|| sūkshma ||

The ISSS newsletter about micro and smart systems in India

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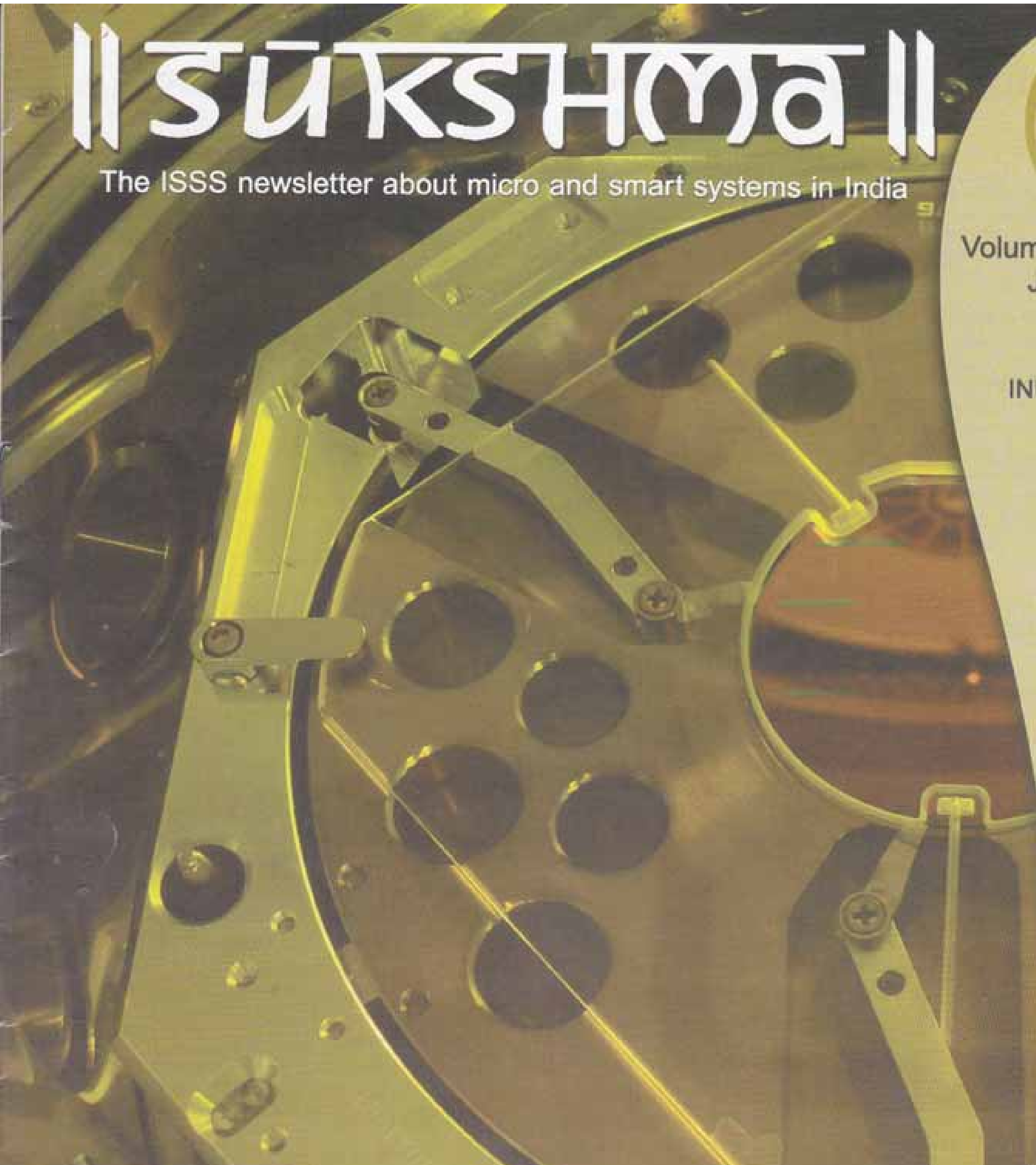
July 2009



INUP Workshops

Unconventional Micromachining

AGM on July 24th in NAL

Don't miss it!

Monsoon Issue

Aligned wafer bonding

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This newsletter is published quarterly by the Institute of Smart Structures and Systems (ISSS) and is sent to all its members by postal mail.

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Editorial

Interdisciplinary Education

G.K. Ananthasuresh
suresh@mecheng.iisc.ernet.in

Microsystems; Smart Systems; Nanotechnology; Synthetic, Systems, and Mechano Biology, etc. are clearly interdisciplinary areas. At present, these emerging subjects are taught at the advanced level in undergraduate courses or in post-graduate courses. When these areas mature and give clear indications that they are here to stay, as it has happened with Microsystems, how do we teach them? At this point of time, introducing a course in these areas in the last year of the undergraduate curriculum is a good start or one may even say that it is imperative to do so if we want to inspire next-generation scientists. But very soon, it may prove to be too late if we wait until the fourth year of the undergraduate programme. An area such as Microsystems is, at this time, only a mix of different engineering disciplines and not so much of science. But then, this and other emerging disciplines encourage us to think of an undergraduate curriculum wherein science and engineering/technology are not separated out. Imagine an undergraduate curriculum in which a student learns the following subjects: mechanics of solids and fluids, electrostatics and electromagnetism, thermodynamics, transport phenomena, statistical mechanics, quantum mechanics, information science, and structure of matter along with essential aspects of physics, chemistry, and biology and a good dose of mathematics that ties all of them together.

It will probably not be fruitful if the subjects mentioned above are taught in isolation. They have to be taught by drawing interconnections among them. For example, in a "strength of materials" course, one should not stop at the deformation and stresses in a beam. It should be pointed at that time itself that there will be a difference in temperature between the compression and tension sides of a beam and that it leads to dissipation of energy. It should also be mentioned at what size this effect becomes significant and what other things happen when we consider miniature beams. We can talk about how a virus or a single molecule could be detected with a cantilever beam and how we can 'see' atoms with such a simple mechanical structure. A student who learns the aforementioned fundamentals and knows their interdependencies would not only be at ease with interdisciplinary areas but also would have the capacity to learn the technological or deeper aspects of any chosen individual discipline. Are we ready for it?

