CeNSE Newsletter

October - December 2015 | Volume 2 | Issue 5

CONTENTS

Cover photo: A Nanopropeller | Size range between 0.5 to 5 microns (length) and 0.1 to 1 micron (width)

Handing over to NPMASS of high pressure MEMS transducers designed, developed, fabricated, packaged and tested in-house

The **N**ational **P**rogram on **M**icro **A**nd **S**mart **S**ystems (**NPMASS**), coordinated by the **A**eronautical **D**evelopment **A**gency (**ADA**), identified the **Ce**ntre for **N**ano **S**cience and **E**ngineering (**CeNSE**) for carrying out the development of MEMS-based Pressure Transducers for aerospace applications. The goal was to indigenize such sensors by designing, developing, and packaging them in the in-house facility of CeNSE and take the devices to the level (TRL-9) from where industry can license the knowhow and develop products for aerospace and other commercial applications.

As a first step towards the development of a series of indigenous MEMS-based pressure sensors ranging from very low to high pressures, the NPMASS, awarded (May 2012) to CeNSE a project entitled, "Design, Development, Fabrication, Packaging, Limited Qualification and testing of Pressure Transducers for Aerospace application". The project involved the design, fabrication, packaging, calibrating the sensors of different types (Gauge, Absolute and Differential) for a wide range of pressures, viz., 150 mbar to 400 bar; integrating the sensors with electronics; packaging and testing them, all indigenously, in house, at CeNSE. This was indeed a challenge. The first of the series - high Pressure Gauge Transducers for operation in the range 0-200 bar and 0-400 bar - were designed, fabricated, and tested at CeNSE's National Nano-fabrication Facility. These transducers are rugged; adequately temperature-compensated from -40°C to 85°C; and withstand the needed tests for Vibration, Proof Pressure, and Calibration. Typical nonlinearity and hysteresis were found to be <0.3% of the full-scale output. The Transducers have withstood the rigorous tests needed to meet the stringent requirements of aerospace applications. Pressure sensors of the high pressure-type, viz., 0-200 bar and 0-400 bar Gauge Pressure Transducers developed at CeNSE to meet M/s. DEBEL's specifications, were handed over recently to Padma Vibhushan Dr. V.K. Aatre, the former Scientific Advisor to Raksha Mantri and the Founder-President of NPMASS, by Prof. Rudra Pratap, Principal Investigator of the Project and Chairperson, CeNSE.

In the picture(from left to right):
Mr. K. Sudhakar, Dr. V. K. Aatre, Prof. K. N. Bhat, Dr. K. Vijayaraju, Prof. M.M. Nayak, Prof. Gopalakrishnan, Prof. Rudra Pratap

FANTASTIC NANO-VOYAGERS

CURRENT STATUS

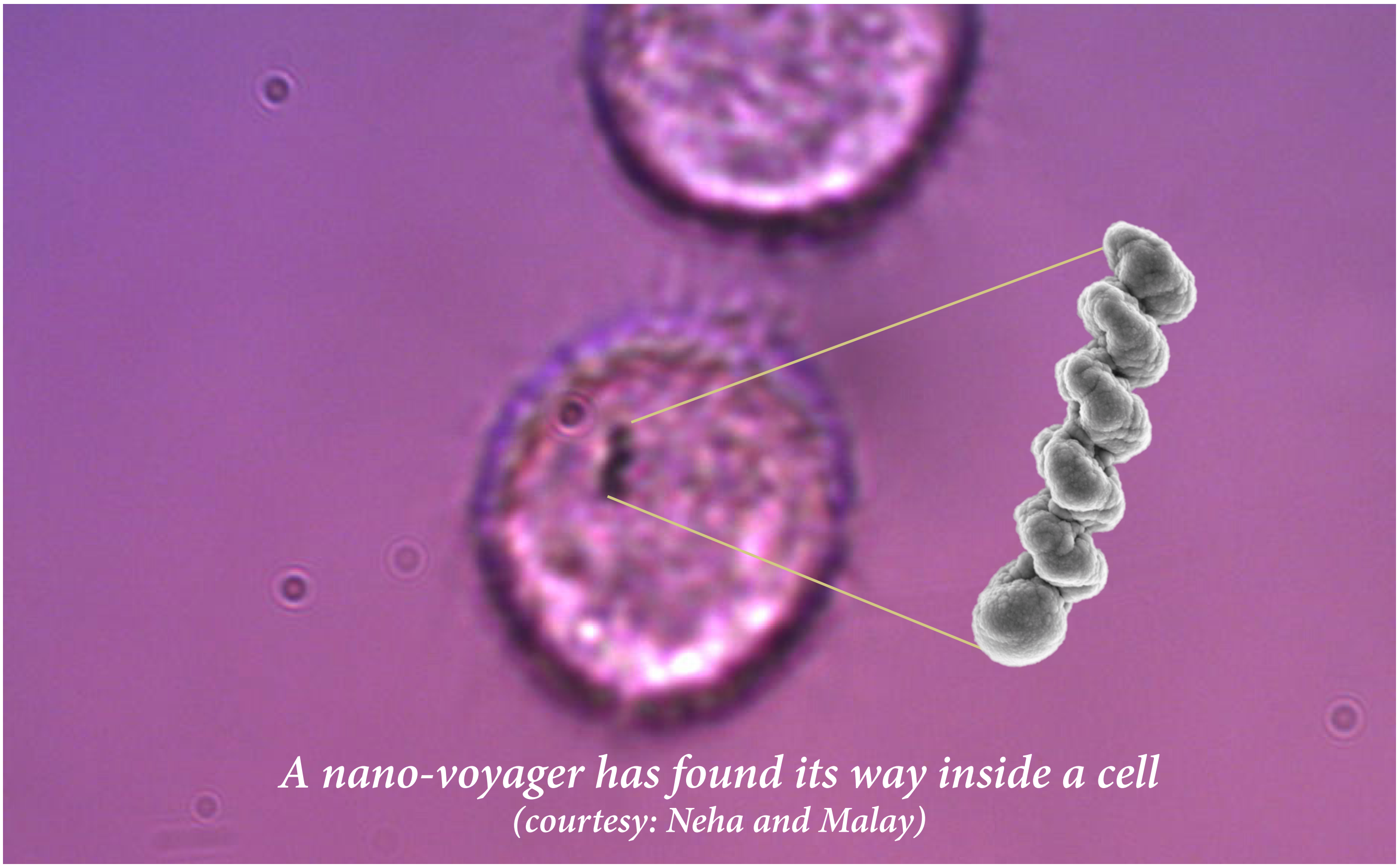
Ambarish Ghosh

"A friend of mine (Albert R. Hibbs) suggests a very interesting possibility for relatively small machines. He says that, although it is a very wild idea, it would be interesting in surgery if you could swallow the surgeon. You put the mechanical surgeon inside the blood vessel and it goes into the heart and "looks" around. (of course, the information has to be fed out.) It finds out which valve is the faulty one and takes a little knife and slices it out. Other small machines might be permanently incorporated in the body to assist some inadequately-functioning organ."

From Richard Feynman in his famous lecture "**Plenty of room at the bottom**" (1959).

