||SUKSHMA||

The ISSS newsletter about micro and smart systems in India

Volume 8 : No. 1&2
April 2013

CMERI-MST Lab

SHM for a UAV

6th Annual
ISSS Conference
Pune, Sep 06-03, 2013

Don't miss it!

Spring Issue

INSTITUTE OF SMART
STRUCTURES AND SYSTEMS

Contents

Editorial

This is the last issue of Sukshma that I am editing. So, it is a fitting moment to look back and reminisce. It all started in 2006 with an enthusiastic team comprising Sayanu Pamdidighantam, S. Gopalakrishnan, G. M. Kamath, K. J. Vinoy and me. We took delight in planning the newsletter, its formatting, printing, and even in choosing the name that captures smart and small—*Sukshma*. We had the unconditional support of all the office bearers and senior members of ISSS. Some had warned us that it is not easy to sustain a newsletter for a long time. They were partly proved right because Sukshma had a long hiatus after 14 uninterrupted quarterly issues spanning 3.5 years. Some hiccups aside, Sukshma has survived this long and has grown from eight pages to 16 pages per issue.

"What has Sukshma achieved?" is a pertinent question. A quick and appropriate answer is that it has kept a record of the activities of ISSS as a newsletter of a professional society ought to do. It has informed ISSS members about the happenings in the country in the micro and smart fields. But these days, very few wait to see the news in print! So, Sukshma tried a few things that people might miss in e-media. Here is the complete list of types of articles that appeared in Sukshma.

- Profiles of leaders of ISSS to document the genesis of ISSS
- Centre-spread tutorial articles on varied topics
- *University Buzz* to highlight the work done in academia
- Technology news
- *Industry Watch* to showcase efforts in the industry
- Individual and institutional accomplishments
- Book reviews
- *Tools of the craft* related to microfabrication and characterization
- Journal publications by Indian researchers in the small and smart fields
- *Lab tour* to describe the work done in specific laboratories in India
- NPSM, NPMASS, and INUP updates
- Conference announcements and briefs

Some of these are continuing as can be seen in this issue. Others can be brought back if ISSS members contribute. More importantly, it will be good if they read and write back to the editorial board. It did cross my mind to do something provocative with Sukshma so that everyone takes notice, for good or for bad, but the wiser counsel prevailed and we treaded a cautious path.

What can Sukshma aspire for in the years to come? If small and smart technologies are here to stay in India, Sukshma can become a magazine to showcase the related developments, primarily in India but not restricted to it.

I thank also those—from the Presidents of ISSS to the printer Raghu of Precision Fototype Services—who helped bring out this newsletter. Sukshma will now be passed onto to the caring hands of Dr. Vidyashankar B, who I trust would keep things going. With your unwavering support, Sukshma will continue to exist and grow along with ISSS.

Prof. G.K. Ananthasuresh, IISc

Journal of ISSS

ISSS has started a biennial Journal to publish original research articles, review articles and short communications in all areas of smart materials, structures, health monitoring, MEMS and smart systems. The journal also publishes important conference/ symposia proceedings which are of interest to scientists involved in Smart materials/Systems technology. The first 2-3 issues of the journal includes submissions based on papers presented at the International Conference of ISSS held in Bangalore from 4th to 7th January 2012 and the ISSS National conference NC-5 held at Coimbatore in Sep. 2012. The Journal will give primary importance to the quality of articles and will strive to keep minimum processing time for publication.

Dr V.K. Aatre and Prof S.B. Krupanidhi will lead the editorial board of the journal as the Editor in Chief and the Executive Editor respectively. Several experts have been enlisted into the editorial board and the editorial advisory board of the Journal. It is expected that with their leadership and efforts the journal will establish itself as a leading scientific publication with quality articles. All ISSS members are requested to contribute to this effort by submitting their manuscripts and by citing articles published here in their other publications.

The inaugural issue of the Journal of ISSS, released at a special function during the Fifth ISSS National Conference on Sept 21, 2012 at Karpagam University, Coimbatore contained eight articles from papers presented at ISSS-2012.

The current issue is available on-line and contains 5 peer reviewed articles including a review paper..

All submissions to the Journal may be communicated to the Executive Editor by email to editor@isssonline.in

DETAILED SCOPE

The Journal of ISSS publishes reviews, full–length papers, and short communications exploring the relationships between Smart Materials, Structures and Systems. The journal of ISSS aims to establish itself as the leading source of primary communication for scientists investigating the multidisciplinary areas of micro and smart structures, systems and properties of all smart engineering materials, some of which are listed below.

Multiphysics: Theoretical and computational advancements and industrial applications of mechanics, acoustics, electromagnetics, magnetics, electrics, fluidics, chemistry, thermodynamics, structures, materials science, biology, etc.

Bio-nanotechnology: bio-photonics, bio-mechanics, bio-manipulation

Smart materials: conducting, electroactive or chiral polymers, smart ceramics, smart composites, micro-and nano-structured materials, self-assembled materials, liquid crystals, biomaterials, etc.

Sensing and actuation: electric, magnetic, acoustic, electromagnetic, infrared, optical, chemical, inertial, mechanical, biological etc.

