MICRO STRUCTURE BULLETIN

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Transducers '97

Every other year there is one event that attracts particular attention among those interested in the field of MST; the *International Conference on Solid-State Sensors and Actuators*, more commonly known as *Transducers*. This event offers an excellent opportunity to get updated on the latest research results, to see to where industry is heading, and to make new contacts. Two years ago Sweden hosted the largest *Transducers* ever held.

In June 1997, *Transducers '97* was held in Chicago, U.S.A., with several courses organized the day before. The conference program featured 12 invited and about 200 contributed oral presentations, and over 150 posters from more than 25 countries. A selection process had proceeded the conference in order to ensure a high technical quality of the presented material. For the first time the proceedings are available also on CD-ROM in addition to the more usual printed form.

The program contained a broad mix of topics grouped into five main themes:

– fabrication technology
– physical sensors
– chemical/bio sensors/ systems
– actuators
– systems and design issues

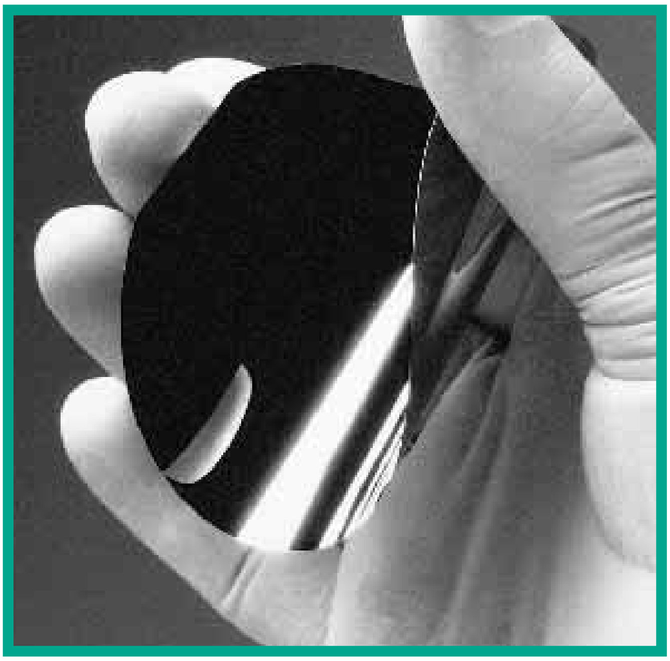
The conference started with three presentations during the initial plenary session. The conference continued thereafter with four parallel sessions. The parallel sessions gave the more than 1,000 participants the opportunity to select the presentations that suit his or her interest. Of course, for participants that have a broad field of interest, there is the possibility of several interesting papers being presented at the same time.

An exciting series of social events were organized in addition to the technical program. This gave the attendees ample opportunity to interact informally while enjoying the sights and richness of Chicago.

Some attendees had the possibility to see more of the Chicago area since they stayed at suburban hotels. The shortage of hotel rooms in the vicinity of the *Transducers '97* site was caused by a plastics convention with more than 100,000 participants that took place in Chicago the same week.

Judging from a sample of the conversations between sessions, many new ideas will be tested as a result of *Transducers '97*. Allowing the mind to be stimulated without the interference of daily routines is important for the success of development projects. *Transducers* is an excellent forum for creating the right atmosphere, and it will be interesting to follow its future. Two years from now, the tenth *Transducers* will be held in Sendai, Japan.

Jan Söderkvist, member of the European Program Committee



New impressions are important for the creativity. As an example, the flexibility of this 0.01 mm thin single crystal silicon membrane might be surprising to those not aware of silicon's possibilities (courtesy of Virginia Semiconductor, Inc., U.S.A.).

CONTENTS

EDITOR'S NOTE

It is fascinating to reflect over the success of the microprocessor. After 25 years of development, it is now a very powerful and important tool used in a wide and rapidly expanding variety of applications. Will similar superlatives be used for micromachined components in the future?

Microprocessors and micromachined components are enablers that make systems with attractive price and performance possible. The total turnover generated by these systems is much higher than that of the microprocessors and micromachined components by themselves. Consequently, it is advantageous to have a clear and broad MST strategy. A cooperation with an existing MST facility can be useful if development resources are limited.