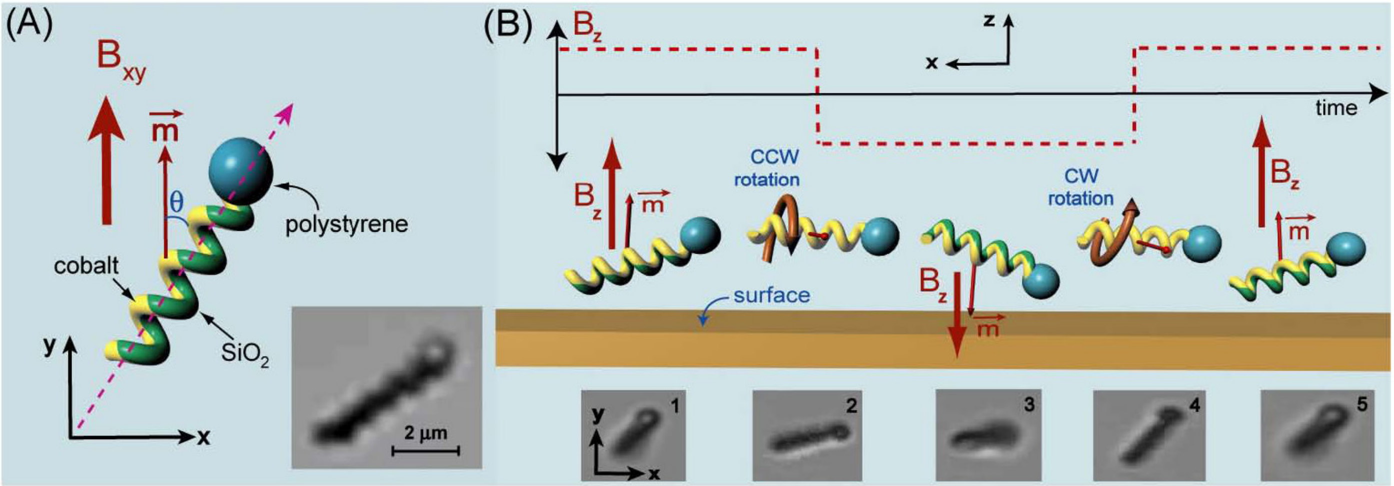
The machine envisioned by Feynman had multiple functionalities: it can move around inside a patient's body in an autonomous manner or be externally controlled, can sense diseases and, finally, deliver medicine to the infected regions as well. This machine, oftentimes called a "voyager" (named after the 1966 movie based on a similar concept), can completely revolutionize medicine the way we know it. In the long term, as Feynman hypothesized, a bunch of such machines can be implanted permanently inside the body, moving around to sense and treat problems, and helping out organs that are not functioning well. Among applications that can be tried soon, drug delivery to cancerous tumours appears particularly impactful. The idea would be to attach certain chemicals on the voyagers, move them around in a tissue so that they get attached to the cancerous cells. The voyagers could be carrying a payload (drug molecules), whose release can be triggered whenever cancerous cells are encountered. The key benefit of this approach would be to reduce the side effects associated with chemotherapy. The sensing and releasing triggers need not be chemical in nature; they could be sensitive to changes in pH, temperature, optical radiation etc., thus providing plenty of toolboxes this technology can utilize.

So, where do we stand and what is stopping us from deploying the nano-voyagers to tackle real world problems in bio-medicine? The problem of moving small things in fluids remotely in a non-invasive manner is not easy, because motion at small scales is dominated by friction (surface-to-volume ratio increases as size decreases). Only in the last decade, this problem has been solved, with small magnetic fields used to move structures in a way similar to the motion of sperm and bacteria. Though things work very well in model liquids like water, most biological media are not so simple. Blood, for example, can be extremely corrosive; so, one would need to protect the nano-voyager from the environment without diminishing any of its functionalities. And, even if you solve the problem related to motion in blood, every biological environment has unique physico-chemical properties; implying that the problem may have to be solved again when you go in a different tissue. The next and equally important task is to give the voyagers multiple properties - chemical, magnetic, optical - to name a few. The extent of multifunctionality will depend on the particular fabrication/synthesis strategy that one uses, and is bound to play a key role in determining the fate of a particular technological approach.



A nano-voyager has found its way inside a cell
(courtesy: Neha and Malay)

Independent manipulation of helical magnetic nanomotors



Needless to say, the technique has to be scalable, i.e., one should be able to scale up the production if need be. To summarize what has been achieved worldwide in this regard: there are a few ways of making voyagers with multiple functionalities, and proof-of-concept sensing or therapeutic applications have indeed been achieved in these systems, mostly under in vitro conditions. In vivo toxicity studies and invoking bio-degradable materials are some of the scientific hurdles that are yet to be tackled in a comprehensive manner. Going forward, research in this field requires large multi-disciplinary teams of bio-chemists, cell biologists, cancer specialists, doctors, pharmacologists, engineers and physicists, working together and integrating multiple functionalities towards a common goal. Given the speed at which this field is moving, it will not be surprising to see the first clinical trials within the next five years.

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http://www.cense.iisc.ernet.in/people/faculty/ambarish.htm

CONJUGATED MOLECULE DESIGN FOR SENSING ENVIRONMENTAL CONTAMINANTS

Praveen C Ramamurthy

Electroactive organic materials are making their way into the electronics world, which is dominated today by devices based on inorganic materials such as silicon and III-V compound semiconductors. The new organic materials are used in OLEDs, electroluminescent displays, photovoltaics, batteries, artificial muscles, polymer RFID tags, and sensors. Electroactive materials are pi-conjugated small molecules and polymer semiconductors. There is delocalisation of electron over the molecular structure, which makes them electronically conducting materials. Conjugated molecules can be designed to exhibit excellent optical, electrical, and mechanical properties that can be used to make chemosensors and transducers. Such sensors are flexible, light-weight and can be produced at low cost. The receptor part of the sensing material recognises and binds or interacts with the analyte; and the resulting change in its properties, such as solubility, absorption, fluorescence, redox potential, and electronic conductivity signals the binding event.

Sensors for monitoring environmental contaminants, such as volatile organic compounds (VOC), heavy metal ions, and microbes depend mainly on analytical methods such as chromatography and spectroscopy techniques. These methods provide accurate, repeatable and trace-level detection of analytes. The disadvantage is that these are laboratory-based techniques, require specialists and have slow response.

Our lab focuses on developing selective sensors with conjugated molecules for the detection of toxic contaminants in both air and water. We design and synthesize conjugated molecules for use as sensing elements: polymers and small molecules with suitable receptors that show affinity towards analytes. The selectivity of a sensor dependents on the sensing material. The chemical and physical properties of organic materials can be tailored to enhance selectivity and sensitivity. The "sensing layer" is designed such that the receptor moiety on it attracts the analyte. This results in increased sensitivity of the sensor.

Sensors are fabricated as a simple resistive structure. For transduction, the sensor depends on a change in the conductivity of the sensing element. For gas or vapour sensors, the solubility of the vapors in the sensing layer is common mode of detection. When the sensor is exposed to the atmosphere, gas (analyte) molecules are adsorbed on the sensing film. This alters the conductivity of the film, which indicates the presence of molecules of the target gas (vapour). To improve selectivity and sensitivity, it is important to understand the mechanism of interaction between the analyte and conjugated (sensor) molecule.

VOCs in paints, building materials and furnishings are slowly released over time. The common VOCs are acetone, toluene and aldehydes.

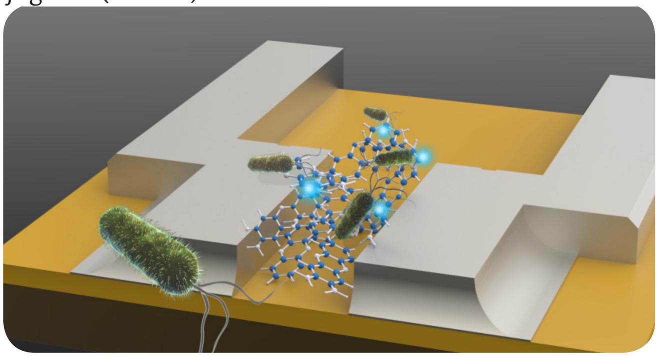


Figure 1: Resistor architecture of sensor

Figure 2: Response of a conducting polymer sensor to various concentration of toluene vapours

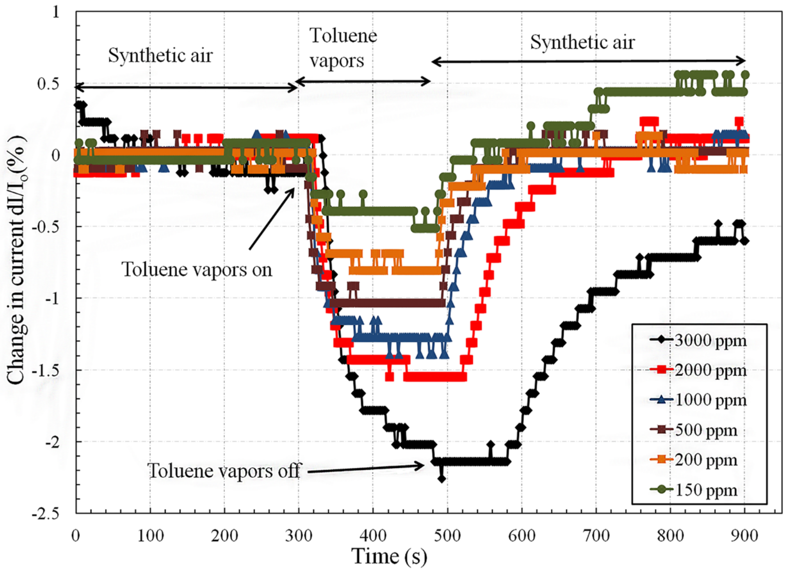


Figure 3: Response of resistive sensor with conjugated molecule as sensing element to various concentration of E. coli cells in water