Who can teach such a curriculum of interdisciplinary education that seamlessly combines science and engineering? It requires the instructors to work harder; they have to learn the 'other' subjects and assimilate them to teach effectively. We need good books that bring in this new flavour. We need training for teachers. Teachers should keep up with latest in science and technology within their own areas of interest. It is easier to do it for a teacher is also engaged in research than someone who is content what he/she learnt and mastered a specialized subject many years ago. What incentives exist for a teacher to take this extra trouble? The responsibility lies with educational institutions to facilitate this. It is easier said than done. A cursory glance at the masters programmes offered by, mostly privately owned, educational institutions indicates that they are making an effort to expose the students to emerging and interdisciplinary areas. But the requisite training of teachers in these areas is woefully lacking. A good starting point may be that educational institutions and the government should invest in training new generation of teachers and help them engage in research.

We need teachers who can teach across the disciplines. We need books that integrate different disciplines at the fundamental level. One feels gratified by leafing through the primary school books of National Council of Educational Research and Training (NCERT). In a Foreword written for Environmental Studies (EVS as it is called) textbook for Class V, we see this: "The syllabi and textbooks developed ... attempt to discourage rote learning and the maintenance of sharp boundaries between different subject areas". In a note to teachers and parents, we find: "There is no place for definitions and mere information in this book". The NCERT books live up to this vision. The books are full of questions and few answers. A lesson entitled "From Tasting to Digesting" does not contain the information about the digestive system. It merely shows an outline of a body and asks the students to sketch the digestive system as they imagine it. But the lesson, with many questions spread although, has answers because the questions make one think. The lesson ties the subject matter to other related topics. It asks why people are dying of hunger in the Kalahandi district of Orissa, a place that grows most rice and exports to other states. It is a question posed to a fifth standard student without an answer given in the text! Since we are doing that at the primary school level, we should get ready to to integrate science and engineering at the undergraduate level.

ISSS News

S. Gopalakrishnan
krishnan@aero.iisc.ernet.in

The Institute for Smart Structures and Systems (ISSS) will be holding this year's Annual General Meeting (AGM) on July 24, 2009 at NAL, Bangalore. The meeting will start at 5:00 PM and will go on up to 7:30 PM. Following the meeting, there will be a dinner at NAL Guest House at 7.30 PM. The agenda for the meeting is given below.

5:00 PM	-	Two Technical Talks
6:00 PM	-	Secretary's Report
6:10 PM	-	Treasurer's Report
6:20 PM	-	Address by Vice President, ISSS
6:30 PM	-	Address by President, ISSS
6:45 PM	-	Election of new office bearers
7:00 PM	-	Address by the incoming President
7:15 PM	-	Vote of thanks
7.30 PM	-	Dinner at NAL Guest House

All ISSS members are requested to attend the meeting and confirm their participation to the Secretary, ISSS, Prof. S. GOPALAKRISHNAN at krishnan@aero.iisc.ernet.in .

[This message was sent to all members by e-mail on June 23, 2009.]

3rd ISSS National Conference

ISSS, as a part of its efforts to spread the awareness of micro and smart technologies, organizes a national conference (ISSS-MEMS) every year in the various parts of India. Previous conferences were held at RCI-Hyderabad and CEERI-Pilani. This year, ISSS-MEMS 2009 will be held in Kolkata between October 14-16, 2009, and it will be jointly organized by CGCRI Kolkata and IIT-Kharagpur. The conference has a National advisory committee headed by Dr. V.K. Aatre, Former SA to RM and currently a Visiting Professor, ECE Department of IISc. The Chairman of the Organizing committee is Dr H.S. Maiti, Director, CGCRI-Kolkata. The conference ISSS-MEMS 2009 will focus on the R&D activities and latest trends in smart materials and microstructures, with the following themes:

MEMS and NEMS: Inertial, RF, Bio, Optical Sensors and Actuators, and Microfluidics

SMART STRUCTURES & MATERIALS: Special Composite Materials, Distributed and Fiber-optic Sensors, Shape Memory Alloys, and Nano Materials

Original full-length papers in IEEE double-column single space format limited to four pages are invited for submission.

Submission of original paper	:	31st July, 2009
Acceptance of Papers	:	17th August, 2009
Receipt of final manuscript	:	15th Sept.2009
Registration deadline	:	1st October 2009

Participants are requested to send the registration form and return it at the earliest to: **Mr. Kamal Dasgupta** (kamal@cgcri.res.in/ dasgupta_kamal@yahoo.co.in) or **Prof.T.K. Bhattacharyya** (tkb@ece.iitkgp.ernet.in / tarunk.bhattacharyya@gmail.com). ISSS life members have a special registration fee of Rs 2,500. All the ISSS members are requested to submit papers and attend in large numbers and make this conference a grand success.

INUP Up and Running

Vijay Mishra
vijay.m@ece.iisc.ernet.in

The best way to learn anything, as Aristotle said, is by doing it. The micro and nano technologies are very much in line with this wisdom. To create access to nanofabrication facilities to all researchers in the country, the Minsitsry of Communications and Information Technology (MCIT), Government of India, is generously funding the Indian Nanoelectronics Users Programme (INUP). Sukshma had three articles on this in the past. This is yet another article that describes the activities of this programme.

All ISSS members should take advantage of this programme to fulfil their micro and nanofabrication needs --Editor.

The first INUP training workshop was organized at IISc, Bangalore, during 24-25 April 2009, to familiarize the potential participants in INUP with the facilities available at the Centre for Excellence in Nanoelectronics in IISc. This was convened as the first of INUP workshops to be held every year at IIT-Bombay and IISc. The workshop was chaired by Dr. Vikram Kumar, Director, NPL. The participants were given an overview of CEN, INUP and the specifics of the training workshop.

The workshop was organized in the form of a series of lectures. It was attended by 57 participants from across the country. Prof. S. A. Shivashankar, one of the Principal Investigators of the INUP project in IISc, gave an overview of CEN and INUP bringing out the historical perspective of the facility and sharing its importance in today's scientific scenario. Setting up and running a Nanoelectronics fabrication facility is expensive. Therefore sharing such a facility is essential. This is a common model across the globe. He expressed hope that several training workshops and execution of research projects will not only

INUP Training Workshops

in IISc and IIT-B

Vijay Mishra
vijay.m@ece.iisc.ernet.in

lead to publications and intellectual property but also lead to incubation of nanoelectronics companies. He, on the second day presented "Nano material research in IISc" wherein he shared with audience the research activities carried out by Material Research Centre, Dept. of Material Engineering, Solid State and Structural Chemistry unit, Dept. of Instrumentation, Dept. of Physics, Dept. of Chemical Engineering, Dept. of Inorganic and Physical Chemistry involving around 25 faculty members and 100 research students. Various recent research activities carried out in this domain were discussed including glass nanocrystal composites, tunnel magnetoresistance, tunnel magnetoresistance, nano-structured ferroelectric oxides, ferroelectric nano-crystal patterned by electron beam lithography, fabrication of nano-size ferroelectrics, ferroelectric nanotubes and nanowires. He also gave glimpses of work carried out on ZnO, Ga_2O_2, CuO nanostructured materials and carbon nanotubes and optical, transport and thermal properties of the structures.

