·|| Sūkshma ||·

A newsletter about micro and smart systems in India

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CONTENTS

NAL's new tape-casting unit for processing piezoelectric materials

NAL-ISSS Seminar on Smart Materials & Technologies

G. M. Kamath

The research in smart technologies was initiated at National Aerospace Laboratories (NAL), although at a modest level, more than a decade back. Materials development has been an important aspect of this effort. Towards the goal of manufacturing indigenous materials leading to new devices, two facilities have been recently set up at NAL: a tape-casting facility for the processing of piezoceramic materials and a vacuum arc melting facility for manufacturing of shape memory alloys. On August 23, 2007, these facilities were inaugurated by Dr. V.K. Aatre, former SA to RM and currently Visiting Professor at ECE Dept., Indian Institute of Science. The inauguration was followed by a Seminar on Smart Materials and Technologies held under the aegis of NAL and the Institute of Smart Structures and Systems (ISSS). It is only apt that Dr. Aatre inaugurated this event. He has been championing the cause of this technology for more than a decade, and has largely been responsible for the government research programmes in this area. In his inaugural address he said that the programmes carried out so far have produced many successes.

(Left to right) Prof. S. Gopalakrishnan, Dr. V.K. Aatre, Dr. T.G. Ramesh, and Dr. A.R. Upadhya.

Dr. V.K. Aatre inaugurating the vacuum-arc melting furnace at NAL.

The inaugural function was presided by Dr A.R. Upadhya, who was wearing the two hats of Director, NAL and President, ISSS. In his presidential address, he recalled how the foundations for this research at NAL were laid with the help of projects funded by agencies such as ARDB and DST. Thus, when the specific programmes such as DISMAS and NPSM (*see* Vol. 1, No. 1, p. 1) were initiated, NAL was well placed to take up and execute the projects. He also highlighted the role of ISSS towards promoting these technologies. This is being done, he said, through its national and international conferences, training programmes for engineering faculty, industry meets, and this newsletter *Sūkshma*.

The one-day seminar, coordinated by Dr. T.G. Ramesh, Head, Materials Division, covered a wide spectrum of research and development. Nine lectures were spread over two sessions chaired by Prof. S. Gopalakrishnan of IISc and Dr. K. Vijayaraju of ADA. Four lectures were from scientists of the Materials Division covering the ongoing work on development of piezoceramics (Dr. P.K. Panda), piezopolymers (Dr. Anjana Jain), shape memory alloys (Dr. S.K. Bhaumik) and Micro-electro-mechanical systems (Dr. Soma Dutta). Two lectures by Ms. Shashikala Prakash and Mr. V. Shankar covered the work in the areas of vibration and aeroelastic control, smart structures modeling, and instrumentation development being carried out in the Structures Division. Technologies related to aerodynamic shape control (Mr. G.N. Dayananda) and structural health monitoring (Dr. G.M. Kamath) being developed in the Advanced Composites Division were the topics of two talks. Prof. G.K. Ananthasuresh from the Mechanical Engineering Dept., IISc, spoke on the devices being designed and fabricated by his group using the SMA developed at NAL.

The day's programme saw a good number of participants from research labs, academia, and industry. Speaking at the concluding session, Dr. Aatre stressed the need to have more of these seminars, which he felt would help in bringing together scientists of different disciplines and creating more opportunities for cross-fertilization of ideas.

Dr. G.M. Kamath is a scientist in the Advanced Composites Division of NAL. He can be reached at gmkamath@css.nal.res.in.

Vice-President's Message

P. D. Mangalgiri

Dr. Prakash D. Mangalgiri is the vice-president of ISSS. He is the lab group manager (smart systems modelling) at the India Science Lab, General Motors R&D, Bangalore. He can be reached at prakash.mangalgiri@gm.com.

In the last two decades or so, the "Smart" technology has grown steadily and has achieved maturity in several areas. MEMS based sensors and devices are finding increasing applications; smart materials such as, piezos, electroactive polymers and shape memory alloys (*see* Vol. 2, No. 3, pp. 4-5) are finding increasing use in building useful actuators for engineering functions; many new smart materials are developed with exotic properties and are now available for the designer; several active system applications are on the anvil in many engineering and non-engineering functions, such as structural health monitoring, vibration control and shape control, bio-fluidics, etc. These developments have also seen fusion of many diverse disciplines – from biology to rocket science – and this has been an essential ingredient in the growth pattern of the Smart Technology. Perhaps, the most important role that ISSS has played and continues to play in the Indian scenario is to bring about this amalgamation of people from various areas and make them conscious about working together in order to make fruitful contributions in the area of smart technology.