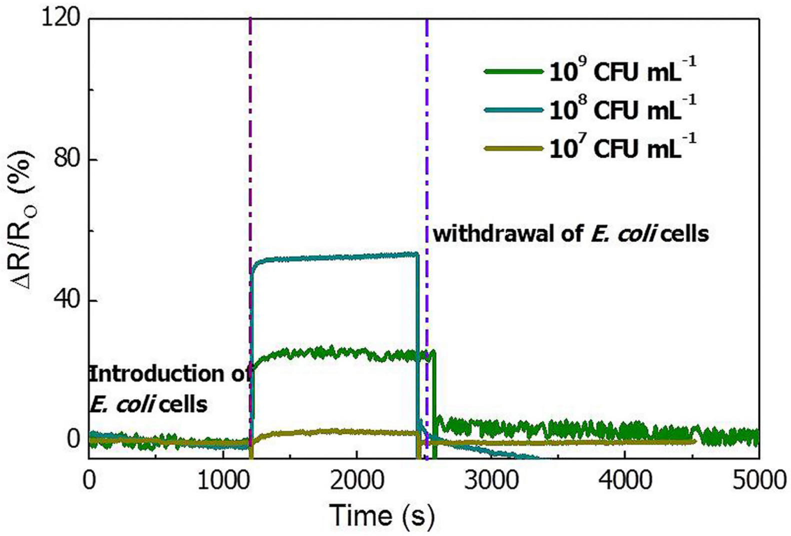
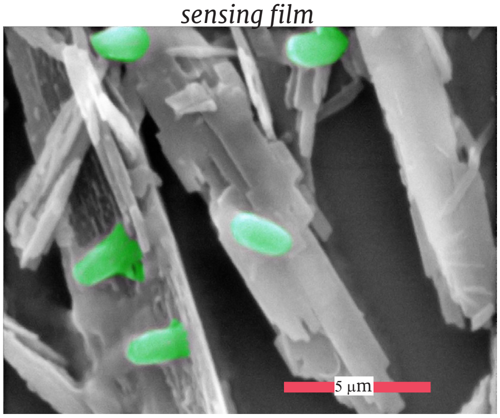


Figure 4: Coloured scanning electron micrograph showing E. coli on sensing film



We have designed conjugated polymers that interact with VOCs, and have employed molecular dynamics simulation to study the interaction between the analyte and the polymer.

By employing resistive, electrochemical, colorimetric, or fluorescence techniques, metal ions like those of Pb, Cd, Cr, and anions such as nitrite in water, can also be detected using such "designed" molecules.

Conventional methods for bacteria detection used in commercially available kits such as count plates, PCR kits, and ELISA kits are time-consuming (10-24 hours) and are laborious. Moreover these methods are based on antibody-antigen interaction, DNA sequence amplification, or detection of enzymes produced by the bacteria. We have used "designed" conjugated molecules as the sensing element. Using the same sensor structure as used for vapour sensors, we have achieved a very short response time of < 1 min for detection of a desired bio-analyte.

These results demonstrate that conjugated molecules with suitable receptor groups can be used for the detection of the various types of analytes: bio, chemical, and metal ions.

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Atomic Force Microscopy capabilities

Golwalkar Sangisetty and Venu V Bhat

The Micro and Nano Characterization facility in CeNSE is the one-stop solution for all research and the industrial needs for material characterization. The MNCF is a 5000 sq. ft. precision-controlled environment, housing four distinct laboratories for Electrical, Mechanical, Optical and Material Characterization. It provides unique opportunity for the students, researchers, and the Industries under one roof, with its variety of high-end equipment, spanning multiple disciplines of Nano Science and Engineering.

The Mechanical Characterization laboratory is equipped with high-end instruments like the Atomic Force Microscope (AFM), Scanning Acoustic Microscope (SAM), Micro System Analyzer, Optical Profilometer, Precision Nano Displacement System (PNDS) and Micro UTM.

The focus of this article is on Atomic Force Microscopy, also known as AFM, a derivative of Scanning Probe Microscopy. Scanning Probe Microscopy is the only technique that enables the study of atoms in three dimensions. AFM is a technique for surface analysis in which a probe (tip) with a nanometer-sized tip scans the sample surface, providing a unique way to study surfaces at the atomic scale. The resolution depends on the van der Waals forces between AFM probe and the sample surface, and the spring constant of the cantilever beam holding the tip. The AFM at MNCF is capable of measuring surface roughness ranging from 0.1 nanometers to 5 microns.

AFM analysis has become mandatory for researches studying material properties at the nano scale. AFM is a non-destructive technique for studying surface morphology, unlike conventional techniques like Scanning Electron Microscopy and Transmission Electron Microscopy. It is the only technique that gathers surface topographic information in three dimension, making it extremely helpful in the study of thin films through their depth.

Abilities of AFM:

- Distinguish a sample based on its mechanical properties

- Perform microfabrication of samples

- Scanning Tunnelling Microscopy

- The surface potential over any surface can be measured by Kelvin Probe Microscopy

- Perform scratch lithography [Fig. 1]

- Micron- and nm-sized magnetic domains can be visualized by Magnetic Force Microscopy [Fig. 2]

- Imaging of biological samples [Fig. 3]

- Piezoelectric behavior of thin films and the drop-cast particles can be studied by Piezo Force Microscopy [Fig. 4]

- Measure sample surface roughness at high resolution [Fig. 5]

- Liquid-mode AFM for biological samples [Fig. 6]

- Using a conductive probe, one can obtain I/V data at a single point [Fig. 7]

