CeNSE newsletter

January - March 2015 | Volume 1 | Issue 2

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Cover photo: The GaN MOCVD reactor (funded by SSPL/DRDO) in the CeNSE clean room (funded by DeitY).

Prime Minister Narendra Modi visits CeNSE

It was the proud privilege of our Centre to receive Prime Minister Shri Narendra Modi, who visited on 18th February 2015.

He was accompanied by Union Ministers Shri Sadananda Gowda, Shri G. M. Siddeshwara and Shri Ananth Kumar. They were received by Prof. Anurag Kumar, Director of IISc, Prof. Rudra Pratap, Chairman, CeNSE, and by the faculty members, students and staff of CeNSE.

The Prime Minister Shri Narendra Modi dedicated the Centre for Nano Science Engineering to the nation

The CeNSE foyer was full of students, faculty and staff members greeting our Prime Minister

Prof. Rudra Pratap introduced CeNSE faculty members to the PM, before briefing him on the inception of the Centre. Prof. Navakanta Bhat introduced the PM to the National Nanofabrication Centre (NNfC) and its focus on semiconductors and nanotechnology, the indigenously developed MEMS pressure sensors and the Envirobat, illustrating how collaboration between academic institutions and various organizations can help develop unique products. Prof. Srinivasan Raghavan briefed the PM about the Centre's ambitious plan in power electronics based on gallium nitride devices and IPs generated at the Centre.

Images of the PM's tour of NNfC

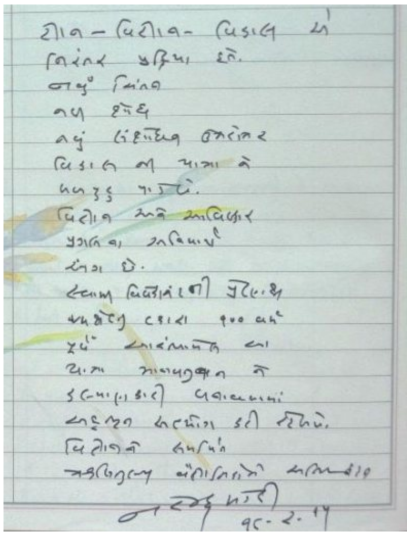
During the nearly half an hour that the PM spent at the NNfC, it was possible to provide him with a brief view of CeNSE and its efforts in R&D at the forefront of nano science and engineering. The Centre presented a picture to the PM of how an interdisciplinary approach at the micro/nano scale enables enormous possibilities for the "**Make in India**" initiative and how top-level research can help meet the associated challenges.

MAKE IN INDIA	CeNSE RESEARCH AREAS
Biotechnology	Nanobiotechnology/ Neuroelectronics
Chemicals	Nanomaterials
Electronics systems	Nanoelectronics
Renewable Energy	Nanophotonics/ Photovoltaics
Space	Space Qualified Sensors
Defence	MEMS/NEMS

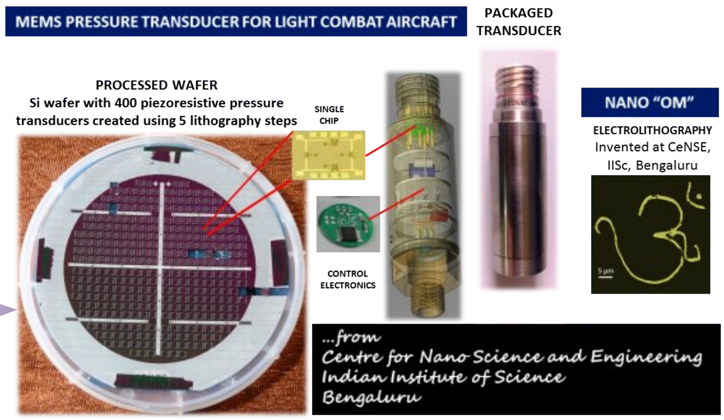
Source of logos: www.makeinindia.com

In his message, the Prime Minister wrote,

"(The growth of) knowledge, and science, and national development must be a ceaseless process. New thinking, new research, new innovations truly augment the path of progress. Science and research/innovation are necessary elements of the path of progress. The journey of progress inspired by Swami Vivekananda and initiated by Jamshedji Tata one hundred years ago has been doing an amazing job in improving the quality of life. Best wishes/ Congratulations to the scientists who are dedicated to science."



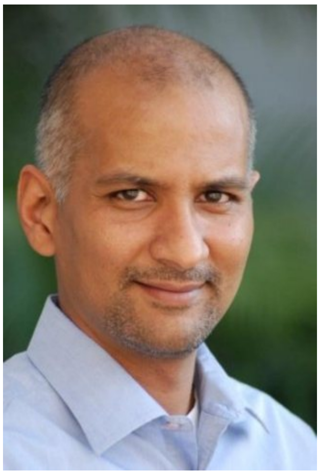
The PM accepted a souvenir: A MEMS pressure transducer and a silicon wafer fabricated at CeNSE



A silicon wafer with selected images etched in it

The PM with the CeNSE team

Faculty Insight: A Light Revolution – LED to GaN



Srinivasan Raghavan

The 2014 Nobel Prize in Physics was awarded to three Japanese scientists - Amano, Akasaki and Nakamura - for "the invention of efficient blue light emitting diodes which has enabled bright and energy saving light sources". The timing could not have been more perfect given that the UN had declared that 2015 would be the International Year of Light. In doing so "*the UN has recognized the importance of raising global awareness about how light-based technologies promote sustainable development and provide solutions to global challenges in energy, education, agriculture and health. Light plays a vital role in our daily lives and is an imperative cross-cutting discipline of science in the 21st century. It has revolutionized medicine, opened up international communication via the Internet, and continues to be central to linking cultural, economic and political aspects of the global society.*"

In talking about light here, the UN is mostly referring to the light that illuminates our lives. Those who are born today are however unfortunate to not have gone through the other light revolution. The internet. They might yet live through another possible upheaval when photons replace electrons in electronic chips.

Let us get back to illumination. As a young adult in the 1980's, a time not far into the past, I saw our homes still lit by Edison's venerable incandescent lamp. A 60 Watt lamp was the norm for lighting up the Common Man's room. At 15 lumens per watt, it gave us about 1000 lumens, a measure of the amount of light we need to reasonably light our lives. Without this, a fairly measly amount, life for many would come to a standstill after the sun goes down. Improvement in standard of enabled this meagre amount of light living cannot be imagined. Indeed, it is the sole aim of many NGOs to arm everybody with at least ONE light.

The biggest hurdle is energy. About 20% of all energy consumed in India is consumed as electricity (Source: IEA 2014 World Energy Statistics).
In advanced economies it is closer to 40%, with 20% taken up by lighting. If the incandescent lamp consumes 60 Watts to deliver the 1000 lumens we need and the tube light about 10 Watts, an LED lamp available in most retail stores consumes only 7 Watts. The latest record stands at 3 Watts!

Power (W) required for 1000 lumens

That's a 20-fold reduction in the energy we need to light up our lives. It is for this light revolution that the Nobel Prize was awarded. It was their research that transformed the LED (light emitting diode) from being an indicator to becoming an illuminator.

The path to blue LEDs was not an easy. Red and green LEDs had already been invented in the 1970s. The search for the elusive blue was on. At the Radio Corp of America, it would have enabled an LED TV! A blue LED based on GaN (gallium nitride) deposited on sapphire and doped with Mg was invented, but performed very poorly. The rest of the world had also tried and given up on GaN-based blue light emission. One lonely pair, Isamu Akasaki and Hiroshi Amano, kept at it and realised good quality GaN layers and p-type doping, two essential ingredients of the p-n junction required for solid state devices. A third contributor, Shuji Nakamura, improved p-type doping and realised GaN/InGaN/GaN double heterostructures that yielded emission large enough to enable LED bulbs. This research not only resulted in a $10 billion LED industry but also in the blue LASER for high density information storage, high-power and high-frequency electronics for wireless communication and power transmission, UV emitters for potential water purification, and solar-blind UV detectors.