Prof. Rudra Pratap talked about Interdisciplinary PhD program in Nanoengineering for Integrated Systems (NIS) implemented in IISc, Bangalore. Around 50 faculty members from 14 different departments of IISc are involved in various research activities making a truly interdisciplinary research program. He also described the central fabrication and characterization facilities available in CEN (IISc). This was followed by Prof. S. Mohan who gave a talk on "Thin Film Deposition Processes" to explain various methods of thin films deposition and different equipments used for the purpose. Prof. K.J. Vinoy presented on "Lithography and Etching" techniques used in Nanoelectronics fabrication.

Prof. Anil Kottantharayil of IIT Bombay presented on "INUP at IITB: Facilities and Projects" sharing contact details of faculties involved in INUP activities at IITB. List of equipment housed in CEN facility at IITB campus was shared and offered to INUP users to compliment the facilities at IISc campus. After this, Prof. Ramgopal Rao from IITB presented on various multidisciplinary research activities carried out IITB in the CEN facility there.

Prof. K N Bhat of IISc discussed the fundamentals of MEMS devices and covered extensive issues related to basic MEMS structure fabrication such as cantilevers, pressure sensors during his talk on "MEMS Devices". Prof. Navakanta Bhat discussed the research activity on "Sensors and Systems" carried out in the CEN facility. He gave an overview of gas-sensing techniques and different building blocks to make a complete gas-sensing system.

The equipment details, their principles of operation and various jobs that can be achieved with them was presented by senior technologists in the second half of 24th and 25th April. Various equipment discussed were laser writer (M. Vijay), pattern transfer by liftoff process (S. Anand), Mask Aligner and wafer bonding (G. Balaji), Nano-lithography (Soumya Gupta), Oxidation, Diffusion and Wet etching (K. Jayashree), thermal evaporation and Sputtering techniques (S. Vedavathi) and CV-IV/RF Characterization (M. Anusha).

Finally, the participants were grouped into batches of 10 individuals each and they were taken for lab tour for quick exposure to all the facilities housed in CEN.

There was a concluding session organized where the members of CCE (Centre for Continuing Education), MCIT (Ministry of Communications and Information Technologies), IITB and IISc shared their observations and summarized various activities covered during the workshop. The audience actively participated in this session and showed enthusiasm in coming forward with future research proposals.

INUP Training Workshop in IIT-Bombay

INUP Workshop organized at IIT-B was held during 30th-31st May 2009. It was also held along the similar lines as the one held in IISc.

Dr. R Chidambaram inaugurated the Workshop and shared his vision on Nanotechnology and his approach of "Directed Research" for technological growth within India. He encouraged fellow members to create a knowledge network amongst various institutes of the country to share the knowledge.

Prof. Anil K. and Prof. Vasi welcomed the audience followed by an address by IIT-B Director, Dr. Devang Khakhar. Prof. Ramgopal Rao gave an introduction to INUP giving a historical perspective of the Project followed by various activities going on at IIT-B under INUP.

Prof. Pinto from IIT-B presented the facilities at IIT-B under CEN in detail and later the audiences were taken for a laboratory visit. Dr. Rina Sharma from NPL, Delhi, presented on "Nanoelectronics and Nanodimensional measurements at NPL. Dr. R. Srinivasa (IIT-B) talked about " Facilities at CRNTS/SAIF, IITB. Dr. D. Bahadur (IIT-B) gave a talk on " Shape forming and Self Organization of ZnO Nanoparticles through soft chemistry". Dr. D.K. Sharma gave a talk on " Nanoelectronics for Medical Applications"

Prof. Venkataraman from IISc presented on "Facilities at IISc Bangalore" to the audience and invited them to come up with proposals to use the facilities at IISc Bangalore. He described the procedures to be followed for a proposal and the proposals under INUP presentlyconsidered by IISc.

There were several technical talks by IIT-B faculty. There were also poster sessions by students on various research activities going on in IIT-B.

Such workshops will be organized every year at IISc, Bangalore and IIT, Bombay to familiarize research community in India about research activities in Nanoelectronics and Nanoscience and encourage research activities in these domains. Additionally, there will be hands-on training workshop too. Details can be found at the INUP website given below.

www.inup.org.in

Tools of the Craft:
Wafer-bonding

G. Balaji and S. Vedavathi
gbalaji@ece.iisc.ernet.in
sveda@ece.iisc.ernet.in

Wafer-bonding is a process by which wafers are bonded together without the application of any adhesive. Packaging and making Silicon-on-Insulator (SOI) wafers are the major applications of this technology. It is also used in many micromachined sensors, infrared detectors, optoelectronic ICs, vacuum-sealed packages, and for protecting the surfaces of semiconductors.

The principle of wafer-bonding is simple as shown in Fig. 1. There are three main methods of wafer-bonding. They include:

- Fusion bonding (or direct bonding) - Bonding of Si-Si/SiO_2
- Anodic Bonding - Bonding of Si – Pyrex(Glass)
- Eutectic Bonding - Bonding of Metal to Metal

For fusion-bonding to be effective, the wafers to be bonded must have a very low surface roughness (less than 1 nm). They should be extremely clean and treated to make the bonding surfaces hydrophilic. After the initial cleaning, the wafers are to be aligned using a double-sided mask aligner and locked onto the bond-tool. The bonding parameters are recommended on most machines are as follows.

- Ambience pressure: 1E-3 mbar
- Piston force: 1000 - 1500 N
- Temperature: 450 - 550 °C in Nitrogen ambience

The Bond thus achieved is sufficient to handle the wafers. The wafers are then heated at 1150°C for two hours in Nitrogen ambience inside a furnace to improve the bond strength.