Please visit www.cense.iisc.ernet.in/mncf.htm for more information

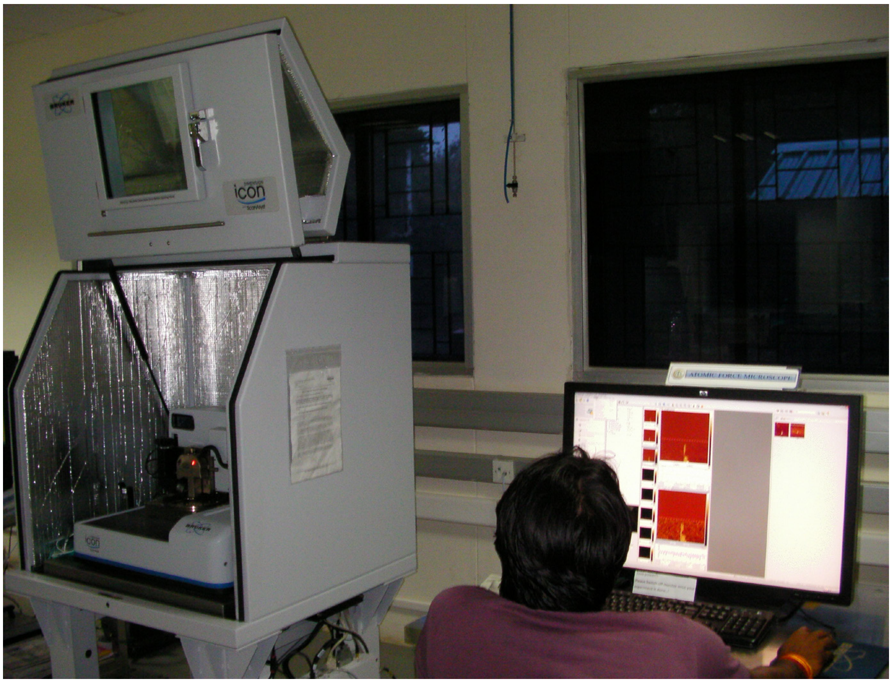


Fig 1: Scratch Lithography on silicon sample

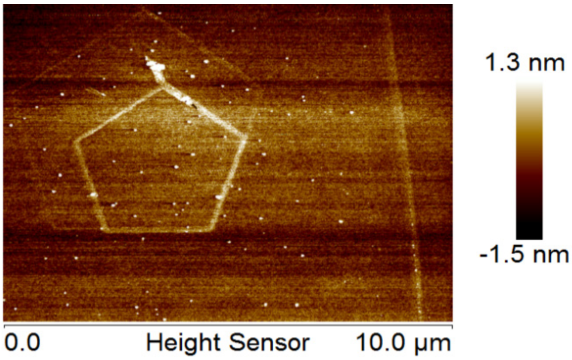


Fig 2: MFM – Magnetic domains of Video tape

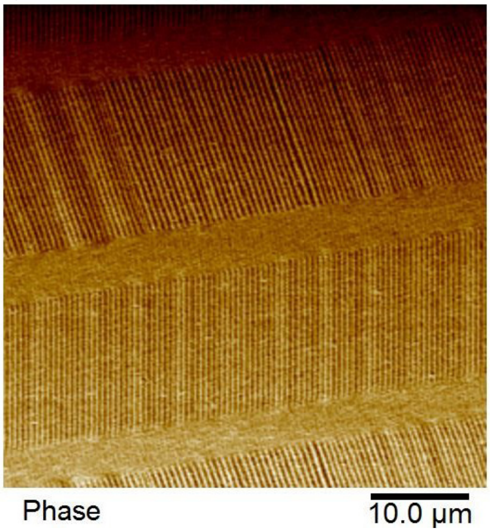


Fig 3: Protein structures

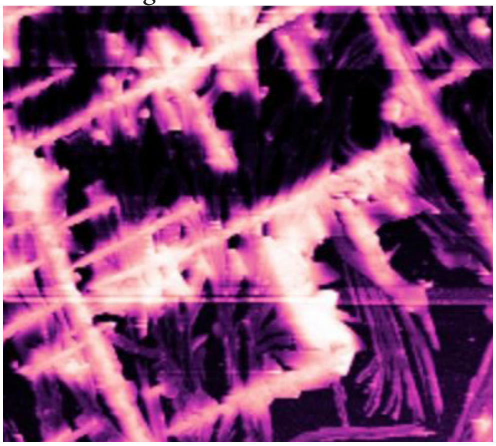


Fig 4: PFM data

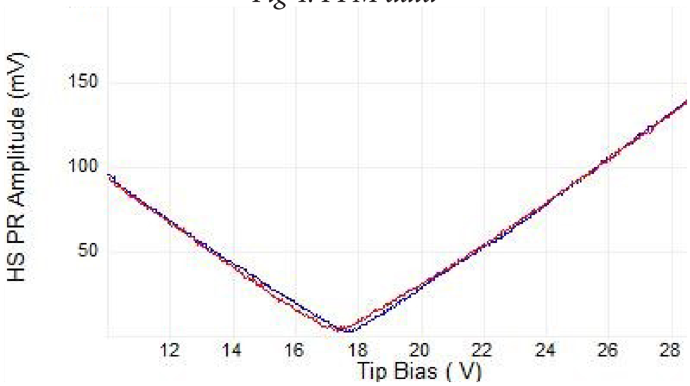


Fig. 5: Roughness of 0.08nm on sputtered film

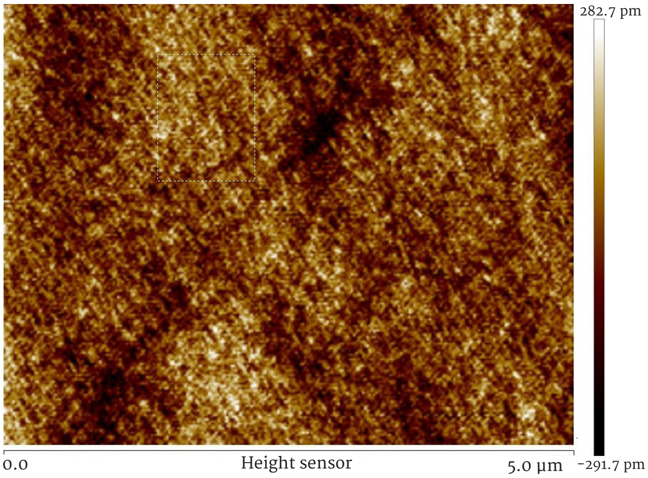


Fig 6: Red Blood cells in Fluid mode

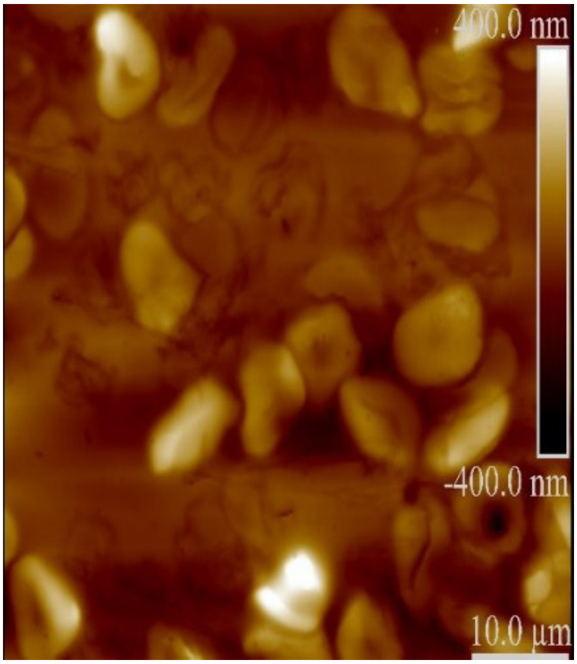
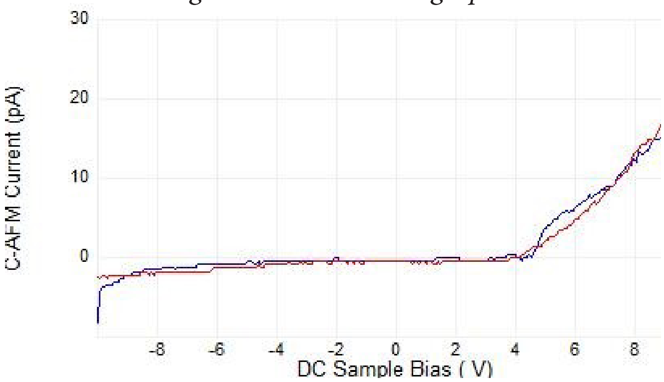


Fig 7: IV curve on a single point



Dynamics of Cricket Song

Vamsy Godthi and Rudra Pratap

Nature is a great source of inspiration for designs that are simple yet very efficient. With the advent of micro and nano fabrication capabilities, we now have the means to take the ideas from nature and make products with similar or even better capabilities. One such source of inspiration is the cricket song. Male field crickets (such as G. bimaculatus) produce mating calls, called cricket songs, from their fore-wings by a remarkable mechanism that results in an incredibly loud sound (80 – 90 dB SPL at 10 cm distance) from a very small radiating area (15 – 20 mm2). If one compares the size of a cricket to a conventional speaker able to produce sound of similar loudness, the conventional speaker is many-fold larger. Hence, for inspiration in designing miniature MEMS (Micro Electro Mechanical Systems) speakers where the design challenges are different from those of conventional speakers, we look up to the cricket song production mechanism. We systematically study the sound production mechanism in field crickets, and mimic the strategy used by crickets to actuate and efficiently produce loud sound from a tiny wing, to come up with a novel design for MEMS speakers. Our initial prototypes, fabricated using simple micro-fabrication processes, are able to produce a sound pressure of 70 dB SPL at a distance of 10 cm.