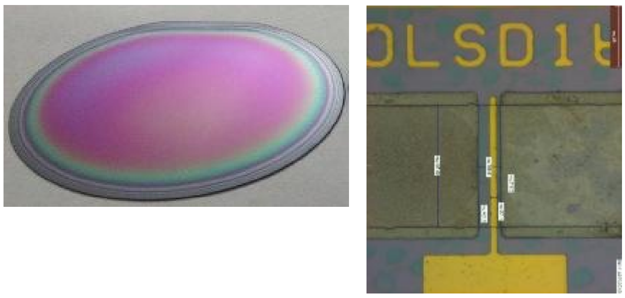
The many applications of GaN-based technologies

Source: Blue LED: blog.opower.com/2014/10/nobel-prize-blue-leds/ LED bulb: www.shopclues.com Blu-ray laser: www.geek.com SteriPEN Ultra Water Purifier: www.steripen.com/ Cellphone Tower: www.shutterstock.com California renewable energy: www.energy.ca.gov

At the Centre for Nano Science and Engineering, a team of 10 faculty members is now actively involved in all aspects of GaN-based power electronics, from basic material development to device fabrication and systems development. Such an effort requires interdisciplinary R&D through a collaboration between researchers from diverse fields. That is a topic for another day. The silver lining for India is that there are many groups in a number of academic institutions and government labs working on GaN-related research. They now constitute a critical mass of researchers large enough to make an international impact.

The GaN reactor (funded by SSPL/DRDO) in the CeNSE clean room (funded by DeitY).

A Si wafer with a power electronics device stack; and a transistor fabricated at CeNSE, IISc.



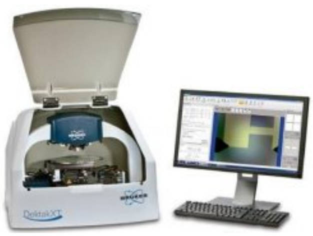
NNfC Update: Thin film stress measurement capabilities at CeNSE

P. Savitha

The National Nanofabrication Centre (NNfC) at CENSE, IISc, is a state-of-the-art national facility dedicated to fabrication of devices in the micro- and nanometer range. The Centre has capability to deposit films of thickness from a few nanometers to microns by ALD, CVD, PVD, and electrodeposition. The stress in such films is an important parameter and precise knowledge of the same is essential for developing stable processes and reliable devices. The presence of large stresses can cause the formation of defects such as hillocks, warping, shorts, and delamination. Stress in the films is also critical in another thrust area of the Centre, i.e., MEMS and NEMS devices.

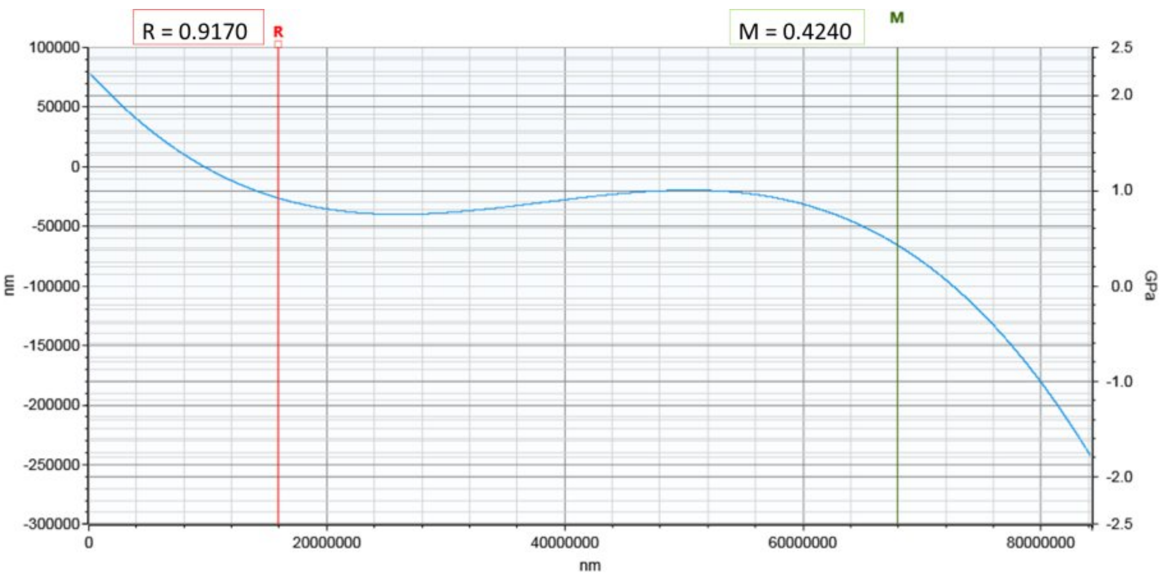
By enabling the development and optimization of processes for characterizing materials involved in the fabrication of different micro and nano devices, the Inline Characterization Bay of NNfC plays a significant role in supporting the process integration team as well as research projects of students and others. In this regard, measurement of stress in thin films and its correlation to the devices fabricated is of great importance.

Thin film stress measurements can be made *ex situ* in the NNfC's Inline Characterization Bay using the Dektak XTA or the kSA MOS Ultra Scan, which is a high-resolution scanning curvature and tilt measurement system. Stress measurement is simple in both the systems: one measures the curvature of the wafer before and after the deposition.



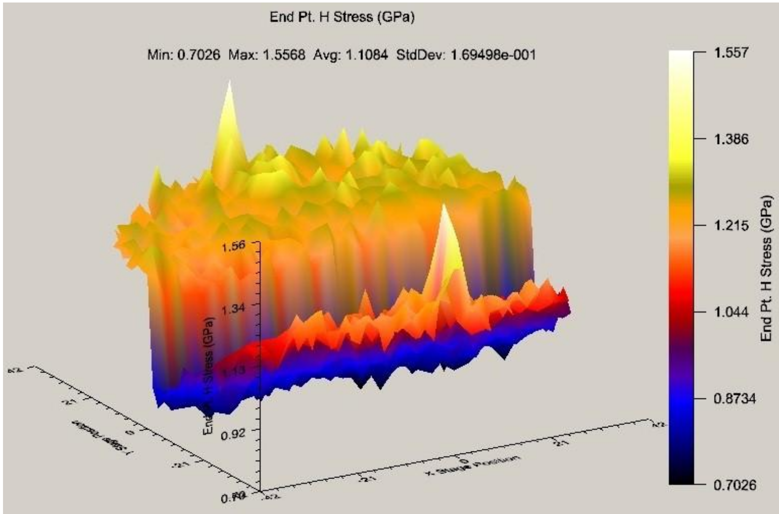
In particular, Dektak XTA is a stylus profiler which uses the change in curvature and material properties of the thin film to calculate stress. Accurate measurement using a line scan requires scanning of at least 70% of the deposited area and precise positioning of the wafer for pre- and post-deposition scans. Stress in thin films deposited on wafers up to 8" in diameter can be measured due to XTA's ability for stitching.

High-stress silicon nitride (tensile stress 1 GPa)



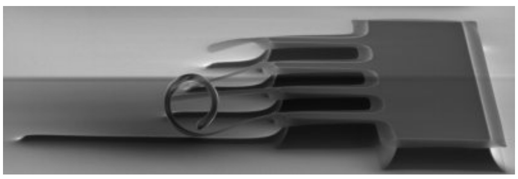
The kSA MOS Ultra Scan, on the other hand, provides a non-contact method which uses a two-dimensional array of lasers to measure the change in curvature. Changes in beam spacing is used to determine the curvature and thus the stress. Since the whole area of the wafer is mapped, stress measurements are more accurate than possible with a single line scan.