The 1996 International Conference at IISc was arguably the first major event which brought forward the need for a forum in India which can bring together professionals from various disciplines and provide them an opportunity to not only work together but also to participate in shaping up the future developments. We as members of ISSS can legitimately be proud of the events that took place subsequently – the creation of ISSS in 1998 under the guidance of Dr VK Aatre, participation of ISSS in major National Programmes (NPSM and DISMAS) not only in the decision making process but also in the implementation of its programmes, and the awareness programmes that ISSS has conducted for various universities and institutions. The series of triennial International Conference that we organize has gained international recognition and prestige with continuously improving technical content and foreign participation. Our efforts of holding an annual conference are showing good results. We now need to bring in more participation of the industries into our fold so that the technologies that are in the pipeline get a chance to be applied in practice. We need to examine and sort out issues which will help us make a good "business case" for the industries to participate. Our membership should spread to the R&D and Engineering units of such industries. This should pave the way for corporate membership of industries and their participation in our activities.

Even as we look back on some of our achievements as a professional society, it is hard to miss the point that the pace of the technological developments in the area of smart systems that are taking place all over the world calls for a more concerted and effective action on our part in order not to be left behind. Our President, Dr Upadhya, in his message to "Sukshma" last month clearly outlined a series of tasks that we need to undertake in order to derive the benefits of the smart technology and make ourselves counted in the international scientific effort.

I thank "Sūkshma" for giving me this opportunity to share some of my thoughts with the fellow members. Let us all dedicate ourselves to the task and follow the path laid out for us.

Conference Announcements

2nd ISSS National Conference on MEMS, Microsensors, Smart Materials, Structures and Systems (ISSS-MEMS 2007), November 16-17, 2007, jointly organized by CEERI and BITS in Pilani, Rajasthan.

http://www.bits-pilani.ac.in/isssmems2007/

Important dates

Submission of abstracts:	October 1, 2007
Acceptance notification:	October 10, 2007
Full paper submission:	October 15, 2007
Advance registration closing:	October 30, 2007
Conference dates:	November 16-17, 2007

One-day Symposium on Compliant Mechanisms in IISc, Bangalore, on December 17th, 2007. www.mecheng.iisc.ernet.in/~cmsymp.

10th International Conference on Advanced Materials (IUMRS-ICAM 2007) on 8-13 October 2007, Bangalore. http://www.icam2007.com.

13th National Conference on Machines and Mechanisms on December 12-13, 2007, Bangalore. http://www.mecheng.iisc.ernet.in/~nacomm07.

Editorial Team

G.K. Ananthasuresh, IISc (Editor)
S. Gopalakrishnan, IISc
J. Gurudutt, Bigtec
G.M. Kamath, NAL
K.J. Vinoy, IISc

Art Design: G. Bharathi

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Industry Watch: Qtech Nanosystems

Rudra Pratap

Qtech Nanosystems, founded in 2004, designs, develops, and manufactures select nanotech products (see picture below for sample nanopositioning products). It also performs collaborative research activities with a number of premier academic and private research organizations, and undertakes consultancy tasks in nanotechnology. The main areas of its current focus are as follows.

Nanopositioning Technology: Precision application requires the ability to position devices and tools accurately within nanometer range. The technology used to achieve this is called *Nanopositioning Technology.* Nanopositioning devices (nanopositioners) are basic tools for a range of research, manufacturing, and test applications in the semiconductor, data storage, optoelectronics, chemical, and biotechnology industries. The ability to probe, measure and manipulate at the nanoscale is essential to nanotechnology R&D. Ultra-precise positioners and motion controllers are key components of larger instruments, such as critical-dimension measurement tools, profilometers, scanning probe microscopes, optical microscopes, and high precision robots—tools used in manufacturing and test operations that involve ultra-precision machining, inspecting, and testing of parts.

Nanomanipulation Technology: The individual control of molecular composition and placement is often cited as the goal of nanotechnology. It is always exciting to play by moving and manipulating cells, molecules and atoms. Qtech is working on nanomanipulators with application focus in biotechnology and medicine.