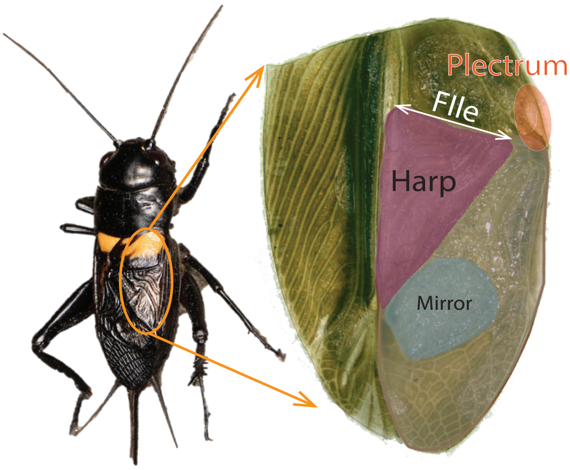
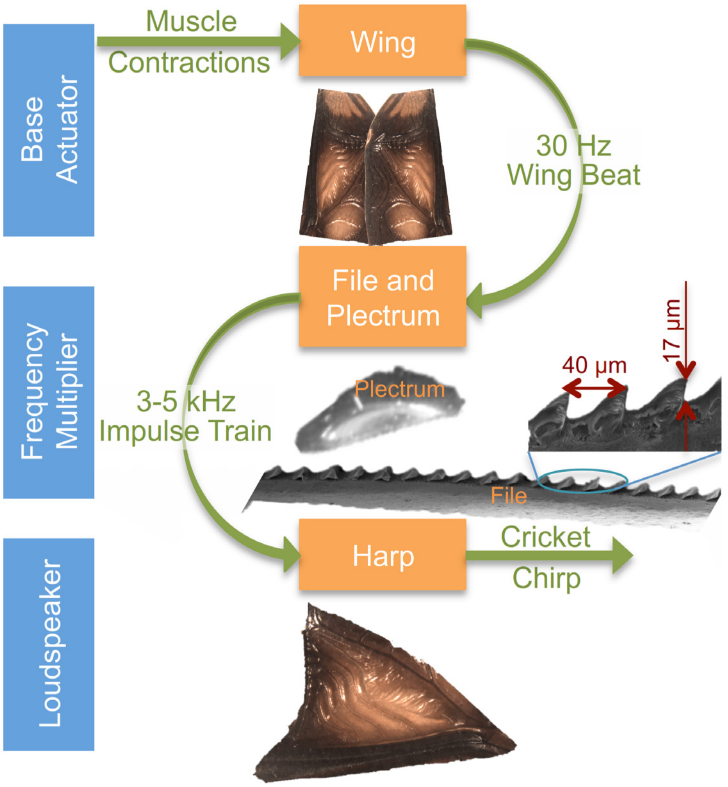


Image of the right wing of G. bimaculatus.

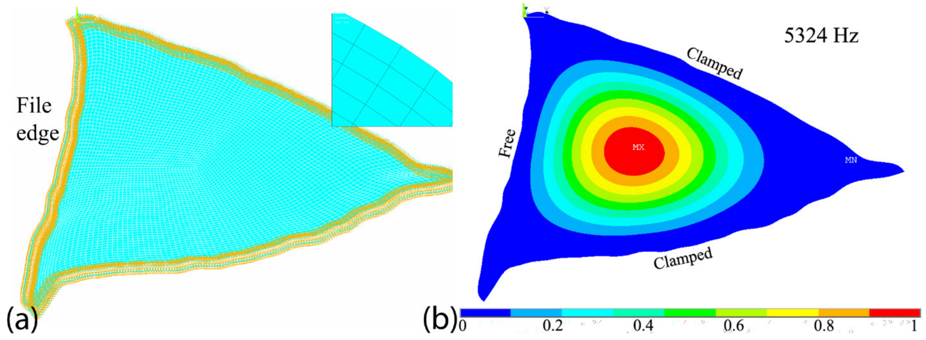
Male field crickets do not use vocal chords for singing. They produce their rather loud mating calls by stridulatory motion of their forewings. The main sound-producing part is the harp—a thin triangular membrane on the wing bounded by veins (figure at right). The underside of the harp bears a series of teeth on one of the bounding veins called the file. The plectrum (a hooked tooth-like structure) is located close to the harp on the side of the wing.



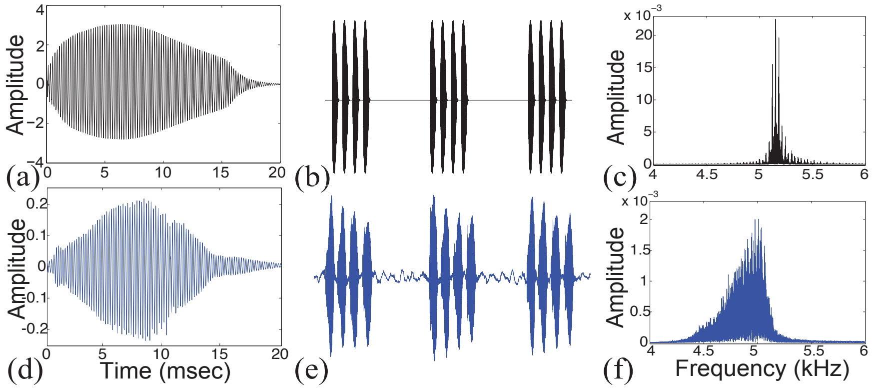
The different stages of transduction involved in the sound production by field crickets.

The sound production mechanism consists of three stages of transduction (figure at left). First, the contractions of wing muscles drive the two forewings together at a low frequency (30 Hz for G. bimaculatus). Second, this low frequency actuation drives the plectrum present on one wing across the file of teeth present on the other wing. As the plectrum engages the teeth intermittently, it produces a series of high frequency (5 kHz for G. bimaculatus) impulses on the wing. Third, the load excites the harp which vibrates in response to the impulse train to produce sound. The high frequency loading is such that it is close to the resonant frequency of the harp structure. Thus the harp radiates sound that is incredibly loud for the cricket's size. We construct a finite element model of the harp in ANSYS (finite element analysis software) by digitizing the shape of the harp and by carefully measuring the harp's thickness and mechanical properties (figure at right).

We model impulsive loading based on a loading scheme reported in the literature and predict the transient response of the harp. We apply a moving train of impulses on the

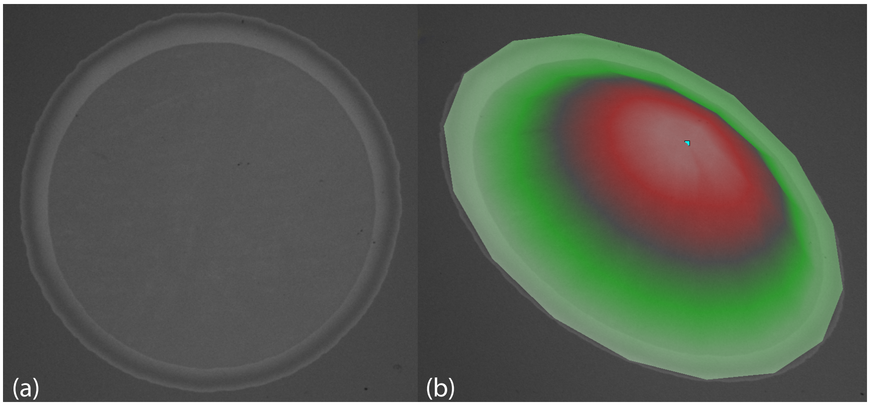


Improved FEM model of the harp: (a) 3-D FEM model, and (b) the first mode shape.



The transverse displacement of the node at the centroid of the 2-D harp model of G. bimaculatus: (a) time response, (b) recreated chirps, and (c) FFT of the response. Analysis of the recorded song of G. bimaculatus: (d) a pulse of the song, (e) recorded chirps, and (f) FFT of the song.

file-bearing edge. The simulated displacement response of the harp in time domain closely matches the pulse envelope of experimentally recorded cricket's sound signal (see the figure at left). The frequency spectrum of the response also clearly shows that the prescribed excitation indeed excites the first mode significantly over the others and matches closely that of the recorded song [1]. When designing MEMS speakers, we are faced with a challenge similar to cricket's, i.e., to produce a loud sound from a very small structure. Inspired by how the cricket actuates, we have designed MEMS speakers. We have been able to realize initial prototype MEMS speakers using simple fabrication processes (see the figure below). By electrostatically actuating the MEMS devices, we obtain a sound pressure of 70 dB SPL at a distance of 10 cm [2].



