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The ISSS newsletter about micro and smart systems in India

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President's message

ISSS is coming of age...

A.R. Upadhya
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As we move forward in the year 2009, we realize that our dear Institute of Smart Structures and Systems has quietly, without much fanfare, completed ten years of existence! The Institute was formally registered as a professional society in Karnataka on 1, September 1998, and we had our first annual general-body meeting (AGM) in 2000. So, we will be formally celebrating the 10th birthday during the 10th AGM later this year, and we welcome your suggestions in this regard. As we begin to get ready with our plans for it, we pay special tributes to our Founder President, Dr. V.K. Aatre and other founder members whose vision and initiative made this possible. Dr. Aatre continues to guide the Institute and the Smart Materials and Micro Systems activity in the country in a variety of ways, most notable being Human Resource Development in the area of Micro and Smart Systems through education and training with the universities and Product and Technology Development as Chairman of the Board of National Programme for Micro and Smart Systems (NPMASS). He has also inspired a number of young scientists to contribute towards the growth of the Society. I also thank our former Presidents for their continued active involvement in the activities of the Society and working for its growth and welfare.

The Institute has done well registering a good growth in membership, both individual and institutional, and having regular programmes including international and national conferences. This year's national conference (third in the series after the ones in Hyderabad and Pilani) will be held in Kolkata in October, 2009. I am grateful to Dr. H.S. Maiti, Director, Central Glass and Ceramic Research Institute (CGCRI) for readily agreeing to our request to take the responsibility of organizing the conference. CGCRI, a premier R&D laboratory under the CSIR, has a number of innovative programmes in the area of smart materials such as peizoceramic sensors and actuators, fibre optic sensors, ceramic devices for bio-medical applications, nanotechnology, etc. CGCRI may partner with IIT, Kharagpur, another internationally reputed academic institution, also having a good number of developmental programmes in smart materials and structures, MEMS, bio-medical devices and systems, etc. We look forward to an interesting event coupled with famous traditional Bengali hospitality.

Recently Dr. S. Gopalakrishnan, Secretary, ISSS, and I had very useful discussions in Research Centre Imarat (RCI), Hyderabad, with Dr. S.K. Ray, Chairman, Dr. D.V.K. Sastry, Secretary, and other members of the Executive Committee of the ISSS Hyderabad Chapter. Dr. Ray and his able team are enthusiastic about expanding the Chapter and its activities in the Hyderabad region, and we have assured them all support. We propose to do the same with the Executive Committees of the Delhi and Pune Chapters apart from initiating action towards formation of the Coimbatore Chapter in the near future.

I understand that interactions of ISSS with a good number of academic institutions on the introduction of microsystems related courses in the curriculum of undergraduate engineering education and training of faculty for the same is progressing well with good response from those already involved. The text book for the course is nearing completion and the laboratory demonstration kits are already available. I request all the concerned institutions to make the best use of the programme offered by ISSS for their benefit. I have no doubt that this will benefit the smart materials and microsystems community in the long term.

Indian Institute of Science (IISc) hosted an excellent Interdisciplinary Workshop on Micro and Nano Technologies as a part of its Centenary Celebrations on 14 December 2008. There were six scholarly and informative lectures on various aspects of the technology. I compliment Professors Navakant Bhat, Rudra Pratap and S. Sampath and the IISc authorities on this initiative. Many other workshops and conferences have been held in the country in the last few months. Reports on some of them appear in this issue. Micro and Smart activities are on the rise in India and ISSS too is coming of age. I look forward to having active participation of all the members in the Institute's activities and programmes in this important phase of its growth.

ISSS MEMS Training Workshop
Pune, 22-24 January, 2009

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Under the Faculty Development Initiative of the National Programme on Micro and Smart Systems (NPMASS) and ISSS, a three-day workshop on MEMS Technology and Applications was held at Maharshi Karve Stree Shikshan Samstha's Cummins College of Engineering for Women, Pune. This was jointly organised by the department of Instrumentation and Control Engineering, Pune University), MEMS for Strategic Applications (Dr. Makarand Joshi, R&D Engineers), LTCC for MEMS Devices and Packaging (Dr. G.J. Phatak, CMET, Pune), Polymer MEMS (Dr. D.S. Bodas, Pune University), BioMEMS (Prof. S. Mukharji, IITB, Mumbai), Microfluidics and MEMS (Prof. S. Bhattacharya, IIT, Kanpur), MEMS for Space Applications (Dr. M.M. Nayak,

Dr. V.K. Aatre delivering the keynote talk in the workshop.