Nanoparticles – Solid State Materials / Inorganic

Qtech is developing solid-state materials such as piezos for actuation and sensors. It uses nanomaterials-based concept as a building block. It is trying out several possible options with different nanomaterials such as nanotalc, nanosilica and quantum dots. Qtech has developed NanoTalQ particles of size ranging from 20–100 nm. NanoTalQ is obtained by reducing the size of commercially available Talc (hydrated magnesium silicate) to nanometer scale. The chemical composition of NanoTalQ is $Mg_3Si_4O_{10}(OH)_2$. NanoTalQ developed by Qtech Nanosystems is an inert material. It is also harmless and is available in two forms: (i) Slurry or suspension (colloidal state) and (ii) Powder form. It can be used in fillers, extenders, additives, or as a coating material depending on the application.

Qtech Nanosystems is a very small company — just five bright and enthusiastic young fellows — but it already has five provisional patents in nanotech! This is the kind of company that India Inc. needs to figure out how to replicate in thousands. The energy, the aspirations, the attitude of the young India needs to get channelized in thinking and creating technology to solve problems, deliver products, and create wealth for the nation. We wish such companies the very best and stand to support them in all respects.

Dr. Rudra Pratap is an Associate Professor of Mechanical Engineering in IISc. He can be reached at pratap@mecheng.iisc.ernet.in.

Leaders of ISSS: Professor Ananth Selvarajan

Professor Ananth Selvarajan is a founding member of ISSS. He is a Professor Emeritus of the Department of Electrical Communication Engineering. Prof. Selvarajan was born on 10 September 1938 in Tindivanam, Tamil Nadu. He obtained his B. Sc. degree from Madras University in 1961 standing first in the college. He obtained the M. Sc. degree in physics from Annamalai University in 1964 and Ph. D. from the ohysics department, Indian Institute of Science in 1979.

After a brief period of service in the physics department, IISc, Prof. Selvarajan moved to the department of Electrical Communication Engineering in 1972 as a lecturer and stayed there for nearly three decades. He became a professor in 1991. He was the chairman of the department from 1995-1999. During his chairmanship several important changes were brought about. Notable among them are the starting of two new ME programmes in Signal Processing and Microelectronic Systems, and restructuring the earlier ME (ECE) programme as ME Telecommunications. He successfully organized the Golden Jubilee celebrations of the department in 1996.

Professor Selvarajan's research interests include photonics, MEMS, and smart structures. He has been instrumental in leading India into the photonics era. He has the distinction of developing and nurturing one of the unique groups in India working in both theoretical and experimental areas of applied photonics. He was quick to recognize the emerging areas in applied photonics such as fiber optic communications, integrated optics, smart structures and micro-opto-electro-mechanical systems (MOEMS) at a very early stage and initiated teaching and research in these areas. He has guided nearly 30 research students and has over 150 publications to his credit. He also worked on several research projects sponsored by industry and government on topics such as acousto-optic filters, integrated -optic switches, fiber-optic gyroscope and microwave photonics.

Prof. Selvarajan has also been very active in interacting with peer groups both in academics and industry. He has been an active member of executive committee of IEEE Bangalore Section and has been the Vice-Chair during 2002-2004. He has played a key role in organizing the biannual international conference on photonics in India, the first two of which were held in Bangalore in 1991 and 1994 under his technical chairmanship. He has held several visiting positions at University of Uppsala, Sweden (1969-70), University of Arizona, USA (1977-79), Technical University of Denmark (1986), University college London (1987) and International center for Theoretical Physics, Italy (1991, 1993). He played a major role in NPSM (*see* Vol. 1, No. 1, p. 1) activities. He was instrumental in initiating National MEMS Design Centers under NPSM (*see* Vol. 2, No. 1, p. 1). He was also responsible for creating the satellite MEMS design centers at various Institutions. He is also the chairman of the MCIT technical working group in photonics. Through this he has initiated several research activities in photonics at various institutes in the country. He is presently formulating a national program on nano-bio-photonics to bring together researchers and educators working in the broader area of mico-nano-photonics and make India the photonics hub of the world in the near future.

ISSS thanks Professor Selvarajan for his leadership and contributions in research and education.

MEMS for Space Applications

T. K. Alex

Space exploration in the coming decades is expected to be based on cost-effective missions where ultra-miniature and robust systems are used extensively. This would result in frequent multiple missions that broaden the scope of space science and would allow experimentation with new technologies on a timely basis. Microelectromechanical Systems (MEMS) is one of the important enabling technologies to create such systems for space applications. Last decade has seen many promising examples of MEMS devices which include micro gyroscope, micro accelerometer, magnetometer, micro mass-spectrometer, RF components, and micro propulsion engine. Associated developments are taking place in the area of nano-electronics, nano-materials, optical MEMS devices, nano-devices and nano-sensors, photonics, bio-nano-technology, MEMS-based smart materials and structures, Ferro-electric MEMS, and piezo-electric MEMS.