Anodic bonding tolerates somewhat rough surfaces. Here also, the wafers are to be aligned in the same manner as in fusion-bonding. The parameters for a good bond are:

- Ambience pressure: 5E-2 mbar
- Temperature: 430 °C
- Voltage: 600 - 1000 V

Steps in wafer-bonding are illustrated in Fig. 2. Care should be taken to minimize the voids that form between the bonded surfaces. Acoustic imaging can be used to examine the presence of voids as shown in the figure.

Wafer-bonding makes microfrabrication easy provided that there is a convenient way to etch indidual wafers. One can avoid depositing material in this technique, which is always a good thing given the many issues that we need to deal with depositing material in our own labs.

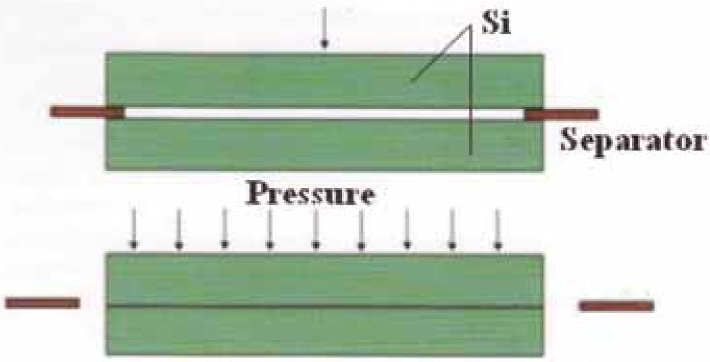


Fig.1 Wafer-bonding principle

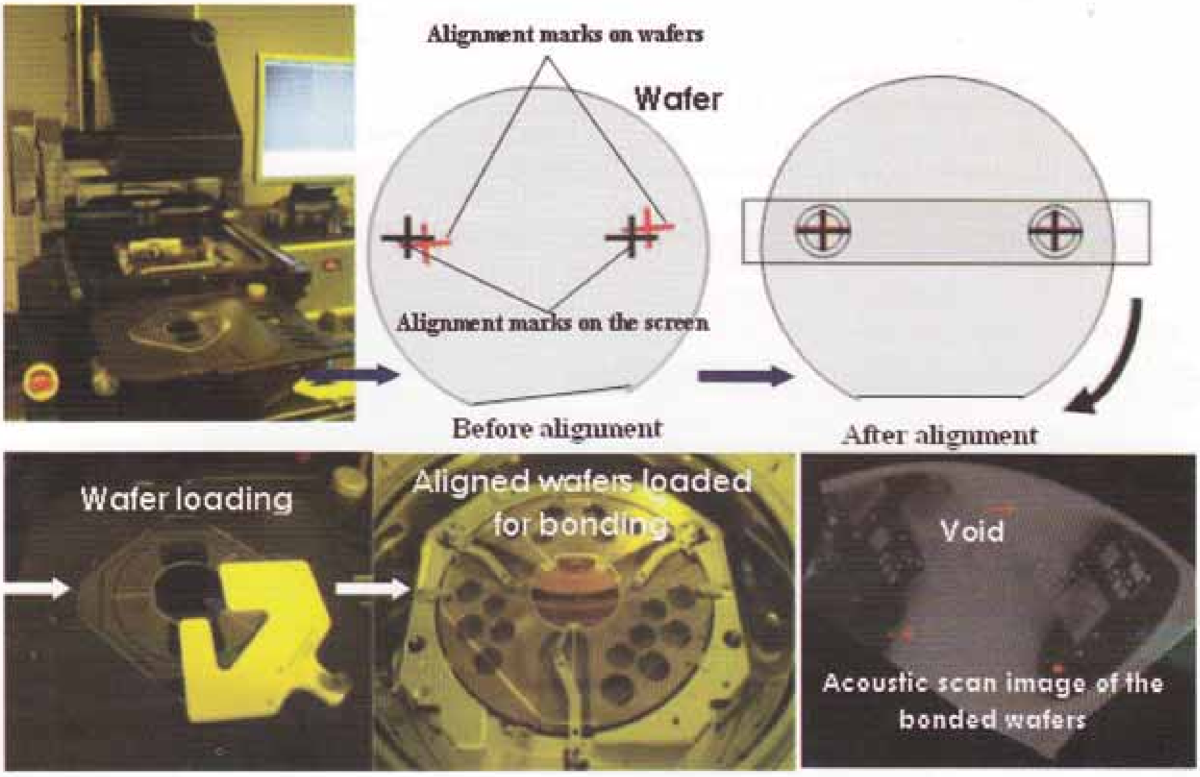


Fig. 2 Steps involved in a typical wafer-bonding process

Micromachining

G.K. Ananthasuresh
suresh@mecheng.iisc.ernet.in

Microfabrication and nanofabrication are 'household' terms used in academic institutions today. Industry too has embraced them but mostly only in certain sectors such as electronics and sensors. What is fabrication? Why is this word used instead of manufacturing? Fabrication means manufacture but microelectronics, when it developed, perhaps needed a term different from conventional macro-size manufacturing to distinguish itself. There is a good reason for making microfabrication stand out. This is because it primarily uses photolithography to create features in bulk materials and on the surface of materials. When microfabrication began to be applied for making movable mechanical structures, the term 'micromachining' came into being. In the early days of microelectromechanical systems (MEMS), when one mentioned 'micromachining', some researchers in other fields actually wondered if it is really miniaturization of macro-scale machining as in metal cutting. At least one senior colleague had asked this author more than dozen years ago if aluminium torsional micro-hinges in Texas Instruments micro-mirror array were machined. He meant whether they were cut on a lathe or a milling machine of small size with micron-sized tools. With a twinkle in the eye, I had replied, "No, John, it is not done that way. It is done with sophisticated microfabrication techniques." Little did I know then that these sophisticated techniques cannot make some features in many materials at the small sizes. And they cannot do that even today.

Imagine making 5 um diameter 1 mm tall posts spaced 5 um apart in an array in any metal or alloy, say, stainless steel. Can that be done today? Perhaps we will jump to say LIGA—a German acronym for lithography, moulding and electroplating. But can all metals be electroplated? You may wonder who needs such an array of posts? Well, there are applications and research studies that need it.

Today micromachining is coming back as really the miniature version of metal cutting. This is happening because the lithography-based chemical etching techniques have limitations. First, they require the big infrastructure for micro or nano fabrication that involves costly equipment and cleanroom environment. Start-up companies even in developed countries cannot afford them. Big companies find it not profitable to sustain their operations if a micro device they are making does not have a large-volume market. Hence, we see today foundry services offered in the area of microfabrication. But these are fixed processes that limit the freedom of a designer and are simply not enough for certain applications.

