·|| SUKSHMA ||·

A newsletter about micro and smart systems in India

Volume 1 : Number 1 : October 2006 Published quarterly by the Institute of Smart Structures and Systems

CONTENTS

This is the inaugural issue of SŪKSHMA, the newsletter of the Institute of Smart Structures and Systems (ISSS), which will be published quarterly. Its purpose is to disseminate the news about the rapidly growing micro and smart systems technologies in India. This newsletter includes, in addition to ISSS news, visionary essays written by leading researchers and eminent technology administrators, elucidating articles on selected topics written in a tutorial style, summaries of significant accomplishments in this field in India, recent activities in this field in univeristies across the country, technology news from around the world, conference announcements, grant opportunties and more.

If you have any suggestions about this newsletter or want to contribute an article, please send an e-mail to: isss@aero.iisc.ernet.in.

More information about ISSS can be found at www.isss.org.in. An online version of this newsletter is archived at http://www.isss.org.in/news.html. –Editorial Team.

President's Message

S. Mohan

Dr. S. Mohan is a Professor of Instrumentation, and the Chief Executive of the Society for Innovation and Development (SID) in the Indian Institute of Science (IISc), Bangalore. He is also the President of ISSS.

Institute of Smart Structures and Systems (ISSS) has come a long way since its inception in 1998. It has supported the National Program on Smart Materials (NPSM) in promoting its objectives of initiating well directed R&D in materials, devices and packaging, establishing design and fabrication centres, mobilizing human resourses for teaching and training by organizing national and international conferences, workshops and seminars. It now has a membership of about 225 representing various R&D laboratories and academic institutions in India. The recent workshops organized for Visvesvaraya Technological University (VTU) have motivated a large number of faculty and students from various engineering colleges under VTU to pursue the work in this area. Now that NPSM has brought enough awareness in this area amongst large R&D and academic communities in the country, the current efforts of ISSS are in the direction of increasing its membership, developing human resource, and initiating technologies for different applications through public-private partnerships. There has been a growing demand that ISSS should introduce new mechanisms to increase the awareness among its members and expose them to micro and smart systems technologies. It has been felt by the governing board that there cannot be any better mechanism than starting a newsletter. An editorial committee has been constituted for this purpose with Dr. G.K. Ananthasuresh (IISc) as its editor, and Dr. S. Gopalakrishnan (IISc), Dr. G.M. Kamath (NAL), Dr. Sayanu Pamidighantam (BEL) and Dr. K.J. Vinoy (IISc) as its members. What you see today in the newsletter is the effort of this editorial board with a lot of support from the members of the Society and active workers in this area in the country. I sincerely hope that the readers will find the information in the newsletter useful for not only carrying out R&D in this area but also to interact with other active scientists all over the country. ●

National Programme on Smart Materials (NPSM)

V.K. Aatre

The last two decades have witnessed significant progress in the area of smart materials and structures and Microelectromechanical Systems (MEMS). The creation of microsystems by integrating sensors, actuators, and the control electronics on a chip has lead to myriad of applications in the areas of aerospace, communication, automotive electronics, health monitoring, healthcare, entertainment and many others. Recognizing the potential and the importance of such a technology, five government departments–DRDO, DOS, DST, CSIR and DIT–initiated a six year National Programme on Smart Materials (NPSM) in the year 2000. The main objectives of this bold national initiative were:

- ☐ Sensitize academic institutions and technology communities about the potential of microsystems;
- ☐ Initiate well directed R&D work in materials, devices and packaging;
- ☐ Establish design and fabrication centers;
- ☐ Mobilize human resources teaching and training; and
- ☐ Support activities such as workshops, seminars and conferences.

Dr. V. K. Aatre, the founding president of ISSS, is a former Scientific Advisor to the Raksha Manthri. He is currently a visiting professor in the Electrical Communications Engineering Department in IISc.