Maharshi Karve Stree Shikshan Samstha's Cummins College of Engineering for Women, Pune, the department of Electronic Science, University of Pune, and the Centre for Materials for Electronics Technology (CMET), Pune, during 22 – 24 January 2009. The workshop was attended by 38 teacher participants from the colleges and universities in Maharashtra and 15 MSc and BE students.

The workshop was organised to make the participants aware of the various issues in MEMS and encourage them to consider this field for their research or further studies. Various issues were discussed through lectures, software demonstrations, and visits to the related departments in Pune University and to CMET. Dr. V.K. Aatre, former Scientific Advisor to Raksha Mantri, inaugarated the workshop and delivered the keynote address by giving an overview of Micro and Smart Systems. His lecture excited the participants which could be evidenced through a long Q&A session. Eleven lectures each of one and half hour duration were delivered on the topics related to Smart Materials. They were: MEMS for Acrospace Applications (Dr. K Vijayaraju, ADA), Microfabrication: Processes and Technologies (Prof. S.A. Gangal, SCL, Chandigarh), Inertial Sensors: Design and Modelling (Prof. Rudra Pratap, IISc, Bangalore), Electronics Interface for MEMS (Prof. Navakant Bhat, IISc, Bangalore), and RF MEMS (Prof. S.K. Koul, IIT, Delhi). Representatives from BigTec and Conventor demonstrated MEMS design software Intellisuite and Coventorware respectively.

The participants enjoyed the visits to CMET-Punc, which demonstrated their packaging facilities. The department of Electronic Science, University of Pune, arranged visits to their facilities. At the end of the program, Prof. Navakant Bhat explained the availability of the two-week hands-on training at CEERI, Pilani, under the sponsorship of NPMASS. All the participants expressed their willingness to participate in the hands-on training program. Dr. Ashok Gaikwad, Convener of the workshop and Chairman, Board of Studies (Instrumentation Engineering), University of Pune, mentioned that an elective course on MEMS is already introduced in the engineering curriculum of Pune University. Some participants gave feedback on the workshop and expressed that they were very well exposed to this new topic and enjoyed the content. They are looking forward to joining the hands-on training at CEERI, Pilani.

Journal publications by Indian Researchers...

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... in the following journals in the last three months:

IEEE Transactions on Industrial Electronics
International Journal of Engineering Science
Journal of Applied Physics
Journal of Intelligent Material Systems and Structures
Journal of the Mechanics and Physics of Solids
Journal of Reinforced Plastics and Composites
Journal of Scientific and Industrial Research
Journal of Sound and Vibration
Microelectronic Engineering
Smart Materials & Structures
Thin-walled Structures

Active constrained layer damping of geometrically nonlinear transient vibrations of composite plates using piezoelectric fiber-reinforced composite , Author(s): Ray MC, Shivakumar J, THIN-WALLED STRUCTURES, Volume: 47, Issue: 2, Pages: 178-189, Published: FEB 2009.

Investigation of RF sputtered PSG films for MEMS and semiconductor devices, Author(s): Bhatt V, Chandra S, MICROELECTRONIC ENGINEERING, Volume: 86, Issue: 1, Pages: 24-32, Published: JAN 2009.

Micro gripper for micromanipulation using IPMCs (ionic polymer metal composites) , Author(s): Jain RK, Patkar US, Majumdar S, JOURNAL OF SCIENTIFIC & INDUSTRIAL RESEARCH, Volume: 68, Issue: 1, Pages: 23-28, Published: JAN 2009.

Electrohydrodynamic pulsatile flow in a channel bounded by porous layer of smart material , Author(s): Ng CO, Rudraiah N, Nagaraj C, INTERNATIONAL JOURNAL OF ENGINEERING SCIENCE, Volume: 47, Issue: 1, Pages: 103-115, Published: JAN 2009.

Shape and vibration control of a smart composite plate with matrix cracks, Author(s): Umesh K, Ganguli R, SMART MATERIALS & STRUCTURES, Volume: 18, Issue: 2, Article Number: 025002, Published: FEB 2009.

Electrochromic characteristics of pulsed spray pyrolyzed polycrystalline WO3 thin films, Author(s): Bathe SR, Patil PS, SMART MATERIALS & STRUCTURES, Volume: 18, Issue: 2, Article Number: 025004, Published: FEB 2009.

Anomalous behavior of acoustic phonon and central peak in Pb[(In1/2Nb1/2)(0.65)Ti-0.35]O-3 single crystal, Author(s): Sivasubramanian V, Tsukada S, Kojima S, JOURNAL OF APPLIED PHYSICS, Volume: 105, Issue: 1, Article Number: 014108, Published: JAN 1 2009.