Second, the tolerance achieved in micro and nano fabrication is poor. It may surprise us to know that micro and nano fabrication can give us really small features size up to a fraction of a micron but the relative tolerance in these is as high as 0.01 to 0.1. That is, if we are making a beam of 100 microns, we can only guarantee an accuracy of 1 micron. Think of masons who build the structures we live in. If they build a doorway of 1 m wide, we hardly mind if it is 99 cm or 101 cm instead of 100 cm. That is the kind of relative tolerance masons can promise! Microelectronics, and arguably nanoelectronics too, does not have relative tolerance better than that. But things change when we consider microsystems with movable solids and fluids. We need much better tolerance than this. We need 0.001 to 0.00001. Such applications include micro-scale optical devices and workbenches; fluidic devices such as pumps, valves, mixers, and others; bioMEMS devices such as needles, nozzles, probes, and others; and mechanical devices that need precise control of shape in general.

Third, photolithography based processes remain in two dimensions or as some would say in 2.5 dimensions with the advent of some deep etching techniques. But can a micron-sized screw or a helical compression spring be made? Yes, perhaps by using focused ion beam (FIB) milling. But that would be very expensive and painfully slow. What about general 3D shapes? One might ask: "who needs 3D features in microsystems?" The answer really is that if it were indeed possible to create any 3D geometry at the micron size, designers' imagination will increase by several orders of magnitude and the functionality, performance, and cost might improve in the same way too.

Fig. 1. Developmental phases of microfabrication

Micromachining

G.K. Ananthasuresh
suresh@mecheng.iisc.ernet.in

A desktop miniature milling machine.

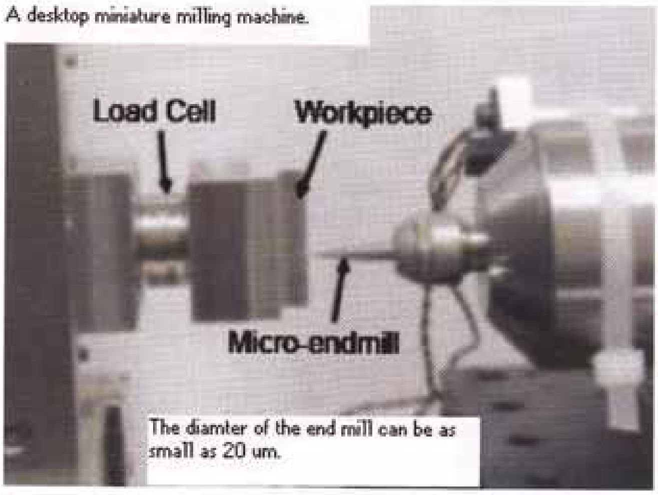


Fig. 2. A miniature milling machine, not much bigger than a laser printer. It can machine metals with feature sizes as small as 50 microns with a surface finish of few 10s of nanometers.

Further reading

Comprehensive Microsystems, Vol. 1., Y.B. Gianchandani, O. Tabata, and H. Zappe (ed.), Elsevier, Amsterdam, 2008, pp. 341-402.

"The Mechanics of Machining at the Microscale: Assessment of the Current State of the Science," X. Liu, R.E. DeVor, S.G. Kapoor, and K.F. Ehmann, ASME Journal of Manufacturing Science and Engineering, Vol. 126, pp. 666-678.

Fourth, photolithography is not universally applicable to all materials. It is not the lithography's limitation per se but that of the selective removal of material through a mask. Silicon is a good material that way because its compounds, oxide and nitride, serve well as masks for selective etching and because highly selective and anisotropic etchants have been developed for it. But the same is not true with steel or titanium, for example. The etchants for these materials will simply etch it at the same rate in all directions resulting in isotropic etch. This leads to etching under the mask and makes realization of very narrow beams or trenches with vertical side walls impossible. Imagine the problems if we want to carve out real 3D features!

Silicon is a very good mechanical material and it has been the choice material for microsystems. But its position as the king of the small world is slowly fading. In view of economy, ease of fabrication, small-volume specialized markets, or specialized requirements (e.g., high temperatures), one looks for polymers and ceramics today. Metals too are slowly competing in the game. It is pertinent at this point to recall early thinking in the field. When in mid nineties, National Research Council (NRC) in the USA wrote a vision paper for MEMS, it talked of four phases of development in microfabrication. See Fig. 1. We are in the fourth phase today—developing newer techniques for newer materials. Well, new and old in this refer to their relative familiarity to the micro technologists. What are the new materials? The answer: polymers, ceramics, metals and alloys, and perhaps even natural materials. What are these new techniques? There are some.

Two chapters in Comprehensive Microsystems, Vol. 1 (see Book Review in Vol. 4, No. 1, p. 11) entitled "Low-cost MEMS Technologies" and "Micromachining" describe a number of techniques. They include: inkjet printing, screen printing, stamping, laminate microfrabrication, injection moulding, micro-casting, hot embossing, soft lithography, electro discharge machining, and electrochemical machining. We can see that all of these are not applicable to all materials, particularly to metals. But there are efforts in real micromachining now--the one in which there is a miniature cutting tool that removes the material from small workpieces. Let us examine the advantages of doing it and the challenges involved in it.

If milling, turning, and drilling can be done at the small sizes, a variety of 3D shapes can be achieved. It can be done for soft materials such as polymers and hard materials such as metals and ceramics provided there is a suitable material for the cutting tool. We can achieve unprecedented tolerances and surface finish. Since the overhead involved will be quite small (typically one machine), it will be more economical than lithography-based microfabrication. The cost of the machine itself might be low.

There is a sub-field that is old called ultra precision micromachining. Here, 10 nm surface finish is possible. But the machines used in these are often quite expensive and are also large in size. They have thermal and vibration compensations, are housed in air-conditioned rooms, and need high maintenance. But the micromachining that we now require should be a simple desktop machine that does not need any special attention. The challenges involved in such true micromaching are many.