NPSM, and its executive board BSMART which operated through Aeronautical Development Agency (ADA), have several firsts to their credit by running a multi-departmental, multi-institutional, highly application oriented emerging technology programme successfully. NPSM's success can be gauged by its achievements, viz.:

- ⇨ Over 40 projects on materials and devices completed with several fabricated and tested;
- ⇨ MEMS fabrication and packaging centers establish at SCL and BEL;
- ⇨ Over a dozen design centers established all across India with IISc center acting as the hub;
- ⇨ Numerous workshops and training sessions for academic institutions, national laboratories and industries;
- ⇨ Three international conferences conducted along with ISSS that saw the publications from Indian researchers jump from 10% to 60%; and
- ⇨ Microsystems courses and laboratories springing up in engineering colleges across the country.

The NPSM national initiative on smart materials and microsystems has achieved most of its original objectives. We are now contemplating launching of a larger equally directed second phase with greater industrial participation. ISSS and its members have to play a key role in this national endeavour. ●

Genesis of ISSS

S. Gopalakrishnan

A decade ago, the commonly used vocabulary of today, namely Smart Systems, Smart Materials, Smart Structures, Microsystems, MEMS etc., were known only to a very few in India. For many, these were terms directly taken from science fiction. Unlike the superconductivity research in early eighties and nineties, many scientists in India were not aware of micro and smart technologies and their huge potential in various defence and civilian applications. In the year 1996, a great visionary, Dr. V. K. Aatre, the then Chief Controller, DRDO HQ, Ministry of Defence, Government of India, took leadership to assemble the renowened reseacrhers such as Professors Vijay Varadan and Vasundara Varadan, who were then at Penn State University, USA, and organized an international conference on Smart Structures and Systems at the Indian Institute of Science, Bangalore, in July, 1996. This conference was first of its kind to be organized in India and it was a big success in terms of the international participation. However, there were fewer than 10% of the papers presented from India. On the final day of this conference, a panel discussion was held to address the ways and means to give impetus to this technology in India. Many scientists from India felt that India should not miss out on the microsystems technology-popularly known as MEMS (Microelectromechanical Systems), which was then revolutionizing the technological world. It was felt that many more such conferences and awareness workshops should be held in India at regular intervals for spreading this technology along the length and breadth of the country. The panel members felt that this can be achieved only by creating a professional society. Thus, ISSS took its origin at this meeting.

Subsequently, many meetings were organized by Dr. Aatre with a group of scientists from IISc, NAL, ISRO, ADA and other DRDO labs to finalize the modalities. In these meetings it was unanimously resolved that the new professional society be called **INSTITUTE OF SMART STRUCTURES AND SYSTEMS (ISSS)**. See the box below for the list of founding members of ISSS.

In its meeting on August 14, 1998, the by-laws were approved by the founding members. And then, September 1, 1998, the society was registered under the Government of Karnataka. This was the first step in establishing this cutting edge technology.

The results of the creation of ISSS were immediately visible: the membership of the society increased substantially. It was decided by the executive board of ISSS that an international conference on smart systems technology be organized every three years by ISSS. As a sequel to this, the first international conference on Smart Structures and Systems (ISSS-1999) was organized under the aegis of ISSS in July 1999 with Dr. Aatre and Prof. Vijay Varadan as the conference chairs and Dr. A.R. Upadhya and Dr. P.D. Mangalgiri from ADA, as the organizing secretaries. This conference was held at Indian Institute of Science. It attracted over 400 Indian delegates and 40 delegates from 10 different foreign countries. Some of the top scientists in this area attended the conference and shared their experience in this emerging technology. The percentage of papers from India also dramatically increased to 25 %. The huge success of the conference in addition to substantial increase of Indian papers prompted ISSS to think in terms of a national programme. Dr. Aatre and other founding members of ISSS prepared a proposal and submitted to the Government of India, which paved the way for the creation of National Programme on Smart materials (NPSM) (see page 1).

Since then, ISSS has grown even more rapidly. It organized the second and the third international conference in December 2002 and July 2005, respectively. The second conference in 2002 was co-sponsored by the SPIE of USA. Again, these conferences saw the percentage of papers from India increase from 25% to 60%. The second conference in particular got international recognition with SPIE bringing out separate proceedings of the papers presented at the conference. This has been indexed by many international scientific databases. The number of foreign delegates in these conferences also increased substantially.