Despite the maturity-level of the microprocessor, Intel still manages to double its performance every 18 months. A processor now contains 5.5 million transistors (up from 2,300 in 1971). This progress is made possible by their capital and R&D investments exceeding $90 for each of their more than 50 million processors sold (1995). In micromachining, the developmental efforts and investments are smaller, which compensates well for the lower profit margin. Five years ago who could have predicted Intel's rapid growth? Five years from now what will the comments be regarding the MST status in 1997?

Jan Söderkvist

Plenary Presentations

A plenary session commenced the *Transducers '97* conference. It featured three interesting overview presentations.

Soft Lithography

There is a desire to develop smaller and smaller micro-features. However, it is difficult to fabricate features smaller than 100 nm with classical photolithography due to the wavelength-dependent transparency of materials used for lenses.

In his presentation, G. Whitesides from Harvard University, U.S.A. outlined the rapid progress in soft lithography. This technique includes the use of self-assembled monolayers as nanometer resists, the patterning of these monolayers using microcontact printing, and the fabrication of small polymer structures using transfer and replica molding, conformal phase-shift lithography, and other, related techniques.

Soft lithographic techniques are well suited for rapid prototyping and low cost production. The most plausible areas of application are in simple types of fabrication where moderate sizes are required (> 1 µm), single-level fabrication is adequate, and some types of distortions in the pattern are acceptable. Nevertheless, it is possible to easily make certain types of very small structures (< 50 nm).

Soft lithography is at the beginning of its cycle of development. New techniques are being invented and demonstrated rapidly, but the serious development work required for commercialization is still in progress. Its potential as a technique for microfabrication is, therefore, still being defined.

Micromachines in Japan

T. Hattori from Denso Corporation in Japan presented the achievements of Japanese micromachine projects. He focused on the national R&D program "Micromachine Technology". This ten-year, 25 billion yen project was launched in 1991.

The first half of this program focused on basic technologies, including fabrication, assembly, micro-mechanism and sensor technologies, and energy supply. The second half will focus more on micromachine systems using these technologies.

In Japan, micromachining is not seen as a separate technology, but as a continued downscaling of precision mechanics. As a consequence, the Japanese *Micromachine* field is broader than their European (Microsystems Technology, MST) and American (Micro Electro Mechanical Systems, MEMS) counterparts.

Although micromachining constitutes a major aspect of the Japanese *Micromachine* definition, there are also many components that are produced with improved precision machining techniques. For example, a replica smaller than a grain of rice of a 1936 Toyota AA car, with a built-in stepper motor, has been produced with electro discharge machining. Super precision cutting tools that can produce surfaces smoother than a mirror have been developed. Such tools offer interesting possibilities for the fabrication of truly three-dimensional masters for replication-based production.

Harsh Environments

J. Lasseur from Schlumberger in France shared his experience from the oil exploration field. Here, harsh environments denote mainly high temperatures and large mechanical shocks. It is important that sensors, such as pressure sensors, accelerometers, flow sensors and densitometers, can withstand these environments if an accurate evaluation of possible oil and gas fields is to be obtained.

The sensors must survive temperature up to 350°C and function up to 225°C at the same time as the drift of the output is very small. The entire system must be considered if the sensor is to fulfill these tough requirements.

It is important to know the physics of various failure modes when estimating the lifetime of sensors. Accelerated tests can be used if the operation time is too long for a realistic evaluation to be carried out. Such tests assume that most temperature dependent failure mechanisms follow Arrhenius law. For instance, increasing the temperature from 200°C to 240°C can accelerate failure mechanisms by a factor of 10 under certain assumptions. It is also essential to use an extensive qualification procedure for new components.

The money involved in oil exploration means that accurate sensors and a fast qualification time are extremely important. The vast knowledge generated when designing such sensors should be useful for other application areas as well.

Jan Söderkvist

Truly three-dimensional structures can be fabricated using soft lithography. This buckled cylindrical-shaped silver mesh is obtained by electroplating a pattern that has been transferred onto a glass rod via rolling, followed by dissolving the rod (courtesy of G. Whitesides, Harvard University, U.S.A.).

Highlights of TRANSDUCERS 97 CHICAGO

Several trends were noticeable at Transducers '97. First, there is a continued shift toward devices and systems. This is natural for a scientific area that is maturing. Another trend is towards increased domestic and international collaborations. This is apparent from the author lists of the presented papers.

Processing

Only a few papers presented novel additions to the micromachining processing toolbox. Most of the processing oriented presentations described improvements to already existing process steps.