Fabrication technologies: tools, processes, and materials, vacuum technologies, new fabrication and integration techniques for both silicon and non-silicon materials, top-down and bottom-up approaches, low cost approaches, packaging

Electronics: integration of interface circuits with micro-and nano-scale devices, reliability and sensitivity enhancement

RF MEMS & MOEMS: switches, phase shifters, reconfigurable antennas, integrated optics, optical fibre technology, tunable optics

Energy harvesting: means for accumulation and storage of mechanical forms of energy

Smart Structures: smart aerospace structures, civil infrastructures, transportation vehicles.

Controls: structural acoustic control, real-time implementation, stability of adaptive structures

Structural Health Monitoring: damage assessment, alleviation, and health monitoring of composites, aerospace structures, civil infrastructures and transportation vehicles; self-healing structures

Applications: smart materials and sensors in defense, agriculture, aerospace, automobile, biomedical, etc. field implementations of sensor networks

TYPES OF ARTICLES

Full-length Research Papers: (up to 10 journal pages). Reports of original scientific research, techniques and applications are published.

Short Communications/Technical Notes: (up to 4 journal pages). These are short technical communications containing information typically insufficient for publication as a full scientific article but revealing new technical procedures. These are also expected to serve as Rapid Communication of significant research outcomes or new innovative concepts.

Topical Review Articles: (up to 20 journal pages) These are intended to highlight and summarize currently accepted practices and report on some of the recent progress in areas requiring special attention. Please check with the editorial board on the suitability of a topic before preparing the manuscript for Review Articles.

PLAN FOR ISSUES

Each issue of the Journal may contain up to 10 full-length papers, up to 8 technical notes and one review article totaling about 120 printed pages in a two-column format. All articles will have title, abstract, list of keywords and references.

The first issue of the Journal of ISSS was released at a special function during the Fifth National Conference of ISSS held at Karpagam University, Coimbatore during 21-22 September, 2012.

Journal of ISSS is distributed in print as well as online. The online access is provided through http://www.isssonline. in/journal-isss.

The first three issues of the Journal will be distributed free of cost to ISSS members and relevant institutions. Please contact the editorial team for subscription information. Please note that special subscription rates are applicable for life members of ISSS. Institutional Libraries and personal subscriptions will be charged differently.

Limited opportunities exist for full page and half page advertis ements in the Journal of ISSS. These will be located inside the back cover and the page nest to it, of each issue. For further details please get in touch with the editorial team

PHOTO ALBUM OF ISSS 2012

(Continued in back cover) **Plenary Talks**

The sixth ISSS International Conference was held in Bangalore during January 4th to 7th, 2012. Pre-conference tutorials on RF MEMS and microfluidics were held on January 4th, 2012. The conference was inaugurated by Prof P. Balaram, Director Indian Institute of Science Bangalore. The conference was attended by about 250 delegates including nearly 20 from abroad. There were six plenary lectures and 24 invited talks during this conference. In addition 90 contributed papers were also presented.

Plenary lectures

IIT Kanpur: BioMEMS and Microfluidics

The BioMEMS and Microfluidics initiative has been started at IIT Kanpur in the year 2008-09 by a CARE funding which was provided to a team of faculty members from the departments of Mechanical Engineering, Chemical Engineering, Chemistry, Biosciences and Bioengineering, Physics and Electrical and Communication Engineering. The seed money provided was used to establish the Microsystems Fabrication Laboratory at IIT Kanpur which has been created at the Department of Mechanical Engineering over an area of around 2500 sq. ft out of which around 1700 sq. ft. is a yellow room with several clean hoods containing mask aligner, PECVD, sputtering, oxidation, dicing and wire bonding facilities. The lab also houses characterization facilities like non-contact profilometer, microscopes and spectro-photometers. The figure below shows some representative optical micrographs of the various modules fabricated at this Laboratory. The current research thrusts are described below.

