-bandgap, non-centrosymmetric oxide. Polycrystalline films deposited at room temperature are n-type with a Hall mobility of 0.7 $cm^2V^{-1}s^{-1}$. DFT calculations suggest that the valence band is composed of both O 2p and Mo 3d orbitals – which could lead to higher hole mobility than that of typical oxides. The valence band composition was experimentally determined using resonant photoelectron spectroscopy, which confirms this assertion. Unfortunately, DFT calculations also show that ZMO has high energy Frenkel excitons, which will not dissociate at room-temperature, leading to reduced voltage in solar cells. Au/ZMO/TiO_2 Schottky diodes with ZMO films deposited at room temperature show photoresponse but no photovoltage. This shows that ZMO is a carrier conducting semiconductor that can be used in a



photodetector but not as a solar absorber.

Ag_2CrO_4 (ACO) is a known photocatalyst with low bandgap and low melting point. The latter leads to highly crystalline films, even when substrate temperatures are low. DFT shows that ACO has a valence band composed of O 2p and Ag 4d, which could lead to higher hole mobility. Schottky solar cells using ACO show typical photovoltaic behaviour, with a photocurrent and photovoltage. However, the power conversion efficiency is low, just like other emerging oxide absorbers. An investigation into the possible reasons showed that the Urbach tail at the bandgap is very large, a sign of significant electronic disorder in the film.

$Mn_2V_2O_7$ (MVO) was previously demonstrated as a photocatalyst with a low bandgap. Like AMO and ACO, MVO also has a d-contribution to the valence band which leads to high hole mobility. MVO has a low melting point allowing deposition by PLD at high homologous temperatures which result in films with a large lateral grain size >10 µm on SiO_2 and ~1 µm on $SrTiO_3$. These films are p-type with high Hall mobility (>200 cm^2/V^{-s}) and low Urbach energy 76 meV. These values are comparable to CIGS, a commercial solar absorber. The conductivity of MVO changes across five orders of magnitude by changing the deposition pressure. The ability to deposit 'conductive' MVO allows one to make rectifying devices. Annealed MVO films show significant solar cell performance with a short circuit current of 0.46 mA/cm^2 and an open-circuit voltage of 0.21 V. These annealed films show photoluminescence at low temperatures – an indicator of enhanced electronic quality. The analysis of the temperature-dependent PL shows shallow dopant levels but a complete absence of deep defects. An interdigitated back-contacted cell with carrier-selective TiO_2 contact shows improved performance with open-circuit voltage of 0.33 V and a short circuit current of 0.2 mA/cm^2.