There is continued discussion whether bulk or surface micromachining should be used. Novel process steps result in improved possibilities of combining bulk micromachined structures and electronics on the same chip. It is also possible to combine bulk and surface micromachining. Therefore, the slow trend toward surface micromachining is temporarily halted.

One or Two Chips

The ongoing discussion whether a one-chip or a two-chip solution should be used continues. It is currently only for simpler sensors that true one-chip solution are used. For more complex sensors, only part of the electronics is normally included on the sensor element chip (quasi 'one-chip'). Two-chip solutions are sometimes used also in the microelectronics world, for instance for the Pentium Pro microprocessor.

The process steps used for the sensor elements are often incompatible with those used for the electronics if optimum performance is sought. For the one-chip solution, costly compromises regarding process steps affecting performance and yield must often be made. Future development of more compatible process steps will make it easier for one-chip solutions to approach optimum performance.

Materials

The previous trend has been to choose the best material for each application. A surprising change is now an increased focus on silicon. This could be a result of the heavy investments in production equipment for silicon made by some large companies. To use outsourced, non-silicon based sensor elements is not of interest to these companies.

Of course, the research society is affected since it nowadays is easier to acquire funding if one has industrial partners. Reduced research budgets might also make financiers less keen on supporting projects using 'unconventional' materials. Nevertheless, the quartz watch crystal shows that non-silicon materials can be inexpensive and have very attractive characteristics.

Bioanalytical Systems

A very promising development area is liquid and particle handling and manipulation. The toolbox is rapidly expanding, and industrial interest is increasing. Today, this toolbox is not limited to valves and pumps. Individual particles, such as cells, in liquids can be moved to specified locations and individually counted (see page 6).

A micro-scale analysis system capable of handling 10 micro liter reaction volumes was presented. This system use pressure differences to move and store fluid samples in a maze of channels and chambers. Air plugs that can be added and subtracted are used to separate different fluid samples. Mixing and measuring is also handled in the system, which has been tested with a diversity of enzyme reactions.

The recent advances in micromachining and related technologies have brought molecular manipulation into reality. There is even discussion regarding molecular surgery using microsystems. Researchers have been able to stretch, position and immobilize DNA-chains, paving the way for possible future 'DNA-surgery' using lasers, atomic force microscope tips, enzyme labeled probes, or micro-temperature gradients.

Sensors

Five sessions were devoted to inertial sensors. These sessions attracted much attention, and it was even difficult to find empty seats during some of the gyroscope focused sessions. Several gyroscopes that are close to production were presented by industry. Unfortunately, questions from the audience were often left unanswered since this area is becoming increasingly competitive.

To design micromachined gyroscopes with good performance is a challenging and complex task. Such projects are, therefore, becoming popular among researchers. However, the research society may have difficulty catching up with industry considering the extensive development resources industry already has spent on this area. Researchers are moving toward gyroscopes while industry is already developing complete inertial sensor chips that include three accelerometer and three gyroscopes.

In contrast, only one session was devoted to pressure sensors. The pressure sensor market is a mature, low-cost, high volume market for which research is currently aimed at niche applications, e.g. for harsh environments.

Optical Systems

The field of surface micromachined comb-shaped electrostatic actuators has been advanced further. Today, such projects are often device oriented.

Hinges fabricated with surface micromachining enable the creation of three-dimensional micro-optical benches constructed of two-dimensional walls. Actuators make it possible to move the walls such that the focal length of micro-lenses and the direction of reflected light can be varied.

Other optical components include large arrays of electrostatically adjustable mirrors supported by tethers. Electrostatically driven micro-wheels are also used, e.g. in optical shutters, but wear might limit the lifetime here.

Data Storage

The turnover for disc drives is four times greater than that for the accompanying microprocessors. The read-write head is the key component in hard disc drives, and accounts for 30% of the total costs. The use of conventional production methods is expensive and makes further miniaturization difficult.

Micromachined recording heads are expected to play an important role in continuing the present 60% annual increase in recording density. They will allow for a substantial cost reduction and fulfill the strict requirements for surface roughness. In addition, high-yield batch fabrication is well suited for the one billion unit market.

Jan Söderkvist

STATISTICS

There were almost 1,100 participants at *Transducers '97*. The largest delegations came from U.S.A. (617), Japan (117), Germany (84), Switzerland (73), Korea (36), The Netherlands (30), Sweden (22), …, Norway (15), Denmark (14), …, Finland (9). The participants represented 32 countries.