The evolving MEMS technology promises to revolutionize many sensor and control systems for satellites. Besides these subsystems, MEMS technology has shown the way to realize scientific instrumentation to spacecraft engineering subsystems leading to nano and pico satellites which opens up new avenues for space exploration.

Space is considered a key player in new technologies. However adaptation of new technology for long-time missions is always considered with great caution. The reasons for this are the long and costly qualification programs that are directly linked to the combination of long life-time (15 years for geostationary orbit (GEO) satellites) and operation in harsh environment. But the satellite industry could experience in the coming years its biggest evolution thanks to increasing constraints on performance, cost, and development cycles. It is possible that space industry could be at the cutting edge of the major technical evolution which is taking place in the MEMS technology.

Indian Space Research Organization (ISRO) centers have been active in experimenting with MEMS technology with the ultimate objective of consolidating these efforts to be able to rapidly incorporate MEMS into future space systems. Future space missions of ISRO incorporating new miniaturized instrument designs could benefit significantly from the application of MEMS technology. The facilities available at the ISRO laboratories (Laboratory for Electro-Optics Systems (LEOS) and Semiconductor Complex (SCL)) will enable the design, testing, and implementation of a broad range of MEMS devices such as magnetic sensors, accelerometers, gyroscopes, RF components, and micro propulsion systems (see some of ISRO's MEMS devices in Figs. 1-4).

Microsystems on a chip

The application of MEMS technology does not end with devices; the logical extension is towards 'microsystems on a chip'. The creation of microsystems that sense, think, act, or communicate requires electronic circuitry coupled with mechanical elements. Monolithic integration of electronic circuitry on the same chip as electro-mechanical devices has many advantages over approaches that involve complex multi-chip packaging schemes. Reducing the chip count, eliminating the bond wires connecting electrical to mechanical circuits, and reducing the complexity of the packaging assembly process would improve reliability. For effective development of micro-navigation system three-axis accelerometers and gyroscopes are required. Additionally, 'system on chip' would become necessary to get maximum benefits.

MEMS for in-situ characterization instruments

MEMS sensors and actuators are ideal candidates for instruments for in-situ characterization of gases, minerals for lunar and interplanetary missions. Some of the instruments used include micro fabricated gas spectroscopy system, quadruple mass spectroscopy system, X-ray diffraction/ fluorescence Analyzer, laser induced break down spectrometer etc. These instruments are used for mineral and elemental identification and soil/rock analysis from probes to be deployed from the lander or included as a part of a rover.

Development models of MEMS accelerometers have been realized at LEOS (see Fig. 1), ISRO Inertial Systems Unit (IISU) and SCL. The design challenges for the accelerometer include minimizing area, maximizing sensitivity, maximizing the detectable acceleration range and minimizing movement of the proof-mass in the orthogonal direction to sensing. Upgrading of the cirrent micromachined accelerometers to inertial grade sensor needs improving the sensitivity, reducing the bias instability, enhancing the reliability, and suppressing the noise in the mechanical and electronic elements.

Micromachined gyroscopes have been developed by different researchers. One of the commercially available MEMS gyros features analog electronics and compensation circuits, giving a bias drift of 10 deg/Hr and 0.1 deg/Hr bias repeatability. The sensor can survive 50 g acceleration and consumes 250 mW power. Advanced designs feature digital drive scheme, better compensation and low flicker noise. Electrostatic balancing provides very low noise performance. Fully ASIC version for three axes giving random walk better than 0.1 deg/Hr/Hz $^{1/2}$ and with a power consumption of less than 3 W and radiation hardened for GEO orbits is the design target taken as the next challenge by the developers.