In addition to organizing conferences, ISSS has also organized a number of theme oriented workshops to propel this technology in India. Furthermore, ISSS is working to bring out theme oriented monographs written by top scientists/engineers in the world. In this regard, ISSS released a monograph on **STRUCTURAL HEALTH MONITORING** in July 2002 with Prof. B. Dattaguru, Dr. Mangalgiri and Prof. A. Selavarajan as its editors. Two more monographs on **MEMS** and **ACTIVE VIBRATION CONTROL** are being planned for future release. This period has also witnessed a huge increase in the awareness of this technology in the country at large: many research laboratories and

Founding Members of ISSS

President
Dr. V. K. Aatre (DRDO)

Vice-president
Prof. B. Dattaguru (IISc)

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Dr. A.K. Subramanian
Dr. T. Srinivas (IISc)

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Genesis of ISSS

S. Gopalakrishnan

academic institutes have organized many national and international workshops, which were co-sponsored by ISSS. ISSS has also funded many young scientists from the country to attend various international conferences in this emerging area through partial travel grants. ISSS is actively participating in all the major initiatives in this emerging area in the country. ISSS president is a member of the Board for Smart Structure Technology (B-SMART), the main monitoring body of the National Programme on Smart Materials (NPSM). Currently ISSS is striving hard on one hand to improve the R & D in the area of Smart Technology in India and on the other hand to convince the Indian industry to try out Indian made smart and micro devices in their products. In this regard, realizing that the automobile sector is a huge market for these devices, ISSS is acting as an interface between the scientists of the country and the automobile manufactures from India for the manufacture of the smart devices required by these companies. If this experiment works out well with the automobile sector, ISSS will extend this approach to all other relevant sectors. ●

Visit
www.isss.org.in

Some R&D and Sponsoring Institutions for Micro/Smart Research in India

ADA: Aeronautical Development Agency, Bangalore	www.ada.giv.in
ADE: Aeronautical Development Establishment, Bangalore	
BEL: Bharath Electronics Limited, Bangalore	www.bel-india.com
CMET: Centre for Material Research Institute, Hyderabad, Pune and Thrissur	www.cmet.gov.in
CSIR: Council for Scientific and Industrial Research	www.csir.res.in
DAE: Department of Atomic Energy	www.dae.giv.in
DST: Department of Science and Technology	dst.gov.in
DRDO: Defence Research and Development Organization	www.drdo.org
ISRO: Indian Space Research Organization, Bangalore	www.isro.org
MCIT: Ministry of Communications and Information Technology	www.mit.gov.in
NAL: National Aerospace Laboratories, Bangalore	www.nal.res.in
NPL: National Physical Laboratory, New Delhi	www.nplindia.org
NPOL: Naval Physical and Oceanographic Laboratory, Kochi	
RCI: Research Center Imarat, Hyderabad	
SSPL: Solid State Physics Laboratory, Delhi	www.drdo.org/labs/ecs/sspl

In the coming issues...

...articles on:
RF Switches
Microphones
Microfluidics
SMA Wires
CSIR Network program
NMDC-IISc
BEL
TIFR

Made in India

Silicon pressure sensor
Piezo-stack actuators
Micro accelerometers
Shape-memory-alloy wires
Thin films for microsystems
and more...

The above successes have been made possible with the support of ISSS and NPSM. Some of these will be highlighted in the coming issues of the newsletter. We begin with the pressure sensors (see **ACCOMPLISHMENTS** on page 7).

Pressure sensor
(K. N. Bhat/BEL)

Leaders of ISSS

The visionaries who founded ISSS and nourished it at its inception and afterwards will be introduced in the first few issues of this newsletter. We begin with the founding president, Dr. V.K. Aatre.

