MICRO STRUCTURE BULLETIN

Newsletter for Nordic Micro Structure Technology, Vol.7, No.3, Aug 1999

TRANSDUCERS '99

Once upon a time...
... in the early 80's it was apparent that the transducer community was very much in need of a forum of its own. In 1981, about 120 people from Europe, Asia and the USA gathered in a small conference room in one of Boston's big hotels for what turned out to be *Transducers '81*. Since then *Transducers* has evolved into the largest meeting of its kind in the field of solid-state sensors, actuators and microsystems. It is now a biennial conference that is held in a different city on a different continent each time. In the same year, 1981, a second initiative came from Elsevier Publisher, who started to publish the journal *Sensors & Actuators*. These two events made it possible for members of the transducer community to share the results of their research with their fellow scientists. The history around this was outlined by Professor S. Middelhoek in a very well-appreciated special talk during the opening plenary session that focused on celebrating the 10th *Transducers* conference.

The *10th International Conference on Solid-State Sensors & Actuators, Transducers '99*, was held in June 7–10 in Sendai, Japan. The conference program featured, in addition to the 14 invited talks and 17 late news contributions, more than 200 oral and 225 poster presentations.

After the opening session and the special celebration talk the conference preceded with three interesting invited presentations during the second plenary session. The conference continued thereafter as usual with four parallel sessions. In this way there is almost always at least one presentation that attracts one's attention. The various sessions were related to different aspects of sensor and actuator research, where the trend from basic processes and material characterization to applications and complex microsystems is becoming more evident every conference. Since the field of µ-TAS (micro total analysis system) is rapidly expanding, a new session concerning this was created this year.

The conference facilities and the experienced staff contributed markedly to the success of *Transducers '99*, the third *Transducers* held in Japan.

Next time *Transducers* is held in Asia it will be hosted by Korea (2005). Before then, *Transducers* visits Europe (2001, Munich) and U.S.A. (2003, Boston – back to where it started).

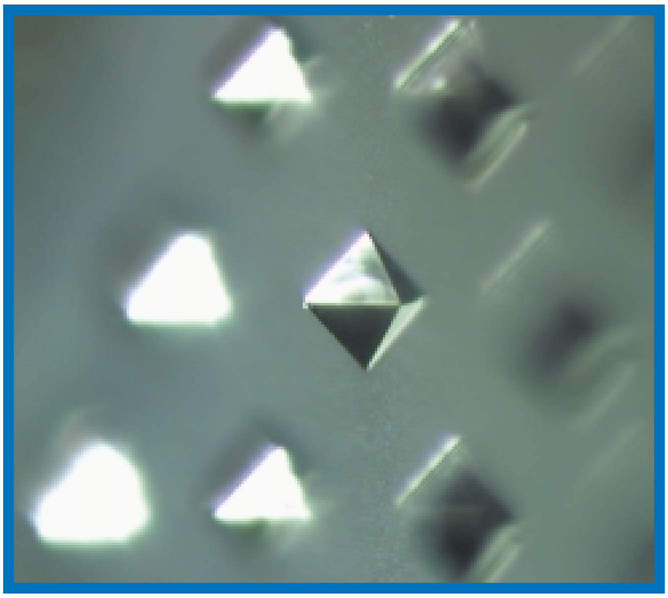

Photo of a polycrystalline diamond tip used for field emission experiments, presented at Transducers '99. *As with this structure, the conference was also many-facetted.*

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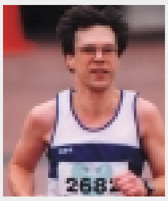
EDITOR'S NOTE

This *MSB* focuses on the *Transducers* conference, a conference at which the Nordic region was well represented. Regional thinking is rapidly gaining acceptance even in sports, with the Finish-Norwegian application for the 2006 Winter Olympics as a typical example. In addition, this trend continues to penetrate the MST-area and is triggered by the complementing nature of our MST-activities. I forecast that Nordic collaboration soon will be encouraged explicitly in research programs for MST.

I wish to share two sayings:

"But still try – for who knows what is possible?" (Michael Faraday): In 1984, I got involved with tomorrow's gyroscopes. Due to an erroneous assumption, I initially predicted a depressingly small response ('single electrons' per °/s). I soon caught the error and predicted a more realistic signal level ('ampere' per °/s). If decisions had been based on such errors, or if I had considered it impossible to detect vibration amplitudes as small as 0.1 Å (fractions of an atomic radius), then Colibri would have cancelled the gyro project and it would not have reached commercialization for automotive applications.

"Success is a journey, not a destination" (origin unknown): The progress of technology means that today's technological destinations will be forgotten tomorrow. Better is to make the journey towards the destination as interesting, challenging and target-oriented as possible. This usually ensures good results, and creates a self-rewarding situation.



Jan Söderkvist

Impressions at Transducers

There were numerous interesting presentations and posters at *Transducers*. Trying to cover the whole conference in a short summary would be too difficult. Instead, some general impressions will be reported. The technical program committee must have had a difficult task of reviewing, selecting and organizing the more than 825 submitted abstracts into a comprehensive technical program. Of course, they did succeed and, with an accept ratio of 53.5%, a high quality conference program was constituted.