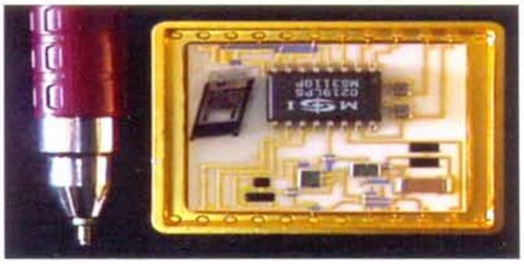


Fig. 1. LEOS's micromachined accelerometer

Fig. 2. LEOS's micro-bolometer

Silicon photo detectors in very many geometries and infrared bolometers (which are instruments measure radiation) have been realized using MEMS technology. Micro-machining allows thermal isolation of small detectors, enabling both uncooled and cooled bolometer arrays to offer very high performance. Micro-bolometers for use in IR-Earth Horizon sensors are commercially available. JPL/ Caltech (Jet Propulsion Laboratory and California Institute of Technology) have developed a MEMS bolometer for the ESA/NASA (European Space Agency and National Aeronautics and Space Administration) Planck Surveyor mission in 2008. LEOS has developed a micro-bolometer (see Fig. 2) with a sputtered thermistor detector and a compensating thermistor in a TO5 Package. SCL has demonstrated an array of uncooled micro-bolometer for thermal sensing application.

MEMS for nano and pico satellites

The logical extension of MEMS technology for space is the development of nano and pico satellites. Satellites are classified according to their weight. Picosats are less than one kilogram while nano-satellites range from 1 to 10 kilograms. Other classes are microsats (10 to 100 kilograms) and smallsats (100 to 1,000 kilograms). The smallest category envisioned is the femtosat, less than one-tenth of a kilogram, a satellite that would handle very simple missions.

Nano-satellites are finding many applications that include cooperative constellations, synthetic aperture antennas, local swarms of nano-satellites, inspection and service missions, etc. Mass production using semiconductor technology and incorporating high-level building blocks called application-specific integrated micro-instruments, or ASIMs, would characterize nano satellite architecture and assembly. The use of MEMS technology enables the realization of low-cost, reliable, integrated space systems. Nano-satellites would become excellent platforms for a number of scientific studies in space.

The first PICOSAT pair, OPAL/PICOSAT was launched into space by the US Air Force on 26th January, 2000. The EL SEGUNDOA mission developed under the sponsorship of the US Defense Advanced Research Projects Agency is a test bed to validate MEMS devices. This experiment consists of two tethered picosatellites, each weighing less than 250 g. Picosats can also serve as a link to nano-satellites. The two orbiting picosats are to be tethered so that they will communicate via micro power radios. The tether will keep them within range of each other. The tether contains thin strands of gold wire to facilitate radar tracking. Concepts for the future involve optical communication via fiber optic tethers and other cluster architectures for miniature satellites for which experience with tethers is useful.

Microfabrication facilities of ISRO

Recognizing the importance of MEMS in space applications, ISRO has established specialized facilities for MEMS development at LEOS, Bangalore, and SCL, Chandigarh. They include design software, wet and dry lithography facilities, photo-mask writer, double side bonders, and test and evaluation facilities for sensors. Limited packaging facilities also exist at SCL. Using these facilities ISRO plans to develop sensors and other devices both as hybrid micro packaged devices and monolithic devices integrated with processing electronics.

Reliability and packaging of MEMS are of concern for space technology. Special attention is required in generating specifications, quality control in various processes, and test and evaluation methods.

MEMS devices for space applications

Accelerometers, gyroscopes, photo detectors, RF MEMS, optical MEMS, micro propulsion systems, magnetometer, various types of sensors, etc.

Suggested Reading

Proceedings of the ISRO workshop on MEMS, Nov. 2006, and the references therein.

Dr. T.K. Alex is the Director of Laboratory for Electro-Optics Systems (LEOS), Indian Space Research Organization (ISRO), Bangalore. He can be reached at tkalex@leos.gov.in.

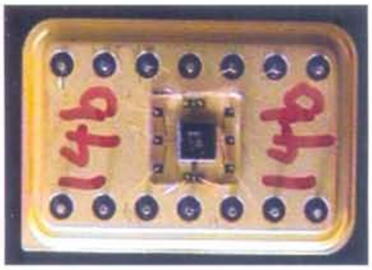


Fig. 3. LEOS's RF switch

MEMS technologies enable the fabrication of very compact low-loss RF switches (see Vol. 2 No. 2, pp. 4-5), as well as capacitors with a large tuning range. MEMS can be integrated into satellite payload subsystems to achieve a higher degree of functionality, for example in phase shifting unit, low level routing networks or reflecting array antennae. Temex (www.temex.com) has developed very small flat-pack oven controlled crystal oscillator (OCXO) for space applications. The 25 by 25 mm sized low-consumption OCXO is designed specifically for synchronization applications such as outer-space uplink/downlink communications where a wide operating temperature range and low energy consumption are critical. Such devices are just starting to be commercially available, for example from Teravicta (www.teravicta.com). RF switches were flown in space on the OPAL Picosats in 2000. IMEC, a laboratory for advanced research in microelectronics in Belgium, has led several studies into the reliability of RF MEMS for Space. Major satellite developing companies in the USA and Europe are considering introducing RF MEMS in their future telecom payload.