Today, among many other things, Dr. Aatre's name is synonymous with micro and smart systems technologies in India. It is our privilege to introduce Dr. Vasudev K. Aatre, the chief architect of these technologies in India to the ISSS community. Dr. Aatre obtained his B.E degree in Electrical Engineering from Visveshwaraiah College of Engineering, Bangalore and M.E degree from IISc. He got his Ph.D. degree from University of Waterloo, Canada. Subsequently, he was a faculty member in the same school for a period of 13 years before he decided to return to India. After Returning to India, he joined NPOL, Kochi, as a scientist and went on to become its director. After serving as its director for almost eight years, he moved to DRDO headquarters at New Delhi as the Chief Controller R & D and eventually became the Scientific Advisor to Raksha Mantri (Defence Minister) in 2001. He retired from active service in 2004. He has numerous awards to his credit. The most notable among them are the prestigious Padma Bhushan award from the Government of India and the Fellow of Indian National Academy of Engineering. Dr. Aatre, through his tireless effort and energy has brought ISSS to its current high standing and he is still continuing his effort even more after superannuation. We are sure that all the ISSS members will join us in applauding Dr. Aatre for his enormous contributions in making ISSS a vibrant professional society. ●

Structures, natural or manmade, are inexorably led through the process of aging and degradation towards the ultimate denouement: death. However, as a quip goes, everyone wants to live forever, but no one wants to grow old! Among the manmade structures, those that result in substantial material loss and human casualties due to their failure include aircraft, buildings, bridges, nuclear installations, etc. These structures are constantly being pounded by the external environment. In the case of an aircraft, each flight results in a variety of cyclic loads that causes fatigue in the structure. No material is perfect. Inevitably, there are flaws in the form of cracks and other defects that, under fatigue, grow in size. That is what happened with the B737 aircraft of Aloha Airlines on 28 April, 1988 (Fig. 1). So, it is obviously beneficial to monitor the condition of the structure and use this information to foresee and take remedial action, thereby averting catastrophic accidents.

Aircraft are currently grounded periodically for inspection. This results in costs due to (i) loss of revenue due to downtime, (ii) disassembly and reassembly, and (iii) inspection of the structure. The inspection interval is decided based on factors related to damage growth in the structure. These are estimated based on fracture mechanics methods as applied to the structure. Since safety is the primary concern, these factors are usually conservative. This in turn results in inspection schedules being more frequent than necessary wherein more often than not no snag is detected. Thus, a "maintenance-on-demand" system that would continuously monitor the health indicators of a structure and recommend a more thorough inspection only when required would result in tremendous cost savings.

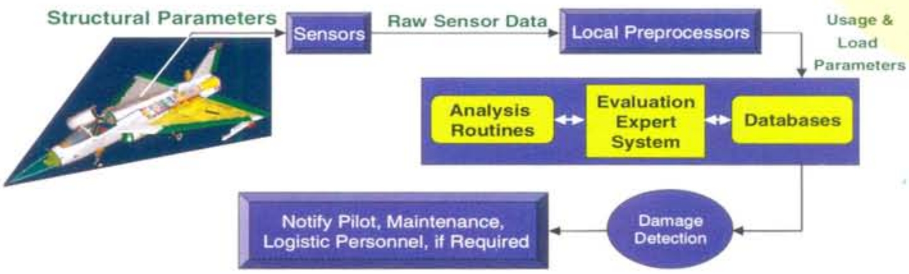

Fig. 2. A schematic of the aircraft structural health monotoring system.

Composite materials are increasingly being used in aircraft structures due to their superior properties. Although composites have a higher ability than metals to withstand fatigue loading, they have a lower resistance to impact. Moreover, unlike in metals where impact results in a visible dent or damage, impact on composite structures results in internal defects, which cannot be detected through a regular visual inspection. Thus composites necessitate more sophisticated methods of non-destructive inspection resulting in higher maintenance costs. However, composites also offer a solution that metals cannot. The laminated construction of composite structures makes them eminently suitable for embedding sensors within the structure. Thus, the health monitoring system becomes an integral part of the composite structure.

Another aspect of aircraft health management is monitoring of loads that the structure experiences during flight. This especially becomes more relevant in the case of military aircraft wherein the pilot might be forced to execute maneuvers that the aircraft is not designed for. This excursion needs to be noted, recorded, and its consequences assessed. Thus, an aircraft structural health monitoring system has the objectives of measuring flight loads and detecting defects or damage in the structure. The components are as shown in Fig. 2.