Characterization of IPMC as Passive and Active Damper as an Alternative Novel Smart Actuator, Author(s): Bandopadhya D, Bhattacharya B, Dutta A, JOURNAL OF REINFORCED PLASTICS AND COMPOSITES, Volume: 28, Issue: 2, Pages: 183-200, Published: JAN 2009.

Frequency-Shaped Sliding Mode Control Using Output Sampled Measurements, Author(s): Mehta AJ, Bandyopadhyay B, IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, Volume: 56, Issue: 1, Pages: 28-35, Published: JAN 2009

A nonlinear generalized continuum approach for electro-elasticity including scale effects, Author(s): Skatulla S, Arockiarajan A, Sansour C, JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS, Volume: 57, Issue: 1, Pages: 137-160, Published: JAN 2009.

Pseudo-rigid Body Modeling of IPMC for a Partially Compliant Four-bar Mechanism for Work Volume Generation, Author(s): Bandopadhya D, Bhattacharya B, Dutta A, JOURNAL OF INTELLIGENT MATERIAL SYSTEMS AND STRUCTURES, Volume: 20, Issue: 1, Pages: 51-61, Published: JAN 2009.

Simultaneous Optimization of Structure and Control of Smart Tensegrity Structures, Author(s): Raja MG, Narayanan S, JOURNAL OF INTELLIGENT MATERIAL SYSTEMS AND STRUCTURES, Volume: 20, Issue: 1, Pages: 109-117, Published: JAN 2009.

Theoretical and experimental investigations on the active structural-acoustic control of a thin plate using a vertically reinforced 1-3 piezoelectric composite, Author(s): Ray MC, Faye A, Patra S, et al., SMART MATERIALS & STRUCTURES, Volume: 18, Issue: 1, Article Number: 015012, Published: JAN 2009.

Optimal vibration control of smart fiber reinforced composite shell structures using improved genetic algorithm, Author(s): Roy T, Chakraborty D, JOURNAL OF SOUND AND VIBRATION, Volume: 319, Issue: 1-2, Pages: 15-40, Published: JAN 9 2009.

Tools of the Craft: Aligned wafer bonder

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A significant obstacle limiting the predicted commercial uptake of MEMS devices has been the problems associated with packaging. Whilst many MEMS devices have demonstrated excellent performance at the R&D phase, this performance has often been lost when trying to move the device to high volume production due to the lack of a cost-effective packaging solution. An attractive means of addressing this issue is to move as much of the packaging process as possible to the wafer scale using wafer bonding techniques to package the devices. This approach thereby amortises the packaging cost over all the devices on a wafer. This WLP (Wafer Level Packaging) capability puts added demands on the specifications of the wafer bonding tool, which traditional aligned wafer bonding equipment does not adequately address, especially when the packaged devices need to operate in vacuum or a defined gas pressure. This article describes a wafer bonding tool ideally suited to such applications and covers two examples of its use for MEMS fabrication and WLP.

Fig.1 AML AWB04 wafer aligner-bonder

The AML AWB04 aligner-bonder is shown in Figure 1 and schematically in Fig. 2. The tool is capable of 1 mm alignment accuracy in both manual and automatic modes. By incorporating the alignment function within the bond chamber, the tool enables wafers to be kept in wide separation prior to heating, alignment and bonding – all under vacuum. This enables thorough out-gassing of all wafer surfaces and produces the following benefits: (i) No need for separate mask aligner, (ii) Fast throughput (large pumping path for out-gassing, plus simultaneous heating, pumping and alignment), (iii) Differential temperature control for the two wafers (allows getter activation on one wafer whilst holding temperature sensitive materials at lower temperature on the other wafer), (iv) In-situ viewing of interlayers when developing and optimising bonding processes, (v) Capability for viewing and compensating for misalignment if shift occurs during adhesive bonding, (vi) Use of reducing gas in the bond chamber to remove oxide from eutectic layers, and (vii) Accurate gas pressure encapsulated in device cavities (from 10^{-3} mbar to 2000 mbar cavity pressure) – important for critically damped MEMS oscillators.

It is possible to adjust the machine process parameters to suit different tasks. For example, the parameters can be tuned for a getter activation process (required temperature 500°C) for bonding to a device wafer which could not be heated above 380°C. This enables eventual device operation at a cavity pressure of $<10^{-2}$ mbar for the wafer level packaged devices.