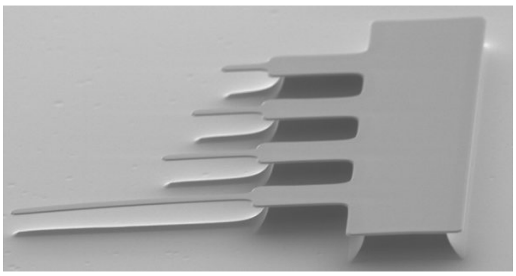
silicon nitride (tensile stress: 1 GPa)

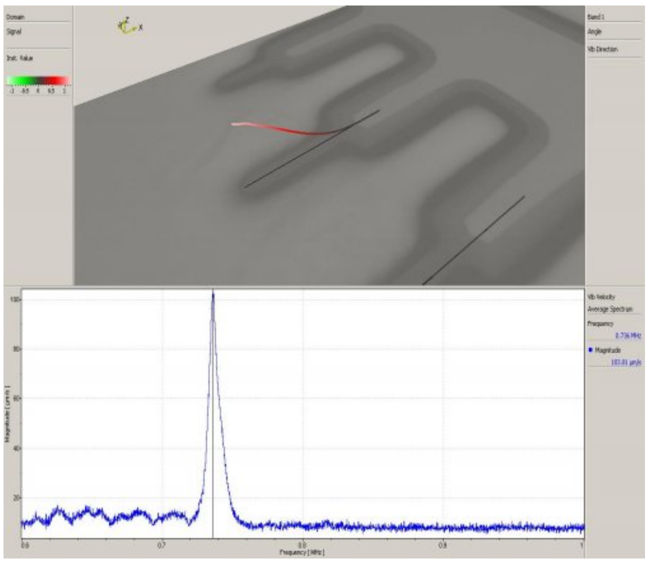


Stress measurements were carried out using Dektak XTA and kSA MOS Ultra Scan on silicon nitride thin films obtained by low-pressure chemical vapour deposition (LPCVD). Silicon nitride has been widely used to make MEMS devices like sensors, interferometers and AFM cantilever probes. The stress in the silicon nitride film has a huge effect on the performance of these devices, with high stresses causing films to fracture or buckle. Stress in thin films also influences the resonance modes of the beams fabricated with them, and a knowledge of the stress and its local variation is critical for developing sensors capable of mass resolution down to one atomic mass unit.

At the NNfC, cantilever beams of various dimensions were fabricated using high-stress (~1 GPa) and low-stress (~160 MPa) silicon nitride films on silicon. It was seen that beams made from high-stress silicon nitride bend upwards at higher beam lengths, making frequency measurements difficult. By contrast, frequency measurements are possible for low-stress silicon nitride cantilevers which could be fabricated with no buckling.







In summary, stress measurements made on various thin films deposited at NNfC provide valuable information on the behavior of devices fabricated using them.

Research Highlight: Fabrication and Testing of RF - MEMS Switches

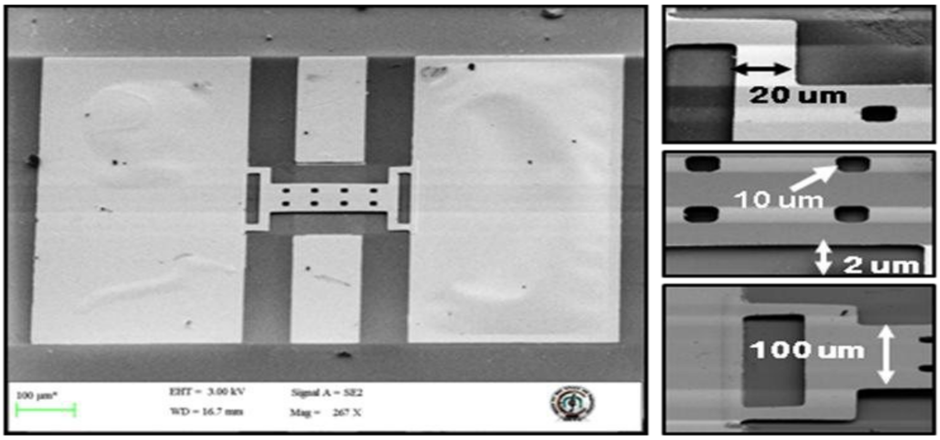
Sudhanshu Shekhar

Advances in microfabrication in the past three decades have enabled MEMS technology to become a candidate for radio frequency and microwave frequency applications. When MEMS technology is used in RF applications, it is referred to as RF MEMS. Switches, varactors, resonators, and filters are the most common components of RF-MEMS. The function of a switch is to 'close' or 'open' the electrical signal between input and output ports. An RF-MEMS capacitive switch uses a thin dielectric layer between the top movable membrane and the bottom electrode to avoid direct contact as well as to perform the switching action through capacitive coupling. RF-MEMS switches are aimed at replacing the p-i-n diode and field-effect transistor (FET) switches which have the limitations of high insertion loss and low isolation at very high frequencies. The reason that RF-MEMS switches are favoured is their superior RF performance, such as very low insertion loss, high isolation, near-zero power consumption and greater linearity at microwave frequencies than in semiconductor switches. An RF-MEMS switch was therefore designed with a low actuation voltage and high isolation at CeNSE and fabricated in the NNfC. At MNCF, a variety of characterization techniques were then used to study the properties and behaviour of RF-MEMS switches (see Table).

Parameters	RF MEMS Switch
Metal Bridge (Au)	0.5 µm
Gap height	2.0 µm
Dielectric (Si_3N_4)	0.15 µm
Insertion loss	< 0.6 dB
Isolation	> 40 dB
Actuation voltage	4.8 - 6 V

Extensive electrical characterization of the RF-MEMS switches was carried out to determine various parameters including RF measurements up to 60 GHz, capacitance measurement, static deflection measurement and Laser Doppler Vibrometry (LDV). To get the complete characteristics (electrical & mechanical) of these devices, six different measurements were made in proper sequence which yielded interesting results. Various programs and setups allowed complete characterization under one roof, as illustrated below.

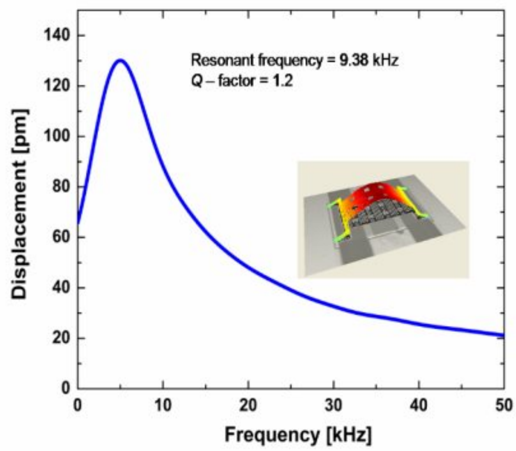
SEM images of the capacitive RF-MEMS device fabricated at CeNSE, showing the critical parts and their dimensions.

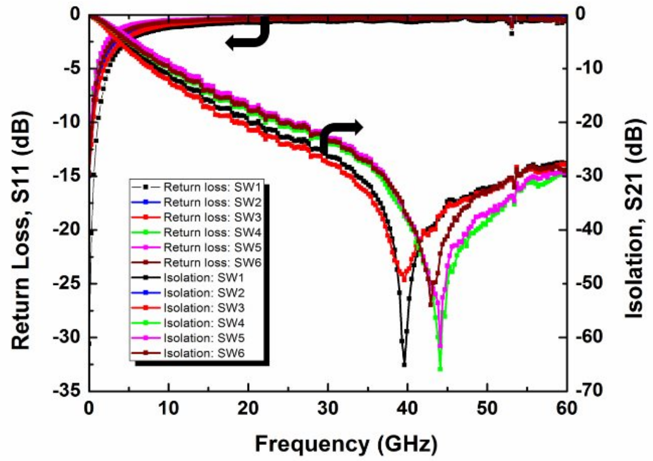


Using an Optical Profiler, switches were tested to determine the height difference and confirm the air gaps and their geometrical profiles.

Laser Doppler Vibrometry (LDV) was used to extract the mechanical resonance frequency and the Q- factor of the switch. An LDV uses the Doppler shift to measure the displacement and the velocity of the switch. The frequency response of the switch due to 2 V DC and 0.8 V AC is shown below.