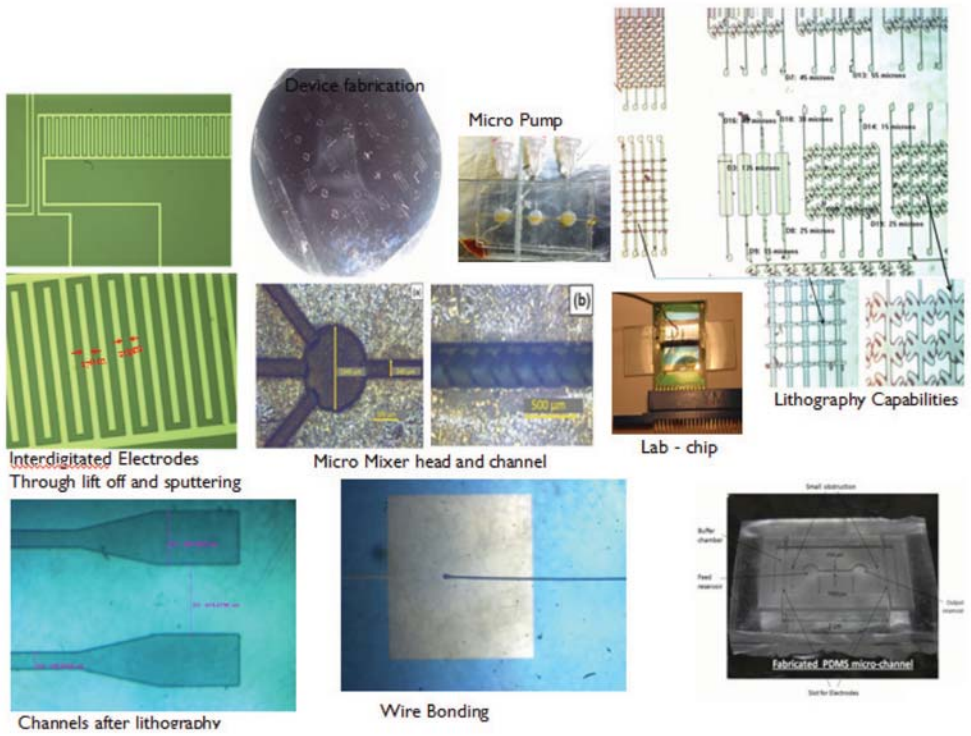

Figure1: Optical micrographs of (a) Interdigitated electrodes creating dielectrophoretic forces (DEP), (b) SU-8 based molds done by optical lithography, (c) Micromixers fabricated using PDMS by the micro-replication by double inversion techniques (d) PDMS microchannels for DEP based capture of pathogens (e) Wirebonded platinum pad in silicon (wire size is 10 microns) (f) Surface elecrphoresis channel in PDMS fabricated using a laser micromachined acrylic mold (g) Lab on chip platform for DEP based capture and real time PCR based identification of pathogenic bacteria (f) Lithography done using SU8.

Dielectrophoresis assisted concentration of micro-particles

The detection and counting of micro-particles having sizes comparable to biological entities can provide a tremendous impetus to rapid diagnostics and clinical applications. For this purpose a concentration step is normally added prior to the detection process. We have designed, developed and characterized a MEMS counter which captures micron size fluorescent beads using dielectrophoresis (DEP) and monitors their accumulation in a 12 ìm×230 ìm size channel and monitors this accumulation as a measure of the growth of overall fluorescence.

Bilayer staggered herringbone micro-mixer (In collaboration with Prof. Ashutosh Sharma, IITK and Prof. Keshab and Shubhra Gangopadhyay, UMC)

Micro-mixer design and development plays a vital role in a wide variety of fields like environmental sensing, clinical and biochemical diagnostics, protein labelling and separation, chemical/biochemical micro-reactors etc. Hence, to increase the efficiency and compactness of the device, novel flow strategies and geometrical parameters are estimated and designed to reduce the mixing channel length and the mixing time. We have attempted to study in detail the comparison of mixing efficiency particularly by designing herringbone like features in more than one surface enclosing the flow and also by introducing a high degree of asymmetry between the patterned surfaces. We have further varied this asymmetry level and studied the impact on mixing length.

Surface Electrophoresis of ds-DNA (In collaboration with Prof. Wickramashinghe, UCI and Prof. Jayant Singh, IITK)

Fractionation of ds-DNA based on different molecular lengths by passing them through a sieving

medium has been regularly explored for all diagnostics. The technique is widely used for critical applications like gene sequencing, mapping, confirming post PCR fragments etc. Some of the widely used methods include slab-gel electrophoresis, zone electrophoresis, capillary electrophoresis in micro capillaries, micro-fabricated channel arrays etc. One of the major problems with the above processes is the poor thermal conductivity and frequent melting of the sieving medium due to the application of a high fractionating electric field. Another major limitation is resolution loss due to complexity of the gel structures, which causes entanglement of longer DNA fragments as they move through them. Typically fragment sizes above 10 kbp are resolved very poorly by the above bulk electrophoresis techniques. We have investigated the surface electrophoresis process for ds-DNA in PDMS micro-channels.

Micro-vibration Damper (In collaboration with Prof. Bishakh Bhattacharya, IITK)

Three-Dimensional micro-channels have been produced in Poly dimethyl siloxane (PDMS) by a novel soft lithography technique. We have been able to realize an array of 40-80 micrometer diameter round channels with high precision and a simple approach. We use replication and molding of the polymer around a well knit array of thin copper wires which are commercially available with a minimum diameter of 80 micrometers. Passive vibration control using blocks of viscoelastic materials is a widely explored area. However, many changes occur in their vibration response as hollow channels and shapes of the micrometer size range are carved out from the solid blocks. We have explored the passive response of a block of polydimethyl siloxane (PDMS) with replicated and structured array of micro channels. These structured blocks are tested for constrained and unconstrained vibration damping by using a beam like configuration.

Peristaltic micro-pump (In collaboration with Prof. P.K. Panigrahi, IITK)

Micropumps are one of the most extensively used devices for controlled delivery of miniaturized fluid volumes. They find wide applicability in a number of areas such as drug delivery Proteomics and Genomics. Some of these pumps are based on the principle of peristalsis in which a travelling contractile on a flexible fluid containment helps in transporting the fluid. We have designed, fabricated and tested a layered design to create a discreet peristaltic effect in a soft polymer material, Polydimethyl Siloxane (PDMS).

Identification of Food Pathogens in a Single Microchip (In collaboration with Prof. Keshab and Shubhra Gangopadhyay, UMC)

A novel on-chip architecture has been proposed with integrated capabilities of continuous flow electro-kinetic capture of bacterial cells, their immobilization onto the surface of a silicon dioxide wafer using biotin avidin linkage and specific antibodies for different stains followed by their genetic identification using real time polymerase chain reaction. The first module of electro-kinetic capture of micron sized entities had been realized earlier. We have captured the bacterial cells within the DEP chip and validated the capture by plate culture and count. We have also developed a protocol wherein the nano-particle is attached chemically to the bacterial cell with antibody chemistry. We find out a shift in the capture frequency because of the presence of the nano-particles. We have also achieved microchip PCR within the capture chamber thus providing a specific recognition basis to the bioassay.