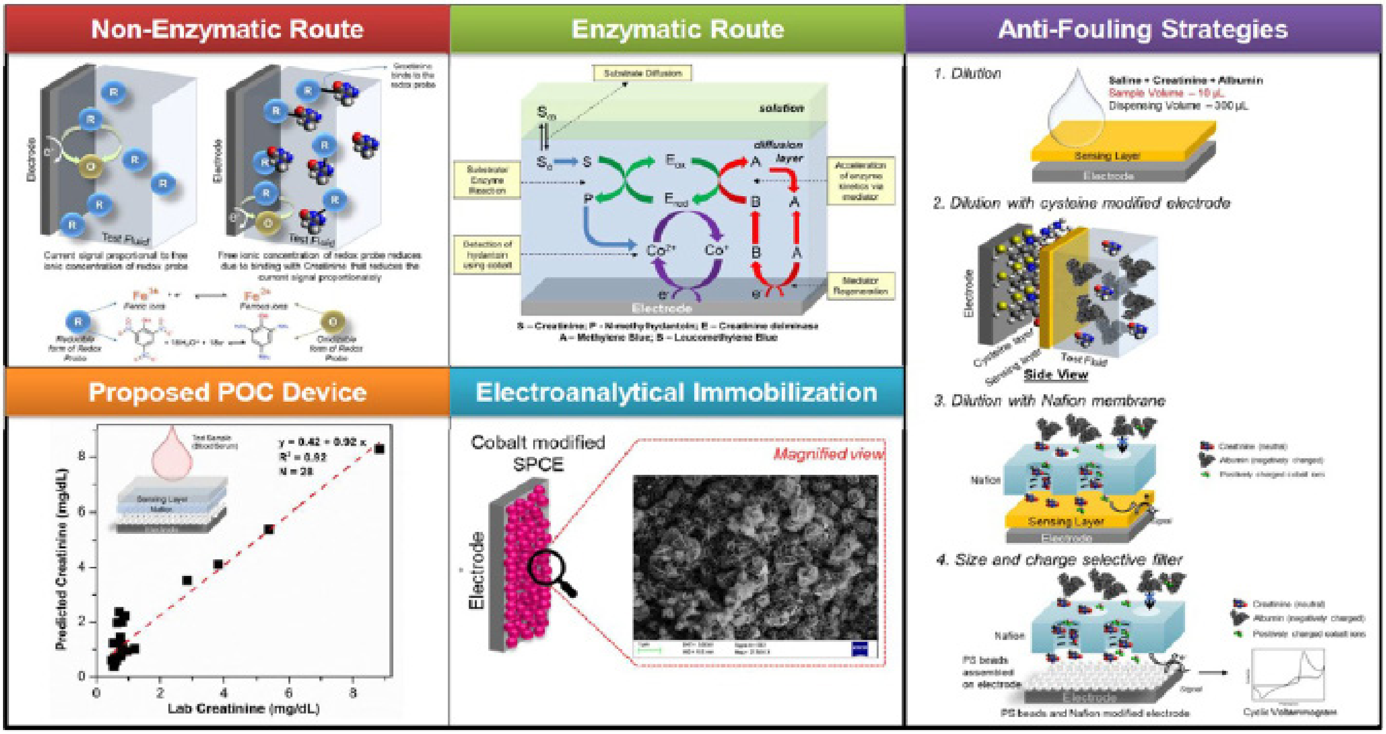
Just like oxide-absorbers, p-type oxides are also quite uncommon. There are few known p-type wide-bandgap oxides, like Cu_2O, but band-alignment and interfaces are often the limiting factors for their integration in devices. This work demonstrates successful integration of type Cu_2O with a silicon absorber to make hole-selective contact. Photoelectron spectroscopy measurements reveal that the band-alignment between Cu_2O and Si block flow of electrons from silicon to Cu_2O but allows the passage of holes. Interface recombination was reduced by integrating an ultra-thin SiO_2 layer between Cu_2O and Si. The p-Cu_2O/n-Si heterojunction with the passivating SiO_2 interlayer showed an open-circuit voltage of 0.53 V, which at the time was a record among cells without back surface passivation.

In summary, among the transition metal oxide thin films whose properties were investigated for application in photovoltaics, MVO proved to be a promising candidate as an oxide absorber, and Cu_2O a candidate for a hole-blocking layer. This work is expected to contribute to the development of efficient all-oxide solar cells.

Robust Electrochemical Sensing Techniques for Serum Creatinine Biosensor

Pallavi Dasgupta

Creatinine is an important biomarker for evaluating renal function and its concentration in serum can be utilized for early detection of kidney disease, thyroid disorders and muscular dystrophy. The conventional analytical techniques to estimate serum creatinine are limited by their non-specificity, high cost, and sophisticated instrumentation. This underlies the focus of this thesis as it primarily discusses various approaches and challenges faced in developing the intended sensor. This work explored both, non-enzymatic and enzymatic approaches for the detection of serum creatinine. The non-enzymatic approach involves utilization of a transition metal – iron in one case. The other case involves electrochemical estimation of creatinine by picric acid that is already utilized in the optical Jaffe reaction. Both the cases provide reliable estimation of creatinine in saline and prove the feasibility of estimation of the reduced concentrations of serum creatinine by non-enzymatic techniques. The enzymatic approach involves one-step hydrolysis of creatinine by creatinine deiminase. The resulting N-methylhydantoin is quantified by a highly selective transition metal-based redox probe – cobalt. This is a novel route for



creatinine estimation that has provided reliable quantification in serum and whole blood. The enzymatic approach assures a higher sensitivity and specificity of detection of creatinine in real samples.