After the plenary sessions there were always four parallel simultaneous sessions, except during the poster sessions. In this way you could always find one session concerning basic fabrication processes and material characterization, another session dealing with all kinds of sensors and actuators, a third covering more complex microsystems, and a fourth session dealing with biosensors and µ-TAS. The latter was new for this conference and attracted many papers. In total, 53 papers were presented in the µ-TAS session.

Trends

There remains a continued shift towards fully developed devices and systems, but this trend has two basic approaches. The first uses expensive and more complex processes in order to realize discrete devices with satisfactory characteristics.

The other approach uses standard processes to fabricate components with moderate performances. This behavior is improved using complementary electronic circuits for signal processing. The electronics is sometimes integrated onto the same chip as the sensor element, (the one-chip solution) and sometimes forms a separate chip (the two-chip solution).

The Aoba castle in Sendai (courtesy of Sendai Convention Bureau).

Highlights

Just to mention a few highlights of the conference: E.T. Carlen from the University of Michigan presented a new actuation technology based on micromachined paraffin where the actuation medium produces large forces and displacements. M.A. Schmidt from MIT showed results from combustion tests conducted in the 6-wafer static structure of a micro gas turbine engine.

Still, trying to be objective, the presentation of the "Butterfly-gyro" by G. Andersson, IMEGO, was very competitive compared with all the other gyroscope presentations. Another popular presentation was held by T. Ebefors, KTH, who made an outstanding performance presenting his walking silicon micro-robot (see *MSB 98:3*). The robot video is now available on the web for those interested (www.s3.kth.se/instrlab/research/photoandvideogallery).

Exhibitions

A selected number of companies displayed their latest products in a exhibition at the conference. Another special exhibition to celebrate the 10th commemorative conference was also displayed. Memorable papers and items from past conferences were exhibited and gave an overview of the progress in sensor and actuator research.

Social Events

In addition to the technical program, optional tours and excursions were offered to the conference participants and their guests. Apart from the conference banquet, one social event seemed to have appealed to the Nordic delegation in particular, the sake tasting evening. Most probably, this is because it did not interfere with the technical program … Sure! (Editor's remark).

Visit

Another well-attended and appreciated event which occured in close connection with the conference was the open house at Venture Business Laboratory, Tohoku University. This was very interesting for those who have previously only read about the scientific results of Professor M. Esashi (the general chairman of Transducers '99).

Next Transducers

Four years ago Sweden hosted the largest *Transducers* ever held. The next *Transducers* will be held in Munich, Germany, June 10–14, 2001. Perhaps then the participant record of *Transducers '95* in Stockholm will be exceeded since this will also be a joint *Transducers-Eurosensors* conference. Hope to see you there!

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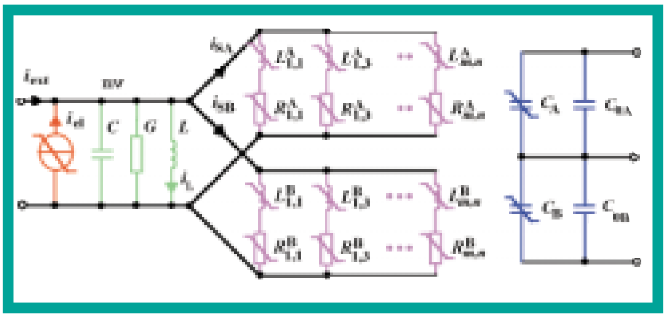
STATISTICS

Transducers '99 featured almost 1,000 participants from 29 countries. The program included 14 invited, 212 oral, 227 poster and 17 late news presentations which were selected from among 826 papers submitted from 39 countries and regions (a 53 % acceptance ratio).

The Nordic region was represented by 61 participants, and in the author list by 20 oral and 9 poster presentations (see page 7, a 70% acceptance ratio). This made the Nordic region the third largest participatory region in Europe after Germany and Switzerland.

Simulation of MEMS Dynamics with a Circuit Simulator

The variety of design and simulation aids of micromechanical devices is large. One of these tools is the circuit simulator. It is a robust tool that handles both linear and nonlinear, and transient and frequency-domain simulations. Combined electrical and mechanical dynamic simulation of micromechanical devices is possible by means of electrical equivalent circuits.



Electrical-equivalent circuit representation of an accelerometer. The model consists of a resonator (green), a squeezed-film damping circuit (magenta), an electrostatic force (red) and gap capacitances (blue). The nonlinear components are controlled by several voltages.

Electrical-Equivalent Circuits

The idea of using electrical equivalencies to model other energy domains, e.g., mechanical and fluidic, is old. Small-signal, linear models have been traditionally generated. However, the same idea can be extended also to large-signal, nonlinear models. In this way, the fundamental non-linear properties of, for example, an electromechanical transducer can be accounted for in the simulation.