There is also a provision for the in-situ observation of the bonding interface when bonding two wafers using a thick (20 um) adhesive layer. The conventional method for performing this process is to use align and bond systems in which the wafers are aligned in a modified mask aligner, clamped in a jig and transferred to a bonding tool for the wafer bonding step. This often results in wafer shift due to the lubricating properties of the adhesive prior to curing, and this shift does not become apparent until after the bonded wafers are removed from the process tool. With an in-situ aligner-bonder this shift can mostly be prevented, and if some alignment shift does take place, it can be observed as it occurs and compensated for before the thermal curing step. In addition the force applied to the wafers can be adjusted to achieve the required adhesive flow/spread before thermal curing is performed thereby simplifying the optimisation of the process.

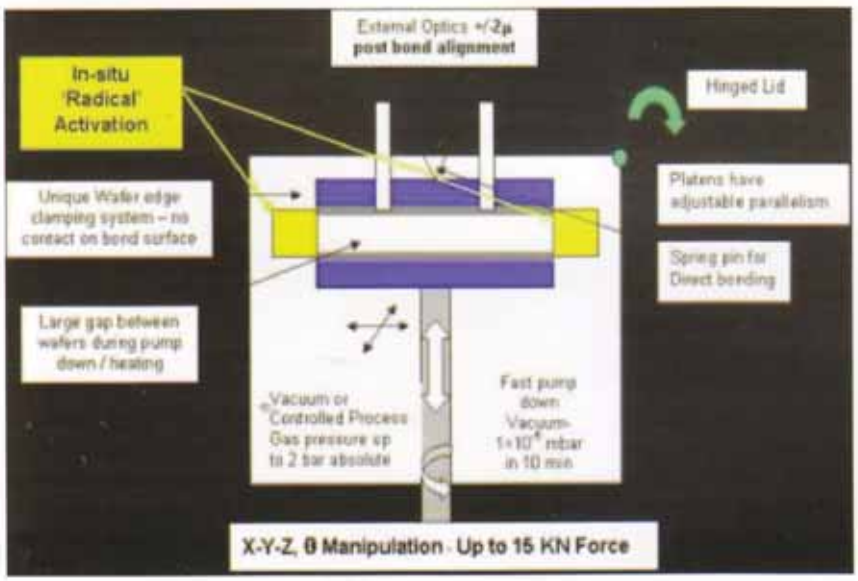

Fig. 2 Schematic of a bonder-chamber

In conclusion, wafer bonding is a ubiquitous process in the fabrication of MEMS devices but conventional aligning and bonding equipment is not suitable for the commercialisation of many MEMS align / bond processes. In-situ aligner bonders overcome many of the problems in particular when vacuum encapsulation is required or when reliable alignment is necessary for wafers prone to contact shift. The in-situ capability is also useful for optimising processes during development.

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218	SHANKAR, V	14/02/00
219	SHARMA, ANESH KUMAR	30/04/06
220	SHARMA, MUKESH KUMAR	16/01/08
221	SHEEPARMATTI, B.G	29/01/04
222	SHIREESH, PHADKE D	16/04/02
223	SHIVARAM A C	27/8/07
224	SIKKA, RAJEEV	02/04/04
225	SANJEEV SIKKA	02/04/04
226	SINGH, D N	27/01/03
227	SINGH, R.K	18/07/01
228	SINGH, GAJBIR	23/12/03
229	SIVAGNANAM	11/09/00
230	SIVAKUMAR, M S	03/05/02
231	SMITHA, A N	18/12/00
232	SOMASHEKAR, B R	10/06/05
233	SRIRAM, B	25/04/06
234	SRINIVASAN, PRABHA	30/07/05
235	SRINIVASA G V	28/07/05
236	SRIDEVI, V	12/04/06
237	SUBRAMANIAN, A K	22/03/00
238	SUDANA, MADHU	09/04/01
239	SUDHAKAR, VELURI	04/02/03
240	SUNDARAM, RAMESH	07/01/00
241	SUNDARAM, V J Gen.	06/10/99
242	SURESH, G	27/09/01
243	SURESH, B.S.	14/12/05
244	SURYANARAYAN, S	19/12/02
245	SWAPNA, J	31/03/04
246	THAKARE, AMOL	10/06/08
247	TALABATTULA, SRINIVAS	08/11/00
248	UDPA, LALITA	*
249	UDPA, SATISH S	*
250	UPADHYA, SANJAY	16/01/08
251	UPADHYA, SARALA	30/07/05
252	UMA, G	21/12/04
253	UMAPATHY, M	14/02/06
254	UPADHYA, A R	09/11/99
255	VALSARAJAN, K V	09/11/99
256	VASUKI, B	12/04/06
257	VENKATRAMAN, KARTIK	15/02/00
258	VENKATESH, K P	18/01/06
259	VENKATESH, P	25/04/06
260	VIKRAM KUMAR	25/06/99
261	VINOY, K J	28/07/05
262	VIJAYARAJU, K	08/11/02
263	VISHNUBHATLA, R M R	*

If each ISSS member brings in another member, the ISSS membership will easily double. So, get a new member and help ISSS grow.