A generic issue that plagues a majority of the electrochemical biosensors involving microelectrodes is signal attenuation due to electrode fouling, caused by the non-electroactive components of the blood. This work investigates different strategies to minimize this fouling by serum proteins – albumin. The strategies differ based on the interaction of the redox probe with albumin, and are classified into albumin-reactive and albumin-non-reactive systems. A unique size and filter composite has been devised that can be tuned and further optimized with any disposable electrode platform based on the required extent and nature of filtration. An alternate approach of immobilization of the redox probe on a low-cost, disposable screen-printed electrode by a simple and facile process of electrodeposition has also been investigated. Of all the different strategies adopted, the sensor based on enzymatic technique has demonstrated success in estimating creatinine from whole blood samples of patients with no sample pre-processing, a reduced turnaround time (within 1 minute) and high accuracy over a wide dynamic range (0.2 – 4 mg/dL) and has laid the foundation for the intended point-of-care device.

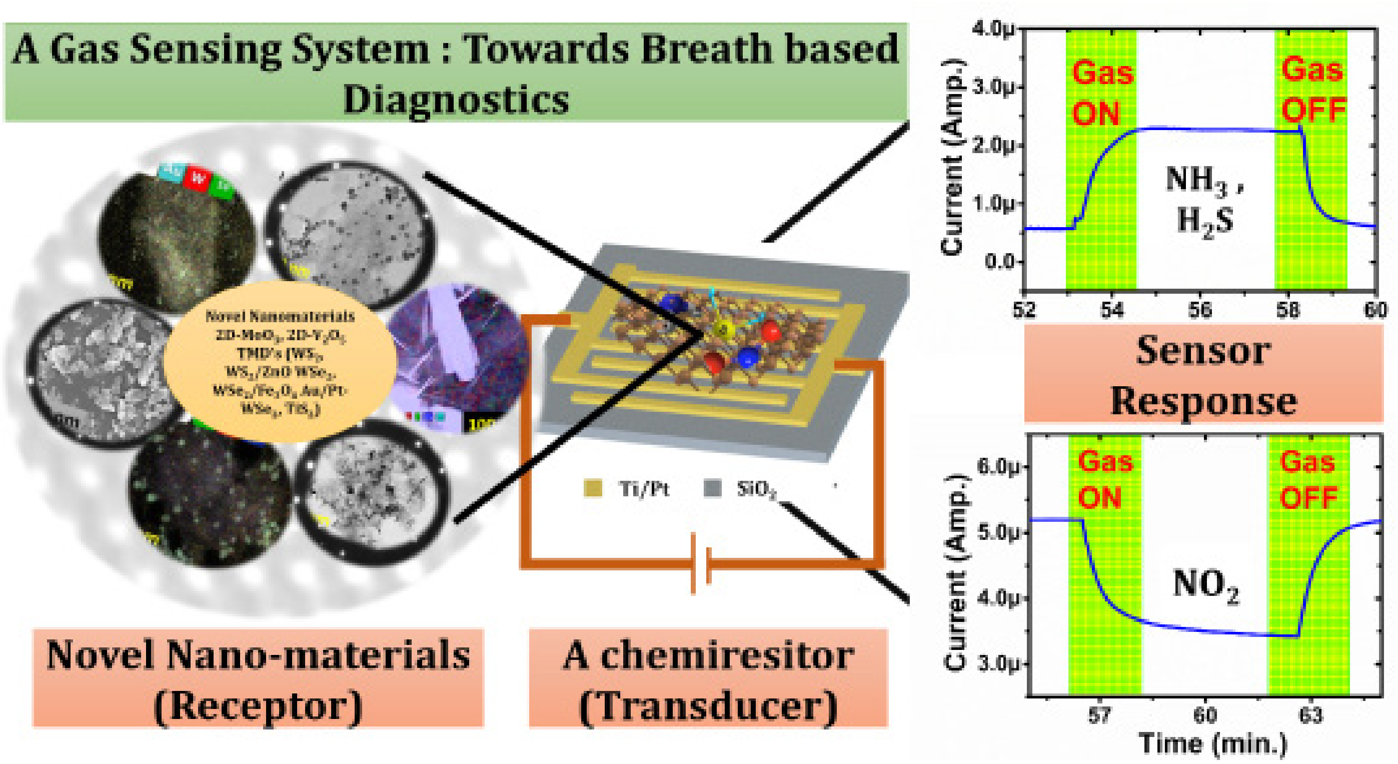
Two-Dimensional Nanomaterials for Chemiresistive Gas Sensors: Towards Development of Breath based Diagnostics