The Structural health monitoring methodology broadly comprises three steps shown in Fig. 3. The first step includes the raw sensor data, the knowledge about the structure (structural models), the damage targeted and its influence on the structural behavior (damage mechanics models). This step anticipates various damages of concern and their manifestation in the specific structure, which is measured using appropriate sensors. This step is solving the *forward problem*. Having obtained the sensor data, the second step is to extract features in the data using suitable signal processing tools. These features could be

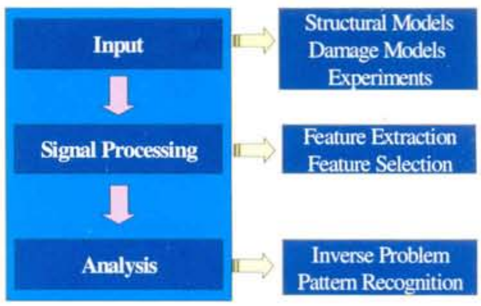

Fig. 3. Three steps in structural health monotoring system.

fast Fourier transforms (FFT), wavelet transform, statistical quantities, etc. Essentially this step converts the raw signal into a usable form. Having obtained the features, the third step is to make sense out of these features. This is solving the *inverse problem*. Essentially, the first step indicates that if this is the damage or flight load, then this is the way it manifests itself. The third step infers that if this is the manifestation, then this has to be the damage or the load. Thus, each step comprises a large number of possibilities and various domains of knowledge. Different combinations of these

Fig. 1. Photograph of Boeing 737 of Aloha Airlines. The aircraft lost 1/3 of its roof due to a stress fracture while cruising at 24,000 feet. One Flight Attendant was sucked from the airplane, which subsequently made a safe emergency landing.

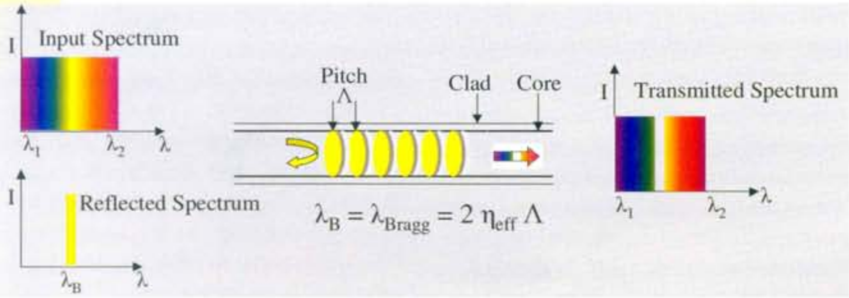

Fig. 4. A schematic of the working principle of the Fibre Bragg Grating

Fibre optic Strain Sensor Based SHM

This approach uses fibre optic sensors to measure static or dynamics strains. These strains are then used to diagnose loads and damage using different pattern recognition techniques such as neural networks, statistical regression analyses, etc. Fibre optic strain sensors have several advantages over conventional electrical resistance strain gauge sensors. They have higher sensitivity and bandwidth. They are immune to electromagnetic interference (EMI), which is an important feature to obtain clean noise-free signals. Another important advantage is that some of the fibre optic sensors have the multiplexing capability, i.e., many sensors can be used in a single fibre with one input/output lead. Optical fibres are small in size and hence can be easily embedded in composites without causing any degradation in the host properties. They are lightweight, robust and have high tensile strength. With a suitable protection of the fibre surface, the mechanical integrity of the fibre can be maintained. One of the fibre optic sensors is the Fibre Bragg Grating (FBG) sensor. An FBG consists of a periodic modulation of the refractive index in the core of a single mode optical fibre. When light propagates through periodically alternating regions of high and low refractive index, it is partially reflected at each interface between those regions. If the pitch of the grating is an integer multiple of the wavelength of incident light, the reflections at each interface are in phase and hence add up. This total reflection can be quite substantial even if the individual reflections at each interface are small. Hence this condition will only hold true for specific wavelengths. All other wavelengths will get transmitted through the FBG. The schematic of the FBG principle is shown in Fig. 4.