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Activiy reports from NMDCs will be published in these columns. Please include good quality photographs/images of devices fabricated/ designed. Coordinators of NMDCs may send these reports to sukshma@isssonline.in.

Rajalakshmi Engineering College, Chennai

A National MEMS Design Center at Rajalakshmi Engineering College (NMDC - REC) has been established under National Program on Micro and Smart Systems (NPMASS). Seven faculty members from various departments are coordinators of this centre. NMDC-REC is a centralized facility at the college and it offers great opportunity to the students and faculty members to carry out projects / research activities in the field of Micro-Electro-Mechanical-System (MEMS). REC motivates the research activities in the field of MEMS by proper utilization of the facilities provided by NPMASS from design to fabrication of prototype MEMS products. REC will also facilitate external researchers from other institutes to use the design tools. NMDC at REC has been provided with several licenses of MEMS CAD tools. We are working on Smart materials like Porous Silicon and Polymers, MEMS Sensors and Microactuators. Fig 1 shows the photograph of the NMDC-REC with students working on MEMS CAD tools. In addition, the centre has the following research i**nfrastructure**:

Porous Silicon formation Setup
Separate Wet Lab for research
LCR meter – Agilent 4263B (under AICTE Funding)
Data Acquisition / Switch Unit (Under AICTE Funding)
Precision Source/Measure Unit (AICTE)
Spectro Fluorimeter (AICTE)
Rotary Evaporator (AICTE)

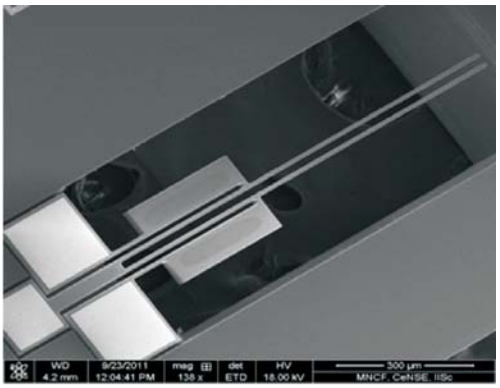

Fig 1 SEM picture of the Micro Tweezer

Training programs/ Workshop/ awareness programs are being organized frequently by NMDC-REC. Students, research scholars and faculty members from various engineering colleges in Tamilnadu are attending these programs. The faculty members and students of REC are also taking up the training

offered by IISc, Bangalore, IIT Mumbai and various other universities.

U.G and P.G students from various departments are taking up the projects in this lab. Research Scholars from REC and other institutions are utilizing this lab for their research work. We are also submitting the project proposals for funding / fabrication. Ongoing/ completed projects include:

Fabrication of Super capacitors using conducting polymers

Fabrication of Porous silicon based Optical biosensor for detection of E-Coli (In collaboration with Dr. Prita Nair, SSN Engineering College, Chennai)

Community Chip Program:

NMDC-REC submitted the design for the fabrication of Micro Tweezers under the Community Chip Program during the academic year 2010-2011. The devices were fabricated by SOI-MUMPS process and the devices have been characterized at Centre for Nano Science, IISc., Bangalore. The results of the above devices were analyzed and the manuscript is under preparation to submit for the journal. Fig 2 shows the SEM picture of the fabricated silicon Micro tweezers. The designs for Micro heater and Gyroscope are now submitted for fabrication in this academic year (2011-2012)

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NITTE MEENAKSHI INSTITUTE OF TECHNOLOGY Bangalore -64

The National MEMS Design was setup at NMIT in 2010. About 5 staff members from different departments like Mechanical Engineering, Electrical and Electronics Engineering, Electronics and Communication Engineering are involved in MEMS activity in the institute. Under the program we have set up a MEMS Lab with COMSOL, Coventorware, LEDIT and MEM+ software.

MEMS as a course is currently being offered at the undergraduate level by department of Electronics and Communication Engineering, Electrical and Electronics Engineering and Mechanical Engineering. In addition to this Prof. Kiran Aithal from Mechanical Department is conducted a short term course on MEMS modelling using FEM for students and staff members. This has helped the interested members to understand different aspects of MEMS modelling. Research work is being carried out at this centre in the field of RF MEMS, MEMS Sensors like microphone, pressure sensors etc. MEMS microthrusters is being designed by the research scholars, B.E and M.Tech students for space applications. M.Tech. and B.E students have worked in RF MEMS projects like variable inductors and tunable capacitors.

In the year 2011, a MEMS Thermal actuator was designed, fabricated as part of NPMASS community chip. The characterization of the fabricated device was carried out at IISc Bangalore. This experience of fabrication has highly motivated the staff, students and management and propelled activities in the field of MEMS. The MEMS thermal actuator has been fabricated using SOI MUMPs technology. These thermal actuators are used in micro legs, micro grippers, micro positioning applications etc. The operating principle is based on the asymmetrical thermal expansion of the beams with different lengths and cross sections. By applying voltage (current) on contact pads, the narrow arm heats up and expands more than the wide arm deflecting the device toward the cold arm thereby the microactuator produces bilateral motion in plane.

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MICROSYSTEM APPLICATIONS IN BIOELECTRONICS AT BESU

A number of faculty members from ETC department and Center of Green Energy and Sensor Systems are involved in the NMDC activities at Bengal Engineering and Science University at Shibpur.