Neha Sakhuja

Breath based Diagnostics (BbD) can enable a paradigm shift in the Point-of-Care Diagnostic (PoCD) devices. Exhaled human breath has been demonstrated to contain over 2000 volatile organic and inorganic compounds, some of which report marked change in concentration under disease conditions. A sensitive, selective, cost-effective and portable gas sensing system could thus non-invasively diagnose multiple diseases from a single breath sample. However, there is a need to develop highly sensitive gas sensors with very low limit of detection (LLoD) down to ppb to ppt, and high selectivity to meet this requirement.

This thesis focuses on developing such gas sensors based on novel 2D nanomaterials and their hybrids while using a simple, scalable synthesis route. This is in contrast to the conventional choice of sensing materials (metal oxides, polymers, CNTs etc.) and expensive fabrication methods. This work explored layered materials namely Transition Metal Dichalcogenides (TMDC) and Layered Transition metal oxides (TMO) and their hybrids for the detection of Ammonia (NH_3), Hydrogen Sulphide (H_2S) and Nitrogen Dioxide (NO_2) - three important constituents of exhaled breath. The synthesis of these layered materials was carried out at room temperature via the liquid phase exfoliation (LPE) technique using low boiling point solvents. This technique is attractive because it is simple, scalable and does not require sophisticated instrumentation.

The key findings from this work can be summarized as follows. Layered Transition metal oxide (TMO), namely 2D MoO_3-based devices demonstrated reasonable response to NH_3 at room temperature but only down to 300 ppb which was not sufficient for the intended application. Further, it was observed that the layered TMDs WS_2, WSe_2 and its hybrid with Fe_3O_4 demonstrate remarkable ammonia sensing. WS_2 demonstrated high sensitivity towards NH_3 (detection down to 50 ppb) with fair selectivity but at an elevated operating temperature of 250°C. On the other hand, WSe_2/Fe_3O_4 hybrid-based devices demonstrated enhanced sensitivity and selectivity towards ammonia, that too at room temperature, with a 50 ppb LLoD. Another notable observation was response of pristine WSe_2 nanosheets towards NO_2 similar to (towards) NH_3. Hence, the NO_2-sensing performance of WSe_2-based sensors was enhanced by functionalizing their surface with noble metals such as Au and Pt using a simple wet chemical route. Interestingly, this yielded highly sensitive (down to 100 ppb) and selective response towards NO_2 at room temperature. More importantly, the complete recovery to the original baseline without any external energy source was remarkable since it is known to be challenging.



While exploring other inorganic TMOs, it was observed that 2D V_2O_5-based devices detect H_2S non-selectively at 350°C and down to only 500 ppb. Further improvement in H_2S sensing is helped by TMDs again as the surface of WS_2 was modified in such a manner that it suppressed NH_3 sensing, by using low temperature microwave irradiation-assisted synthesis technique. Thus, it demonstrated highly selective, sensitive, and prompt H_2S detection, though at an elevated temperature of 250°C. Later, it was observed that a novel material of this same class (1T-TiS_2) could provide similar attributes at room temperature. This material had not been investigated before for gas sensing; hence a theoretical study was conducted that presented a plausible mechanism based on vdW interaction, substantiating physisorption between adsorbate and adsorbent.