LEOS is developing a series and shunt RF switches in the 6-8 GHz range. Space Applications Centre (SAC) has initiated the design of different MEMS RF components under the Technology development programme.

MEMS technology has been successfully used for the development of flux-gate magnetometers and other types of magnetic sensors. The fabrication involves LIGA (a German acronym for electroplating and moulding) techniques for the magnetic circuit realization and electro-plating of high-permeability magnetic material as the core. LEOS has developed a MEMS magnetometer for use in ISRO's small satellite programme (see Fig. 4).

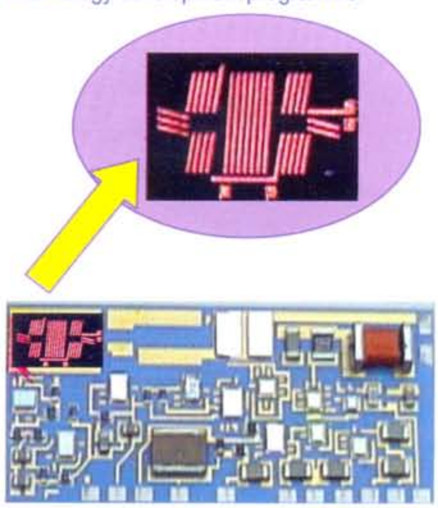
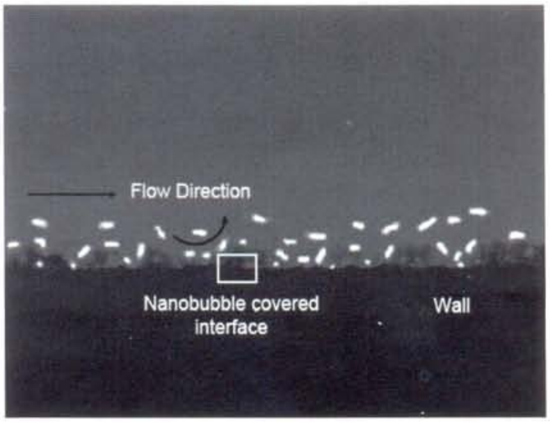


Fig. 4. LEOS's MEMS magnetometer

The ability to create structures and patterns on microscopic and sub-microscopic length scales has triggered a wide range of scientific investigations, leading to the development of novel miniaturized devices and systems for transporting and manipulating fluidic samples in a rapid, efficient and controlled manner. Microscale transport processes and microfluidics are becoming increasingly important in several emerging applications due to their inherent advantages such as high transfer coefficients (on account of large surface area to volume ratios), efficient process management, miniaturization of devices for specific applications, and addressability of cellular length scales. The applications are many in diverse high-technology areas including biotechnology and biomedical engineering, inkjet printing, and thermal management of electronic devices/systems. Keeping these thrust areas of research in vision, intensive interdisciplinary activities on these topics were initiated at the Indian Institute of Technology (IIT) Kharagpur several years back. With an initial grant from the Institute, a new facility titled "Microfluidics and Microscale Transport Processes Laboratory" was recently set up to advance these activities to a higher level.

As a background to this new facility, an agglomerated research initiative had already been taken up by the researchers in the Institute over the last 5 years, encompassing the Department of Mechanical Engineering (the nodal Department where most of the related research facilities are hosted) and other major contributing Departments, including Departments of Chemical Engineering, Electronics and Electrical Communication Engineering, and Biotechnology, in support with the Advanced Technology Development Center (ATDC). More than 100 high-impact international journal papers emerging from this group over the past four years aptly emphasize this background. At present, the laboratory hosts some of the most advanced research facilities in the area, in the forms of powerful optical microscopes and other flow visualization arrangements, micro-array spotter, micro-fluidic toolkits, potentiostat and zetameter, interfacial phenomena and contact-angle/film-thickness examination apparatus (goniometer/ellipsometer), novel microchannel-fabrication protocols for micro-mixing studies, and cell/DNA handling facilities in microfluidic systems. The laboratory is also equipped with the state-of-the-art design/analysis and computational fluid dynamics (CFD) software. Furthermore, in-house codes are continuously being developed and updated to cater to the needs of molecular to system-scale simulations.