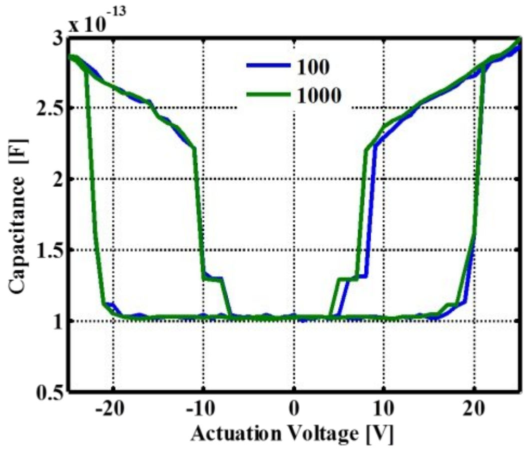
RF measurements: The S-parameter of the devices were measured at frequencies from 100 MHz to 60 GHz to obtain data on their insertion, return, and isolation. DC actuation voltage was provided by a DC bias Tee available in the Network Analyzer. An Agilent B1500A was used to supply DC bias to the VNA. Shown below is the S-parameter in the UP & DOWN-states up to 60 GHz.

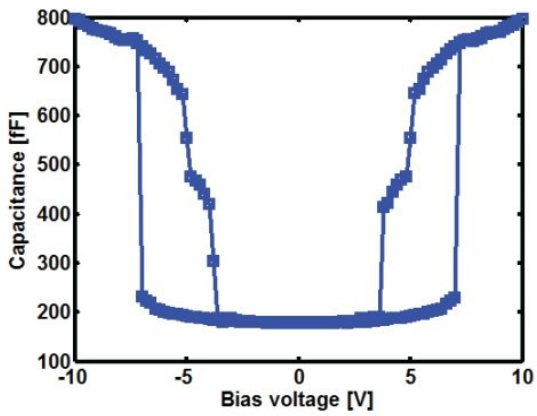




Capacitance measurements were made using a DC Probe station/ Device Analyzer: All the released devices were further tested for PULL_IN analysis using the Agilent B1500A Device Analyzer. A series of devices was tested at various DC bias and frequencies.

Reliability measurement: The reliability of the switches was checked immediately after PULL-IN information became available and programs were initiated to repeat the measurement for 100 to 1000 cycles, and the best devices were sorted out. Shown below is a typical hysteresis diagram depicting PULL-IN and PULL OUT in sequential order.

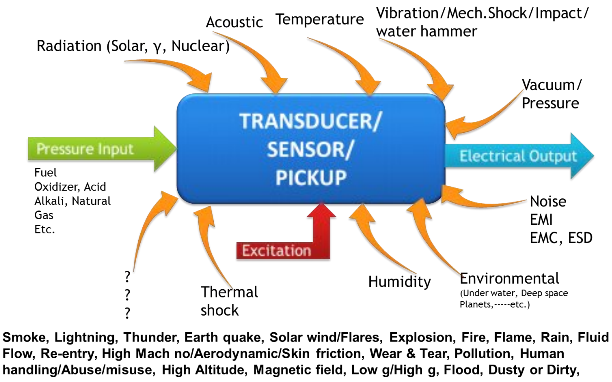




The RF-MEMS devices were fabricated on a glass substrate using a simple four-mask surface micromachining process. The fabricated switches need low-actuation voltage in the range of 4.8 V to 6 V for actuation and show excellent RF performance up to 60 GHz. A comparison with recent literature indicates that none of the RF performance parameters is compromised in the CeNSE design. Repeated measurements up to 10 million cycles did not show any degradation in performance. Thus, capacitive RF-MEMS switches with a very low-actuation voltage have been successfully designed and fabricated at CeNSE, followed by a comprehensive characterization that demonstrates their high reliability.

Update: The CeNSE MEMS Pressure Sensor

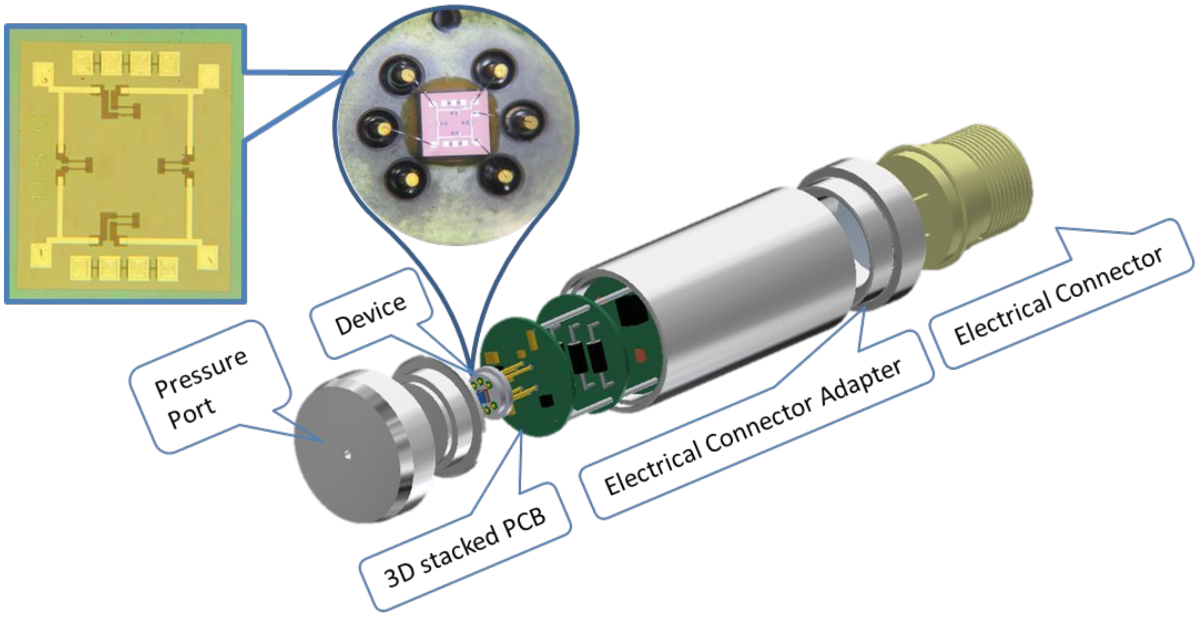
K.N. Bhat and M.M. Nayak



Pressure sensors comprise about 60% of the MEMS market. Among the various types of pressure sensors, piezo-resistive pressure sensors are easy to design to suit a wide range of pressures. Our pressure transducers are miniature piezoresistive-based sensors fabricated using silicon micromachining techniques, which enable great precision in realizing the diaphragm. The diaphragm acts as the sensing element and the piezo-resistors serve as transducers. MEMS pressure sensors are popular because they are inexpensive, simple to fabricate, compact, lightweight, highly sensitive and accurate, while consuming little power. They also offer excellent repeatability and the ability to build redundancy in same size, as they lend themselves to mass production. Devices designed to sense low pressures can be "scaled" to measure much higher pressures without changing the overall dimensions of the pressure transducer.

All the finer elements of design, fabrication, packaging, characterization and calibration of silicon micromachined piezo-resistive sensors for pressures ranging from 150 mbar to 600 bar were fabricated at the National Nano Fabrication Centre (NNfC) of CeNSE. The effort was made under the project entitled "Design, Development, Fabrication, Packaging, and Testing of MEMS Pressure Sensors for Aerospace Applications", funded by the National Program on Micro and Smart Systems (NPMASS).