Tunable Microstructure for Electrical Detection and Characterization of Biological Cells

One of the thrust areas of research in the field of micro/nano electronics at Bengal Engineering and Science University (BESU) is in the development of tunable microstructures in the range of 50nm to 2µm to electrically detect and characterize biological cells. The primary approach for the fabrication is by electrochemical etching of silicon of 10-20Ù-cm resistivity with a mixture of HF (hydrofluoric acid) and DMSO (dimethyl sulfoxide) using a constant current density. This technique results in uniform growth of micro and nanostructures which can be readily oxidized and then bio-functionalized for electrical detection of biological cells like bacteria and also molecules like protein markers. The most captivating feature of these structures is that they enable maximum interaction of the electric field lines with the biological cells of different sizes like those in widely reported photolithographically patterned electrodes, just by electrochemically tuning the channel diameter. This results in the development of low cost, sensitive, electrical biosensors. Another interesting application of such structures which is being explored is the dynamic electrical characterization of biological cells during their growth, regeneration, apoptosis and others. It has been observed that such structures are capable of electrically distinguishing the adhesion and proliferation stage of HeLa cells unlike the commercially available ECIS platform.

Microwell Electrode Structures for Single Cell Trapping and Impedance Measurement:

We have reported the design and fabrication of micro well electrode structures for single cell trapping and impedance measurement. In this

work, the micro well electrodes of parallel and elliptical geometry have been fabricated by electroplating of gold electrodes of optimum thickness. This has enabled the formation of electrode traps without requiring any precision alignment between separate insulating traps like PDMS and the bottom gold electrodes. Further the improved uniformity of the electric field between the trapping electrodes as observed from COVENTORWARE simulation significantly reduces the effect of cell position inside the microwell on the electrical measurement. This makes it possible to directly extract the equivalent cell parameters from the electrical measurement without introducing any correction factor corresponding to cell position. We have performed impedance spectroscopy with both the microwell electrode structures with single HeLa cell at two different positions of trapping. It has been observed that there is almost no change in the extracted values of cell resistance and capacitance for different positions within parallel electrodes and there is only 0.7% and 0.85% change in cell resistance and capacitance for the two positions within elliptical electrodes. Thus these microwell electrode structures can be used as an improved and a more convenient platform for single cell electrical characterization.

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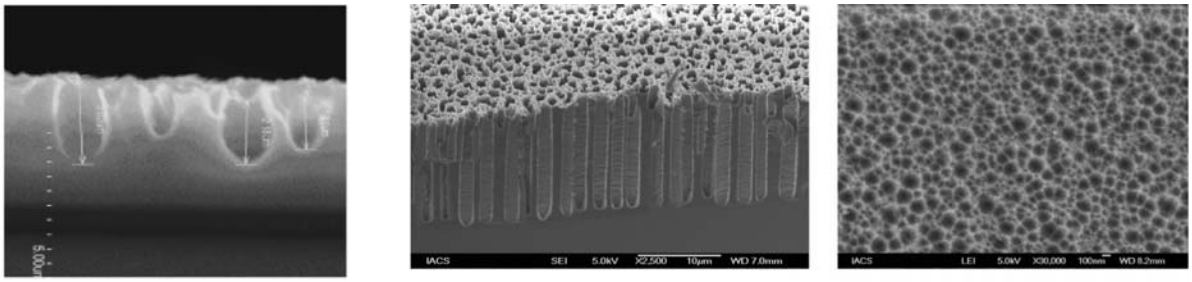

Fig.1 Different micro/nano structures fabricated by electrochemical etching

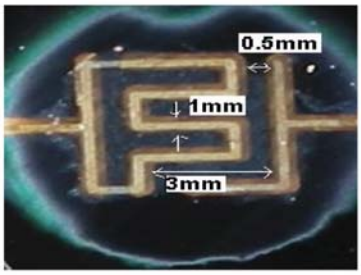

Fig.2a Functionalized microchannel sensor for bacteria detection

Fig.2b Picture of portable system

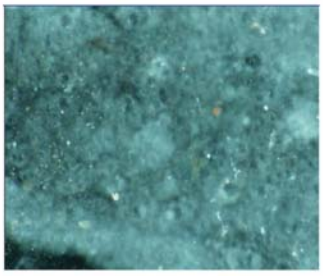

Fig.2c Confluent Growth of HeLa cells on microstructured surface

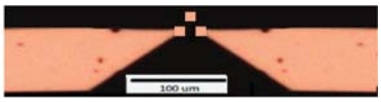

Fig.3a Picture of rectangular electrode

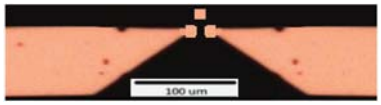

Fig.3b Picture of elliptical electrode

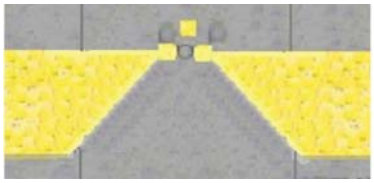

Fig.4a Cell trapped between elliptical electrodes touching both the walls on the upper side

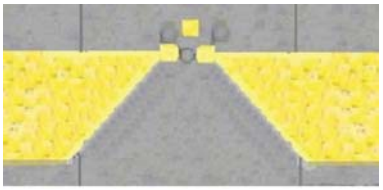

Fig.4b: Cell trapped between elliptical electrodes touching both the walls on the lower side

Experimental Modal Analysis of Microsystems Using Laser Doppler Vibrometer

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With the increasing use of micromanufacturing techniques for producing sensors and actuators, it becomes increasingly important to devise ways of carrying out certain essential tests before these devices can be packaged. For most dynamic MEMS and NEMS devices, it is essential to ascertain if the sensing structure is free to oscillate and if it has the right frequency and damping characteristics. These characterizations can be done using a scanning laser vibrometer.