Ultrasonic wave based techniques

While the fibre optic sensor based technique is a passive technique, ultrasonic acoustic waves (also known as Lamb waves) can be used to actively interrogate a structure for defects. Lamb waves are guided acoustic waves that can propagate over large distances along the plane in thin plate-like structures. The characteristics of these waves are modified along the way by defects in the structure. Thus by understanding the wave propagation behaviour and the effect of damages and defects on these waves, it is possible to detect damage by examining the modified wave. The schematic of a typical system isshown in Fig. 5. T1-T4 are transmitters and R1-R4 are receivers. The transmitters and receivers are usually piezoelectric materials, which can act both as actuators and sensors. Piezoelectric materials are materials which, when a stress is applied, generate a charge (sensor mode), or undergo deformations when an electric field is applied (actuator mode).

For example, the wave that is transmitted by T4 when received by R1 has a characteristic that is different from that received by R2, which in turn is different from that by R3, and so on. Thus by comparing the different received signals using advanced signal processing techniques, the defect can not only be located but also mapped. This technique has been well established in the medical field wherein tumors are detected and sized. The advantage of this method is that using the same set of transmitters and receivers, a defect can be located anywhere on the structure.

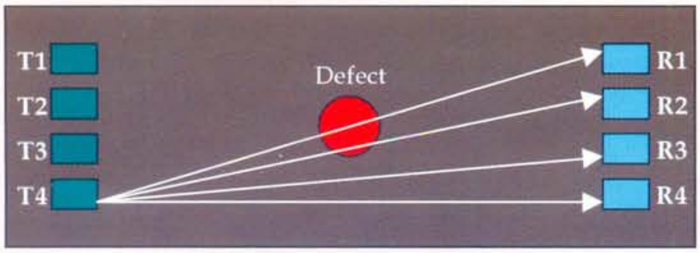

Fig. 5. A schematic of a Lamb wave based health monitoring. T1-T4 are transmitters; R1-R4 are receivers. The waves transmitted by T4 and received by R1-R4 have different characteristics.

Suggested Reading

1) Structural Health Monitoring, (Eds.) B. Dattaguru, P.D. Mangalgiri, and A. Selvarajan, A Monograph Published by Institute for Smart Structures and Systems (ISSS), December 2002.

2) Proceedings of the Fourth ISSS International Conference on Smart Materials, Structures and Systems, Eds. R.V. Krishnan, R. Sundaram and G.M. Kamath, 28-30 July 2005, Bangalore, India.

3) Proceedings of the Third European Workshop on Structural Health Monitoring, Ed. A. Guemes, July 5-7, 2006, Granada, Spain.

4) Journal of Structural Health Monitoring, Sage Publications.

5) Journal of Intelligent Materials Systems and Structures, Sage Publications.

6) Smart Materials and Structures, Journal published by Institute of Physics, IOP Publishing Ltd.

Drs. G. M. Kamath and Ramesh Sundaram are scientists in the Advanced Composites Division of the National Aerospace Laboratories, Bangalore. They may be contacted by e-mail at: gmkamath@css.nal.res.in, rameshs@css.nal.res.in.

steps result in different health monitoring strategies. Among these, two popular approaches to structural health monitoring are: (i) Based on fibre optic strain sensing and (ii) Ultrasonic wave based techniques (see boxes above). Apart from these two techniques there is a host of other methodologies for structural health monitoring. These include techniques such as comparing the vibration characteristics of a structure with and without a defect. This method has not become very popular due to the fact that global vibration characteristics of an assembled structure such as that of an aircraft are not significantly affected by small defects and damages in the structure. Structural health monitoring is an extremely promising concept, which is moving out of the academic research domain to practical implementation in actual aircraft. The ideas and methodologies discussed above are being transitioned into technology that fits in with the industry needs and expectations. Much is at stake because the returns in terms of cost savings are indeed high. ●

Biological structures monitor and heal themselves!

University Buzz: A New UG Course for VTU

K.J. Vinoy

ISSS in association with Indian Institute of Science (IISc), Bangalore, has recently undertaken an educational initiative in the micro and smart systems area for Vishveswaraiah Technological University (VTU). The original idea was floated by Dr. V. K. Aatre who suggested that ISSS should take the responsibility to come up with a syllabus for an undergraduate course for VTU's engineering colleges in the rapidly growing area of *Micro and Smart Systems Technologies* taking into consideration the requirements and the projected demand for manpower in the country and abroad. Towards this goal, ISSS in collaboration with VTU, has worked out a multi-phase approach. In the first phase, experts from within and outside Bangalore were invited by ISSS to conduct a series of four workshops (held at Bangalore, Mysore and Belgaum) each spanning over six days, during January to March 2006. These workshops were well attended by the teachers of various colleges affiliated to VTU. Altogether there were about 100 participants from more than fifty engineering colleges.