Absolute pressure sensor (1.2 bar) with its electronic innards and an exploded view of the assembly



The specifications and potential applications of CeNSE MEMS pressure sensors/ transducers

		Absolute Transducers	Gauge Transducers		Differential Transducers		
							
Specifications	Pressure range:	0 - 1200mbar	0 - 10 bar	0 - 600 mbar	0 - 600 mbar	0 - 150 mbar	0 – 200, 0 – 400, 0 – 600 bar
	Characteristics:	0.25Vdc (at 0 mbarA) to 5Vdc (at 1200 mbarA)	0.2Vdc (at 0.4 barG) to 5Vdc (at 10 barG)	0.25Vdc (at 0 barG) to 5.25Vdc (at 600 mbarG)	0.25Vdc (at 0 barD) to 5.25Vdc (at 600 mbarD)	0.25Vdc (at 0 barD) to 5.25Vdc (at 150 mbarD)	0.25Vdc (at 0 bar) to 5.25Vdc (at Nom. Pr.)
	Sensor supply:	28Vdc (16 Vdc-32 Vdc)	28Vdc (16 Vdc-32 Vdc)	28Vdc (16 Vdc-32 Vdc)	28Vdc (16 Vdc-32 Vdc)	28Vdc (16 Vdc-32 Vdc)	28Vdc (16 Vdc-32 Vdc)
	Accuracy:	±1% of FSR (0°c to 50°C), ±1.5% of FSR(-25°C to 0°C & 50°C to 80°C)	±2.5 % of FSR	±1 % of FSR	±1 % of FSR	±1 % of FSR	±1 % of FSR
	Proof pressure:	2bar (Absolute)	20bar (Absolute)	1.2bar (Gauge)	1.2bar (Differential)	0.3bar (Differential)	2x nominal pressure
	Operating temperature:	-25°C to +85°C	-40°C to +85°C	-40°C to +85°C	-40°C to +85°C	-40°C to +50°C	-40°C to +65°C
	Storage temperature:	-55°C to +85°C	-55°C to +85°C	-55°C to +85°C	-55°C to +85°C	-55°C to +85°C	-55°C to +85°C
Potential applications*	Bio-medical	-	Plantar's foot	Bio-medical, blood pressure monitoring, respiratory disorder diagnostic equipment	-	Intra cranial pressure monitoring, heart beat/ pulse monitoring	-
	High end	Pressure monitoring in aircraft cabin, engine, wings, fuel plumb lines, hydraulic systems, oxygen cylinders, control valves, ignition system etc.					
	Automotive	Air flow management, tire pressure monitoring systems, airbag safety systems, fuel injection, braking system and fuel + air mixer ratio control.					
	Industrial	Automatic weather stations *with modifications*, process industries, boilers, turbines, pumps, ocean depth, mining safety, gas & oil exploration, oceanography, fire safety, liquid level sensing, flow sensing, vacuum /cavitation study, penstock, earth quake, balloon launch, etc. *(with different electrical & mechanical interfaces)*					Tsunami ocean bottom pressure recorder
	Other	Household appliances such as white goods (washing machine)	Household appliances such as white goods (Fridge), Pumps	Household appliances such as white goods (washing machine, refrigerator)	-	-	Explosives research, Nuclear reactors, High pressure gas cylinder, Hydraulic jacks, High pressure containers, Mining safety etc.

**All potential applications are subject to interface modifications and specified calibration.*

Effort is under way to develop sensors to measure pressures of micro/nano bars using nanotechnology based on nanowires, nanoparticles and nanocoatings. Graphene-based nanowires, CNT, nanosilicon wires, PVDF, thin film PZT and lead-free piezoelectric crystals are candidate materials for such sensors of the future. The micro/nanotechnology involved can be adapted to develop accelerometers, gyroscopes, angle sensors, vibration sensors, and radiation sensors.

Facilities at the MEMS Packaging Lab					
Wafer Dicing	**Wire Bonding**	**Welding Machine**	**Pressure Calibration**	**Hot and Cold Test Chamber**	**Parylene Deposition System**
					
The Tools/Equipment/Instruments at the Packaging Lab include Dynamic Pressure Calibration, Ultrasonic Drilling, Environmental Chamber, Profile Projector, Hydraulic Press, Deflection Measurement System, Helium Leak Detector, Insulation Resistance Tester, Continuity Tester, Prober, etc.					
To know more about the MEMS Packaging Lab, contact Prof. KN Bhat or Prof. MM Nayak or visit: http://www.cense.iisc.ernet.in/MEMS					

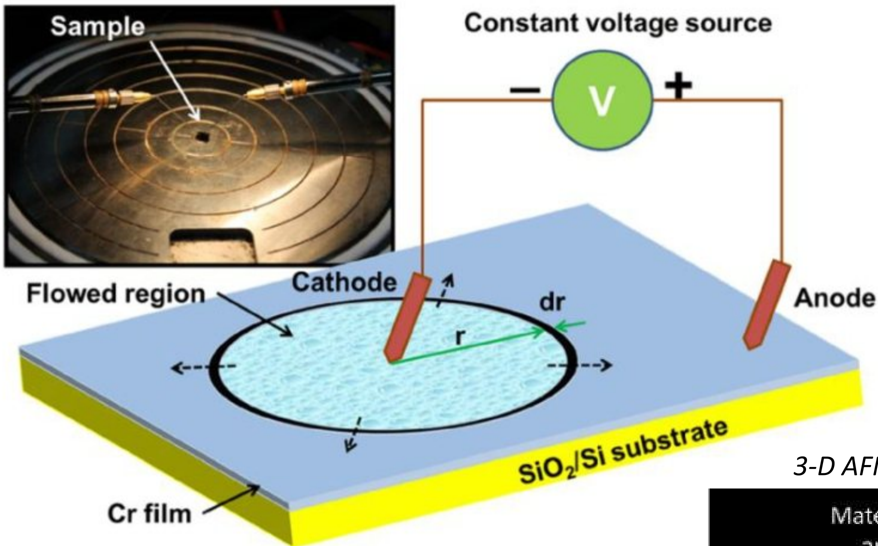
Student Column: Material Transport by Liquid Electromigration

Santanu Talukder

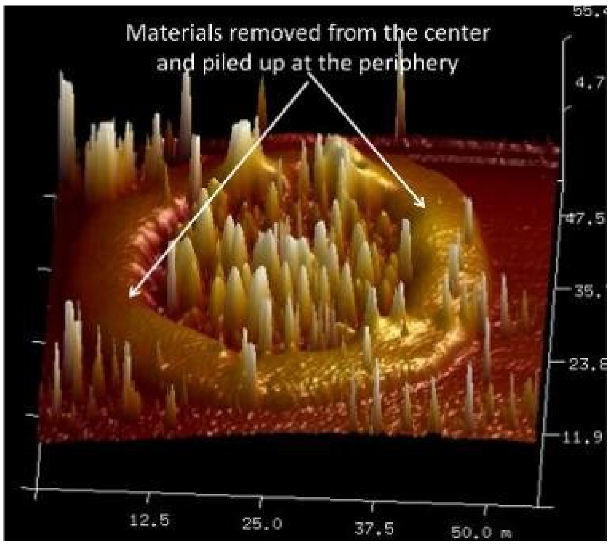
Electromigration is generally known as a major reliability issue for solid metallic interconnects. In case of solid metals, the electromigration forces generally push metal ions from cathode to anode, creating voids near the cathode and hillocks near the anode. However, in liquid electromigration, the material first melts and flows either in or opposite to the direction of the electric field, depending on the material properties. Being a mass transport phenomenon, electromigration has been shown to be useful in patterning and sensing. We have therefore studied electromigration-driven material transport in an infinite, thin Cr film, and its dependence on parameters such as the current, voltage, and film thickness.

In experiments, electric current was passed through the as-deposited thin films using two widely spaced "point" electrodes, as shown below. Because of joule heating, the material melts and flows in a radially symmetric fashion away from the cathode probe, forming ring patterns upon solidification. The textured-shaded region in the image below represents the flow-affected region, where the film liquefies and flows under the influence of an electric current. The dashed arrows show the direction of the liquid metal flow, and the inset shows a digital picture of the sample-probe assembly.