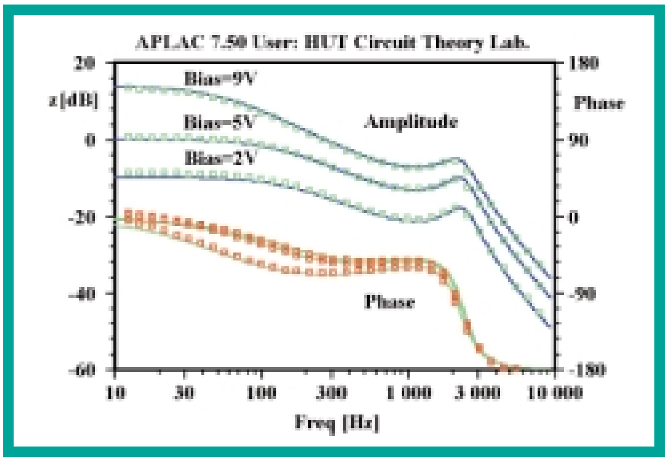
Lumped and Distributed Macro Models

The phenomena in micromechanical devices are usually described with one or several nonlinear PDEs (partial differential equations). In many cases, simplified forms of these equations can be applied leading to lumped models. They can be implemented in practice with a few electrical components. If this simplification is not possible, distributed PDEs can also be implemented. Advanced circuit simulators are able to generate component meshes which implement the PDEs approximately with finite difference techniques.

Gas Damping in Microstructures

One of the fundamental problems in the dynamic operation of micromechanical devices is the damping. It is usually caused by the squeezed gas-film in narrow gaps or by the shear stress in lateral structures. An accurate solution for the gas flow problem is complicated. It is essential to be able to reduce the PDEs in order to get compact damping models. One of these reduced models is the Reynolds equation, and can be applied in simulating the squeezed-film damping of micromechanical devices.

However, the small dimensions in microstuctures invalidate the direct use of this equation. The dimensions of small structures (1 µm) exceed the mean free path of the gas, even at atmospheric pressures. The models for viscous flow are no more valid in this case. Gas rarefaction effectively decreases the damping. This can be accounted for in the model with an effective viscosity. It is a function of the gap separation, mean free path of the gas, and surface conditions (e.g. purity, roughness).



Measured (❑) and simulated (—) frequency response of an accelerometer at different electrostatic bias voltages. The bias voltage effectively changes the spring constant of the system.

Accelerometer Model

An electrical-equivalent circuit model for the accelerometers manufactured by VTI Hamlin has been constructed. The model describes the dynamic, nonlinear operation of the sensor. It includes the electrostatic actuation and large-displacement, gas-film damping model. The model is accurate at a wide range of parameters, e.g., gas pressure. The model has been implemented in the circuit simulation tool APLAC, and can be used in the design of the sensor electronics, and in the design of similar devices.

Library of Micromechanical Components

Using the equivalent circuit blocks implemented in the accelerometer model development, a library of electromechanical components has been created. The library consists of resonators, electromechanical transducers, and gas-film dampers. Using these components, a model for a gyroscope, currently under development at VTI Hamlin, has been constructed.

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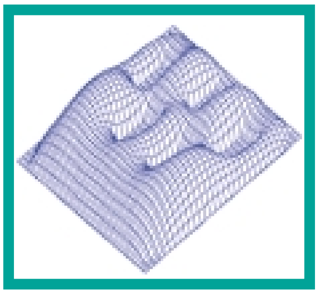

Simulated pressure distribution at the accelerometer's surface, solved with a finite-difference equivalent circuit.

PROCEEDINGS

The "Digest of Technical Papers" of the *Transducers '99* conference is available both in paper and in CD-ROM format. If you would like your own copy, order forms can be obtained from:

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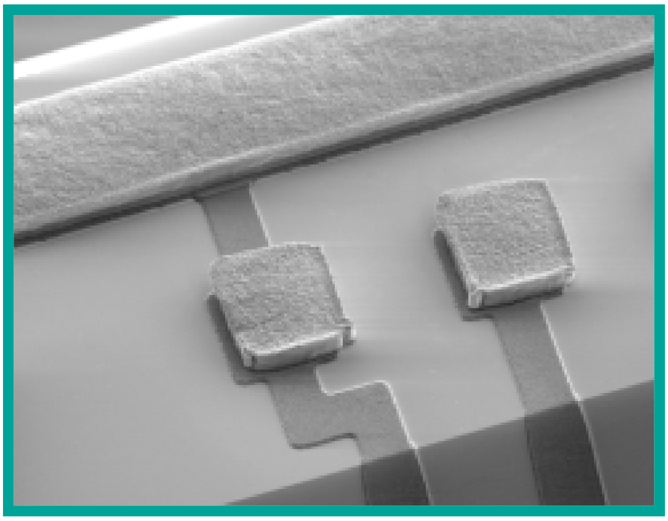
Stacking for MEMS

Packaging technologies have a high impact on the commercialization of microelectromechanical systems (MEMS). In the European collaboration project HISTACK (see *MSB 98:2*) and the Danish project MSC, Mikroelektronik Centret (MIC) developed a stacking technology based on electroplated front to backside interconnects and fluxless flip-chip bonding technologies.