A number of new research projects have been taken up by this group. The notable ongoing research projects include "A Study of Microscale Transport Processes leading to the Development of a Cooling Strategy for Electronic Components" (sponsor: DIT, Govt. of India), "Cell culture inside Microfluidic channels with extended air-water interface" (sponsor: DBT, Govt. of India), "DNA hybridization in microfluidic channels" (sponsor: DST, India and NSF, USA), "Characterization of Surface Roughness for Pressure-Driven and/or Electro-osmotic Liquid Flow in Microchannels" (sponsor: DELPHI). The laboratory has intensive international collaborations (including student and faculty exchange programmes) with the Bio-MEMS Research group of the University of California, Irvine and the Micro/Nano-Technology group of the University of Illinois at Urbana Champaign, which are being supported by the Indo-US Science and Technology Forum. Research is also ongoing towards the development of novel bio-microfluidic devices for blood extraction, in collaboration with the University of Tokyo and Tokai University, Japan, as supported by the JSPS (Japan) and DST. Furthermore, extensive research collaborations exist in the area of the fundamentals of interfacial phenomena and fluid mechanics over small length scales, involving University of Erlangen (Germany). A special workshop (IWMNST-2006) on Bio-MEMS and Bio-Microfluidics was conducted by the Microfluidics research group of IIT Kharagpur and its collaborators in December 2006, involving eminent speakers from USA, Japan, and India. More than 60 participants cutting across various disciplines of physical, chemical, biological and medical sciences attended this Workshop. At present, approximately 15 graduate level students/research scholars from IIT Kharagpur and 2 research scholars from the University of California, Irvine, are involved with the activities of the research group. Moreover, eight faculty members are actively involved with the research agenda undertaken by this group. Professors from this group are routinely invited by Universities such as Massachusetts Institute of technology (MIT), University of California-Berkeley, Northwestern University, University of Tokyo and many other top-level universities in the world and to reputed international conferences for delivering special lectures on this rapidly emerging area of scientific and technological research.



Flow visualization at the liquid-solid interface in a micro-channel

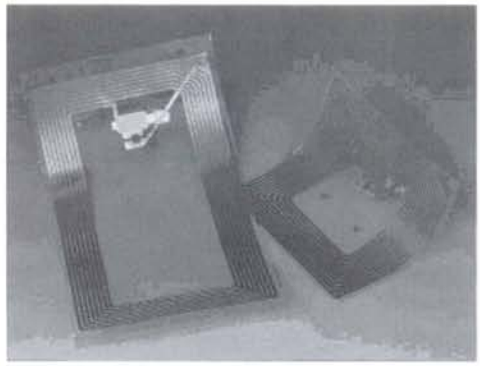
The research group has already achieved a breakthrough in developing new theories on hydrophobic interactions and slip phenomena in micro/nano channels, in devising new strategies for rapid DNA hybridization, and in designing novel CD-based lab-on-a-chip devices. Furthermore, important contributions have been made by this group on issues involving physics of micro/nano films during phase change, novel micro-flow actuation, augmentation and separation mechanisms, development of optical techniques for measuring the shape of thin liquid films near the contact line region and successful utilization of phase change heat transfer from micro-grooved surfaces with applications in thermal packaging of electronic devices and chips. *In vivo* and *in vitro* modulation and prevention of tumor growth has opened an entirely new paradigm in the field of biotechnological research, followed by invention of a mice model for in vivo study of the effects of various chemical agents, drugs and natural compounds. In-house novel manufacturing techniques for several micro-devices such as tunneling accelerometer, cantilever based sensor arrays and RF modules have also been developed. Active research is also ongoing towards the development of efficient and inexpensive CD-based biomedical diagnostic devices for making the research outcome reachable to common people in India.

Dr. Suman Chakraborty is an Associate Professor of Mechanical Engineering at the Indian Institute of Technology, Kharagpur. He can be reached at suman@mech.iitkgp.ernet.in.

Vinukumar Ranganathan

Smart RFID systems

A smart combination of radio frequency identification (RFID) and the microelectromechanical systems (MEMS) technology is carving a niche of its own in embedded or ambient intelligence applications. RFID technique offers an automatic and contact-less identification method in which data is stored and retrieved remotely using radio waves. It is seen as a cheaper and more efficient alternative than the barcode system to get supply-chain and identification system. RFID systems are being used in product tracking, transport payments (toll gates), passports, livestock health monitoring, access management, mobile payments, and biometrics. Next generation MEMS and RFID tags warrant innovation due to the complementary nature of manufacturing over silicon and the needs of the industry. Research in the recent years is showing trends towards the next logical step of integration of MEMS and RFID. The RF antennas (which are the basic building blocks of RFID systems), the standardization of communication protocols, and the use the power from inductive coupling of radio waves in passive RFID systems help build wireless and battery-less MEMS modules. Simple devices such as temperature, pressure and humidity based micromachined sensors integrated with RFID systems help monitor the state of the identified object remotely. Immediate applications are in food and beverage industries, logistics applications, military, smart homes, and smart apparel.