The corresponding statistics for the first authors of the presented papers is U.S.A. (135), Japan (60), Germany (49), Switzerland (26), The Netherlands (15), Korea (11), …, Sweden (8), …, Denmark (5), …, Finland (3), Norway (3). The authors represented 30 countries.

International Reports

International activities in microsystem technology is an area where many technology experts and marketing specialists would like to have a closer look at. International cooperation in microsystem technology is gaining more importance as prices decrease with increasing production volumes, and the markets for microsystems are increasingly being viewed in global terms.

A valuable background reference to those who wish to contact and cooperate with partners in the USA and Canada is the publication ***mst news special USA & Canada 1996***. This 160 page compilation is a guide to technology, international cooperation, and federal programs, and is intended to foster European-US/Canadian cooperation. It has been made available by VDI/VDE-IT in Germany and NEXUS, the European Network of Excellence in Multifunctional Microsystems. A corresponding publication for Japan is now also available.

Some excerpts can be viewed on the World Wide Web at: http://www.vdivde-it.de/it/IMSTO/mstnews.html. The complete 160 page printed version can be ordered for DM 80. For more information contact:

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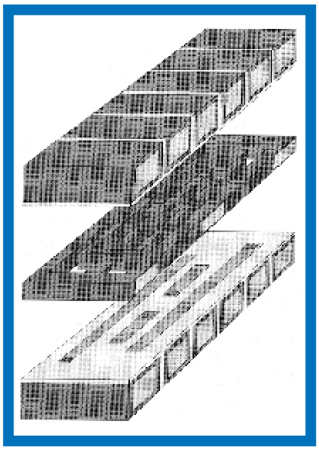
A Bulk Micromachined

VTI Hamlin is a market leader in low-g accelerometers with it's silicon capacitive sensor. This sensor is based on bulk micromachining and on a unique glass isolation technique. The same process with minor additions has been used to produce an angular rate sensor. The sensor has market opportunities in the same automotive field as the low-g accelerometer, i.e. in the control of vehicle dynamics, including anti-lock braking, anti-skid prevention, traction control, and active and adaptive suspension systems. Each of these applications demand input from inertial sensors, such as accelerometers and angular rate sensors.



A double gimbal angular rate sensor with feed-throughs based on vertical and lateral glass layers.

A Gimbal Structure

A vibrating angular rate sensor is based on the generation of Coriolis force when a body in primary motion experiences rotation. This force is proportional to the rotation rate. At least three basic configurations have been proposed for a vibrating sensor: a tuning fork, a cylinder and a double gimbal structure.

The latter, with angular motions, was selected by us over the more commonly used tuning fork approach. The reason for the selection was a combination of factors:

– This structure is well suited for bulk micromachining since the coupled torque to be detected is proportional to the second power of the material thickness.

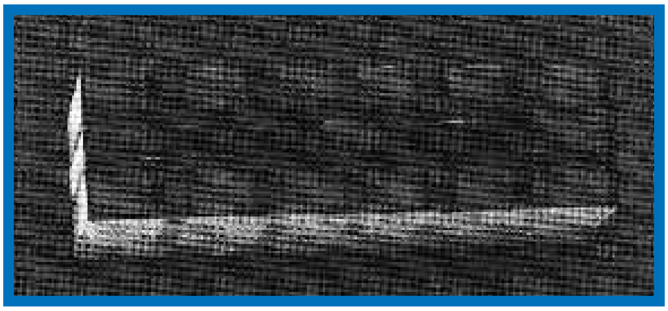
–The exact orthogonality required is produced mainly by the photolithography, not by the 3-D shape of the vibrating structures.

–The electrodes for excitation and detection are in plane and the distance from the electrode to the moving body can be varied from one to several tens of micrometers.

A central beam is suspended on a frame with a pair of torsion springs. The frame is suspended on the sensor body by another pair of springs creating two orthogonal modes for angular motion. The operation of the sensor is based on measuring the coupling between the modes under an external angular rate.

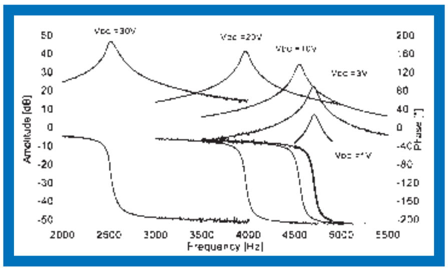
Feed-Throughs

To obtain perfect balance, several electrodes are needed for the electrostatic excitation of the primary motion and for the capacitive detection of the coupled motion. We have created a unique feed through scheme to obtain electrical contacts to the electrodes located in the vacu-



Angular rate sensor with contact pads.

d Angular Rate Sensor



Resonant frequency tuning by voltage in the detection mode.

um space inside the sensor. A silicon wafer is divided into electrically isolated sections. The sections are isolated with glass layers which also form the isolating surface of the wafer. This technique is based on melting, grinding and polishing of glass on silicon. There are only two processing steps in addition to those used for producing the acceleration sensor.