Dynamic characterizations can be done in (i) contact mode where measuring device is in direct contact with the vibrating structure, or (ii) non-contact mode where optical sensing is used to extract the behaviour of the system under different loading conditions. Experimental modal analysis or modal testing consists of different ways of actuating a structure, measuring its response, and extracting the modal parameters of the structure. In this note we describe some common ways of actuation of MEMS devices, capturing their mode

shapes and measuring their response under different loading conditions.

In MEMS devices such as gyroscopes, drive mode is usually in-plane and sense mode can be either in-plane or out-of-plane. These modes must be matched for a gyroscope to be useful. So it is essential to determine the frequencies in the drive and the sense modes of the structure. Here we discuss measurements carried out to determine the response of MEMS resonators exciting in-plane and out-of-plane motions. Characterization of yaw rate sensor for in-plane measurements is explained, while the out-of-plane measurements are done for many devices with different actuation schemes

Experimental modal analysis or modal testing techniques are traditionally used for dynamic characterization of macro systems for various purposes including determination of lumped parameters of the dynamic system (mass, stiffness and damping). Majority of modal testing techniques include excitation of a structure via a signal of known frequency characteristics (impulse, random, periodic, etc.) using, e.g., a shaker, and measuring the associated response using force or motion sensors. Generally, a description of system characteristics is obtained from establishing Frequency Response Functions (FRFs) calculated from power spectral density. The traditional modal testing techniques are not suitable for Microsystems where, ideally both excitation and the measurement must be conducted through noncontact means. For these reasons, a number of optical techniques, such as video imaging, blur envelope and interferometry are employed for modal testing of micro mechanical structures.

In addition to dynamic characterization, modal testing can be used as a tool to measure the mechanical and geometric properties, such as Young's modulus, residual stress, average density and thickness. These quantities can be deduced by dynamically testing various structures and comparing results with analytical formulae for natural frequency and mode shapes. Modal testing is also used for modelling and validation of coupled-physics phenomena, such as effect of electrostatic forces and fluid damping. Another important use of modal testing is in studying the post fabrication effects and diagnosing the defects before operation.

Here, we present a methodology for experimental modal analysis of microsystems. Electrostatic excitation, base excitation and acoustic excitations are used to actuate the device. The response is measured using Laser Doppler Vibrometer (LDV) coupled with an optical microscope.

Experimental modal analysis essentially involves (1) exciting the structure with a force of known amplitude and frequency, (2) measuring the input and associated response, (3) acquiring and processing input output signals to obtain FRFs, and (4) extracting dynamic parameters based on modal model. While performing modal testing on MEMS devices, the first two pose challenges that cannot be overcome by conventional techniques. For this reason, a number of different techniques are employed for modal testing of microsystems. This section provides the overview of techniques employed in modal testing of microsystems.

Excitation Methods

Direct excitation methods, such as impulse provided by an impact hammer or input provided by a shaker that is directly attached to the structure, cannot be generally applied to MEMS devices due to their small size. Typically a non-invasive approach is used for actuating several microsystems. In addition, the natural frequencies are typically higher than its macro counterparts, from few kHz to MHz. The excitation method must be capable of exciting in the required frequency range. In this section we explain the different excitation techniques used for modal testing of MEMS devices.

Electrostatic Excitation: As most of the surface micromachined devices have electrodes, electrostatic forces can be applied for excitation of microstructures by applying an electric potential across top and bottom electrodes. At small scales, significant electrostatic forces can be generated even at low voltages. Although fairly simple to apply, electrostatic forces themselves are nonlinear and functions of structural motions, as hence cannot be independently characterized. In addition, actual input to structures cannot be measured. Application of this method as a viable modal testing technique for thorough dynamic characterization of microsystems requires coupling of accurate models for structural and electrostatic forces.

Base excitation: One of the most promising alternative to electrostatic actuation is base excitation using external elements, which is a viable technique that doesn't alter the structural characteristics. In this case, a shaker is used to excite the structure. Although the input is not measured since a sensor, such as load cell, cannot be included, it is possible to derive motion over FRFs by taking base motion as the reference. Since the response is affected by dynamic characteristics of the testing apparatus, care must be taken during the design of experiments.

Focused acoustic excitation: Another promising alternative is acoustic excitation using an acoustic horn attached to the speaker. Here we disturb the air molecules with a known frequency by means of a speaker attached at the entrance. The disturbance in the air column gets transferred through the horn and the pressurized acoustic waves act as pressure load on the structure. Vibrations of the structure are measured using LDV.