The CD containing all the workshop presentations and pre-workshop reading materials is available upon request. Please email your request with full contact information to: isss@aero.iisc.ernet.in.

Since we believe that teachers need to be given an in-depth training rather than a superficial exposure to the field, these workshops covered almost the entire panorama of the micro and smart systems field in depth. The topics covered included materials, microfabrication, modeling and design, packaging, sensor-actuator-system applications, software demonstrations, hands-on training and a visit to the fabrication facility at BEL. A fairly exhaustive pre-workshop reading material was also prepared and distributed to the attendees before the workshop. The intention was to enable them to come prepared and get the most benefit from the workshop.

About 12 faculty members and other experts from IISc were involved in this effort. In addition, experts from BEL, ADA, and NAL Bangalore, IIT-Madras, and NPL New Delhi whole-heartedly contributed in providing an exhaustive perspective of the field to the participating VTU faculty. Software vendors such as *Intellisense* and *Comsol* presented case studies based on their respective tools. Another major attraction of many of these workshops was that several simple exercises that could be done using Matlab were introduced to the attendees. These could be put to use to convey underlying physical principles to undergraduate students. Ample time was allocated in the workshop for interaction between the participants and the speakers.

Since we felt that it is important to get the feedback from the VTU faculty to judge which aspects of this field can be taught within the resources of the VTU colleges, a questionnaire was given at the end of each workshop to seek feedback from the attendees. We used the feedback of the previous workshops to revise the contents in the subsequent workshops. This has lead to the most appropriate content for the later workshops. The feedback was also very useful in formulating an university-wide syllabus for an undergraduate course. The Vice Chancellor of VTU attended the first and the last workshops as he is keen on introducing this course as early as next year. Thus, VTU has followed up with the momentum gained by these workshops and constituted a committee consisting of experts from IISc and VTU colleges with Dr. Aatre as the chairman to suggest a syllabus for the proposed UG course. This committee has recently completed this task and has sent the necessary documents for the approval by various Boards of Studies in VTU. ISSS has also undertaken the task of preparing a textbook for this course. Several academicians from IISc and VTU will collaborate in authoring this book. ●

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Conference Announcements

First National Conference on Smart Structures & MEMS Systems for Aerospace Applications (ISSS-MEMS 2006), 29-30 November 2006, Research Centre Imarat, Hyderabad, India. Contact Person: Dr. DVK Sastry, dvksastry@yahoo.co.in.

Sixth Stanford International Workshop on Structural Health Monitoring, 11-13 September 2007, Stanford University, Stanford, USA. Website: structure.stanford.edu/workshop.

National Symposium on Instrumentation, 12 - 15, October, 2006 at the Institute of technology & Management, Gwalior, Madhya Pradesh.

Interational Conference on Emerging Mechanical Technology-Macro to Nano (EMTM2N-2007), 16-18, February, 2007, Birla Institute of Science and Technology, Pilani.

Micromachined microphone in consumer electronics products

When Bell Labs developed the first electret condenser microphone (ECM), it was perhaps not foreseen that the qualifier "micro" in microphone would be made obsolete by a competent competitor that should be called a micro microphone. Today, according to a market survey by Wicht technologie Consulting (WTC: www.wtc-consult.de, Munich, Germany), micromachined microphones are likely to take a 25% share of the microphone market by 2010. From 2005 to 2006, the MEMS microphones have doubled to a market value of $130 M. There are a number of companies (e.g., Knowles Acoustics: www.knowlesacoustics.com, Sonion: www.sonion.com, Akustica: www.akustica.com) that manufacture MEMS based microphones for consumer electronics applications such as mobile phone, notebook computers, hearing aids, etc. Since the long-standing ECMs cost less than $1, MEMS microphones have to be highly competitive in terms of cost. Some of the advantages of MEMS microphones, as noted by WTC, include reducing the footprint and height with a surface-mount design, robustness against environmental changes such as vibration and temperature, arrays for directionality and noise cancellation, on-chip integration of electronics and increased immunity to RF and EMI. It is also anticipated that in the next few years, micromachined microphones will find their way into automotive markets by building up on their success in consumer electronics market.