Thus, this thesis investigates novel materials, hybrids, and methods for scalable production of ultrasensitive, selective, stable, and low-cost sensors for NH_3, H_2S and NO_2, which can potentially find applications for field-usable

Organic-Inorganic Heterojunctions for Application in Perovskite-Based Photovoltaics

Arun Singh Chouhan

Research on organic-inorganic lead halide perovskite solar cells (PSCs) has seen most notable progress in the field of photovoltaics (PV). The very first PSC was reported in the year 2009 with efficiency of 3.8%, which rapidly increased to the record 25.2% in year 2019. These numbers are quickly approaching the record values achieved for single-crystal silicon-based solar cells. Defect-tolerant nature of perovskites, high carrier lifetime, ability to tune band-gap, and low-cost solution-based processing, in addition to many rare properties, makes them ideal candidates for future solar cell technology. These are the properties which also allow this material to find applications beyond PSCs, like photodetectors, memory, thin-film transistors (TFTs), etc. However, given the many valuable properties of this class of materials, they also come with some dominating issues which hamper commercialization of this PV technology. Problems like, ion-migration and degradation in ambient condition have yet to be fully solved and understood. This area of research still has many unanswered questions, such as finding suitable composition engineered lattice to make a system stable, role of interface on charge transport, and device stability.

Through this work, we have developed a novel process to grow micron-size grains of $CH_3NH_3PbI_3$ (MAPI) using a custom-made glass reactor. Pristine films were spin-coated on substrate in a glove-box and transferred to methyl-amine gas filled reactor, followed by annealing of the whole setup in a controlled environment. The resulting films were conformal with average grain size of > 1 micron, and were used to demonstrate the increase in minority carrier lifetime upon methyl-amine gas annealing. Fabricated devices also showed improvement in device performance upon inclusion of large-grained MAPI film as compared to pristine MAPI film. At a later stage, optimization of compact layer (c-TiO_2) and mesoporous layer (m-TiO_2) was performed, followed by improved device fabrication methodology. This yielded device efficiency up to 17.5% with high reproducibility. Major contribution to the improvement of device efficiency was from fill-factor (FF) of the device. It was found that most of the resistive drop came from transparent conductive oxide (TCO) and the current path was changed within the TCO to substantially lower the series resistance of the device and improve FF. FF can also be affected by interface defect density and to see the effect of interface defect density on device performance, simulations were performed by taking experimentally found parameters as input to the simulator.

High efficiency device fabrication involves deposition of c-TiO_2 at 250°C in an ALD chamber and thermal annealing of meso-TiO_2 at 500°C for 1 hour, increasing the thermal budget of the device. To address this problem, the conventional FTO/TiO_2(c)/TiO_2(m) stack was replaced with Aluminium doped zinc oxide (AZO), considerably simplifying the fabrication process and reducing thermal budget. Photoelectron spectroscopy suggests that AZO is an effective ETL for perovskite (MAPI) thin films, with a large valence band-offset and a small conduction band offset, but with a possible path for carrier recombination at the interface. It was shown that treating the surface of AZO with ozone gas (AZO:O3) improves the charge carrier extraction at the interface. Furthermore open-circuit voltage (V_{oc}) and efficiency (η) of 1.03 V and 10.5%, respectively, were achieved.

Given the stability issue of the MAPI, a couple of inorganic materials were explored as potential candidates for a solar absorber. The first material was Barium Bismuth Oxide ($BaBiO_3$, BBO), thin-films of which were deposited by pulsed laser deposition (PLD). Complete electronic band-diagram of BBO was constructed and TiO_2 has been used to make single-sided type-2 heterojunction to test BBO's opto-electronic properties. The second material was Caesium Titanium Bromide (Cs_2TiBr_6, CTB), thin-films of which were deposited by thermal annealing of caesium bromide (CsBr) thin-films in titanium bromide ($TiBr_4$) vapors in a glove-box. Proof-of-concept device with efficiency of 3.2% has been shown on flexible stainless steel (SS).

EVENTS

BASIC TRAINING PROGRAM IN NANO SCIENCE AND TECHNOLOGY

20 - 22 January

This Level 1 training program organised as part of the Indian Nanoelectronics Users' Program, had 54 participants from a total of 37 organisations from around the country. In accordance with its theme, this familiarization workshop had various introductory modules on nanofabrication technologies and applications such as CMOS processes/scaling, MEMS, Sensors, Nanomaterials/Phenomena, Microfluidics, IPR, Characterization techniques, RF-MEMS, Photovoltaics, etc.

Poster session

Seminars during the training program

Participants of the training program

WORKSHOP ON NANO MAGNETICS

18 February

This mini workshop on “Nano Magnetics: Properties and Applications” was organized by our Centre as part of the DST-JSPS bilateral research project initiative. Talks were given by faculty members and graduate students from CeNSE and Tohoku University, Japan.