Feedthrough metal wires, solder bumps (as-deposited) and sealing ring (as-deposited).

Monolithic vs. Hybrid Integration

Monolithic integration enables to reduce electrical parasitics to a minimum and has a large cost saving potential for high volume production. One inherent incompatibility of CMOS and micromachining technologies is that CMOS depends on very flat surfaces. Cross-contamination of the two different process lines is a potential problem in combining CMOS and micromachining as well. A practical obstacle for using monolithic integration is that availability of foundry services is unstable. These obstacles can be overcome by compromising about device design and processes. This will be, however, time consuming and costly, and the reliability risks are unknown.

Hybrid technologies will therefore dominate when building increasingly complex microelectromechanical systems (MEMS). Hybrid technologies enable separating micromachining and CMOS technologies which leads to faster, separate component designs, optimized processes, and higher flexibility to change design and processes.

Vertical Feedthroughs and Flip-Chip Bonding

MEMS often need a second port to the outside world in addition to the electrical. Flip-chip technologies in combination with front-to-backside electrical interconnects (through-wafer interconnects) create electrical contacts which can be separated from active transducer surfaces. This facilitates device protection and helps to ensure a defined transducer interface to the environment. Flip-chip bonding yields lowest electrical parasitics and forms a very compact package whose size is determined by the footprints and the height of the assembled components (chip-size package, CSP).

In order to produce low parasitic multiple through-wafer interconnects on slanted KOH etched sidewalls an electrodepositable photoresist (EDPR) technology was developed. Solder bumps for flip-chip bonding and solder sealing rings can be fabricated as well using EDPR technology. After flip-chip soldering, bumps and sealing ring establish mechanical stability, electrical contacts and, optionally, hermetic sealing. A SEM picture of feedthrough lines, solder bumps and sealing ring is shown to the left.

Flip-chip technologies for MEMS need to be fluxless in most cases, because fluxes would clog nozzles, air gaps or movable parts of transducers. Therefore a fluxless soldering technology was developed which also has demonstrated excellent self alignment properties.

Application Example: Microphone for Hearing Aids

The integrated microphone is designed to be part of a new generation of completely in-the-ear-canal hearing aids. This application requires a very small total volume of the fully packaged system. The four components of the stack are a micromachined condenser microphone with a backchamber, a passive interconnect layer and an ASIC for signal conditioning (see also *MSB 98:3*).

Besides the electrical through-wafer interconnects, the intermediate interconnect layer supplies additional functionality for this application: it ensures an acoustic frontchamber and a sound inlet to the microphone, it provides the electrical terminations to the outside world, and it protects, after bonding, the microphone from mechanical damage during subsequent assembly steps.

The most important parameters of the feedthrough technology are series resistance and parasitic capacitance since the microphone is a low power application with a capacitive readout. Copper with a thickness of 3 µm and a width of 40 µm are electroplated to obtain the electrical feedthrough lines and 2 µm of nickel is electroplated as under-bump metallization. The electrical parameters achieved with this technology are 0.9 pF for a 650 µm long copper line on top of 1 µm thick silicon dioxide. The resistance of a copper line of the same length is 100 mΩ.

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HARMST 99

Scheduled to follow *Transducers '99*, the *High Aspect Ratio Microstructures* (*HARMST*) Workshop drew some 140 people to Kazusa Academia Centre in Kisarazu, near Chiba in Japan. *HARMST* has its roots in LIGA technology, but LIGA now forms only one third of the workshop.

Some 10 papers were presented on LIGA technology (including sources, masks and resists) and another ten on applications. UV-LIGA with SU-8 and electroplating technologies formed a major part of the workshop. Molding techniques for polymers and (piezo)ceramics also had a sizable presence. More traditional micro (milli) machining techniques, like electrodischarge machining, were presented side by side with new developments, like photoforming (stereolithography).

Nordic presentations covered electroplated actuators fabricated with an SU-8 resist (MIC, Denmark), ion track etching (Ångstrom Laboratory, Sweden), and deep RIE etching (VTT/HUT, Finland). Silicon had a very minor role, just 6 presentations: 5 on DRIE and one about electrochemical etching. The workshop also included a number of status reports about major institutes and service providers, e.g. prototyping of LIGA devices.

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A Self-Testable Pressure Sensor

In many cases, pressure sensors operate in remote locations. Without direct access to them the possibility to control their behavior is lost. Hence, they must be as reliable as possible to make certain that they are still properly functioning after being put into operation. One solution for improving reliability is to include an active test system.

In the design presented here (conceived at K.U. Leuven, Belgium), the testing feature is realized via a built-in actuator. The sensor's pressure sensitive diaphragm can thereby be affected, which enables the investigation of its behavior resulting from the response to a known stimuli. In our case, thermal actuation based on the bimetal effect is used for this purpose. It relies on the heat-induced displacement of a sandwich structure, consisting of materials with different coefficients of thermal expansion.