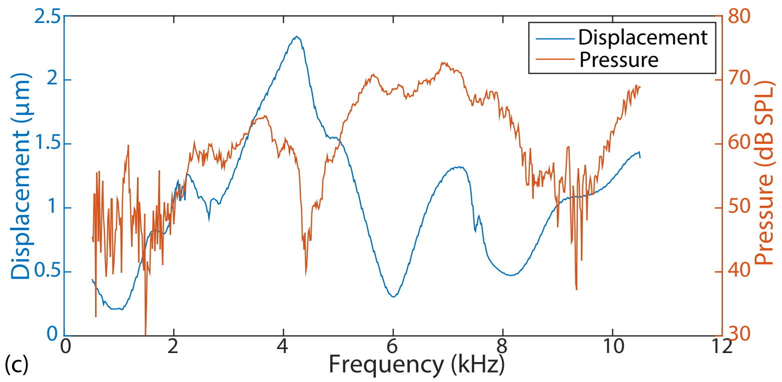


Figure showing (a) the optical image of the fabricated MEMS speaker, (b) the experimental mode shape of the structure, and (c) the displacement response and the pressure radiated (at 10 cm) from the device.

References:

[1] Godthi, Vamsy and Rudra Pratap. "Dynamics of the Cricket Sound Production". In: Journal of Vibration and Acoustics 137.4.

[2] Godthi, Vamsy, Jayaprakash Reddy .K, and Rudra Pratap. "Nature-Inspired MEMS Speakers". In: Proceedings NSA 2015, Goa, October 7-9, 2015.

Electrochemical detection of Glycated Albumin

Vinay Kumar and Navakanta Bhat

Diabetes is rapidly emerging as a major threat to public health. Diabetes is not a single disorder, but is a collection of several disorders with different underlying causes and with multiple hormonal abnormalities. It is characterized by disordered carbohydrate metabolism, with hyperglycemia resulting from dysfunction of insulin secretion, insulin action or both. The long-term complications of diabetes mellitus include the progressive development of retinopathy, nephropathy, foot ulcers, neuropathy, cardiovascular diseases, and amputation. Several international diabetes studies, like the diabetes control and complications trial (DCCT), have already established the relationship between glycemic control with diabetes complications.

Albumin is one of the most abundant proteins in plasma. The normal concentration of the albumin in plasma is 3.5 to 5.0 g/dL. Albumin protein has three domains, I, II, III, that are further subdivided into two subdomains, A and B, which enable its functional conformational structure (Fig. 1). The presence of 17 disulphide bridges makes albumin resistant to change in the pH and other changing environment. Inside the human body, serum albumin acts like a molecular taxi, binding a variety of substances, including pharmaceutical drugs, bilirubin, metallic porphyrin, and metal ions.

Hyperglycemia in diabetes mellitus induces the formation of the advanced glycation end products (AGE), thought to be toxins that bind to proteins present in plasma. HbA1c, which gives the 90-day average blood glucose level, is clinically recommended as the gold standard for assessment of the glycemic control in diabetic patients. Glycated albumin (GA) has recently emerged as another clinical gold standard indicator of glycemic control. Since the half-life of human serum albumin is 2 weeks, it could serve as a more efficient marker of short-term glycemic control than HbA1c. Further, HbA1c test results can be affected in a number of situations, such as structural hemoglobinopathies, thalassemia syndromes, and chemical alterations of haemoglobin. Moreover, any condition that reduces the mean erythrocyte age, such as chronic kidney disease, will falsely lower HbA1c test readings, regardless of the assay methods employed. Hence there is a need to develop an accurate and efficient technique for the detection of Glycated Albumin.

Figure 1 showing structure of human serum albumin

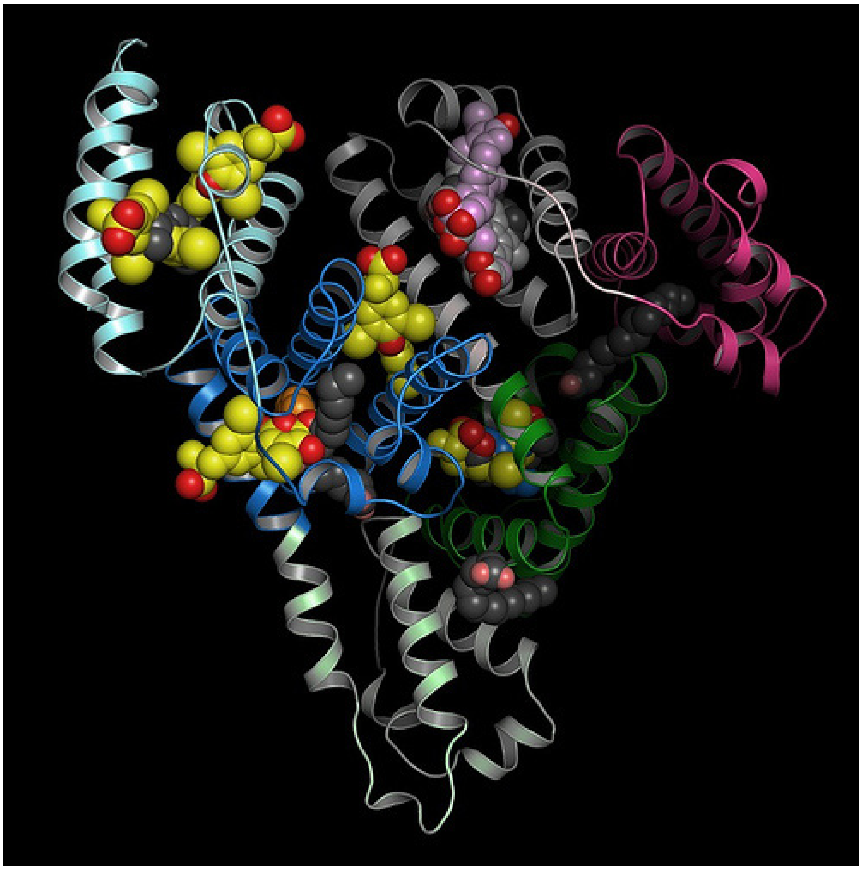
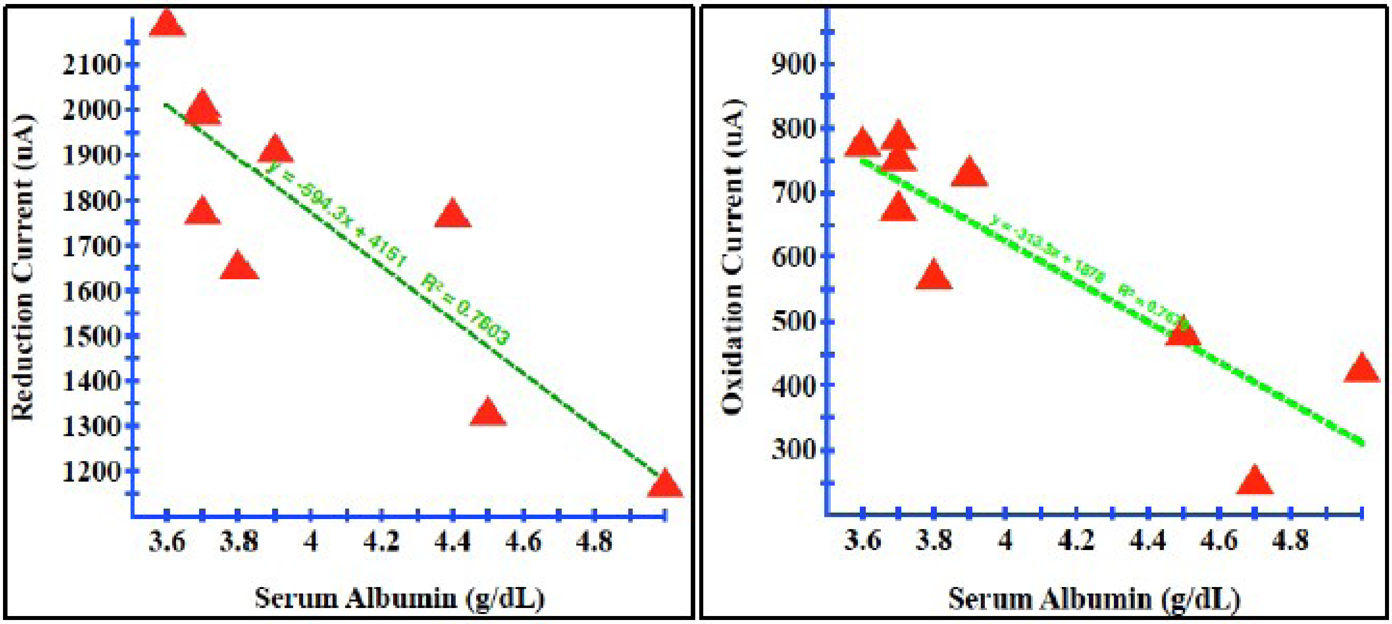
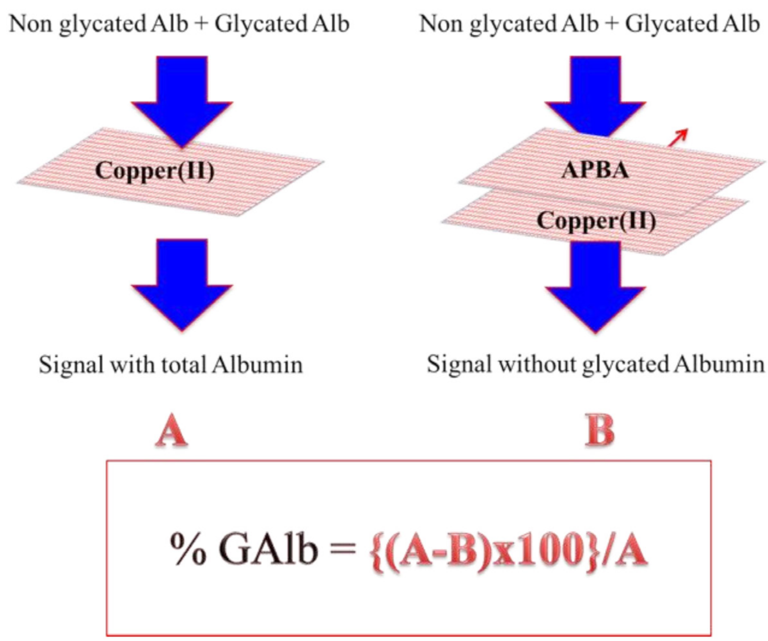