Mechanical Resonances

The sensor has a mechanical resonance in both orthogonal angular modes. The resonance in the excitation mode ought to have a high Q-value for efficient generation of high amplitude primary motion. Q-values are limited by the internal gas damping of the sensor. Values up to 70,000 have been obtained. In addition to the rotation mode, a higher frequency translation resonance is present.

In the detection mode, resonance is useful for mechanical amplification and for improved impedance matching to the electrical circuit. For an adequate system bandwidth, a Q-value in the range of 10-100 is optimum.

Frequency Tuning

A very fundamental, but seldom used feature of an electrostatically driven mechanical oscillator, is the ability to adjust the spring constant by a DC voltage. This is based on the non-linear dependence of force on the voltage. We have developed a system where the output mode resonance is automatically locked to the excitation resonance, thus eliminating the need for tight manufacturing tolerances or individual mechanical trimming.

Conclusions

We have presented some basic ideas behind our angular rate sensor development. Thousands of sensors have been produced, and tens of them have been tested. Working sensor systems have been built. Currently, we are undertaking the design of a second generation sensor where some mechanical design deficiencies will be corrected.

In the first design, the emphasis was on the minimization of electrical noise and instability with some ignorance on mechanical noise contributions, i.e. the brownian motion of gas molecules inside the sensor is dominating. With this new design, we expect to achieve a low cost sensor with performance equal to or better than the present generation of sensors in today's high end vehicles.

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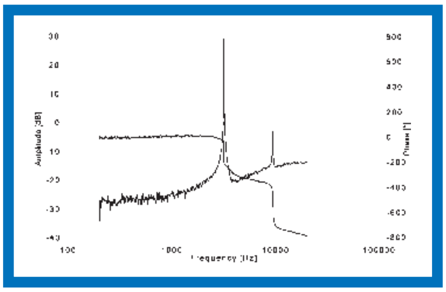

Resonances in the excitation mode.

DISSERTATIONS

MSB wishes to congratulate Eva Hedborg Karlsson on successfully having defended her doctoral theses, *Gas Sensitivity of Modified Metal-Oxide-Semiconductor Devices*, on May 23 at Linköping University.

It has been demonstrated that thin, discontinuous films of Pd, Pt, and Ir when used as gates in metal-oxide-semiconductor (MOS) structures are very sensitive to ammonia. Hedborg Karlsson *et al* have demonstrated that such nano-structured metal films serve as gas permeable structures when they are placed into an electrolyte after being made hydrophobic by silanization. This was observed as an electrical polarization of the metal film measured as a shift of the capacitance-voltage curve of a MOS structure along the voltage axis when the structure was exposed to various gaseous species in water. This shift is due to diffusion of the molecular species into air pockets formed at the bottom of the metal cracks.

In order to increase the selectivity of the gas sensor, a photoresist was used as a gas permeable membrane. Furthermore, thin polymer membranes containing molecular imprints against certain molecules were tested as the sensing layer.

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Microchip Based Coulter Particle Counter

The Microchip Coulter Particle Counter (µCPC) is the name of a micro device employing the Coulter principle for the counting and sizing of living cells or other particles in a liquid suspension. The µCPC is constructed of a planar silicon structure covered with glass which enables detailed observation during operation.

Coulter Counting

In the original Coulter Particle Counter the particles are injected into an electrolyte and hydrodynamically focused into a single cell stream. The flow of particles and sheathed electrolyte is passed through a small orifice in a plate separating two electrically isolated chambers. When a particle transverses the orifice, the resistance across the orifice rises. This is recorded as a transient signal for each passing particle.

It is possible to use the recorded signal to count the number of particles and from the height and area of the pulses to determine the size of the individual particles. The principle used in the µCPC is similar to that used in a conventional Coulter counter.