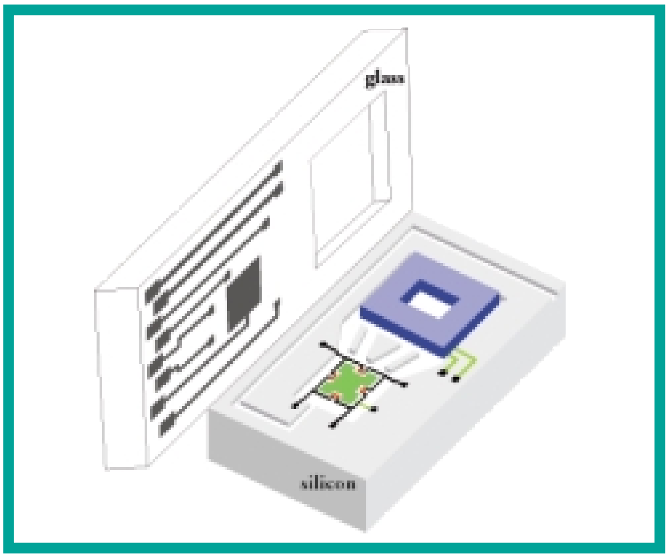
The Design

In a pressure sensor with only one flexible membrane, its dimensions are determined by the requirements for optimal sensor performance, i.e. for an optimal trade-off between sensitivity and linearity. As the actuator makes use of the same membrane in this case, its efficiency is usually limited by these dimensional restrictions.

Another approach consists of separating the sensing and the actuating functions. Using separate membranes for each of the tasks allow their dimensions to be optimized according to their specific functions. Moreover, the negative effects of the actuation function on the pressure sensitive diaphragm can be reduced.

The figure below presents a schematic drawing of such a twomembrane device. One membrane (0.7 mm wide, 10 µm thick) is used as the pressure sensitive element, combining the capacitive and the piezoresistive sensing principles. The other (2 mm wide, 10 µm thick) is a bimetallic actuator, involving a silicon/aluminum pair. A diffused meander situated under the thick (4 µm) metal layer serves as a heating resistor. Applying a current to this resistor creates a controllable downward movement of the composite membrane. The resulting increase in the cavity's pressure modifies the differential pressure over the pressure sensitive membrane. The magnitude of the resulting response from the pressure sensor provides information about the correctness of the sensor behavior.

Note that a long and narrow channel is etched to connect the cavities to the outside. This assures that the reference pressure in the cavity does not depend on the anodic bonding process which is used to join the silicon and the glass wafers. During operation of the device, the influence of a slowly varying ambient temperature on the cavity pressure is counteracted by air leakage through this channel. On the other hand, the large time constant of this channel assures that the pressure built up by the actuation persists during the functionality test of the pressure sensor.



Schematic drawing of the double-membrane, self-testable pressure sensor based on bimetallic actuation.

Experimental Results

A current flowing through the heating resistor was used to actuate the large membrane. Meanwhile, the change in the bridge resistance was measured. The results demonstrate the feasibility of the approach. For example, the response caused by an electrical heating power of 5 mW corresponded to a pressure change of 180 mbar over the pressure sensitive membrane.

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DISSERTATIONS

MSB *wishes to congratulate the following individuals on successfully having defended their theses this year.*

Petronella Norberg, LiU

Her PhD thesis, *Gas Flow and Chemical Reactions in Submicron Channels*, addresses molecular flow in shallow (~100 nm) micromachined channels with an extreme length-to-depth ratio (~500,000). Surface phenomena are enhanced by the numerous molecular-wall collisions suffered by the transmitted species ($\sim 10^{11}$). Some channels were made catalytically active via a thin platinum film.

Several findings are presented that contribute to the understanding of surface induced effects, such as adsorption, reflection and chemical reactions (see e.g. *MSB 97:2*). Gas transport under Knudsen-like conditions were thoroughly characterized and modeled, including water-forming reactions, the hydrogenation of ethylene, and hydrogen induced CO_2 formation.

Jon Nysæther, U. of Oslo

His PhD thesis, *Silicon Test Structures for Microsystems*, explores how polymeric packaging materials influence the performance and reliability of silicon-based micro-assemblies.

Transfer molded packaging, as well as the rigid underfill material used in flip-chip-on-board circuits to enhance bump lifetime, introduce high levels of thermal stress in a silicon die. Its distribution in pressure sensor diaphragms and specially designed test structures, with and without glob top coverage, was characterized. The lifetimes of the flip-chip solder connection was measured and successfully compared to a lifetime model.

Greger Thornell, UU

His PhD thesis, *Minuscular Sculpturing*, deals with process technologies that enable truly three-dimensional structures, as well as the integration of materials in a way not feasible by planar IC processes and semiconductor materials.

Ion bombardment was used to tailor the anisotropy of wet etching. Subtractive electro-discharge machining, combined with wet etching and electrodeposition via the direct writing of metal structures, were used to minutely structure conductive materials. Finally, ceramic structures were built drop-by-drop using a micromachined jet nozzle and a particle suspension.