Figure 2 showing Redox current Vs. serum albumin in whole blood samples



Since Albumin does not contain any redox-active metal ions in its structure, electrochemical detection of Albumin has not been possible. We have developed a first-of-its-kind technology for the electrochemical detection of serum albumin, based on the doping this biomolecule with metal ions and metallic porphyrin receptors, such as copper and hemin [1]. Fig. 2 shows the linearity in reduction and oxidation current as a function of albumin concentration using copper ion as the receptor. The present technology is being extended to glycated albumin measurement for point-of-care application by exploiting the Boronate affinity principle, as shown in Fig. 3. The glycated part of Albumin is trapped in an Amenophenylboronic acid membrane, thereby facilitating the measurement of the percentage glycated albumin.

Figure 3 showing percentage glycated albumin detection



Reference:

[1] Vinay Kumar and Navakanta Bhat, "ELECTROCHEMICAL BIOSENSOR AND A METHOD OF SENSING ALBUMIN AND ITS COMPLEXES", PCT International Application No. PCT/IB2015/056619.

EVENTS AND ANNOUNCEMENTS

Seminars

Oct

"Understanding Liquid- Soild Interfaces And Its Industrial Applications" by Dr. Martin Kirchner ***13th Oct***

Lecture as a part of the CeNSE Course NE-101, Entrepreneurship, Ethics, and Social Impact by Dr. Suri Venkatachalam, CEO and Founder Connexios Life Sciences, Bangalore ***21st Oct***

Nov

"Gate-tunable transport in the Al2O3/SrTiO3 interface two-dimensional electron gas" by Dr. Shamashis Sengupta ***12th Nov***

"Nanostructured hybrids with engineered interfaces for efficient electro, photo and gas phase catalytic reactions" thesis colloquium by Leelavathi A, ***16th Nov***

"Nanophotonic Devices for Information Processing and Sensing Applications" by Sofía Rodríguez ***18th Nov***

"3D Printing for Micro and Nanofabrication (NanoScribe)" by Dr. Krishna C. Balaram ***17th Nov***

"Profiling an Entrepreneur" lecture as a part of the CeNSE Course NE-101, Entrepreneurship, Ethics, and Social Impact by Shri Naganand Doraswamy, EVP and Co-Founder SPAN Infotech India Pvt Ltd. President- TiE Bangalore ***18th Nov***

"Joint Physics-CeNSE Seminar: Outstanding scientific achievements in nanosciences developed at Grenoble thanks to the Foundation" by Dr. Alaine Fontaine ***18th Nov***

"Climate and Clean Technology Policy in the United States, with Lessons for India" by Dr. Varun Sivaram ***27th Nov***

"Perpendicular magnetic anisotropy: from ultralow power spintronics to cancer therapy" by Dr. Russell Cowburn ***27th Nov***

Dec

"Photonic Semiconductor Nanostructures: Optical properties, Technology and Applications" by Prof. Srinivasan Anand ***8th Dec***

"MEMS+ 6 (MEMS System level integration)" by Mr. Rahul Jhaveri ***9th Dec***

"3D integrated bionanotechnology: From bionic devices to untethered surgical tools" by Dr. David Gracias ***10th Dec***

"Designer Nanomaterials for Energy Harvesting" by Dr. Ayaskanta Sahu ***10th Dec***

"Impulsive Enzymes: A New Force in Mechanobiology" by Dr. Krishna Kanti Dey ***17th Dec***

Workshops

IEEE Nanotechnology workshop ***17-18th Oct***

Airbus Event ***26-27th Oct***

Workshop on Raman Spectroscopy by Mr.R.L.Narayanan, Application Specialist Lab India and CeNSE ***3rd Nov***

INUP Hands-on Training Workshop ***19-27th Nov***

Industry Affiliate 3 days Analog Device Workshop on Gyroscopes ***02, 11, 18th Dec***

Announcements

Dr. Sam Pitroda, visited CeNSE on ***21st Oct***

Prof. Supradeepa joins the prestigious journal Optics Express, as an Associate Editor

Prof. Navakanta Bhat is being elected for the Electron Devices Society Board of Governors (BoG) for the three-year term of 2016-2018.

Ph.D student Santanu Talukder and professors Praveen Kumar and Rudra Pratap — found a way to etch nano-circuits on silicon chips at room temperature, which could potentially accelerate research efforts at the fundamental chip level called as Electrolithography- A New and Versatile Process for Nano Patterning. The work exclusively interviewed and featured in a Economic Times article.

For Upcoming events:

Visit www.cense.iisc.ernet.in/news_events.htm

IEEE Nanotechnology Workshop

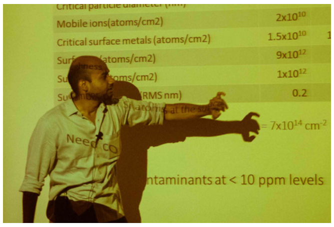
16th & 17th Oct 2015

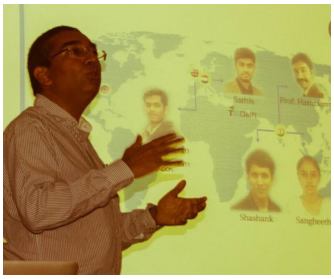
IEEE NC-SC
JOINT STUDENT CHAPTER

The IEEE IISc Joint Student Chapter, Bangalore, organized a two-day Nanotechnology Workshop at CeNSE on the 16th and 17th of October, 2015. The aim of the workshop was to disseminate theoretical and practical information on nanofabrication, nanocharacterization, and packaging techniques used in the field of MEMS/NEMS, Nanoelectronics, Nanophotonics, BioMEMS and nanomaterials. The workshop was attended by 70 enthusiastic undergraduate and graduate students from various parts of the country. The sessions included lectures by eminent faculty members of CeNSE, technical talks by experts from CeNSE industry affiliates, and tours of the acclaimed nanocharacterization, nanofabrication, and advanced MEMS packaging facilities at CeNSE.

Day 1 of the workshop began with an inaugural talk by Dr. Gopal Hegde. This was followed by session 1, which saw Prof. Rudra Pratap, Chairperson, CeNSE, talking about MEMS sensors, which find applications in a number of fields like acoustics, ultrasonics, inertial navigation and diagnostics. Students seemed really excited to learn about Prof. Rudra's fascinating research work on mechanobiology and principles of multifunctional small scale natural transducers present naturally in animals and insects like crickets.