(from http://rfid-handbook.com/english/index.html)
A smart RFID label on a flexible substrate.

Mr. Vinukumar Ranganathan works at Bigtec Private Ltd., Bangalore. He can be reached at vinu@bigtec.org.

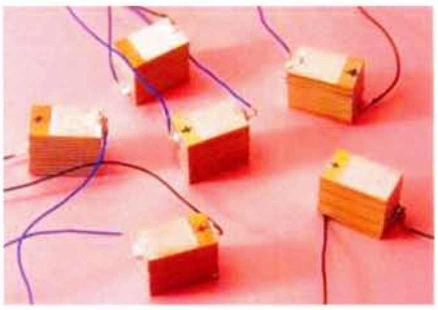
Accomplishments: NAL (Part 1 of 2)

G. M. Kamath

National Aerospace Laboratories (NAL) is India's premier laboratory for aeronautical and aerospace R&D (website: www.nal.res.in). A constituent of the Council of Scientific and Industrial Research (CSIR) under the Ministry of Science and Technology, Government of India, it was set up in 1959 in New Delhi and then moved to Bangalore in 1960. Among its wide ambit of research activities, smart materials and technologies is one. The first of this two-part article focuses on the materials research and MEMS device development being carried out in the Material Sciences Division of NAL. The aerospace applications research using smart materials would be covered in the next issue.

NAL has successfully developed NiTi and NiTiCu Shape Memory Alloy wires for thermal actuator applications and has the capability to process SMA wires up to 0.1 mm diameter (*see* Vol. 2, No. 2, pp. 4-5). All the processing facilities ranging from melting to secondary processing to wire drawing have been established in NAL. The wires developed at NAL are now being explored for the development of actuators for various engineering applications.

Piezoelectric materials development has been achieved in good measure at NAL. The piezoelectric charge constant d_{33} of the NAL-5A material is of the order of 375-430 pC/N and that of NAL-5H is 590-610 pC/N. Similarly, pyrochlore-free PMN powder with high dielectric constant (79,098 at 4.18MHz) has also been prepared. Multi-layered PZT stacks (Fig. 1) have been fabricated both by "cut & bond" method and tape casting method. The static linear displacement of these stacks is about 0.1%. The required driving voltage reduced from 650V to about 120-150V for stacks prepared by tape casting technique.



Piezo-stacks made at NAL (twenty five 0.65 mm -thick layers)

Alpha-PVDF film made at NAL

PVDF (Polyvinylidene Fluoride) is a well-known polymeric material with piezoelectric properties and is used mainly for sensing applications. PVDF films (Fig. 2) have been prepared at NAL using the solvent cast method. The films are being characterized for structural, mechanical, surface, and electrical properties.

A program on MEMS has been initiated at NAL to develop piezoelectric micro-sensors and micro-actuators. The work envisaged in this program encompasses the design, analysis and prototype fabrication. Towards this, a systematic design and optimization of a novel piezoelectric beam structure has been carried out. Simulation results show that a maximum of 1600 μN block force and 21μm deflection can be achieved with the optimized design depending on the controlled process parameters. The fabrication of this device is in progress.

Thermoelectric coolers are widely employed in microelectronics to stabilize microprocessor temperatures, to cool infrared detectors and charge-coupled devices, and to reduce unwanted noise in integrated circuits. A prototype thermoelectric microcooler has been fabricated at NAL using four thermo elements (pair of n and p type Bi_2Te_3 element) through which a temperature difference of 25°C (down to room temperature) has been achieved. Work is in progress for design and development of micro cooler array on a chip dimension of 800μm.

The author, G.M. Kamath who is a scientist in NAL, acknowledges the inputs of his colleagues for this article. Oversights, if any, are that of the author. Queries may please be sent to director@css.nal.res.in.

S Ū K S H M A
Institute of Smart Structures and Systems
Department of Aerospace Engineering
Indian Institute of Science
Bangalore - 560012
India