Field Emitting Structures for Miniature X-ray Sources

Different field emitting structures intended for a miniature X-ray source was one of the Swedish contributions at *Transducers '99*. It was the first international presentation of a new interdisciplinary project at The Ångström Laboratory (UU), for which Leif Smith at RADI Medical Company AB, Uppsala, is the project leader.

Tentative Applications

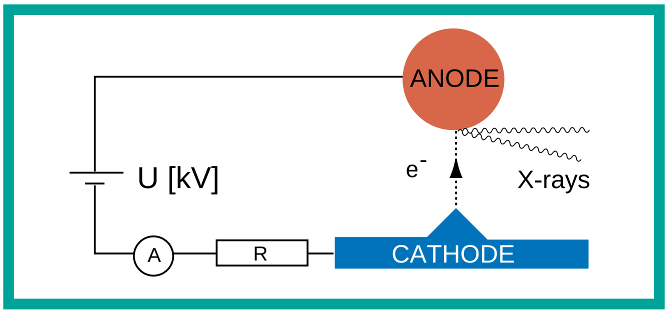
A miniature X-ray source would be useful in several application fields, both technical as well as medical. An X-ray source for minimal invasive use would be of great interest in radiation therapy, since it would allow the administration of a controlled dose confined to a small tissue region. Besides the treatment of tumors, a small X-ray source could be used to prevent scar formation after balloon dilatations of coronary artery stenoses.

Basic Principle

The concept of the miniature X-ray source is based on field emission. Field emitted electrons are accelerated from a cathode towards an anode. X-rays are generated when the electrons impinge on the anode material.

The X-ray energies are determined by the applied voltage and the anode material. Since the source is voltage controlled it is possible to turn it on and off. This is an important advantage in comparison with radioactive sources. The dose can be controlled by the applied voltage and the treatment time.

The reasons for choosing a field emitting cathode are several. First of all, a cold cathode would diminish the need of cooling. Second, high current densities could be achieved. Third, micromachining of the electrodes would allow for miniaturization, and eventually batch fabrication.



The principle of the miniature X-ray source.

Results

Many field emission, but even more failed emission experiments have been performed. Different types of cathodes made out of various materials have been manufactured and evaluated as field emitters.

The most feasible structures evaluated thus far are the polycrystalline diamond tips shown in the photo on the front page. Sufficient emission currents have been achieved and both bremsstrahlung and characteristic radiation have been detected. The concept has thus been experimentally verified.

The next objective is to study anode designs and to manufacture an integrated source.

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MST Learns from Mother Nature

At the *Photonics West* conference in January in San Jose, U.S.A., several speakers addressed micro-optical systems. An important topic was how to adjust reflection losses, an area in which Uppsala also has some research activities.

Due to the difference in the indices of refraction between an optical element, such as a microlens, and its surrounding medium, usually air, all such elements suffer from Fresnel reflection losses. The conventional way of reducing these losses is to coat one or both sides of the optical element with a multilayer coating. Such antireflection (AR) coatings can very efficiently reduce the reflection losses, both for wideband and for large angular ranges. However, as more and more micro-optical elements are being produced in low cost polymeric materials, the AR coating process becomes responsible for the main cost. Moreover, due to material mismatch problems between the optical elements and its coating, AR coatings may suffer from poor adhesion.

To overcome the costly coating step and adhesion problem, optical researchers have found a solution by studying the performance of moth eyes. The surface of a moth's cornea has microscopic raised protuberances that are roughly 200 nm in height and 300 nm spaced apart. This subwavelength structure provides a very efficient AR interface, which is essential for the moth in order not to reveal its presence. From a theoretical standpoint, the subwavelength structure can be modeled as a modulated graded-index, which reflects very little light because there are no abrupt index changes.

By using electron-beam lithography we have artificially produced such subwavelength structures superimposed onto micro-optical elements, and verified that the reflection is indeed lowered. The main advantage with this technique is that the AR structure, in the form of a shallow surface relief, is embedded within the optical elements. By replicating these elements, e.g. by use of injection molding techniques, low cost micro-optics with polymer AR structures can be realized.

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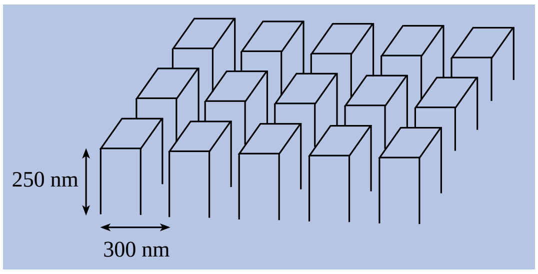

Artificially produced subwavelength gratings which mimic the function of moth eye antireflection structures. This is one example where MST can benefit from microstructures already developed in nature.

Finnish Boost for MEMS Research

The *Research Program for Electronic Materials and Microsystems* (EMMA) will be carried out during a three-year period in 1999-2002. It will concentrate on basic research and the training of young scientists. The Board of the Academy of Finland has allocated a total of 30 million FIM (5 million Euro) for the program. The first projects under the program's umbrella will start up during the summer of 1999.

