



Indian Institute of Technology Bombay

IITB Sensor Workshop: Sensing the World

March 5 - 6, 2021

About the workshop

Sensors are ubiquitous in our lives. They have improved all aspects of our lives including health, smart homes, automobiles, industries, agriculture etc. The purpose of this workshop is to bring together experts who work in varied aspects of sensors and systems starting from sensor's design, materials, theories, fabrication and developing real time applications using sensor interfacing, software, algorithm, data analysis, etc. The workshop would not only provide a platform to showcase the activities going on in the institute in the sensors domain, but would also bring in experts from industries and other academic institutions to gauge the current developments and opportunities in this domain. Through the panel discussions, the workshop would try to understand the challenges, needs of specific technologies and leverage on the existing expertise to bring out the solutions that potentially would enhance socio-economic growth.

Conveners:

Prof. Swaroop Ganguly (Electrical Engineering, IIT Bombay)

Prof. Dipti Gupta (Metallurgical Engineering & Materials Science, IIT Bombay)

The workshop was conducted in virtual mode and 645 participants registered. All the sessions were attended by more than 150 participants.

DAY-1

Opening Session:

Prof. Dipti Gupta started the workshop by giving the overview of the workshop, which was followed by opening remarks from the Director, IIT Bombay, **Prof. Subhasis Chaudhari**; and welcome remarks by the Dean R&D **Prof. Milind Atrey**.



Keynote Addresses:

The keynote address by Shri Nilesh Desai (Director, ISRO-SAC) focussed on showcasing different types of sensors used by ISRO in various applications.

Session 1: Sensor Theory, Materials, Design, Fabrication:

Chair: **Prof. Pradeep Dixit** (Mechanical Engineering, IIT Bombay)

Speakers:

- Prof. C. Subramaniam (IIT Bombay) - Nanomaterials for Sensor Applications
- Prof. Anil Kumar (IIT Bombay) - Nanomaterials for Sensor Applications
- Prof. Kasturi Saha (IIT Bombay) - Quantum Sensors
- Prof. Hsiao-Wen Zan (National Chiao Tung University): Gas Sensors
- Prof. Amit Agrawal (IIT Bombay) - Microfluidic Devices
- Prof. Prasanna Gandhi (IIT Bombay) - Multi-scale manufacturing

In the very first session, 6 eminent speakers shared their research work on various aspects of chemical/biosensors and the associated processes.

Prof. C. Subramaniam

Nanostructured Materials for Point-of-Care Chemical and Biochemical Sensors

Prof Subramaniam presented the first talk of the session and the workshop on Single walled Carbon Nanotubes (CNTs) based conductive ink, which was applied on low-cost cotton thread to create a conductive thread. This thread was transformed into laminated platform to monitor metal ions levels in various biological fluids.

Prof. Amit Agrawal

Development of State-of-the-art Bio-Microdevices

Prof. Agrawal presented his pioneering work on the separation of plasma from the blood using the micro-fluidic fundamentals. Various low-cost micro-devices fabricated in PDMS polymer are shown which were used to efficiently enrich, or deplete and separate platelets in the blood plasma. The platelet separation device demonstrated the platelet rich plasma separation, platelet poor plasma separation and biological assessment of samples obtained from the micro device post separation.

Prof. Kasturi Saha

Diamond Quantum Sensor for Neuronal Imaging

Prof. Saha introduced the fundamentals of diamond quantum sensor used for the neuronal imaging and explained the spin phenomenon in the presence of impurities like nitrogen and boron. She presented a magneto-striction model based on anisotropic domain rotation to find a Terfenol-D thin film's magnetization characteristics.

Prof. Hsiao-wen Zan

Ultrasensitive Gas Sensors and their Applications in Breath Detection

Prof. Zan discussed about the ammonia gas sensors for Kidney function monitoring in chronic kidney disease patients. She also talked about nitrous oxide gas sensor with vertical channel Nano porous organic diodes that has applications in breath detection for asthma patients and in environment monitoring.

Prof. Anil Kumar

AI-based Approach for Generic and Versatile Chemical and Biological Sensors based on Fluorescent Transducers

Prof. Kumar presented versatile as well as very promising fluorescent based chemical sensors for detecting explosives. A working device based on this work is already commercialized. A cost effective organic field effect transistors were demonstrated with regioregular poly 3-hexylthiophene (rr-P3HT) and hexafluoro-2-propanol-substituted polysiloxane (SXFA) as an organic layer. The demonstrated explosive sensor is having very good sensitivity.