NPMASS Update

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The National Programme on Micro and Smart Systems (NPMASS) (*see* Vol. 3, No. 1, p.1) is being run by DRDO through Aeronautical Development Agency (ADA), Bangalore. Since its sanction in September 2007, the programme has made considerable progress. Meticulous efforts were made in the first six months to identify the roadmaps for a number of thrust areas where Micro and System Technology can make significant contribution. Brainstorming sessions and discussions were organised by all Project Assessment Review Committees (PARCs) chairs with experts from industry, users, and academicians. Various groups that are involved in the related fields were also invited for these meetings. At the end of this exercise, roadmaps were drawn for the programme to focus on specific developments aimed towards the realization of systems and their demonstration. Based on these recommendations, 29 projects have already been sanctioned covering device development, facility augmentation, infrastructure for characterization and facilitate human resource development through National MEMS Design Centres (*see* Vol. 2, No. 1, p.1).

Most of the device development projects focus on applications in the area of aerospace, essentially concentrating on inertial sensors such as accelerometers, gyroscopes, etc, and RF-MEMS. In addition, projects have also been sanctioned to demonstrate the use of smart materials technology and devices such as actuators for aerospace applications. As part of this programme, it is planned to establish a few facilities under Infrastructure development for fabrication and characterization. These include facilities for the fabrication of polymer-based microdevices, characterization of materials, mechanical characterization of microdevices and RF-MEMS. It is also planned to augment Microsystems related fabrication facilities at SCL (Chandigarh), BEL (Bangalore), CEERI (Pilani) and C-MET (Pune).

As a part of Human Resources Development activities, a few academic institutions across the country are being identified as tier 1 and tier 2 centres in addition to the resource centres funded through the earlier programme NPSM (*see* Vol. 1, No. 1, p. 1) for setting up National MEMS Design Centres. Resource centres (IISc-Bangalore, IIT-Bombay, IIT-Delhi, IIT-Kanpur, IIT-Kharagpur and IIT-Madras) will act as the nodal centres for hand-holding the tier 1 and tier 2 centres. These centres will be supported with the requisite hardware and licensed software tools. In order to encourage the students, provision is being made to fabricate the prototype designs made by them through Indian Institute of Science (IISc). As you are aware, ISSS has been organizing MEMS workshops jointly with NPMASS across the country for the benefit of faculty and students from engineering institutions in the neighbourhood. It is also proposed to give hands-on training at CEERI, Pilani, for a few selected participants from each of these workshops.

An attempt is also being made to involve the private industries in the activities of NPMASS. It is heartening to note that some of the industries have already come forward to participate in the programme and the details will be given in subsequent reports. While many of the technologies that are being developed for strategic applications under NPMASS, it is expected and sincerely hoped that the commercial exploitation of these developed technologies will find adequate use in the civilian sectors such as medical and automotive industries.