Experimental set-up for the electric current loading



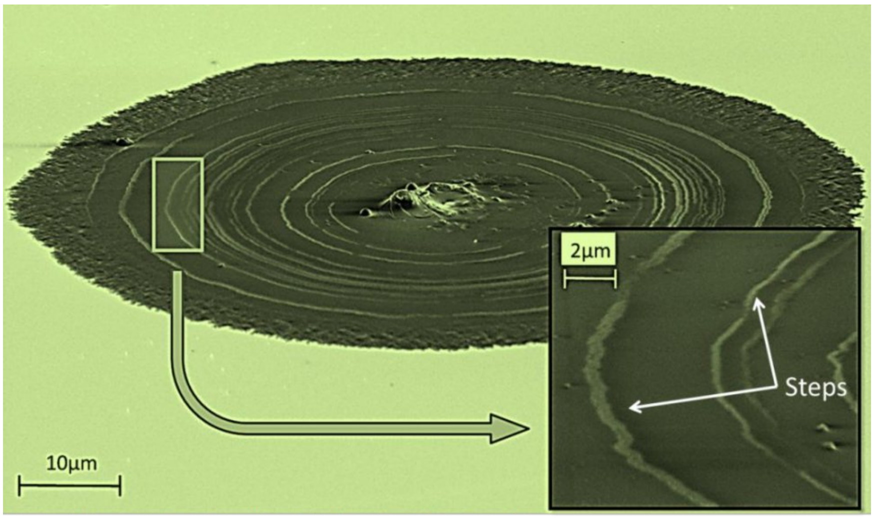
3-D AFM image of an electromigration ring



Outcomes: The ring diameter of the flow-affected region and the velocity (or, speed) of the liquid material flow were directly proportional to (approximately) the square of the applied voltage and the magnitude of the electric current, respectively. It is also observed that the ring diameter increases in sigmoidal fashion with increasing thickness. This effect mainly arises due to the variation of the electrical resistivity, which is dominant at very small thicknesses, and viscosity, which is dominant in relatively thick films.

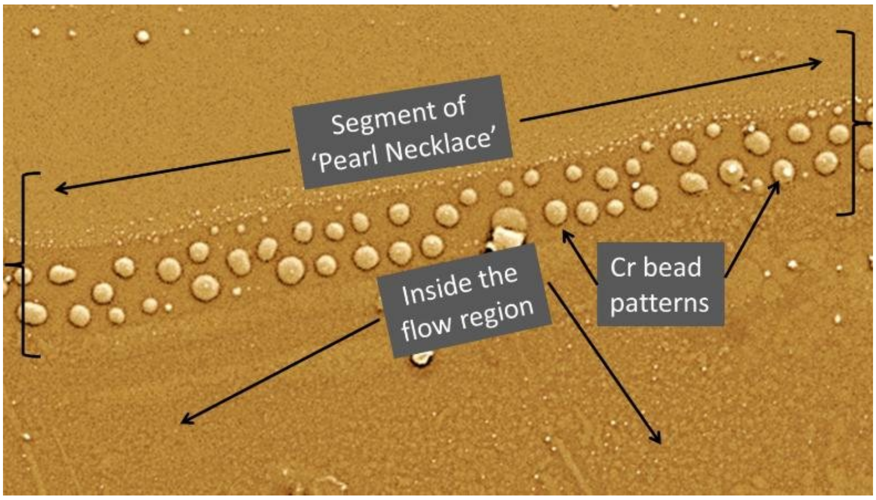
Applications: Such electric field-driven material transport can be used as a tool for micro-scale patterning.

SEM micrograph of ring patterns with step structure



Micro – to nano-sized hemispherical bead patterns can also be formed using this technique. These metallic beads can be arranged at the periphery in such a way that a 'pearl necklace'-like pattern is formed around the electromigration ring. By controlling electromigration, one can control movement of materials precisely, which can be useful in different patterning and sensing technologies.

SEM micrograph of 'necklace segment' formed of metallic bead patterns



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1. "Film thickness mediated transition in the kinetics of electric current induced flow of thin liquid metal films", Santanu Talukder, Praveen Kumar and Rudra Pratap, Appl. Phys. Lett., vol. 104, pp. 214102_1-214102_4, 2014.

2. "Electric current induced mass flow in very thin infinite metallic films", Santanu Talukder, Praveen Kumar and Rudra Pratap, IEEE Trans. Elec. Dev., vol. 60, pp. 2877-2883, 2013.

Alumni Column

Revathy Padmanabhan, Postdoctoral Fellow, Technion - Israel Institute of Technology

My journey at IISc began when I joined the interdisciplinary program, 'Nanoengineering for Integrated Systems (NI),' in 2008. At the time, we did not have CeNSE as a separate entity. We were spread across different departments in IISc. While I was going through the rigors of coursework, trying to cope with assignments/exams and grumbling sometimes about having to put in a few extra hours, our Professors worked day and night (literally) to build the Centre with all its facilities, while also teaching courses and guiding students in their research. Often, CEN faculty meetings started in the evening (after "office" hours). It was, truly, an educational experience to witness, in a small way, a great idea/project become a reality (and a thriving one, at that) through hardwork, perseverance, passion and wisdom of our faculty, who came together to build what today is CeNSE.

I was privileged to have had the opportunity to work in the old CEN cleanroom in the (now demolished) Microelectronics building; and at CeNSE, after 2012. In my opinion, the fabrication and characterization facilities at CeNSE are one of the best in the world, in an academic setting; and I'm very grateful to have had the opportunity to use these facilities. It was possible to use the state-of-the-art equipment only because of the hardwork of NNfC and MNCF staff in maintaining these facilities. They've always been accommodating and very patient in training us to use the equipment.

Our faculty gave us the opportunity and encouraged us to work in collaborative projects with other research groups, be it in academia or industry. I was very lucky to have had the opportunity to work in one such collaborative project with the industry during the course of my PhD. It was a formative experience and I benefited greatly from this collaboration. The ability to think critically and reason, and benefiting from the intellectual freedom to pursue an idea, are part of the education that I received at CeNSE.

I enjoyed the opportunity to have discussions with people from diverse technical backgrounds, which was always interesting and helpful. The vibrant discussions with my fellow students over technical and non-technical matters were memorable, and I cherish them very much. It was an interdisciplinary education in every way, and I'm grateful for it.

Nanotech Demystified: Hybrid Triboelectric Nano Generator

Hybrid Triboelectric Nano Generator by Wang et al. in the Nano Energy (2014) is demystified through images and sequential drawings (Collected and annotated by Shreevar Rastogi, CeNSE)

The Hybrid TENG harvests energy from both electrostatic interfacial effect and mechanical impact. In detail, electrostatic interfacial harvesting design allows for harvesting of electrostatic interfacial energy at the saline water-solid interface, wherein a short circuit current of 5.1 µA is obtained for sea water. The mechanical impact-harvesting design allows for hydropower scavenging from sea waves and raindrops, wherein a short circuit current of 4.3 µA is obtained from sea-wave travelling at 0.5 m/sec.