First, we need small cutting tools (e.g., mill and drill bits and turning tool bits). The smallest diameter of a mill that is commercially available today is 20 um. These tools wear fast, especially when they are used to cut hard materials. They also break more easily and hence we need excellent control or modelling to estimate the forces involved. Mounting of the work-piece, i.e., the fixturing, is an issue. Lubrication is a problem. Often, the droplets of lubricant may be much larger than the cutting tool or the feature that is machined. So, some sort of atomization of the lubricant is needed. Alignment is not easy. The spindle speed needs to be sufficiently large to get good material removal rate because the cutting tool is very small. Proper feed rates and depths of cut need to be established for different combination of the tool material and workpiece materials. All these can be addressed and are being addressed. See Fig. 2 that shows a machine that is not much bigger than the space occupied by a laser printer and addresses some of these challenges successfully.

In summary, one can make a case for true micromachining as in metal cutting. There is a long way to go here. And there are likely to be good rewards along the way. What is not possible with other techniques might be possible here.

Journal publications by Indian Researchers...

... In selected journals in the last three months:

Ranjan Ganguli
ganguli@aero.iisc.ernet.in

Title: Design and experimental evaluation of simultaneous periodic output feedback control for piezoelectric actuated beam structure Author(s): Ezhilarasi D, Umapathy M, Bandyopadhyay B Source: **STRUCTURAL CONTROL & HEALTH MONITORING** Volume: **16** Issue: **3** Pages: **335-349** Published: **APR 2009**

Title: Multilayer Higher Order Piezolaminated Smart Composite Shell Finite Element and its Application to Active Vibration Control Author(s): Balamurugan V, Narayanan S Source: **JOURNAL OF INTELLIGENT MATERIAL SYSTEMS AND STRUCTURES** Volume: **20** Issue: **4** Pages: **425-441** Published: **MAR 2009**

Title: Effect of the piezomagnetic NiFe2O4 phase on the piezoelectric Pb(Mg1/3Nb2/3)(0.67)Ti0.33O3 phase in magnetoelectric composites Author(s): Sheikh AD, Mathe VL Source: **SMART MATERIALS & STRUCTURES** Volume: **18** Issue: **6** Article Number: **065014** Published: **JUN 2009**

Title: Piezoelectric properties of 0.5(PbNi1/3Nb2/3)O-3-0.5Pb(Zr0.32Ti0.68)O-3 ceramics prepared by solid state reaction and mechanochemical activation-assisted method Author(s): Mahajan S, Prakash C, Thakur OP Source: **JOURNAL OF ALLOYS AND COMPOUNDS** Volume: **471** Issue: **1-2** Pages: **507-510** Published: **MAR 5 2009**

Title: Design and development of a modular valveless micropump on a printed circuit board for integrated electronic cooling Author(s): Verma P, Chatterjee D, Nagarajan T Source: **PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS PART C-JOURNAL OF MECHANICAL ENGINEERING SCIENCE** Volume: **223** Issue: **4** Pages: **953-963** Published: **APR 2009**

Title: Thermal buckling of laminated composite conical shell panel with and without piezoelectric layer with random material properties Author(s): Singh BN, Babu JB Source: **INTERNATIONAL JOURNAL OF CRASHWORTHINESS** Volume: **14** Issue: **1** Pages: **73-81** Published: **2009**

Title: Quasi-static and dynamic strain sensing using carbon nanotube/epoxy nanocomposite thin films Author(s): Anand SV, Mahapatra DR Source: **SMART MATERIALS & STRUCTURES** Volume: **18** Issue: **4** Article Number: **045013** Published: **APR 2009**

Title: Nonlinear free vibration analysis of simply supported piezo-laminated plates with random actuation electric potential difference and material properties Author(s): Jayakumar K, Yadav D, Rao BN Source: **COMMUNICATIONS IN NONLINEAR SCIENCE AND NUMERICAL SIMULATION** Volume: **14** Issue: **4** Pages: **1646-1663** Published: **APR 2009**

Title: Effective properties of thermo-electro-mechanically coupled piezoelectric fiber reinforced composites Author(s): Kumar A, Chakraborty D Source: **MATERIALS & DESIGN** Volume: **30** Issue: **4** Pages: **1216-1222** Published: **APR 2009**

Title: Synthesis and piezoelectric properties of PZT-based glass-ceramics Author(s): Rema KP, Kumar V Source: **JOURNAL OF MATERIALS SCIENCE-MATERIALS IN ELECTRONICS** Volume: **20** Issue: **4** Pages: **380-385** Published: **APR 2009**

Title: Amorphous and nano crystalline phase formation in Ni2MnGa ferromagnetic shape memory alloy synthesized by melt spinning Author(s): Prasad RVS, Phanikumar G Source: **JOURNAL OF MATERIALS SCIENCE** Volume: **44** Issue: **10** Pages: **2553-2559** Published: **MAY 2009**

Title: A finite element based substructuring procedure for design analysis of large smart structural systems Author(s): Ashwin U, Raja S, Dwarakanathan D Source: **SMART MATERIALS & STRUCTURES** Volume: **18** Issue: **4** Article Number: **045006** Published: **APR 2009**

Title: Hybrid structural control using magnetorheological dampers for base isolated structures Author(s): Ali SF, Ramaswamy A Source: **SMART MATERIALS & STRUCTURES** Volume: **18** Issue: **5** Article Number: **055011** Published: **MAY 2009**

Anurekha Sharma
anu67s@gmail.com

The Department of Electronic Science in Kurukshetra University was established in 1990 with a grant from UGC and MCIT with a thrust area of VLSI with the objective to generate trained personnel for the state-of-art technology. With the recent advancements in MEMS and nanotechnology, the department has undertaken research activities in the field of MEMS in collaboration with CEERI, Pilani. The department has also become the part of NPMASS and it will acquire the state-of-the-art design tools to carry out design and simulation of MEMS. The activities related to MEMS research are as follows:

Modelling of Pull-in voltage and Touch-point pressure for Capacitive MEMS Transducer with square Diaphragm: Square diaphragms find applications in many real life applications such as pressure sensors andin actuators. The behavior of the capacitive transducer has been investigated under the influence of applied mechanical pressure as well as electrostatic pressure by proposing a new model. This model takes into account the influence of residual stress, charges in the dielectric as well as the roughness of both the electrodes on the pull-in voltage and touch-point pressure. The results are validated by simulation using Intellisuite and is published in the international journals. [Work done by Dr. Anurakha Sharma.]