Prof. Prasanna Gandhi

Novel lithography-less multi-scale fabrication methods via shaping of nanoparticle slurries

In the last talk of this session, Prof. Gandhi discussed a low-cost and faster technique to fabricate a wide variety of fractal-like structures over micro and very large scale. The proposed technique employs multiple-ports or source-holes in this cell, to spontaneously shape a stretched fluid film into a network of well-defined webs/meshes and ordered multi-scale tree-like patterns. Controlled fractal-like structures using alumina nanoparticle slurry were obtained which has applications is chemotaxis/drug screening platform.

Keynote Address 1:

Prof. Navakanta Bhat (Dean – Division of Interdisciplinary Sciences, Indian Institute of Science)

Biochemical Sensor Systems

In his keynote talk on Bio-Chemical Sensors systems, Prof. Navakanta Bhat shared his personal experience of sensor development and translation towards healthcare diagnostic products, with a few examples. He particularly mentioned the importance of skills like patience, perseverance team building and business acumen. Prof. Bhat emphasized the importance of parallel sensory engines, possibly based on upcoming printing-based techniques, working in conjunction with silicon-based storage and

memory. He pointed out that understanding the process of biorecognition remains the bottleneck of biosensors that needs to be solved.

Session 2: Sensor Interfaces, Signal Processing, Packaging:

Chair: Prof. Kasturi Saha (Electrical Engineering, IIT Bombay)

Speakers:

- Prof. Pradeep Dixit (IIT Bombay) - Sensor Packaging
- Prof. Pramod Murali (IIT Bombay) – Sensor Circuit Design
- Prof. Swaroop Ganguly (IIT Bombay) – Sensor Design
- Prof. Ravindra Gudi (IIT Bombay) - Sensor Network Design
- Prof. Ajit Rajwade (IIT Bombay) – Sensor Data Processing
- Prof. Mrinal Kumar (Ohio State University) - Sensor Data Processing

Prof. Pradeep Dixit

Development of through-glass vias interconnects by electrochemical discharge machining

Prof. Dixit talked about through-hole vias-based glass interconnects. for MEMs integration into IC packages. Etching with electrochemical discharge is a low-cost alternative to laser and plasma etching. Electrochemical discharge etching can also be done on glass, which the advantage of good insulation and transparency over silicon. He showed examples of 3D inductors produced by his technique.

Prof. Pramod Murali

Miniature Sensor Interface Circuits

Prof. Murali explained that a single sensor has to encompass a lot of functionality in one chip. These include many sensors, ADC, digital signal processing, and communication protocols. He showed a gas sensor on a CMOS chip, with a passivation layer replaced by gas sensing material. Biological flow sensors based on magnetic field sensors and contamination sensors were discussed.

Prof. Swaroop Ganguly

Vibration-based Electronic Nose Sensing – circuits and ML perspectives

Prof. Ganguly discussed the development of a vibration-based electronic nose sensor. An electronic nose has many applications in defense, perfume, food industry, and disaster management. The sense of smell might originate from the vibrational spectra of a compound. Inelastic tunneling spectroscopy can be used to make an electronic nose based on vibration sensing.

Prof. Ravi Gudi

Sensor Network Design – critical design factors

Prof. Gudi gave a talk about networks of sensors in modern applications like aircraft, power distribution, defense technologies, wherein efficient intercommunication is critical. Prof. Ravi Gudi talked about general design parameters like network observability, controllability, lexicographic optimization, noise, and disturbance reduction.

Prof. Ajit Rajwade

Compressed Sensing: Measuring Data Smartly in the Big Data Era

Prof. Rajwade described efforts in his groups, along with collaborators, to draw inferences from large amounts of sensor data using relatively few measurements through intelligent acquisition. Their uses inherent properties of the data to enable under-sampling and thereby save measurement resources. He illustrated this approach with applications: COVID testing, and medical imaging (MRI, CT scan).

Prof. Mrinal Kumar

Separating uncertainty from ignorance for sensors operating in an adverse environment

Prof. Kumar described the efforts of his group to enable correct inferences from sensors operating in adverse environments, where they are desirably autonomous in order to keep humans from harm. He illustrated this with the topical example of evolving wildfire (in New Mexico), monitored by a combination of temperature sensors, vision sensors and computational forecasting – based on evidential fusion and Bayesian fusion.