Basic structure of the generator

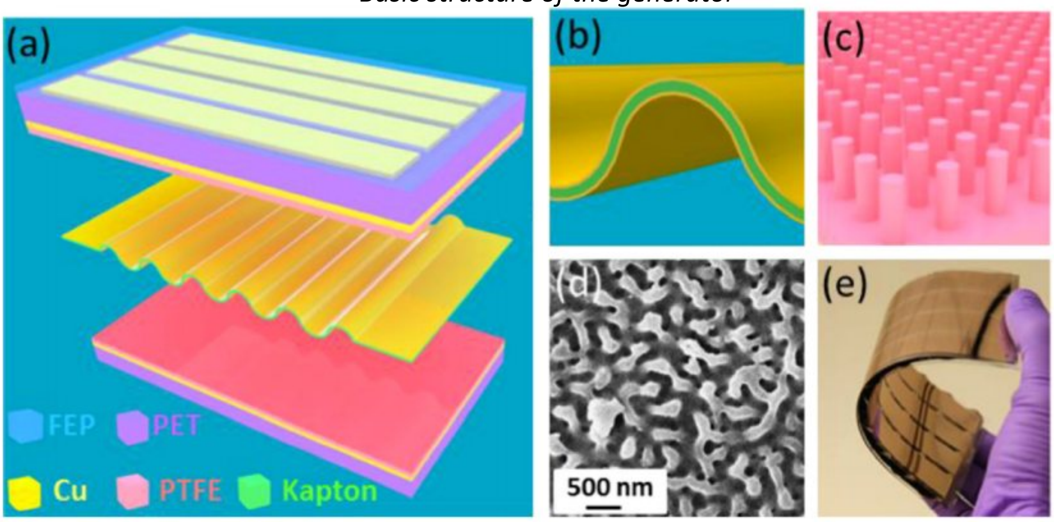
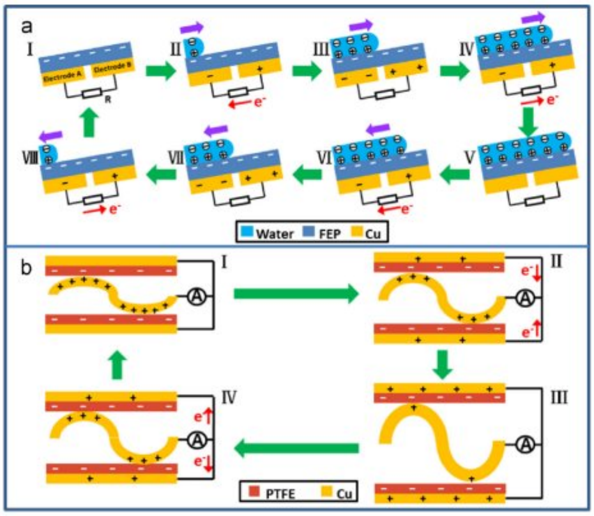
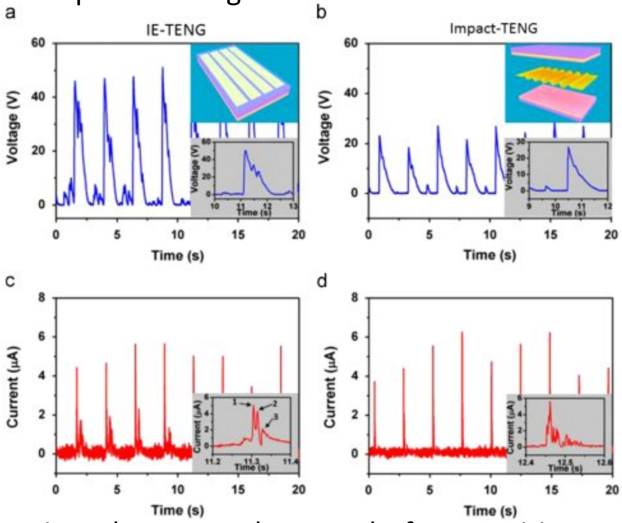


Figure 1 Structural design of the hybrid TENG. (a) Schematic diagram of the fabricated hybrid TENG. (b) Schematic of the inner elastic wavy electrode. (c) Schematic of the PTFE surface with etched nanowire structure. (d) Scanning electron microscopy (SEM) image of the PTFE surface with etched nanowire structure. (e) Photograph of the prepared hybrid TENG.

Working principle of
(a) the Interfacial electrostatic nanogenerator
(b) the impact nanogenerator



Output characteristics
(a) & (b) Open circuit Voltage output of nanogenerators (c) & (d) Short circuit current output of nanogenerators



Applications include self-powered marine units that can be used for maritime sensing, environmental monitoring and emitting distress signals. TENG has been installed on life jackets and used as a self-powered distress signal emitter. TENG is also able to supply power to 50 LED lights.

To view the video, access the link: http://dx.doi.org/10.1016/j.nanoen.2014.07.006.

Events at CeNSE | CeNSE Visitors | Awards

Jan

Seminars

"Collective Behaviour of Electrons and Atoms in the Solid State" by Prof. Prashant K. Jain
8th Jan

"Mechanical Switching of Conductance and Thermopower of Helicene Molecular Junctions" by Prof. Yonatan Dubi
13th Jan

"Promise of 2D Materials" by Dr. Saptarshi Das
21st Jan

"The next steps in Orthogonal Scaling – Scaling the Package and the Board" by Dr. Subramanian S Iyer
28th Jan

Workshop

Brainstorming Workshop on Micro – Nano Systems
15th Jan

3rd CeNSE Annual Research Student Symposium
23 – 24th Jan

INUP Familiarization Workshop
28-30th Jan

Awards

Prof. Rudra Pratap received VASVIK Award for Industrial Research from Vivdhlaxi Audyogik Samsodhan Vikas Kendra (VASVIK), Mumbai on 30th Jan.
The award was given for his outstanding contribution to MEMS research and for his portfolio of patents on MEMS devices. The award was conferred by the Union Minister, Mr. Piyush Goel.

Feb

Seminars

"Gallium Nitride Vertical Electron Transistors" by Dr. Ramya Yeluri
5th Feb

"Integrated Si Photonics for Today's and Tomorrow's Systems" by Prof. Shayan Mookherjea
16th Feb

"Steep-slope ferroelectric gate transistor - theory versus experiments" by Dr. Kausik Majumdar
19th Feb

Workshop

INUP Hands on Training:
3-12th Feb

Introductory Workshop on "Nanotechnology"
13-16th Feb

IISc Open day
28th Feb

Awards

Best paper award at International Conference on Computational Electromagnetics ICCEM 2015 (Hong Kong) entitled "A reduced order model for electromagnetic scattering using multilevel Krylov subspace splitting" by Neeraj Kumar Ph.D. candidate.

Mar

Seminars

"Self-Assembly of Nanoparticles: Can DNA Lead the Way?" by Dr. Radha Boya
6th Mar

"Engineering of MEMS & NEMS by combining patterning & self-assembly" by Dr. Juergen Brugger
17th Mar

"Intense THz generation, detection and its applications" by Dr. Gargi Sharma
19th Mar

"Photonics-aided MEMS: Towards High Performance RF oscillators" by Dr. Siddartha Tallur
23rd Mar

"Transforming Plasmonic and Metamaterial Devices into Technologies" by Dr. Gururaj Naik
24th Mar

Workshop

INUP Hands on Training
10-19th Mar

Awards

Dr. S B Rudra Swamy Best Thesis Award at 2nd International Symposium on Physics & Technology of Sensors, Pune on 8-10th March. He obtained Ph.D. degree from CeNSE with a thesis entitled "Design, fabrication and development of metal oxide semiconductor based gas sensor system for CO_2 monitoring"

Jude Baby George, PhD scholar has been awarded IBM Ph.D. Fellowship

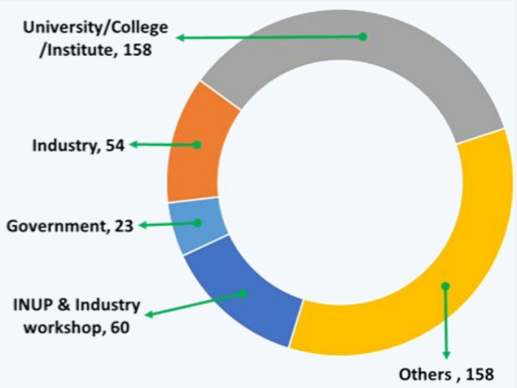
Upcoming events: Visit www.cense.iisc.ernet.in/news_events.htm

CeNSE Visitors

The Honourable **Prime Minister Shri Narendra Modi**, 18th Feb

Mr. Peter Real
SVP & CTO, Analog Devices, 5th Feb

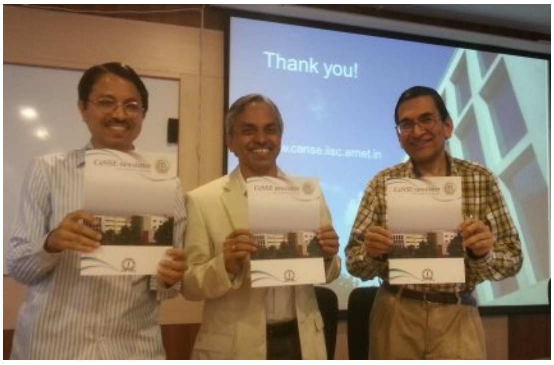
Phillip A. Min
U.S. Consul General, Chennai, 29th Jan



Total: ~460 visitors | January to March

The Third Annual CeNSE Student Research Symposium

Manoj Varma



The 3rd Annual CeNSE Student Research Symposium was held on 23rd and 24th January 2015. The event was inaugurated by the former Director of IISc, Prof. P. Balaram, who has been a constant source of encouragement for our Centre.