Measurement Methods

Since it is not possible to place sensors on microstructures, a number of alternative non-contact detection methods have been developed most of which use optics. Due to the high frequencies involved, the measurement of the motion of micro structures poses a critical challenge. One of the enabling techniques adopted from optics to effectively slow the motion is stroboscopy. Stroboscopy can be used in conjunction with the measurement methods described below to increase the applicable frequency range. In this technique, stroboscopic light is flashed on the

moving structure (excited at a prescribed frequency), and the image is frozen at the time of the flash. By coordinating the stroboscopic light with the excitation frequency, and by changing the time of flash, phase can be swept through and image can be detected as a function of time. The maximum detectable frequency is limited by the pulse time of the stroboscopic light, i.e., the shorter the flash pulse time, higher the detectable frequency.

Use of a LDV is an attractive method that uses noncontact measurement technique with high positional accuracy. LDVs measure out-of-plane velocities by interferometrically measuring the change in frequency and phase of the laser light reflected from the surface. In the case of microsystems analyzer, the laser light is fed through a microscope to reduce the focused spot size of the laser light. This is important since the velocity is averaged over the spot area and the motion of the small features can only be measured with a small spot. Single point LDVs require multiple measurements for establishing a mode shape. Since it is not possible to measure input forces, one common technique is to use the excitation voltage as a reference. However, this assumes that the frequency response between the voltage and the structure being tested is essentially flat, and thus ignores the dynamic behaviour of the actuation unit. Response measurements can be sequentially taken at several points, and then compared to provide mode shapes. Due to the aforementioned advantages, the use of single-point LDV is the measurement technique of choice for the experiments presented here.

Out-of-plane Measurements: To excite and measure the dynamic characteristics of the structures, we use MSA 400 Microsystem Analyzer — a Polytec product to characterize the out-of-plane vibrations by Scanning Laser Doppler Vibrometer. It works on the principle described in fig. 1. An electrical excitation causes the suspended structure to vibrate. A laser beam from the interferometer in the scanning head is positioned to a scan point on the object by means of mirrors. The reflected laser light interferes with the reference beam in the scanning head and a photo detector is used to record this interference. A decoder in the vibrometer provides a voltage which is proportional to the velocity of the vibration parallel to the measurement beam. The voltage is digitized and processed as vibrometer signal.

In-plane Measurements: When the structure vibrates in the plane, we measure the in-plane displacements of the device using planar motion analyzer (PMA), which makes use of stroboscopic principle to measure the displacement of the device. under a video microscope which uses a normal CCD camera. The motion of the device is first captured by an illumination source such as a strobed light (flash) with certain durations. During that time, the short light pulses, i.e., shots per period, may record the position of the device at precise angles. Since a camera shot is a sequence of flashes within the camera exposure time, the motion of the device over a period can be measured by shifting the timing of those pulses as shown in fig. 1(c). For each shot, the total number of flashes (periods) are illuminated for a specific flash duration (generally, for 1ns). If δT_s is the time between two shots, which is a cyclic duration of the camera-framing rate, the phase delay of the strobe illumination $T_{\text{phase delay}}$ with respect to the driving signal may be adjusted by setting the time delay between the shots from the relationship:

$$T_{\text{shot}} = n_p T_{\text{driving}} + T_{\text{phase delay}}$$

where T_{shot} is the total length of the sequence of flashes (in s), n_p is number of periods to be observed (number of flashes per shot), and T_{driving} is the period of the driving signal (in s). For a given shot time T_{shot}, illumination can maximize the number of flashes per shot (n_f) as follows:

$$n_f \propto \frac{T_{\text{Camera}}}{T_{\text{Shot}}}$$

Therefore, to obtain natural frequency with PMA, the flash frequency should be selected properly to accurately capture the image of the oscillating microstructures.

Experimental results

We now present some experimental results as examples for different input signals, for different devices vibrating in-plane and out-of-plane.

Out-of-plane measurements

To excite the structures by electrostatic means, we apply potential across the electrodes. So the structure starts to vibrate normal to the plane; which is captured by change in frequency and phase of the reflected light.

The MEMS device under investigation here is an electrothermal actuator. In such devices, hot and cold junctions are generated on application of voltage due to Peltier effect. Due to thermal expansion, the structure tends to bend. Upon application of a sinusoidal signal, structure starts to vibrate about its equilibrium position. To capture the modal parameters (resonant frequency and damping) of the structure, we apply a pseudorandom signal of voltage 8±2 V during the experimentation. After averaging the FRF of the output signal over 5 times, we determine the resonant frequency of the structure using the frequency response curve, and the corresponding mode shapes are obtained from presentation mode of the vibrometer. Figure 2(b) shows the frequency response of the structure, natural frequencies and the corresponding mode shapes for the first 28 out-of-plane modes are vibration.

The second MEMS device is a cantilever beam which has several applications ranging from pressure sensor to AFM. The natural frequency and mode shape dictate the suitability of the cantilever for the desired application. Figure 2(c) shows the structure, frequency response and mode shapes captured using MSA.

In-plane measurements: *Figure 3(a) shows the structure of a yaw rate sensor. The structure is realized using SOI MUMPs process, to measure the in-plane vibrations of the device, we apply 8±2 V across the sense capacitors, which makes the structure vibrate in the sense direction. Displacement in sense direction is measured using Planar Motion Analyzer, which uses stroboscopic effect to capture the motion of the object. Figure 3(b) shows the sense mode response of the yaw rate sensor.*

Sixth ISSS National Conference on MEMS, Smart Materials, Structures and Systems at Research & Development Establishment (Engineers) Pune on September 06-07, 2013

ISSS has been organizing National conferences since 2006 on years on which the International Conference organized by ISSS is not scheduled. It has been more than fifteen years since ISSS started the series of triennial International Conference on Smart Materials Structures and Systems, during which there has been a spurt of activity in the area of smart structures in general and MEMS in particular. These years have seen significant and copious research on different aspects of smart materials, structures and systems. These include development of new actuator and sensor materials, smart and nano materials, constitutive modeling, newer methods of analysis, device design and fabrication, electronics and packaging, smart structural design for optimum power and performance, development of control algorithms, and finally, applications.