Prof. Yamaguchi discussed a new magnetic material technology to countermeasure desensitization of receiver circuit, and advanced packaging technology to shield radiated emission and improve immunity of an IC chip.

Other topics included ‘therapeutic applications of Superparamagnetic nanorobots’ and ‘Localization technique of magnetic particles for hyperthermia in cancer treatment’, among others.

सत्यमेव जयते

Department of Science and Technology (DST)

JAPAN SOCIETY FOR THE PROMOTION OF SCIENCE • FOUNDED 1932 •

JSPS

RESIDENTIAL TRAINING PROGRAM ON NANOTECHNOLOGY RELEVANT TO MEDICAL RESEARCH

2 - 13 March

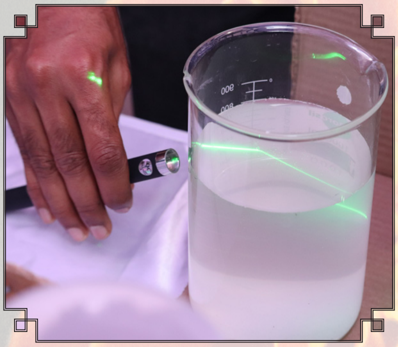
These training programs, conducted by CeNSE in collaboration with Rajiv Gandhi University of Health Science (RGUHS), Karnataka, are aimed at creating awareness about the recent advancements in the field of nanotechnology. The fourth workshop in this series was conducted with the participation of around 30 candidates.

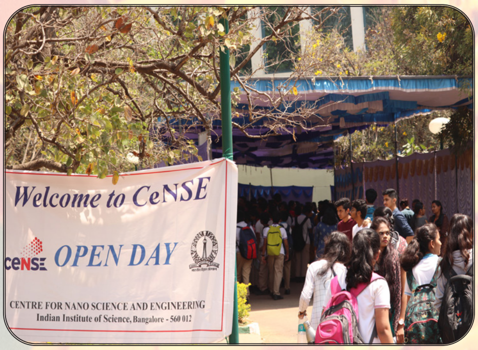
OPEN DAY

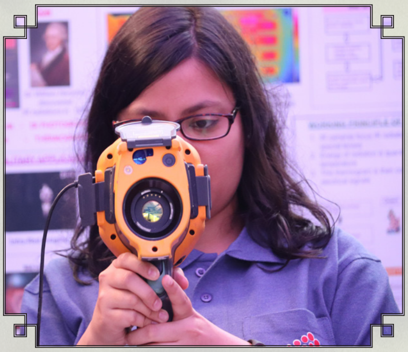
29 February

This year, CeNSE organized the following activities to address the curiosity of over 8000 visitors:

- Open Labs: Project and tool demonstrations, posters describing the work done in various laboratories.
- Interactive Demos: A plethora of models related to the research in our department.







ITEC-sponsored Course on Science, Technology, and Innovation Policy (STIP), exclusively for Senior Academics and Policymakers from Ecuador

25 February - 3 March

Prompted by the favourable input provided to him by Ecuadorian participants in previous ITEC-STIP courses held in CeNSE, His Excellency Hector Cuevo Jacome, Ambassador to India from Ecuador, requested the MEA to conduct the STIP Course exclusively for Senior Academics of Ecuadorian Universities and Govt. officials. The MEA agreed and, accordingly, the special STIP Course was held in CeNSE for twenty one Deans/Rectors (Vice Chancellors) of Ecuadorian Universities and Govt. officials, from Feb. 25 – March 2, 2020. As in previous STIP Courses held in CeNSE, lectures on policy-related issues were delivered by Dr. R. Chidambaram (former Principal Scientific Adviser to the Govt. of India), Prof. Shailesh Nayak (Director, National Institute of Advanced Studies), Prof. Sundar Sarukkai (philosopher and leading author), Mr. M.N. Vidyashankar (Former Senior Official, Govt. of Karnataka), and Prof. Seema Purushottaman (Azim Premji University). Presentations were also made by the distinguished participants on policy issues handled by them in their Universities. Participants were given a tour of the Incubation Centre (C-CAMP) of the National Centre for Biological Sciences, in addition to a detailed view of the state-of-the-art facilities of CeNSE.