Design, fabrication and characterization of RF MEMS Symmetric Toggle Switch (STS) for communication applications: The objective of the work is to design and fabricate RF MEMS switches for X-band applications. The innovative design approach of STS addresses many relevant issues except the switching speed, which is a compromise between the low actuation voltage and beam restoration time. STS is a capacitive type switch, based on push–pull mechanism to obviate the problem of self-biasing and external vibrations. The mechanical structures which include springs, overlap area, torsion actuators and connecting levers are to be realized using surface micro-machining, electroplating (Au) and a modified CMOS process. [Work done by Manider Kaur, Prof. Dinesh Kumar, and Dr. K.J. Rangra (CEERI).]

Study of reliability issues related to RF MEMS Design and Fabrication: MEMS structures fabricated using low temperature deposition techniques including sputtering, e-beam evaporation and electroplating are highly prone to in-built stresses and stress gradients. Composite structures generally used to realize metallic cantilevers, bridges and diaphragm-based configurations further complicate the problem and undermine the reliability of MEMS devices. This is currently being studied through design and modeling of test structures for materials and process parameter extraction. [Work done by Akshadeep, Prof. Dinesh Kumar, and Dr. K.J. Rangra (CEERI).]

Study of MEMS Transducers: The motivation of the work was to fabricate a MEMS-based ultrasonic transducers in different array configurations (i.e., 10x10, 5x5, 5x1) and a single cell to be used for non-destructive Testing. The transducers have been fabricated by two methods: surface micromachining and recently developed wafer-bonding technique. The structural, electrical and mechanical analysis of transducers has been studied. A schematic of MEMS-based Ultrasonic Transducer and the 5x5 and 5x1 array of fabricated devices are shown in the Figs. 1 and 2. [Work done by Anil Arora, Prof. P.J. George, and Dr. V.K. Dwivedi (CEERI).]

Study of Sputter-Deposited ZnO Thin Film as Piezoelectric Acoustic Sensor for MEMS Devices: The objective of work was to fabricate MEMS-based piezoelectric acoustic sensor to be used for aerospace applications. The chip was fabricated successfully and has been space-qualified. The chip has been used in GSLV, PSLV and Chandrayaan recently launched by ISRO, Bangalore. The structural, electrical and optical characteristics of ZnO have been studied for highly c-axis oriented films. The characteristics are improved by post-deposition treatments in three different environments of oxygen, forming gas and hydrogen peroxide solution. [Work done by Arti Arora, Prof. P.J. George and Dr. V.K. Dwivedi (CEERI).]

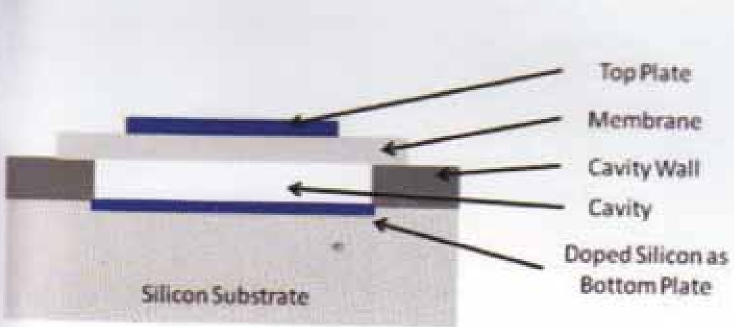


Fig. 1. MEMS capacitive transducer

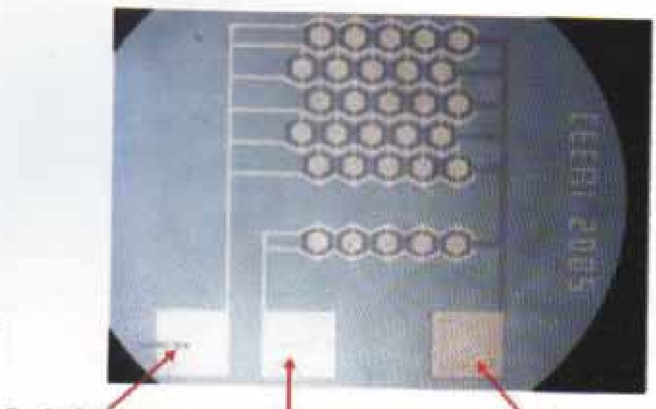


Fig. 2. Fabricated 5x5 and 5x1 array devices

Technology Development

Two-ton force SMA actuator

G.N. Dayananda
dayanand@css.nal.res.in

As a part of the project entitled "Deployment of Mousche Using Shape Memory Alloy" awarded by Aeronautical Development Agency (ADA) under the DISMAS program, a 2000 kgs (two-ton) force-generating Shape Memory Alloy (SMA) actuator bank has been developed at Advanced Composites Division, National Aerospace Laboratories (NAL). The SMA actuator bank moves a distance of 15 mm while generating a net actuator force of over 2000 kgs. This force is used to deploy the additional aerodynamic surface (referred to as a 'mousche') measuring 790 x 215 x 32 mm against a simulated lift and drag load acting simultaneously (that is, the resultant lift load of 331.6 kgs and drag load of 33.16 kgs acting at the centre of gravity of the mousche). The SMA bank consists of 130 wires of about 1 mm in diameter and 650 mm in length. The actuation of these wires is electronically and mechanically synchronized. See Fig. 1. The mousche has been analyzed using standard finite element analysis codes for the combined lift and drag load. Experimental and simulated values have matched well. The electronics circuit assembly of Smart Actuator Driver Electronics (SADE) that powers the SMA actuator bank has been designed and developed in the form of mother and daughter boards. Each daughter board has six miniaturized DC-DC converters and the required power and control signals are routed to the motherboard. The SADE has been integrated to carry out the full load test. NI 6009 DAQ card along with GUI software LabVIEW is used to conduct the experiments. The schematic diagram of the drag load and lift load mechanisms are shown in Fig. 2.

The NAL team that worked on this consists of: G.N. Dayananda, P.Senthilkumar, S.Jayasankar, Byji Varughese, B. Ramanaiah, Satisha and H.V. Ramachandra.

The inputs provided by the ADA team consisting of Dr. K. Vijayaraju , T.C.Subba Reddy and V. Sudhakar are gratefully acknowledged.