The progress in the above areas has been covered in innumerable fora all over the world, including the previous six international and five national conferences held at various locations in India. The evolution and maturing of these technologies are clearly evident over the years. The present conference, which is the sixth in the series of National Conferences continues this evolutionary thread and aims to provide a forum to academicians, researchers and technologists to not only assess the current status in these technologies but also to steer towards a more effective utilization of these technologies by exploiting the strengths, recognizing and filling the gaps, and bridging several disciplines hitherto considered as disjointed.

This conference will be held at R&DE (Engineers) Pune and the details like deadlines for paper submissions are available on ISSS website. Several exciting events are planned on the sidelines of this event. The ISSS Young Scientist Award, and UG and PG student awards for this year will be presented during this conference.

ISSS Announcements

Membership Database: We are very happy to announce that the membership of ISSS has crossed 500. We request current members to take active interest to ensure that we cross 1000 membership soon! Also, all existing members are requested to update their contact information by filling out the membership form available at ISSS website and sending this by email to admin@isssonline.in. It has been observed that several emails as well as snail mails to members based on the addresses in our current database are bouncing back. The current database of members joined before 2010 is available on the website. We urge all the members to send their latest contact info to the society by filling in the relevant form available on the website. We have been proactively reaching out to our members to update their contact information.

ISSS Coimbatore Chapter: A chapter of ISSS with jurisdiction over Tamilnadu, Kerala and Pondicherry has been formed with its headquarters at Coimbatore. The Chapter office is located at PSG Institute of Technology. This chapter represents about 20% of current Life Membership of ISSS. The Chapter was formally inaugurated on September 20th at a function at PSGIT, Coimbatore. The are the following office-bearers for the Chapter Executive Council:

Chairman: Prof. A Kandaswamy, PSG College of Technology
Vice Chairman: C: Prof. G Karuppswamy, Karpagam University
Secretary: Prof. V K Manoharan, PSG College of Technology
Joint Secretary: Prof. Muniraj, Tejaa Shakthi Institute of Technology for Women
Treasurer: Dr.M D Kannan, PSG College of Technology
Members: Dr. Y. Ravi and Dr. S. Subharani

hurry!!!! Last date of submissions/ nominations for ISSS Awards for this year is June 30, 2013. Awardees must receive these in person during the upcoming sixth National Conference held at Pune. Please do plan to attend the Conference.

All members of the region are encouraged to participate in the activities of the Chapter wholeheartedly.

ISSS Awards: Using the funds received as sponsorship from various Industries, the Organizing Committee of the Sixth ISSS International Conference has created an endowment fund to institute the following awards. The objective is to encourage young researchers to take up a career in areas of interest to the Society.

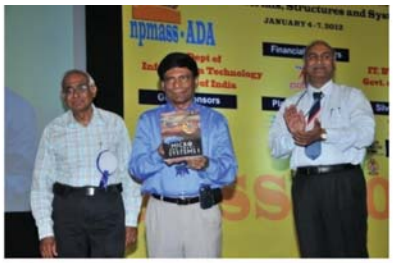
Separate awards are planned for undergraduate (BE, B.Tech. etc..) and postgraduate (M.E., M Tech, MPhil, Ph.D, etc.) students. To qualify for this award, the student(s) should have completed the reported work during the respective course program in the academic year for which the award is conferred. In the case of UG award, an individual or a team can submit their contributions. The submissions are limited to 4 pages and should highlight the project work reported. Supervisor of the student(s) is required to give an undertaking that the work was carried out during the respective course program for which the submission is considered. At least one of the contributor(s) is required to present the work at the conference and receive the award in person. Details of these awards are as follows.

ISSS UG AWARD (for BE/BTech students) I Prize Rs 10,000, II Prize Rs 8,000 (A summary of project work should be submitted)
ISSS PG AWARD (for ME/MTech/MS/MPhil/MSc students) Prize Rs 12,000, (A summary of project work should be submitted)
ISSS PG AWARD (for PhD students) Prize Rs 15,000, (A synopsis the research work and a list of publications should be submitted)

Submissions for this award for 2013 should be sent directly to awards@isssonline.in on or before 30 June, 2013. The decision of the ISSS awards committee would be final in this regard. The winning submissions will be published in the conference proceedings after appropriate revisions, if any, as suggested by the awards committee. Details are available at www.isssonline.in/awards.html.

ISSS Young Scientist Award: ISSS has initiated a Young Scientist Award for outstanding contributions in the area of micro and smart systems. The award will carry an ISSS medal, a citation, and a cash prize of Rs 25,000. The maximum age limit for the nominee is 40 years as of the last date of submission. Nominations for this award for this year may be sent to awards@isssonline.in by June 30, 2013 and may be made by self, head of organization or ISSS members. Nomination form and other details are available at www.isssonline.in.

ISSS/NPMASS Special session




Industry Participation

Side events


Cultural Program


Student Paper contest

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