Most of the MEMS related projects are to be carried out at the Helsinki University of Technology (HUT). The other major MEMS R&D player in Finland, VTT, is mostly funded by TEKES, the Ministry of Trade and Industry funding agency, in regards to more applied projects. TEKES is currently planning a national program for MEMS to be launched later this year.

Selected projects for EMMA:

- Ilkka Tittonen, HUT Metrology Research Inst.: High-Q micromechanical oscillators
- Sami Franssila, HUT Microelectronics Center: High aspect ratio microstructures in silicon
- Nieminen, Risto, HUT Computatational Physics: Modelling of Si processing and Si-based microelectromechanics
- Lauri Niinistö, HUT Inorganic Chemistry: Porous silicon as a material for gas and humidity sensors
- Martti Salomaa, HUT Materials Physics: Microwave filter technologies
- Veikko Lindroos, HUT Materials Science: Multiscale processing and modeling of silicon wafers and structures
- Kaski, Kimmo, HUT Computational Sci. and Eng.: Modeling of electronics materials processing and microelectromechanical systems

Major projects were also funded in silicon wafer characterization, nanostructure technology, functional polymers in electronics, and reliability of interfaces.

Sami Franssila

Nordic Contributions at Transducers '99

Denmark

- AFM Probe with Piezoresistive Read-out and Highly Symmetrical Wheatstone Bridge Arrangement *[J. Thaysen, A. Boisen, O. Hansen, S. Bouwstra (MIC)]*
- Design of Rapid Micromixers Using CFD *[U. Darling Larsen, W. Rong, P. Tellerman (MIC)]*
- Fabrication of Electroplated 3D Microstructures Combining KOH Etching, Electrodeposition of Photoresist and Selective Etching *[L.S. Johansen, M. Ginnerup, P.T. Tang, J.T. Ravnkilde (MIC, DTU), B. Löchel (Bessy GmbH, Germany)]*
- Interconnect Layer with Advanced Multiple Feedthrough Metallization for an Integrated Microphone for Hearing Aid Applications *[M. Heschel, P.T. Tang, J.F. Kuhmann, S. Bouwstra (MIC, DTU), K. Rasmussen (Microtronic)]*
- Low-Temperature Anodic Bonding to Silicon Nitride *[S. Weichel, R. de Reus, S. Bouiadat, P.A. Rasmussen, O. Hansen (MIC), K. Birkelund, H. Dirac (Danfoss)]*
- Microscopic Four-Point Conductivity Probes *[P. Bøggild, C.L. Petersen, F. Grey (MIC), T. Hassenkam, T. Bjørnholm (Univ. of Copenhagen), I. Shiraki, S. Hasegawa (Univ. of Tokyo)]*
- Multi Degrees of Freedom Electro-Thermal Microactuators *[J. Jonsmann, O. Sigmund, S. Bouwstra (MIC)]*
- Packaging-Friendly Flat-Surface Pressure Sensor for Harsh Environments *[G.F. Eriksen (Grundfos), R. de Reus, C. Christensen (MIC)]*
- Removable SU-8 Mould with Small Feature Size for Electroplating Compliant Metal Micro Actuators *[R.K. Vestergaard, S. Bouwstra (MIC)]*
- Tuning Current-Output Fluxgate *[P. Ripka at al (Czech Techn. Univ.), F. Primdahl (DTU)]*

Finland

- Depth and Profile Control in Plasma Etched MEMS Structures *[J. Kiihamäki, H. Kattelus, S. Franssila (VTT)]*
- Finite-Difference Large-Displacement Gas-Film Model *[T. Veijola (HUT)]*

Norway

- A New Concept for a Self-Testable Pressure Sensor Based on the Bimetal Effect *[A. Cozma Lapadatu, H. Jakobsen (SensoNor), R. Puers (KU Leuven, Belgium)]*
- Compensated Differential Pressure Sensor Realized by Triple-Stack Fusion Bonding *[S.T. Moe, K. Schjølberg-Henriksen, D.T. Wang, E. Lund, J. Nysæther, L. Furuberg, T. Fallet, R.W. Bernstein (SINTEF)]*
- The Effects of the Anodic Bonding on the Electrical Characteristics of the p-n Junctions *[A. Cozma Lapadatu, H. Jakobsen (SensoNor), R. Puers (KU Leuven, Belgium)]*