Experimental Kit Demonstration

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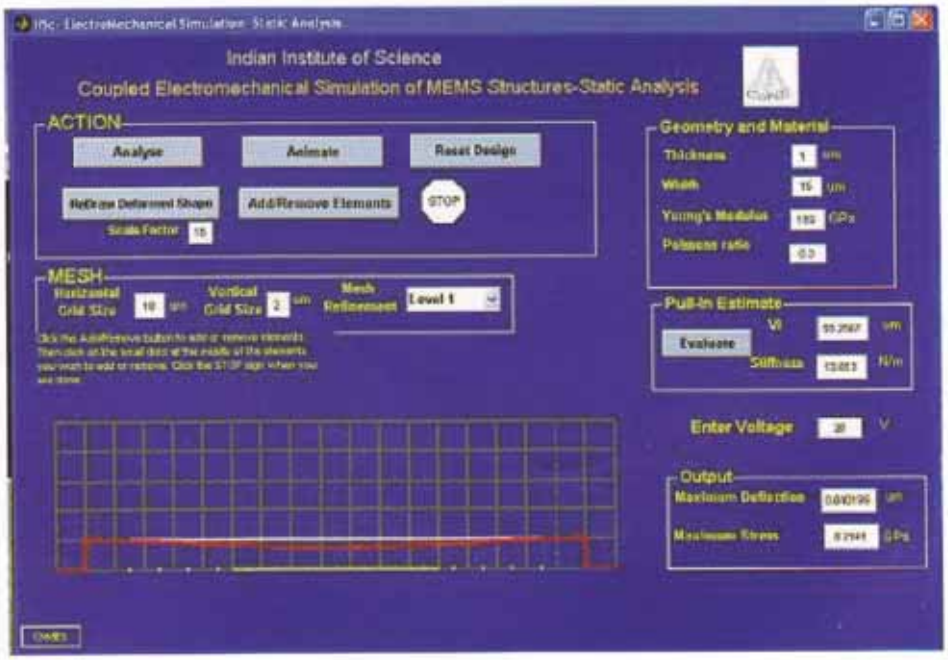
ISSS continues its efforts to bring out an undergraduate level elective course on Micro and Smart Systems in the engineering colleges of Visveswaraya Technological University (VTU), Karnataka (*see* Vol. 1, No. 1, p. 6). This course has been formally approved by VTU as an elective and is likely to be taught this year by a sizeable number of colleges. A textbook is under preparation to help the instructors and students in this course. A unique feature of this course is that it also includes four experimental kits that enable students get a hands-on experience of the the technologies they are learning. A pilot demonstration of the kits was held in the Indian Institute of Science, Bangalore, on 21, February, 2009, under the support of VTU. Except the computational modelling kit (which will be handled by IISc; see the figure on the right), the three hardware kits will be distributed by three companies, viz. Bharath Electronics Ltd. (micromachined pressure sensor kit-*see* Vol. 3, No. 1, p. 5), Spanktronics (vibration control with piezoelectric sensors and actuators), and BigTec (polymerase chain reaction kit) all of which are located in Bangalore. Those interested in buying these kits may contact suresh@mecheng.iisc.ernet.in for further information.



Campus Buzz
BITS, Pilani

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As a core initiative at the Birla Institute of Technology and Science (BITS), Pilani, faculty from across the disciplines is working together for Center for Nanoscience and Technology (CNT) with the theme of MEMS/NEMS design Center and a Lab for characterization and validation of micro and nano devices. In the last five years, the working group at CNT has published over 60 journal papers and presented papers in over 70 National/ International Conferences.

The faculty is doing research on many aspects of micro and nano domains. Investigations on mechanical and electrical properties of metal matrix reinforced with nanoparticle and carbon nanotubes are being pursued to tackle the challenges in developing nanoparticle/carbon nanotubes reinforced metal matrix with enhanced mechanical and electrical properties. The fabrication of the reinforced metal matrix with nanoparticles and carbon nanotubes is marred with many problems such as mixing of the two solids, uniformity and alignment of the nanoparticle/Carbon Nanotubes in metal matrix and finally economic issues vis-à-vis improvisation in mechanical and electrical properties of the developed composites. The Brownian motion assisted electrodeposition to overcome nonuniform electrodeposition and electrodissolution (NEE) is attempted to study and overcome the related issues. Another team is carrying out studies on dispersions of functionalized carbon nanotubes and various nematic liquid crystals with low resistivity. Presumably, the functionalized carbon nanotubes will reduce the residual dc and the driving voltage by significant factor.

NPMASS (Sukshama, Vol. 3, No. 1, Jan. 2008), biomedical Project Assessment and Review Committee (PARC) has sanctioned a project to Biology and Mechanical Departments of BITS, Pilani jointly with CEERI, Pilani, and bigTech Pvt. Ltd., Bangalore, to develop an indigenous chip for testing the antibiotic sensitivity of pathogens found in human urinary tract. The objectives of the project are to design a microfluidic based device with appropriate channels and incubation chambers for various antibiotics and the biological sample and to select the best panel of antibiotics to be used for treating infections by common uropathogens. The aim is to develop a point-of care device for detecting uropathogen's (bacterial) sensitivity and to provide readout of sensitivity to a given antibiotic in the chosen panel.

Two more funded projects from DST and one funded from DRDO are being carried out by Chemistry and Physics departments of BITS, Pilani. The projects pertain to nano-size ordered solid catalysts to provide numerous opportunities for recovering and recycling catalysts from reaction environments. These features can lead to improved processing steps, better process economics, and environmentally friendly industrial manufacturing. The main objectives of the research work of these funded projects are synthesis of nano-size heterogeneous catalysts with surface acid-base properties and to develop new protocols for synthesis of some biologically important lead molecules using these nano-size heterogeneous catalysts and multi-component condensation approach under environmentally benign conditions.