During the inauguration, the symposium handbook containing the entire proceedings and the first issue of the CeNSE newsletter were released. The annual symposium provides the opportunity to showcase the research achievements of the past year and to reflect on the progress made by the doctoral students towards their dissertation. This time, there were nearly 60 abstracts submitted. Out of these, 15 were chosen for oral presentation and the remaining were chosen for poster presentation.

A new feature introduced in this year's symposium was the "**poster pitch talk**", which provided the poster presenters with an opportunity to pitch for their posters using a 2 minute talk with 1 -2 slides. Overall, both the oral and poster presenters did a good job. Awards recognizing outstanding research excellence and poster presentation were presented to 5 students. **Vinay Kumar**, working with Prof. Navakanta Bhat, has developed electrochemical sensors for a variety of medical diagnostic applications. It is hoped that his work will have a significant positive impact on medical diagnostics in this country. **Debadrita Paria**, working with Prof. Ambarish Ghosh, used Glancing Angle Deposition method to create silver nanoparticle pairs separated by a single carbon atom-thick sheet. This was the first time in the world that such large area fabrication of nanoparticle pairs separated by atomic length scales were realized. **Leelavathy. A**, an interdisciplinary Ph.D. student working with Prof. N. Ravishankar from the Materials Research Center (MRC) and Prof. Giridhar Madras from the Dept. of Chemical Engineering, was recognized for her work leading to the development of new Insights into the enhanced photo-electro-oxidation phenomena exhibited by ZnO nanorod/ultrathin Au nanowire hybrid systems. **Shubhi Bansal** and **Jude Baby George** shared the awards in the poster presentation category. Shubhi, who works with Prof. Prosenjit Sen, presented her work on the oscillation dynamics of water droplets, whereas Jude, an interdisciplinary Ph.D. student working with Prof. Bharadwaj Amrutur from the Electrical Communication Engineering (ECE) Dept. and Prof. Sujit Sikdar from the Molecular Biophysics Unit (MBU), presented his work on neuro-electronic hybrid systems.

A wonderful **Yakshagana** performance organized by Dr. Gopal Hegde from NNFC, CeNSE, where Dr. Hegde himself came on stage as Indra, provided a jubilant close to the two-day symposium. As always at CeNSE, we want to keep getting better and better with each step. We hope to showcase even bigger research accomplishments, awesome demos of upcoming technologies, and newer, more interactive ways of research presentation in the symposia to come. Needless to say, this is not possible without a pro-active student body and the hard work put in by the faculty, CeNSE office staff and volunteers. I take this opportunity to thank all those whose services enabled the smooth conduct of this event.

Representing CeNSE at MEMS 2015

Prosenjit Sen and Abinash Tripathy

The 28th IEEE International Conference on Micro Electro Mechanical Systems (MEMS 2015) was held from 18 - 22 January, 2015 in Estoril, Portugal. MEMS 2015 is this year’s edition of one of the premier annual events reporting research results on every aspect of Microsystems technology. The latest developments from around the world in MEMS & NEMS and their applications were presented at this Conference.

At the Conference, we presented our work on “Low-Resistance Liquid Motion for Energy Harvesting” in the Poster Session of the Symposium on Microfluidics and Nanofluidics.

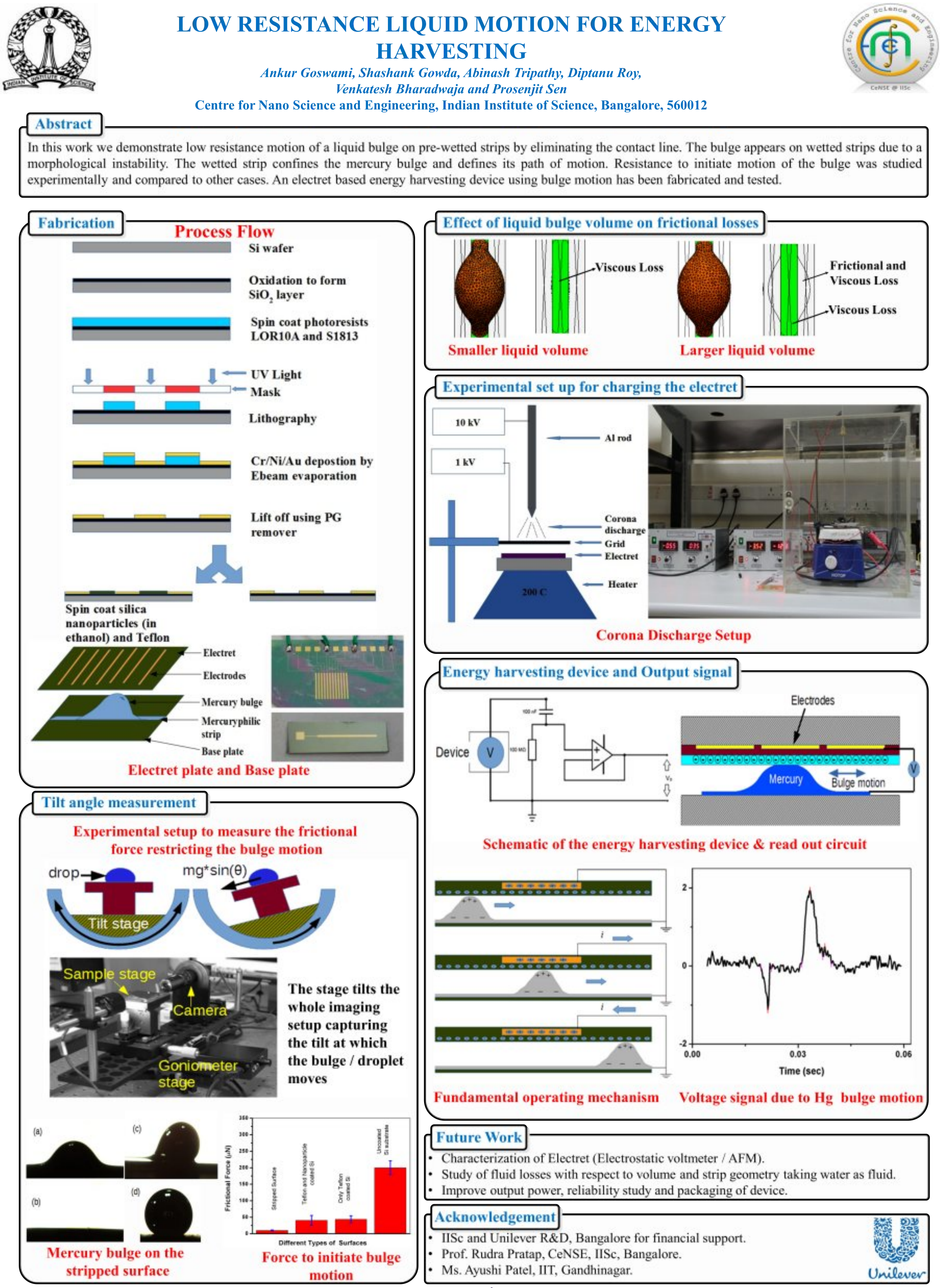



Photo by Mohamed Irfan M.Tech. student, CeNSE

CeNSE newsletter is published quarterly by the Centre for Nano Science and Engineering to keep the community of academia, industry, and government organizations informed of its activities and accomplishments.

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