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- A New Edge-Detected Lift Force Flow Sensor *[N. Svedin, E. Kälvesten, G. Stemme (KTH)]*
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- Combustion Monitoring Field Effect Gas Sensors Based on Silicon Carbide *[A. Lloyd Spetz, P. Tobias, L. Unéus, H. Svenningstorp, L.-G. Ekedahl (S-SENCE), A. Göras, P. Rask (Mecel), P. Salomonsson (Volvo TU), P. Mårtensson, R. Wigren (Nordic Sensor Techn.), P. Ljung, M. Mattsson (Vattenfall)]*
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- Field Emitting Structures Intended for a Miniature X-Ray Source *[P. Rangsten, C. Ribbing, C. Strandman, P. Hollman, K. Hjort, Y. Bäcklund, H. Lundqvist (UU), B. Hök (Hök Instrument), L. Smith (RADI)]*
- Gas Response Dependence on Gate Metal Morphology of Field-Effect Devices *[M. Eriksson, C. Utaiwasin, A. Carlsson, M. Löfdahl (S-SENCE)]*
- Laterally Resolved Gas Sensing by Using a Scanning Light Pulse Technique and Local Gas Sampling-Accounting for Gas Consumption *[M. Löfdahl, I. Lundström (LiU)]*
- Microfluidic Components in Diamond *[P. Rangsten, H. Björkman, K. Hjort (UU)]*
- Novel Burst Technology for Closed Loop Detection and Excitation of Resonant Silicon Sensors *[T. Corman, P. Enoksson, K. Norén, G. Stemme (KTH)]*
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- Study of CO Sensitivity of High Temperature Field Effect Sensors Based on SiC *[S. Nakagomi, M. Nomoto (Ishinomaki Senshu Univ., Japan), P. Tobias, P. Mårtensson, I. Lundström, A. Lloyd Spetz (S-SENCE)]*
- Surface Energy as a Function of Self-Bias in Oxygen Plasma Bonded Silicon Wafers *[D. Pasquariello, M. Lindeberg, C. Hedlund, K. Hjort (UU)]*

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MICRO STRUCTURE BULLETIN NO.3 AUG 1999

PUBLICATIONS

- A Numerical Design Study of the Valveless Diffuser Pump Using a Lumped-Mass Model; A. Olsson, G. Stemme (KTH) and E. Stemme (CTH); *J. Micromech. Microeng.*, **9**(1) (1999) 34–44.
- Gas Flow and Chemical Reactions in Submicron Channels; P. Norberg (LiTH); Doctoral thesis,. *Linköping Studies in Sci. and Techn.* 575, ISBN 91-7219-458-8.
- Minuscular Sculpturing; G. Thornell (UU); Doctoral thesis, *Acta Univ. Ups.* 456, ISBN 91-554-4480-6.
- Silicon Test Structures for Microsystems; J.B. Nysæther (Univ. of Oslo); Doctoral thesis (1999).
- Spatial-Mode Control of Vertical-Cavity Lasers with Micromirrors Fabricated and Replicated in Semiconductor Materials; F. Nikolajeff, T. Ballen, J. Leger, A. Gopinath, T.-C. Lee, and R. Williams (UU); *Applied Optics*, **38** (1999) 3030-3038.

FUTURE EVENTS

Silicon Radiation Systems (course), Oslo, Norway, Sept. 9–10, 1999.
fsrm@fsrm.ch, www.fsrm.ch

Eurosensors XIII, The Hague, The Netherlands, Sept. 12–15, 1999.
eurosensors@ei.et.tudelft.nl
eurosensors.et.tudelft.nl

MME'99 (MicroMechanics Europe), Gif-sur-Yvette, France, Sept. 27-28, 1999.
mme99@ief.u-psud.fr
www.ief.u-psud.fr/~mme99

Etching Technology (course), Stockholm, Sweden, Oct. 4–5, 1999.
fsrm@fsrm.ch, www.fsrm.ch

MEMS-2000 (Micro Electro Mechanical Systems), Miyazaki, Japan, Jan. 23–27, 2000. *Abstract deadline: Sept. 13, 1999.*
mems@mesago-jp.com
www.mesago-jp.com/mems

Transducers '01, Munich, Germany, June 10–14, 2001.

MSB's Future

The outcome of discussions regarding *MSB*'s future is both positive and negative. Not many comments regarding *MSB*'s contents have reached me, and my conclusion is that the current disposition is well received. Another positive ... note is that the financing might be possible to improve without introducing a subscription fee.

However, large organizational changes are needed. My wish to focus on Colibri's core business makes a continued involvement in such a time-consuming 'hobby-project' as MST (*MSB*, *MSW*, etc.) complicated.

It is my wish and obligation to *MSB*'s readers to find a suitable alternative. Unfortunately, despite two years of search, I have still not managed to identify a long-term Nordic alternative that improves and extends the *MSB*-concept without jeopardizing its well-received neutrality and objectivity.

If basic requirements cannot be fulfilled, e.g. that the key players behind *MSB* should not themselves be active within the MST-area or have commercial MST-interests, then it is questionable if *MSB* should continue. Your comments clearly point out that an importand reason for *MSB*'s success is that Colibri fulfills this requirement for neutrality.

My search will continue, but I cannot today make any promise as to what will happen with *MSB* after this year. I hope to bring positive news in *MSB 99:4*.

Jan Söderkvist
Editor-in-Chief

NEXT ISSUE

25th MSB

Next issue will include MEMS-reflections on the new millenium and flashbacks.

THE AIM OF the *Micro Structure Bulletin* is to promote the use of micromechanics and micro structure technology. It constitutes one part of the efforts made by the strategic center for Advanced Micro Engineering (AME) and the competence center for Surface and Micro Structure Technology (SUMMIT) to disseminate scientific and technological information.

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