There are attempts to synthesize polymer-silica nanocomposites, incorporation of vinyl monomers (including functional monomers) and their subsequent polymerization inside the silica pores and development of highly ionically conducting superionic materials based on (i) glasses (ii) glass ceramic nanocomposites.

Readers becoming writers

Readers of Sukshma can contrinute in many ways. Here are some:

Industry Watch: you can write about an industry or a product that you are familiar with.
Book Review: you can share views of a recent book for the benefit of others.
Conference Report: you tell us about a conference you attended or organized.
Tutorial: two pages are yours to describe something you know very well.
Campus Buzz: spread the word about activities in your university.
Accomplishments: describe your organization's accomplishments in a page.
Tools of the Craft: share your experience with a particular instrument.
Recent Papers: send us a note about your recent journal paper(s).

The editorial team welcomes any other contribution. Comments and suggestions are also most welcome. Just contact: sukshma@mecheng.iisc.ernet.in.

Indo-US Workshop on Microfabrication and Fabrionics

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Indo-US Workshop on "Microfluidics and Fabrionics" was organized by the Departments of Mechanical and Chemical Engineering, IIT Kharagpur, during January 9-11, 2009. The Indo-US Center of Excellence on Fabrionics played a pivotal role in organizing this event under the leadership of Prof. Amitabha Ghosh, in which Prof. Suman Chakraborty was the Organizing Secretary and Prof. Sunando DasGupta was the organizing Chairman. This Workshop was financially supported by the Indo-US Science and Technology Forum. More than 20 distinguished speakers from all over the World, including MIT, UIUC, Northwestern, UCI, Nagoya University, IISc, IIT-Kanpur and IIT-Kharagpur presented plenary lectures during this event. The central theme of this Workshop took its motivation from the fact that the ability to create structures and patterns on microscopic and sub-microscopic length scales has of late 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. Intimate relationships between fabrication technologies over reduced length scales and microfluidic transport mechanisms have accordingly been emphasized in details in the lectures presented during the Workshop. The lectures also emphasized the pertinent emerging applications due to their inherent advantages such as high transfer coefficients, efficient process management, miniaturization of devices for specific applications, and addressability of cellular length scales. The applications in diverse high-technology areas including biotechnology and biomedical engineering, and thermal management of electronic devices/systems were discussed in significant details. There were more than 150 participants in this Workshop. More than 100 outstation students, starting from undergraduate to the doctoral level, were accommodated in the Workshop, free of any charges. Dr. Arabinda Mitra, Excetive Director of the Indo-US forum that supported this workshop, also presented the opportunities for research support as provided by them to scientists and engineers of various age groups.

Prof. Suman Chakraborty, the organizing secretary of the workshop on the left;

A slide from a presentation by Dr. Mano Prakash from Harvard University on capillary ratchets in microfluidics, on the right.

International Conference on MEMS at IIT-Madras

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The International Conference on MEMS (ICMEMS 2009) was held from 3 - 5 January, 2009 at the Indian Institute of Technology Madras. It was organised by the Microelectronics and MEMS Laboratory of the Electrical Engineering Department as part of the ongoing Golden Jubilee celebrations of IITM. The conference comprehensively covered the areas of MEMS Materials, Design and Modeling, Fabrication and Characterisation, BioMEMS and Microfluidics, RF MEMS, Optical MEMS, and NEMS. Besides the keynote address delivered by Thomas Thundat, Corporate Fellow of Oak Ridge National Laboratory, USA, there were 7 plenary and 23 invited talks by eminent researchers from academia and industry. Thanks to a rigorous peer review, 78 of the 156 abstracts submitted were selected, with 34 oral and 44 poster presentations. The sessions were of very high quality and participative as was evident from the animated discussions during the presentations, poster session and the tea and coffee breaks. A large number of students attended and benefited from interaction with the experts. Three awards each for best student papers (Delft Tech.Univ., IITM and Jadavpur Univ.) and best posters (Univ. of Alberta, IITM and Kurukshetra Univ.) were presented. There was a special session on the Indian Scenario with presentations from ISRO, BEL and bigtec Pvt. Ltd. There was also a session for presentations from the major sponsors. The conference was funded by IITM, DST, AOARD, AML, GE India, STS and others. Selected papers from the conference are to be published in the International Journal of Advances in Engineering Sciences and Applied Mathematics, the recently launched official publication of IITM, published by Springer.