µCPC Design and Operation

In the µCPC, a cell-containing electrolyte sample is injected into a wide channel through a central inlet. Inlets for a sheathing electrolyte have been placed on each side of the sample inlet. Outside these, there are inlets for a sheathing non-conductive liquid with which the electrolytes and sample zones can be further focused to a specific width. Additional inlets placed along the bottom of the channel allow for focusing in the vertical dimension.

The sample is hydrodynamically focused into a single cell stream with the help of the sheathing flows. When the twofold sheathed flow passes through the channel orifice, it is the width of the three conducting flows that determines the sensitivity. These widths can be scaled to the size of a desired cell type.

In addition to focusing the flow, the sheathing participates also in preventing cells from clogging. Another feature is an integrated four-point electrode arrangement which can be used to reduce the influence of variations in the electrode/liquid contacts.

Flow-Ratio Sensor

When two liquids of different conductivity flow in the same microchannel the total resistivity in a fixed length of the microchannel is dependent on the relative flowrates of the two flows. The relative flowsrates can be determined by measuring the variations in the total resistance. This enables *in situ* measurements and control of the flow in the µCPC. In general this technique can be used in microsystems for the determination of the relative flowrates of two laminated liquid flows.

Experiments

Our experiments with liquids containing particles in a microchannel system show that clogging can be drastically reduced when the cells are suspended in the core of a coaxial flow. The flow-ratio measurements were conducted by pumping liquids with syringe-pumps into the system, which makes it possible to control the sheathing very accurately. This gives rise to a simple method of sheathing non-conductive and conductive liquids in order to improve the detection sensitivity for cells of varying sizes.

Our experiments have demonstrated that the sheathing of liquids with different conductivities allows for the implementation of an elegant *in situ* flow ratio measurement. The evaluation of our design performance is still inconclusive and we have some improvements in mind.

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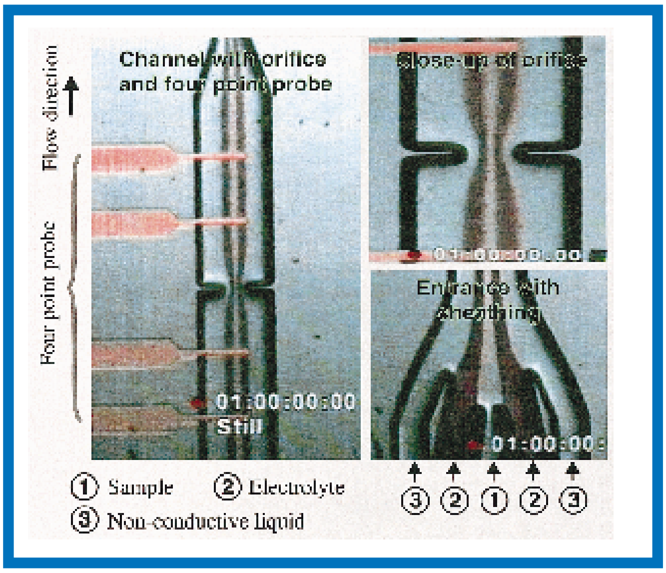
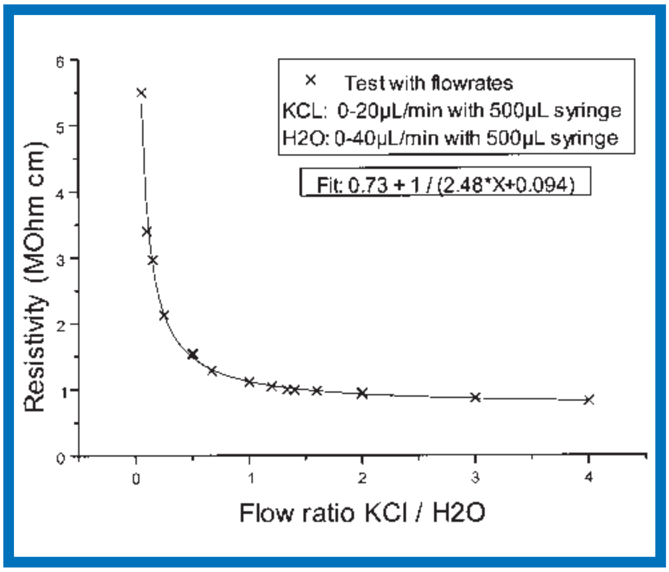


Figure 1. Videoprint of the µCPC with liquids for testing. The photo on the left shows the channel with the orifice in the center. The sample and liquid are clear while the electrolyte used for hydrodynamic focusing is colored with phenol-red. The photo on the right are close-ups of the sheathing and orifice sections. As shown in the figure, no mixing of the liquids occurs.