Panel Discussion 1: Translating Sensor Research into Products in India

Moderator: Swaroop Ganguly

Panelists:

- Dr. Suraj Rengarajan (Applied Materials)
- Prof. Vasant Kumar (Cambridge University)
- Mr. Shashank Kumar (Multi Nano Sense Technologies)
- Prof. Ravi Gudi (IIT Bombay)
- Ms. Poyani Bhatt (SINE)
- Mr. Runal Dahiwade (Peppermint)



Ms. Poyni Bhatt (CEO, SINE)

Society for Innovation and Entrepreneurship (SINE) was set up under the umbrella of IIT Bombay targeted to fill the industry – academia gap in the ecosystem. It was one of the earliest incubators in the country set up in early 2004 when the industry was not in sound engagement with the academia. In recent times, sensor based IoT has seen several start-ups emerging in different fields e.g. medical, agriculture etc. Few of these start-ups have spun up from SINE. The major challenge faced by any start-up is industry – academia integration from within the business to business space primarily due to machine/data security. The time for an innovation to reach the market is further stretched unless there is an upfront capital. Thus convergence is of utmost importance, i.e. an affordable business model that can be useful to the common mass.

Mr. Runal Dahiwade (Founder & CEO, Peppermint)

Mr. Dahiwade explained that Peppermint is a robotic start-up based in Pune specializes in house-keeping robotics for futuristic smart homes/offices. These machines are embedded with a plethora of sensors e.g. ultrasonic, LIDAR, three dimensional depth camera, navigation system, IMU sensors etc. The major challenges in devising these outstanding machines were (i) powering the various sensors simultaneously (ii) assembling and managing the huge sensor response data (iii) ease of production and certification and (iv) powering and large scale integration of the robots.

Mr. Shashank Kumar (CEO, Multi Nano Sense Technologies Private Limited)

Mr. Kumar explained that MNST mostly focuses on MEMS based gas sensors for a variety of application areas e.g. food personal safety, environment monitoring etc. These sensors are mostly designed to carry out smart sensing for intelligent selection. MEMS is not industrially advanced in a developing economy like India and hence collaboration with IIT Bombay plays a key role as: (i) engaging with faculties (ii) research and innovation resource. This academic collaboration has helped a great deal in the translational journey from research to product development.

Prof. Vasant Kumar (Professor, Cambridge University)

Prof. Kumar explained that the journey of translating sensor research spans the following.

- (i) The foundation phase involving basic research
- (ii) The discovery phase focussing on follow-on research, mostly to mark the stakeholders, adequate funding etc.
- (iii) The post research phase involving intellectual property, publicity and network of interests;
- (iv) the real world experts phase including deep collaboration and multiple networking paths
- (iv) The deployment phase which includes licensing, consultancy, mutual knowledge transfer through continuous engagement across networks of technical stakeholders.

He gave the following examples from his personal research experience illustrating the above discussed steps of translational research. First, recycling and recovery of batteries thus generating their circular economy. Second, solar light activated materials for destroying pollutants and microbes in air and water. Third, advanced electrodes and electrolytes for next generation batteries.

Dr. Suraj Rengarajan (CTO, Applied Materials India)

Dr. Rengarajan explained that Applied materials is the biggest semiconductors and display equipment company headquartered at Bengaluru. Sensors have come to play a major role in our daily life with the advent of automation since a huge amount of data is gathered from the artificial intelligence (e.g. Alexa) unlike the initial days when it was mostly manual. So, the sensor market will definitely grow in the years to come. Applied Materials engages with academia (e.g. IIT Bombay, IIT Kanpur, IIT Madras etc.), research institutes (e.g. IMEC, Belgium) and industrial giants (Qualcomm, IBM, VESPER, TSMC, Texas Instruments etc.) mostly as customers to check for proof of concept. In order to take a sensor research to product, it requires involvement of (i) customers (of various application fields) (ii) ecosystem e.g. talent, infrastructure (to run in continuous fashion) and (iii) imperative parameters involving big end market, government initiative etc. The sensors have potential applications in a variety of fields thereby customizing their technology as IoT based sensors, healthcare monitoring wearables, gas and industrial sensors, piezo and MEMS sensors and automotive sensors.