Setting the standards for microsystems

When standards begin to emerge, it is usually an indicator of the level of maturity of a technology. The microsystems technology is well established today. Therefore, it is no surprise that standards are being developed by National Institute of Standards and Technology (NIST, www.nist.gov) and Semiconductor Equipment and Materials Institute (SEMI, www.semi.org). SEMI has task forces set up for standards for microfluidics and wafer-bonding, among other things. One of the things that NIST is focusing on is to set up standards to measure residual stress and stress gradients in polysilicon-deposited and subsequently released micro-mechanical structures.

Implantable microchip with telemetry

Microchips, Inc., in Bedford, Massachusetts, USA, has introduced an implantable controlled drug-release product. This product shown in the above picture (source: www.mchips.com) exploits the integrative and array-friendly features of the microsystems technology. It consists of an array of biosensors and reservoirs that contain medicine along with wireless telemetry and microprocessors. It can operate in a passive mode wherein the sensors and reservoirs are exposed depending on the external stimuli inside the body or in an active mode that can be programmed from the outside using telemetry.

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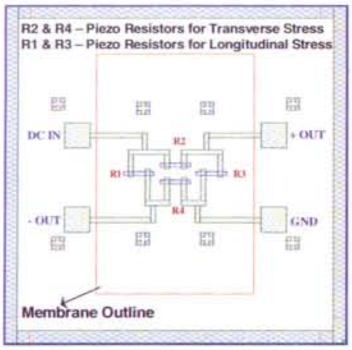
Accomplishments: K.N. Bhat

Sayanu Pamidighantam

The MEMS (Micro Electro Mechancial Systems) laboratory of Professor K.N. Bhat at IIT Chennai is arguably the first academic laboratory that has successfully developed and prototyped a MEMS device and trasnferred its technology to the industry. Today, Bharat Electronics Limited (BEL) enjoys a significant mileage over other establishments in the area of pressure sensors largely due to the borrowed technology developed by Bhat's laboratory.

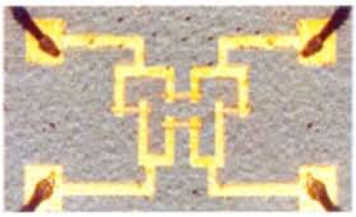
Prof. K.N. Bhat began his academic career at IIT-Chennai in 1969 as an associate lecturer and became a professor in 1987. His academic career spanning nearly four decades has been illustrious. His research on MEMS at IIT-Chennai started in early 1990s with an initial focus on accelerometer devices for defence applications. This work started with a modest fabrication faclity which warranted the development of inexpensive yet conceptually effective techniques. With the support from NPSM and other funding, today this facilty consists of design tools such as COVENTORWARE, INTELLISUITE, ComSol MultiPhysics and ANSYS in addition to the tools for Semiconductor device modeling, furnaces for oxidation and diffusion, deposition systems for metal deposition as well as Silicon dioxide (SiO_2), Silicon nitride deposition (Si_3N_4), double-sided mask aligner and wafer bonding equipment, etc.

This lab used silicon bulk micromachining to build a diaphragm-based pressure sensor with piezo-resistive strain gauges. The salient features of the design are higher longitudinal stress at the edges (denoted by



R1 and R3 in the figure above) and higher transverse stress at the center (denoted by R2 and R4)–a primary requirement for achieving large gauge factors in Wheatstone bridges. The pressure sensor chip (see the optical micrograph image below) fabricated in this lab was subsequently packaged by BEL. The packaged device was successfully tested at different pressures upto 10 bar.

Professor Bhat's lab has also developed an integrated process that combines the mechanical elements and electronics on a single chip using Silicon-On-Insulator (SOI) substrates. His lab has also undertaken the devleopment micro pumps, RF switches and filters, bio-MEMS in addition to pressure sensors and accelerometers. ●



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