Resistance measured over the flow chip with conductive and non-conductive fluids (KCL and distilled H2O, respectively). The resistance changes with the relative flowrate of the two liquids.

World Micromachine Summit

The third *World Micromachine Summit* was held in Vancouver, Canada on April 28–30, 1997. These summits bring together the most influential people in the field to discuss issues of mutual interest in a round table format. In Vancouver, Scandinavia participated for the first time, represented by I. Lundström, Linköping Univ. (chief delegate), G. Edwall, Ericsson Components, and D. Sigurd, IMC. In total, 50 delegates from 13 countries and regions exchanged views on micromachining before an audience of 31 international observers. Most of the delegations were from industry, but the chief delegates were nearly all from universities.

Country/Region Reviews: Circumstances differ markedly from region to region in industrial activity, governmental support and public perception. Nevertheless, there are common issues. In most countries/regions, small and medium sized enterprises (SMEs) continue to lead the way, and the needs of the medical, environmental and automotive industries are driving the development of MST. Finding ways to commence and expand the production of micromachined devices at a cost that SMEs can cope with is a subject of much attention. Advances in packaging, testing and standardization are seen as keys to continued expansion. The importance of the diffusion of knowledge was agreed upon.

Standardization: There is general agreement on the need for standardization at an early stage, but the scope and appropriate mechanisms are still matters for debate. A working group is to be formed which will report on its progress at future *Summits*.

Healthcare: Medical diagnosis and treatment remains one of the most fruitful areas for the application of MST. Some long term trends are: a shifts to non-invasive diagnosis, minimally invasive surgery, greater home care, and *in situ* testing. Close cooperation with physicians and strict attention to the customer's needs are essential in a market characterized by short product life cycles.

Environment: Opportunities are immense for monitoring environments, booth indoors and outdoors, for increased comfort and safety. Many environmental issues are global in nature, such as carbon loading of the atmosphere and water quality. Micromachined sensors are a practical way to minimize cost, energy and materials usage, and waste.

New Horizons: Alternate materials and processes, as well as alternatives to the traditional silicon IC based technology were stressed. Delegates were reminded that micromachining is very much a multi-disciplinary field requiring expertise in chemistry, physics, biology, and mechanical and electrical engineering.

Transportation: The use of micromachined devices in the transportation industry, e.g. in automotive and aerospace applications, provides excellent examples of the process involved in moving from a research concept to a commercially successful product.

Information Technology: Instruments used to create, transfer and store information are continually being miniaturized. Micromachining is expected to play a major role, but the integration of current micromachining research is required. There will be an increased use of optics in telecommunications. Cost can be kept down by using micromachined micro-optical devices.

Distinguished Pioneers

When a new technical area is expanding, it is always individuals that drive the development with their enthusiasm and skill. It is important that the excellent pioneering work of these role models be recognized for having enriched the field in a significant manner. At *Transducers '97*, the *Transducers Career Achievement Awards* were presented for the first time to the following four distinguished members of the MST-community:

Dr. Isemi Igarashi (posthumous), Japan: Dr. Igarashi was a pioneer of the piezoresistive pressure sensor. His silicon pressure sensors, developed at Toyota Central Research Laboratory, have been used predominantly in automobiles. He has been well respected and called "Mr. Sensor" owing to his warm personality.

Prof. Wen Ko, Case Western Reserve Univ., U.S.A.: His work on microsensors, both physical and chemical (gas), represents one of the earliest efforts in this field in the U.S.A. His exploratory research has paved the way for many medical prostheses and biological research instruments.

Prof. Simon Middelhoek, The Netherlands: Prof. Middelhoek is one of the silicon sensor pioneers. His research at Delft Univ. of Technology was on basic physical effects in silicon, silicon sensors and offset correction.

Prof. Richard Muller, U.S.A.: His research in silicon sensors at UC Berkeley dates to the 1970s. He has made major contributions to surface micromachining, material properties, electrostatic micromotors, and micro-optical components.

Sensor 97

Sensor 97, the largest worldwide exhibition for sensors, processing electronics and corresponding services (663 exhibitors), took place for the eighth time on May 13-15, 1997 in Nürnberg, Germany. The present day *Sensor* exhibition is a result of the sensational progress in sensor technologies, microsystems technologies and integrated solutions. This year, the exhibition concentrated on sensor elements, integrated solutions and complete measuring systems, while 15 years ago *Sensor* focused primarily on simple sensor elements and the user had to develop methods for housing concepts, error compensation and signal processing.