Prof. Ravi Gudi (Professor-in-Charge, IIT Bombay Research Park)

Prof. Gudi explained that the Research Park was initiated five years back with the vision and thought of the 4Ds: discover, demonstrate. develop and deploy. This initiative facilitated the easy intermingling of industry and academia and exposed the students to the industrial environment. There are various research centres at IIT Bombay to this effect which has flourished in due course. The current research park clients include Applied Materials, Viacom18, Ubisoft, DRDO etc. Atomberg Technologies, Nanosniff, Igren Energie and Idea Forge were incubated in SINE. There are several modes of engagement of IIT B Research Park with the industry through R&D projects, faculty visiting fellowships, student sponsorship etc. Conclave in data science and AI included 93 participants from IIT B and the industry. In summary, such industrial collaboration has been highly beneficial via joint technology development with the industry and enriching the R&D resource of the country.

DAY-2

Session 3: Sensor Applications for Industry 4.0:

Chair: Prof. Soumyo Mukherjee (BSBE, IIT Bombay)

Speakers:

- Prof. Siddharth Tallur (IIT Bombay) – Sensors for Structural Health Monitoring
- Dr. Ajay Agarwal (CSIR-CEERI) - Sensors for Industrial Applications
- Dr. Nitin Kale (Nanosniff) – Sensors for Explosive Detection
- Dr. T.N. Satish (DRDO-GTRE) - Measurements in Propulsion Systems

Prof. Siddharth Tallur

Sensor System for Structural Health Monitoring

Prof. Tallur described low cost ultrasonic sensors to analyse structural defects in honey comb sandwich structures found in aircrafts and implementation of compressive sensing to prevent data loss during transmission. Also, explained work in cathodic protection system where PZT sensors were developed to monitor corrosion of electrodes. Development of low cost pulse eddy current sensors to monitor corrosion of infrastructures were also discussed.

Dr. Ajay Agarwal

Miniaturized Sensors for Industrial Applications

Dr. Agarwal described major research areas where work have been done such as Inertial sensors, pressure sensors, gas sensors, ISFETs based pH sensors, MEMS, Capacitive micro machined ultrasonic transducers (CMUT), RF switches, microfluidics etc. One of the major applications are in environmental sensing where MOS sensors were developed for the detection of harmful gases such as ammonia, NO, CO, VOCs etc. These gas sensors were then networked for IoT applications. Pressure and temperature sensors were also developed for Naval applications such as MAV launch vehicles and high temperature measurement.

Dr. Nitin S Kale

Nanosniff – an explosive trace detector

Dr. Kale discussed work in the areas of explosive detection and development of the Nanosniff detector. Explained the working of nanosniff detector which has been able to decrease the purging time to 5 minutes, achieved high selectivity and sensitivity. To generate explosive signature micro heater have been used without the need for long baking period of sample swabs. Results are generated in situ with real time measurement.

Dr. T. N. Satish

Challenges in Measurements Related to Propulsion Systems

Dr. Satish described work being done in gas turbine research and challenges being faced during the measurement of signals essential for the improvement of designs. Research is focussed in areas such as propulsion technology, component level testing after simulation, gas turbine engine, temperature probes, pressure sensors, position sensors, resolvers (coordinate transformers), thrust measurements, engine health monitoring, vibration signal analysis, tip clearance measurements, reluctance type chip detector, thin film technology.

Keynote Address 2: Sensor Solutions for Affordable IoT Solutions in the Developing World

Prof. Ramgopal Rao (Director, IIT Delhi)

Sensor Solutions for Affordable IoT Solutions in the Developing World

Prof. Rao explained how technological innovation in Security, Healthcare, Agriculture, Pedagogy, Energy & Environment ('SHAPE') can improve national health, wealth and safety. He emphasized the huge opportunity for sensor technologies in particular. Thereafter, he gave the audience a historical perspective of the development of various sensor technologies at IIT Bombay where he was involved directly, as a collaborator, or as part of a group of faculty members coalescing around a common R&D theme such as microfluidics. He extolled the virtues of collaboration between scientists and engineers for sensor development, and the amplifying power of centre-like projects. He described some of the sensor development in his group that led to products for healthcare sensing, explosive sensing and soil moisture sensing, and how these led to startups. He exhorted faculty members to get into incubation and mentioned his efforts in this direction at IIT Delhi.