Session 2 commenced with a lecture by Prof. Sushobhan Avasthi, who familiarized students with the various fabrication processes commonly used in the semiconductor Industry. The objective of the talk was to introduce students to the technology and processes used in fabricating advanced electronic devices and circuits and the basic principles of science that drive these unit processes. He also detailed how proper integration at different levels eases device fabrication in the microelectronics industry, which he demonstrated by means of various real-life case studies.
After a tea break, the students gathered for Session 3, in which Prof. Digbijoy Nath introduced the young enthusiasts to Compound Semiconductors and discussed the need for integrating devices based on these semiconductors





with conventional Si-based devices, thereby complementing Silicon. He also talked about III-V compound Semiconductors from the materials perspective and familiarized the students with epitaxial growth methods like MBE used in the preparation of these materials. Applications where these devices find importance, like high power and high temperature electronics and energy efficient opto-electronic devices, were also discussed, in addition to the various characterization techniques commonly used to study devices based on III-Vs.

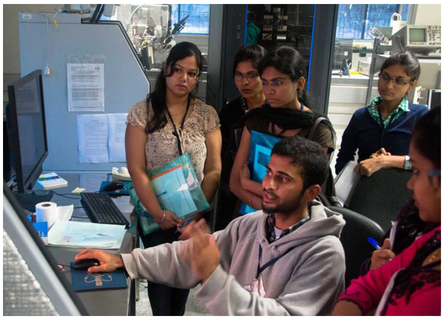
This was followed by Session 4 on Advanced MEMS Packaging by Prof. M.M. Nayak, a Visiting Professor at CeNSE, who was previously with ISRO as the Director, Launch Vehicle Programme Office. The talk highlighted the driving force behind electronic packaging and the importance of packaging to strengthening fabricated devices so that they can withstand harsh conditions and situations, while simultaneously delivering efficient performance. Prof. Nayak used a variety of case studies, ranging from 3-level packaging in micro-scale MEMS devices to 4-level aerospace-fit packaging, to drive home the value of this invisible but indispensable part of device fabrication. He captivated the participants by talking some very interesting recent advances that have been made possible by efficient packaging, such as the integration of electronics into golf balls and "smart dust", which can be used to sense wind, temperature, pressure and humidity.

After lunch, an inspiring talk on Multifunctional Composite System for Aerospace Structures was delivered by Prof. Dinesh Kumar Harursampath of the Department of Aerospace Engineering. "Team Multifun", a team comprising IISc students and alumni, won the "Airbus - Fly Your Ideas" contest under the guidance of Prof. Dinesh. The vibrant talk discussed the innovative research work they carried out as a part of this contest and also highlighted the importance of collaborative team work behind any successful research venture. The research work carried out was aimed at meeting the challenges of noise, fuel, and emission faced by the Aerospace industry, also at investigating the recycling and storage of energy to address these challenges. Prof. Harusampath's group focused on harnessing the large-scale vibrations of aircraft wings to generate energy, using piezo- and battery- reinforced ceramics in the wings, to meet a part of the aircraft's energy requirements. Participants appreciated the novel approach greatly.
The lecture sessions were chaired by Dr. Hegde and each session was followed by a brief question-answer segment, in which the students participated very actively.

Following the lecture sessions, students were divided into groups and were taken on lab tours and demonstrations, to give them a flavor of the experimental work in the field of nanoscience and nanotechnology that takes place at CeNSE. The students visited the state-of-the-art National Nanofabrication

Centre (NNfC) at CeNSE and were introduced to experimental nanoscale fabrication techniques like Sputtering, Etching, Oxidation, Optical and e-beam lithography, PECVD and ALD, in their tour of the various bays of the cleanroom.
The students visited the Photovoltaics Lab where they were able to see lithography, thermal evaporation and etching live in action. They also visited the Functional Thin Films Lab, where the working principles of e-beam evaporation and different types of sputtering – DC, RF and pulsed DC - and residual gas analysis, were explained to them clearly by "opening up" the systems.
The students were also taken a tour of the Micro and Nano Characterization Facility (MNCF) at CeNSE, which is one of the best nanoscale characterization facilities in the world.

At the MNCF, students were demonstrated how mechanical, electrical and optical characterization of the fabricated devices can be carried out using techniques like AFM, XRD, Raman spectroscopy, SEM, XPS and LDV. The measurement of the efficiency photovoltaic devices was also demonstrated by the use of the solar simulator.



Finally, a visit to Advanced MEMS Packaging Lab was organized, where the students learned about the commonly used packaging techniques in the microelectronics industry, such as dicing, welding, bonding, and projection imaging. Day 2 started with an "industry talk" by Mr. Vinod, Vice president, Centum Electronics, an Industry Affiliate of CeNSE. He spoke about the history of Centum Electronics and how the company is proud of being one of the successful Indian-based companies in the domain. He emphasized the need for collaboration between academia and industry, encouraging students to have a holistic approach to research. He also pointed out the qualities that Centum looks for in the candidates they recruit for employment. The talk was chaired by Prof. Mohan, Visiting Professor and faculty-in-charge for the Industry Affiliate Program at CeNSE. October 15^{th} being the birthday of Dr. APJ Abdul Kalam, Prof. Mohan concluded the session with the motivating story of Dr. APJ Abdul Kalam, about his passion and patriotism, which definitely was the perfect closure for the session. After the talk, the lab tours were resumed and conducted throughout the day. The participating students enjoyed the lecture sessions and lab tours thoroughly; the exposure they got through lab tours into the world of nano technology complimented the lectures greatly.

The valedictory ceremony saw Prof. Navakanta Bhat, Advisor for the IEEE Student Chapter, urging students to be a part of IEEE, elaborating on the extensive benefits of doing so. He also gave certificates to members of the previous IEEE Student Committee as an acknowledgement of their contribution.

The participants provided valuable feedback and praised the organizers efforts. The workshop was concluded by Prof. Rudra Pratap, Chairperson, CeNSE, who gave a motivating talk and he announced the next IEEE event: National Student Nano Conference.

The two-day workshop was a confluence of participants from many disciplines, engaged by eminent experts of nanotechnology and dazzled by country's elite Nanofabrication, Nanocharacterization, and Advanced MEMS Packaging Centers. The event was an effort to bring the most motivated students of the country to experience the Nano, and it was a huge success.

Industry visit to Centum Electronics

The IEEE NC-SC student team got an invite to visit Centum Electronics from Mr. Vinod Chippalkatti, the VP. We followed up immediately, and went for a day-long visit to Centum electronics, Centum EMS, Centum Rakon, and Centum Industries, all located in Yelahanka. Mr. Vedaprakash showed us around and answered all our questions. He started the tour by showing us the company portfolio. He told us how Centum products catered to a very diverse clientele, ranging from defence and aerospace to medical and industrial.

We visited Centum's engineering division, which works mostly on mechanical design and the design of printed circuit boards. We were taken next to taken to the fabrication facility, where were exposed to the flying probe test and component assembly. We were briefed about the "Kaizen" principle followed by Centum to achieve continuous improvement of their employees' work. Through this, the management collects feedback and suggestions from the employees, helping them improve their skills. It was surprising to see "green marking" of almost all the employees, which means a job well done. This demonstrates the intention of each and every employee to live up to the company's name "CENTUM", i.e., 100% excellence in the products they develop.

We then moved to the testing facility. This is a mil-grade test facility with different types of equipment catering to various tests needed for product certification. We were also shown around the packaging facility, which had one area separately marked as an ISRO-qualified facility. Centum Rakon, a joint venture between Centum Electronics Ltd. India and Rakon Ltd. New Zealand, is engaged in the design and manufacturing of high-performance frequency control products for the Telecommunications, Industrial, Defense, Aerospace and Space markets. The product range includes OCXO, TCXO, VCXO, clock oscillators and filters. These oscillators are made, assembled on PCB, tested and packaged at Centum. Centum Industries is engaged in the manufacture and assembly of mechanical products.

We were shown thermoplastic and thermosetting molding here. They make products with plastic and sheet metal to provide for their industrial customers.

At the end of the visit, our team felt that it was a day well spent in a company which truly represents the concept of "Make in India".

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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