In parallel, there was an international congress organized with 206 presentations given. The congress covered new advances in research, development and applications of sensor effects and products representing a variety of technologies. For the 609 participants from more than 25 countries, the three parallel sessions presented a wide range of topics.

The Technology Forum "Microsystems Technology" was organized as a combination of special exhibitions and congress sections. It provided a platform for the international exchange of information and know-how, in particular for the many small and medium-sized companies presented. Interested users were given ample opportunity to establish contacts with service providers operating in the field of microsystems technology. In addition to national activities and services, results from EU-funded R&D projects and European activities were presented.

The next *Sensor* exhibition will be held in Nürnberg on May 18–20, 1999.

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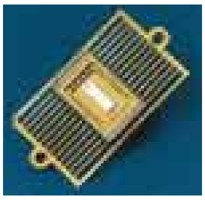
MICRO STRUCTURE BULLETIN NO.3 NOV 1997

NEXT ISSUE

Some topics covered will be:

– MST at Chalmers KiselDesign
– The Norwegian µ-tech program
– A CMOS compatible densitometer



Employment Opportunities at IMC

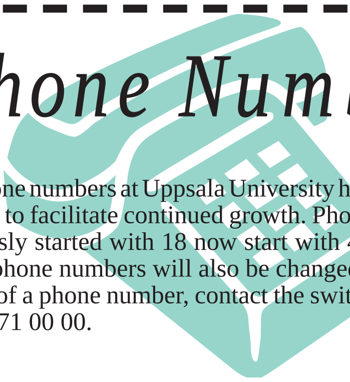
The Micro System Technology group in Stockholm focuses on the development of sensors and microfluidic systems, as well as new packaging technologies for fiber-optics. Several of its projects are expanding.

Project Manager
The assignments will, initially, be to organize and manage the group's participation in a European collaborative project focused on the manufacturing possibilities of micro systems. Academic credentials and industrial experience are highly preferred. Experience in the design, development or production of sensors or microelectronics is required.

Development Engineer
The assignments comprise product development of advanced miniaturized sensors or fiberoptical modules. An MSc degree is recommended. Experience with semiconductor processes and sensor technology is preferred.

More information will be provided by Christian Vieider, phone: +46-(0)8-752 1055, e-mail: vieider@imc.kth.se. Applications must be postmarked/e-mailed before September 30 to: IMC, Personal, P.O. Box 1084, SE-164 21 KISTA.

Phone Numbers



The phone numbers at Uppsala University has been changed in order to facilitate continued growth. Phone numbers that previously started with 18 now start with 471. Some individual phone numbers will also be changed. If you are uncertain of a phone number, contact the switchboard at +46-(0)18-471 00 00.

FUTURE EVENTS

Microsystems in Biomedical Engineering (course), London, England, Sept. 11–12, 1997. For info.: FSRM, Fax: +41-32 720 09 90, or visit http://www.fsrm.ch/programm.htm.

Microsim 97, Lausanne, Switzerland, Sept. 17–19, 1997. For info.: Wessex Inst. of Techn., Fax.: +44-1703-292 853, or visit http://www.wessex.ac.uk/conferences/microsim.

Laser Microengineering (course), Oxford, England, Sept. 18–19, 1997. For info.: FSRM, Fax: +41-32 720 09 90, or visit http://www.fsrm.ch/programm.htm.

Eurosensors XI, Warsaw, Poland, Sept. 21–24, 1997. For info.: Prof. Zbigniew Brzózka, Fax: +48-22-660 54 27.

MEMS 98 (Micro Electro Mechanical Systems), Heidelberg, Germany, Jan. 25–29, 1998. *Abstract deadline: Sept. 15*. For info.: G. Stemme, Fax +46-(0)8-10 08 58, or visit http://www.imit.uni-stuttgart.de/mems98.

Biosensors 98, Berlin, Germany, June 3–5, 1998. For info.: Biosensors 98, Fax: +44-1865-843 958, or visit http://www.elsevier.nl/locate/bios98.

NANO '98, Stockholm, Sweden, June 14–19, 1998. *Abstract deadline: January 15*. For info.: NANO'98, KTH, Fax: +46-(0)8-790 90 72, or visit http://www.kth.se/conferences/nano98.

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