Keynote Address 3: Space-based Remote Sensors & Associated Technologies

Shri Nilesh Desai (Director, ISRO – Space Applications Centre)

Space-based Remote Sensors and Associated Technologies

Shri Nilesh M. Desai explained the role of ISRO-SAC in space technology development e.g. microwave remote sensing systems, deployable antennas, infrared cameras and detectors for payloads of navigation satellites, meteorological and communication satellites. It had developed sensor payloads for several pioneering missions including Mars mission, Bhaskara etc. Microwave remote sensing were first introduced in 1970 as satellite microwave radiometers (SAMIR) in Bhaskara I/II after which it has continuously developed and flourished e.g. X band side looking Airborne Radar (SLAR), high frequency Scatterometers etc. In recent years, Earth observation and deep space observation missions have been greatly enhanced and consolidated with the advent of space based passive microwave sensor payloads Oceansat-2, Scansat I scatterometer etc. Recently, SatCom and SatNav Advanced Applications are being worked on greatly.

Panel Discussion 2: Sensing the Future of Ubiquitous Sensing

Moderator: **Dipti Gupta**

Panelists:

- Dr. Ajay Agarwal (CSIR-CEERI)
- Dr. Chandrasekhar Nair (Bigtec)
- Dr. Beena Rai (TCS)
- Dr. Alpana Dubey (Accenture)
- Prof. Amit Agrawal
- Prof. Kasturi Saha (IIT Bombay)



Sensor usage is growing and almost trillions of sensors would be added up in the next decade. Ubiquitous sensing will enhance awareness of the cyber, physical, and social contexts of our daily activities, that will change our lives. The purpose of this panel discussion was to understand about the key trends, future technologies in sensor development, market trends, is our research adopting to these future trends and is our industry ready to adopt these trends. These questions are very pertinent to ask at this point of time, so that we are able to develop frontier technologies and gauge niche markets. The panelists had a wide spectrum ranging from academia, industry and R&D organization.

Dr. Ajay Agrawal (CSIR-CEERI)

Dr. Agarwal discussed about point-of-care sensors and systems, low power sensors, multi-sensing capabilities and have taken use cases from healthcare, environmental care, food and agri-sector. He also suggested to adopt cost-effective materials and fabrication technologies to have easiness of scale up. He also emphasized that in order to enable quality research to be conducted in futuristic technologies, industries should come in and they should be incentivized by the government such as reducing taxes.

Dr. Beena Rai (TCS)

Dr. Rai talked about soft/virtual sensors and digital twins and their implementation in food quality monitoring as a use-case. She emphasized that it is very difficult to put physical sensors everywhere and has discussed about the issues in food supply chain. The combination of virtual sensors which are based upon models, AI and algorithms would not only enable sensing at a large scale and sensing from

difficult places but would also bring frugality and cost-effectiveness. The digital twins thus would be very useful.

Dr. Alpana Dubey (Accenture)

Dr. Alpana Dubey talked about the importance of human computer interaction, neuromorphic computing, edge computing and virtual reality enabled sensing systems. She gave examples from the sensory systems and emphasized about how human sensing experiences can be modified with a combination of physical and virtual devices. She also mentioned that industry lab research is very much goal, time-based and profit oriented while academic labs have lots of freedom. However, she also emphasized that Accenture supports lots of futuristic research in the industry as well as in academia.

Prof Kasturi Saha (IIT Bombay)

Prof. Saha gave us the glimpses of quantum sensors and in what way they are different than conventional sensors. She mentioned that how can they complement the current sensor technologies and suggested few potential applications. She also emphasized that quantum technology which is currently being considered as very futuristic and expensive would become widely available and cost-effective.

Prof Amit Agrawal (IIT Bombay)

Prof. Agrawal talked about new trends easily adoptable in lab-based research and has taken translation of microfluidic research into products as an example. He also mentioned about the difficulties that one face in academic set up in translating research to products.

Dr. C. Nair (Bigtec)

Dr. Nair discussed about preparedness of the industry in adopting any futuristic or new trends. He emphasized that industry is always ready to adopt any new technology if it finds potential benefits and mentioned that it is industry that makes any technology successful. However, he mentioned that there are lots of hurdles that needs to be overcome before one moves to the market, it is especially long in healthcare sector.