Audience in an ICMEMS session.

Book Review

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Introduction to System-on-Package (SOP)

Miniaturization of the Entire System
McGraw-Hill, 2008
ISBN: 978-0-07-145906-8
Price: US$ 97.50 as published online.

Professor Rao Tummala and his team have brought out this latest book on microelectronics systems packaging focusing on System-on-Package (SOP). According to Dr Tummala, the book is the result of 12 years of research activities from the Packaging Research Center (PRC), Atlanta, GA.

Dr. Tummala had earlier brought out popular books such as the Microelectronics Packaging Handbook (3 vols.) in 1998 and the first-ever textbook in electronics systems packaging came about in 2001 with the Fundamentals of Microelectronics Systems Packaging publication from McGraw Hill. in 2001. Both have been used extensively worldwide and the latter is already a textbook in more than 55 universities globally where packaging is taught as an undergraduate topic.

There are 13 chapters in this book; the first three are introductions to the basic concepts of SOC, SIP (System-in-package) and SOP. Chapters 4-13 then deal with the individual components of the SOP beginning with electrical mixed-signal design, RF, Opto, MEMS packaging in a SOP framework. An entire chapter is devoted to SOP substrate choices with multilayer wiring options. Other crucial research areas covered in the book are thermal SOP, SOP reliability, Biosensors, wafer-level SOP and electrical test of such complex systems.

The authors have at the beginning clearly defined the concept of SOP compared with traditional technologies at the chip and board levels. There are many building blocks in an electronic system and the first chapter identifies for the reader the advantages of moving to SOP to attain high density with better electrical performance. The striking feature of SOP build-up is that is has no package-to-board interconnects; since they are built on the substrate itself minimizing the chip to chip interconnect lengths.

There are many books on SOC but the treatise in chapter 2 deals with SOC which can be read and understood by an engineer from other disciplines also since it covers fundamentals aptly. Since packaging is a multi-disciplinary field, for any packaging engineer there are very good references. The package formats are changing very rapidly, from large footprint packages to bare die and the state-of-the-art Ball Grid Arrays (BGA) and Chip Size Packages (CSP). Although TAB, Wirebond and Flip chip are the main chip connection choices, many decisions need to be weighed in terms of final package format and that is dependant on electrical performance and thermal management issues. Many foundries offer SIP (system in package, stacked die, wirebonded or flip chip attach) formats and currently chip stacking and package stacking (PoP) options have to be considered carefully for high-volume production and cost efficiency. The authors have dealt with these comparisons very elaborately in chapter 3.

Chapter 4 covering almost 100 pages is probably the best one can expect in signal integrity if you are working in the electrical design of mixed-signal, RF and mobile, wireless applications or products. The use of embedded passives (reduces real estate considerably) in RF circuits and the concept of chip-package co-design have been dealt with very well by the chapter authors.

The PRC team working on optoelectronics system packaging has provided ample information about the evolution of optoelectronics packaging technologies (chapter 6) and the prototypes that have been made available in the industry for wireless and mobile communication.

The SOP substrate is the key to housing the active elements, the embedded passives for RF, opto and digital applications, and it also houses the thermal structures for efficient cooling. In addition, wiring alongside the embedded dielectric material, dielectric core and metallic conductors play a significant part in realizing very reliable electrical performance and stability at minimal cost for volume manufacturing. Chapter 7 answers many questions about materials and processes for substrate fabrication including high density via formation, multilayer wiring and through-silicon vias (TSV) and related equipment.

The active methods of thermal management and the thermo-mechanical reliability of the SOP structures are adequately dealt with in different chapters (11 and 8). MEMS wafer-level and Bio sensors are briefly discussed as viable integral options for SOP (chapters 9, 10 and 13). And finally, the very important chapter on electrical test is covered in chapter 12. Electrical test of SOP modules, sub-systems and the system as a whole needs a wide range of electrical test equipments (at various frequencies) and standard procedures. The so-called Known Good Methods are succinctly presented in this book.

This SOP book in all covers a very wide spectrum of topics from different disciplines. Therefore, one can imagine the complexity involved in integrating a SOP prototype beginning from electrical design to substrate fabrication to reliability and finally electrical test. The authors have highlighted the concept of *miniaturization with built-in mega functions* as the driver to SOP technology.

This book makes a good reading for all packaging engineers currently in the field and also a must for universities offering electronics systems packaging as a course in the curriculum. For beginners, the earlier book on fundamentals of systems packaging by Dr Tummala may be more suitable.

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