The highlight of the Course was the visit to the Centre on Feb.25, 2020, by HE the Ambassador Hector Cuevo and his address to the participants and the gathering, in which he stressed on the opportunities for collaboration between Ecuador and India in various domains and, more broadly, between Latin America and India, for greater understanding and development. It was a truly revealing and uplifting call made by the Honourable Ambassador, who was presented a special memento by Prof. Navakanta Bhat, Chairman, CeNSE. (Ambassador Cuevo has since become the Dean of Ambassadors to India from Latin American countries).

Participants in the STIP Course held specially for Senior Academics from Universities in Ecuador. Sixth from right in the front row is His excellency Hector Cuevo Jacome, Ambassador to India from Ecuador, who visited CeNSE on Feb.25, 2020, and addressed the Participants and the large gathering.

VISITORS TO CeNSE

Shri Amit Khare, Secretary, Ministry of Education (formerly the Ministry of Human Resource Development) visited our Centre on 29th January. He said, "I am really excited by the tremendous work being done by this Centre. Really proud of our researchers".

Prof. Anthony K Cheetham, Professor Emeritus, Materials Research Laboratory, University of California- Santa Barbara, Santa Barbara, CA, USA visited our Centre in February. He said CeNSE "is a wonderful facility and I am especially impressed by the outreach opportunities, both in India and internationally".

Mr Paulo Alvim, Secretary, Secretariat of Entrepreneurship Innovation, Ministry of Science, Technology, Innovations Communications of Brazil and Mr. Pedro Ivo Ferraz da Silva, Head of Science, Technology and Innovation Section at the Embassy of Brazil in New Delhi, Brazilian Ministry of Foreign Affairs visited our Centre in January. The agenda for their visit constituted tours of NNfC, MNCF and other facilities at CeNSE, along with a comprehensive presentation on InCeNSE, its activities and outcomes.

In conversation with...

Excerpts from an interview with Prof. Srinivasan Raghavan

1) How did your journey with IISc start?


Prof. Raghavan with his wife and daughter.

Personal and professional reasons played an important role in making this decision. My wife had a career here in India and both our families were close to Bangalore. Family, I believe, is very important and in the midst of all we do, we tend to take them for granted . I also knew the Institute well as I had done my Master's from the Department of Materials Engineering (formerly known as Metallurgical Engineering). So, when one of the best places for research in India, and for that matter the world, made me an offer, it was not a difficult one to accept.

2) Was there a defining moment in your graduate school days at which you decided to take the academic route?

After completing my undergrad, I worked in industry for a year. I did find it interesting for a while, but then it got monotonous when the problems did not change as frequently as I would have liked them to. Focus was more on timelines and deadlines being met. Hence, I decided that I did not want a regular production-oriented job in industry. The alternative was a research career. Academia offered the freedom to choose my own problems and the flexibility to explore. A career in scientific exploration brings in challenges on a routine basis and that excited me. So, it was not a single defining moment that made me choose academia, rather a decision that evolved with experience and exposure. Having said that, it is also up to a person to make his/her job interesting and I am sure, now that I am better at identifying and solving problems, I would probably find interesting angles to the same job, if I went back to it.

3) How did you start working in your field of study? What about your field of study excites you?