Session 4: Sensor Applications for Society

Chair: Prof. C. Subramaniam (Chem, IIT Bombay)

Speakers:

- Prof. Maryam Shojaei (IIT Bombay) - Sensors for Precision Agriculture
- Prof. Rajesh Zele (IIT Bombay) - Sensor Networks for Air Quality Monitoring
- Prof. Soumyo Mukherji (IIT Bombay) - Water Quality Sensors
- Prof. Dipti Gupta (IIT Bombay) - Wearable Sensors
- Prof. Rohit Srivastava (IIT Bombay) - Sensors for Healthcare Monitoring
- Prof. Debjani Paul (IIT Bombay) - Sensors for Healthcare Monitoring
- Prof. Suparna Mukherji (IIT Bombay) - Sensors for Environmental Monitoring
- Prof. Rinti Banerjee (IIT Bombay) - Sensors for Diagnostics

The 4th session of the workshop featured speakers exclusively from IIT Bombay and showcased the technologies that have been developed from various department of IIT Bombay.

Prof. Rajesh Zele

Wireless sensor network design for air quality monitoring

Prof. Zele, from Electrical Engineering, presented the developments in this lab, directed towards the development of affordable and miniaturized air-quality monitoring systems. These battery-run electrochemical platforms could be deployed en-masse and connects to a cloud for deriving air-quality parameters over a large geographical area. This presents a distinct advancement over the conventional, bulky air-quality centres that currently exist.

Prof. Suparna Mukherjee

The need for sensors in water quality monitoring and inherent challenges

The focus now shifted towards water and emerging contaminants of water. Prof. Mukherjee, from the Centre for Environmental Science & Engineering, presented the huge range of possibilities and potentials for developing point-of-care sensors for assessing water quality, particularly in the context of emerging contaminants such as microplastics, heavy metal ions (from industrial effluents). The presentation also detailed the challenges with current methods of estimation of BOD and COD. The discussions veered towards easier routes to achieve rapid validation of such new technologies and the need to sensitize the policy-makers towards emerging environmental contaminants.

Prof. Soumyo Mukherjee

Nanostructure decorated optical fiber sensors

Complementing the previous talk, Prof. Mukherjee from Biosciences & Bioengineering presented the advancements in his laboratory that directed towards the development of optical sensors for water quality monitoring. His presentation showcased the power of U-bent optical waveguides as platforms for qualitative and quantitative analysis of several contaminants such as heavy metal ions, bacteria and other pathogens in water sources and food produce such as cabbages and fishes. The platform is easy to deploy and can be run as a plug-and-lay module for analytes ranging from Hg to pathogens.

Prof. Maryam Shojaei

Sensors and systems for productive agriculture

Prof. Shojaei, from Electrical Engineering, complemented the discussion by presenting advancements in the development of back-end ASIC and micro-processor based technologies for signal acquisition and processing to culminate in a digital readout for the end-user. The impressive range of technologies towards development of sweat sensors, agricultural sensors along with the advantages of these over conventional approaches was presented. This talk truly complemented the other developments that were presented in the workshop.

Prof. Rohit Srivastava

Affordable healthcare technologies

This talk heralded a segue into healthcare sensor technologies. Prof. Srivastava from Biosciences & Bioengineering presented a range of technologies that have been developed in his laboratory and associated start-ups for biomedical diagnostic devices related to cardiac disorders, Hemoglobin levels and glucose detection kits. The concept and path from lab-to-market that were presented was truly impressive.

Prof. Debjani Paul

Detection of sickle cell anemia at point of care

In her talk, Prof. Debjani Paul from Biosciences & Bioengineering presented an optical platform for accurate detection of sickle-cell anaemia. Both these talks presented the various pathways available for translational research in the bio-medical diagnostic domains.

Prof. Dipti Gupta

Wearable sensors and applications

The final speaker for this session, Prof. Dipti Gupta from Metallurgical Engineering & Materials Science, discussed the recent developments in detection of mechanical forces such as tensile and compressive stresses. The sensors developed in her lab, in this direction, have been seamlessly extrapolated for monitoring of breathing patterns, blood flow in the arteries and consequently cuff-less blood pressure monitoring systems. These presented an innovative approach by the synergistic combination of materials and substrates to achieve ultra-sensitive detection of mechanical forces.

Valedictory Session

The closing remarks were given by the Associate Dean R&D, **Prof. A. M. Pradeep**, where he thanked all the speakers, participants and organizers.