Fig. 1. Experimental setup

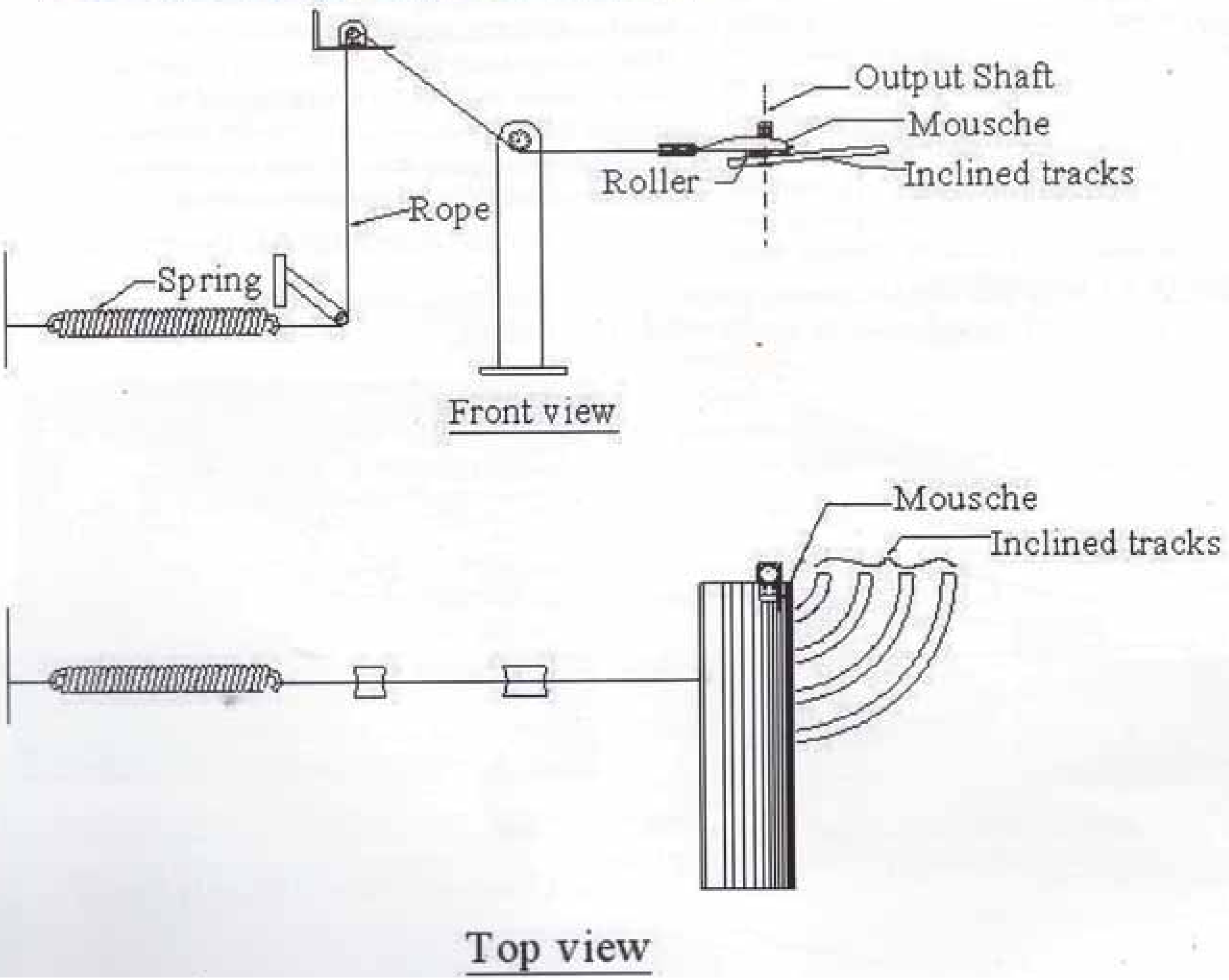


Fig. 2. Schematic of the lift and drag load mechanism

Book Review

G.K. Ananthasuresh
suresh@mecheng.iisc.ernet.in

The Mechatronics Handbook: Mechatronic Systems, Sensors, and Actuators: Fundamentals and Modeling

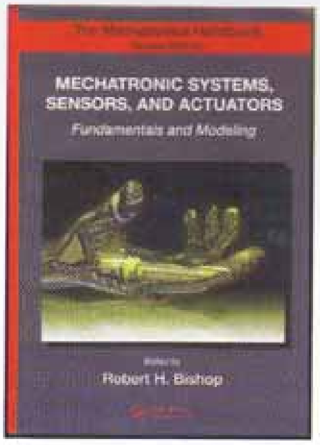
CRC Press 2008
ISBN: 978-0-8493-9258-0

A self-indulging handbook necessarily puts its subject on a pedestal and says that the topic is all-encompassing and is the most important of all subjects. The first sentence of this handbook begins in much the same way: "Mechatronics is a natural stage in the evolutionary process of modern engineering design." It then goes on to describe how mechatronics shaped the later part of the twentieth century and is shaping up the twenty first century. It then attempts to define mechatronics and gives not-so-insightful definitions. But mechatronics is essentially a study of electromechanical systems. But then just as there ought to be a significant difference in 'biochemistry' and 'chemical biology'; and 'biomechanics' and 'mechanobiology'; and other such play of words, mechatronics ought to be more than just electromechanical systems. But this distinction is lost in words.

The book has three sections focusing on 'Overview', 'Physical system modeling, and 'Mechatronic sensors and actuators'. The first section, with six chapters, projects mechatronics as an integrative subject that combines mainly mechanical and electronics. In addition to presenting instruments, control, microprocessor, there is a smattering of micro and nano technology too. The final chapter of this section sheds some light on the curriculum aspects of the subject.

Mechatronics exists as an undergraduate discipline in India. The curricula of these programmes are intriguing. A lot needs to be taught before integration of an electromechanical systems is discussed. The list of topics to be taught is quite long. This handbook, in its 10 chapters in the second section, tries to cover it all. But understandably, this coverage is mostly superficial. The chapter on 'Numerical Simulation' spans just five and a half pages and hardly gives a feel for the topics. Interestingly, there is a chapter entitled 'electrical engineering' but covers only some bits on circuits.

The third section on sensors and actuators is the most sensible part of this book. A good introduction is given to sensors and actuators. After this, in the usual manner, a number of sensors and actuators are described in separate chapters.



The book claims to be the first up-to-date reference on mechatronics. Whether it is true or not, one finds the book to be a quick reference book on the subject matter. In these days of wikipedia and such sites in the Internet, getting introductory and overview information is easy. So, one wonders the need for handbooks that offer only a bird's eve-view of a subject. A book with some insight and details would be much more useful.

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

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