I did my undergrad in Metallurgy and the then current research in metals was quite mature. Research in other areas such as ceramics and polymers were coming up. When I joined IISc for a Master's, I chose to work with Prof. Vikram Jayaram (Materials Engineering) on structural ceramics. Back then he was one of the very few researchers working on non-metallic materials and for various applications. Later I went on to do my PhD at Penn State (The Pennsylvania State University, USA) where I worked on developing materials for thermal barrier coatings (TBC) which involved investigating ceramic materials for 'structural and thermal applications' – particularly the role of point defects on the thermal properties of stabilized zirconias. They are not the kind of electronic materials that I work on now. After my PhD, I got job offers from Westinghouse Electric Corporation and General Electric (GE) – the latter required me to move to their new John F. Welch Technology Center in India. I did give it thought, but then I decided to do a post-doc with Prof. Joan Redwing (Dept. of Materials Science and Engineering, PSU) who had just then joined PSU and was working on Gallium Nitride (GaN). The problems involved in developing this material were similar to the ones involved in thin ceramic coatings on metal blades that undergo thermal cycling. For example, the thin films of GaN that we grow at high temperatures crack after cooling down due to CTE mismatched and similar problems are encountered when ceramic coatings on metallic blades are thermally cycled as in an aircraft engine. I realized that I had the required background and experience in an area that could be applied to a completely new field – electronic materials. Given that I had been looking for an opportunity to work in this area, I decided to make this shift. With Prof. Redwing I worked on 'controlling stresses during the growth of GaN on Silicon'. That is how I started working on GaN twenty years ago and have been working on it ever since – managing stresses during the growth of nitrides on various substrates. The most important reason why I continue to work on GaN is that new applications are emerging especially in the area of GaN RF and power electronics. To put it in perspective, when I started working on GaN, LEDs or light emitting diodes was the application driving the field. Given the problems we were facing with growth then, I was of the opinion that I would not live to see GaN being used commercially. Yet, within 5 years technology had matured to a point where I could walk down the street and buy an LED bulb. Something similar is happening now in the field of GaN electronics – there are other emerging materials as well- and that is why it is exciting.

4) How did you get involved in CeNSE ?

At IISc I had joined the Materials Research Centre. Then, I had plans of setting up a GaN growth facility and was looking for a very stable pad from the point of view of electricity, gas connections, water supply and so on. KJ Vinoy whom I know from my Penn State days suggested that I meet this faculty member called Navakanta Bhat. I went and talked to him and Navakanta suggested that I consider the clean room coming up. I don't remember the exact set of events but before I knew it, a week or so later I was part of a meeting, of about 10 people, in which clean room design was being discussed. I remember a certain other faculty member staring at me wondering who this new guy in the room was. He was, as I then found out a Prof. Rudra Pratap, soon to be Chair of this new department called CeNSE and before I knew it, I had started on this journey of spending endless, countless hours in the company of these two and Anil Kumar. That period was an immensely satisfying one. Then came the time to make a choice. We were told that we had to choose between CeNSE and our parent departments. It was a difficult one – I used to have interesting discussions and coffee twice every day with my good friend Ravi and the other faculty out there - and after talking it over with my faculty friends in MRC, I made the decision to move to CeNSE. In hindsight, I think it was the right decision for both CeNSE and IISc that we were asked to choose one.

Prof. Raghavan (first from left) during the construction of the department building.

5) What kind of environment is most conducive to working successfully in science?

Success in academics for the most part comes from giving freedom to researchers – freedom to explore by not putting any unnecessary constraints. If scientific administration is made more efficient, it would give us more time to think about the research problems we wish to investigate.

6) What do you do when you're not thinking about research/in your leisure time?

Travel and trekking are what I enjoy the most. I am also planning to resume gardening/terrace farming.

Prof. Raghavan, with the locals, on his trip to Jaisalmer, Rajasthan.

Awards

STUDENTS

Gandhian Young Technological Innovation Awards/Appreciations 2020

Mr. Souvik Ghosh

Project Title: A method and a system for remotely controlled manipulation of nanomaterials in fluids.

Research Advisor: Prof. Ambarish Ghosh

Mr. Vivek Singh

Project Title: Deposition Reactor Designed for Low-cost low-temperature deposition of high-quality oxides films for next-generation electronics

Research Advisor: Prof. Sushobhan Avasthi

FACULTY

Prof. Aditya Sadhanala received the Pratiksha Trust's Young Investigator Award for his proposal on neuromorphic computing.

The Pratiksha Trust, a charitable trust established by Kris Gopalakrishnan and Sudha Gopalakrishnan, supports education, research, innovation, and entrepreneurship initiatives targeted towards the poor and focuses on creating systemic changes in society.

Prof. Ambarish Ghosh was awarded Senior Fellowship by the DBT/Wellcome Trust India Alliance, which "is an independent, dynamic public charity that funds research in health and biomedical sciences in India. It invests in transformative ideas and supportive research ecosystems to advance discovery and innovation to improve health and well-being".

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