MICRO STRUCTURE BULLETIN

Newsletter for Nordic Micro Structure Technology, Vol.5, No.4, Nov 1997

In Search for the Extreme

This 1000th-scaled replica of the first passenger car from Toyota (1936) is able to run smoothly at a speed of 10 cm/s (see page 3). It is a true masterpiece of workmanship, and the scientists' way of stretching their imaginations. Without targets like this, technology would not move forward with today's rapid pace (courtesy of DENSO Research Laboratories, Japan).

Creativity is the ability to stretch the imagination in a constructive way. A challenge is that only the future will tell if an action was creative or not. Nevertheless, to dare extreme approaches is essential in promoting technological progress.

For the development of uncharted areas, like the microworld, it is essential to set up complex and challenging long-term goals, for instance regarding size, performance, and functionality. Ideally, such goals should be easy to grasp and span over multiple technical areas, but have solutions that are hard to reach ('Apollo projects'). This will challenge one's creativity the most.

A good example is the miniature car shown in the figure. The target was to miniaturize a car more than had been previously done. Still, the car should resemble the original and move with a built-in motor. Improved design and process tools were developed as a result.

Going to the extreme in R&D is similar to searching for perfection in the performing arts or sports. Curiosity, practice, patience, devotion, new thinking and teamwork are important ingredients for success. The similarities might explain why researchers often practice activities that stretch their personal abilities, like long-distance running.

In fact, the more than 4.2 years of graduate school resembles a 42 kilometer marathon race. Both have a relaxing 10 miles start, an intermediate 10 miles when one realizes that one should have worked or trained harder, and a final 10 kilometers during which one continues on sheer will alone. In fact, the months preceding a PhD thesis defense are among the most hectic in life.

Training and research both have building and harvesting periods. During the latter, the body is allowed to recover, and ideas to flow and mature, i.e. the pieces start to fit together. The building periods are more characterized by frustration, when tested ideas fail, raw material to be read through appears endless, and running shoes wear out. Despite this, the resulting foundation is the key to successful harvesting periods.

Teamwork is essential for both activities. It would be difficult to succeed without encouragement, discussions, water stations, and the delegation of work during crucial periods.

The essence is that one must enter uncharted territory and suffer its pains and exhaustions to reach the immense satisfaction of having stretched the research society's and one's own limits.

Jan Söderkvist

CONTENTS

EDITOR'S NOTE

The preparation of next year's *Micro Structure Workshop* is progressing. The target is to have a meeting as successful as *MSW '96* and *MSW '94*. Set aside the dates March 24–25 now so that you do not miss *MSW '98*.

Important and well appreciated aspects of *MSW* are the ample possibilities to form contacts and stimulate creativity. An excellent way of promoting this is to expose your work by giving a presentation. Therefore, I strongly encourage you all, both industry and academia, to participate actively at *MSW '98*. The abstract deadline is December 31. Do not hesitate to contact me if you have any questions.

Editing *MSB* is a time-consuming hobby that I enjoy. Unfortunately, the desire to satisfy everyone's wishes sometimes creates situations in which every alternative involves drawbacks. Fortunately, only a small fraction of my long-distance running is triggered by such frustration. In contrast, running is a relaxing way of getting me focused.

Jan Söderkvist

Micromachining Basics Part 10:

Surface Micromachining

Micromachining comes in two varieties, *surface and bulk micromachining* (SM and BM). Both date back to the 1960's, and were developed in parallel. The toolbox for SM was more complicated to create, and took longer to mature into commercial usage. Although some process steps are common for both, there are notable differences.

Surface vs. Bulk

The silicon wafer is used only as a carrier substrate for SM, while BM tailors it into the desired geometric shape. For SM, the desired structure is formed via the depositing and etching away of thin layers on one side of the wafer.

The material selectivity during etching is essential for SM, in the same way as the anisotropy of the etching is for BM. The selectivity makes 'sacrificial layer etching' possible in which only selected layers are etched.

Membrane thickness is controlled via etch stop techniques in BM (see *MSB 94:1*). In SM, the structures are inherently thin and the thickness is instead controlled in the deposition phase. Both SM and BM rely on ordinary photolithographic methods for patterning the shapes.

Layers

Early devices used metal for the 'structural' material that remains after sacrificial layer etching. Today, poly-silicon layers are more common now that the technology for depositing such films have been improved. Poly-silicon can be grown on the silicon surface in an epitaxial reactor or with an LPCVD (low pressure chemical vapor deposition) process.

The choice of sacrificial layer material depends upon the structural material and available etching processes. The etching of the sacrificial layer should leave the structural material unaffected. Phosporous doped silicon dioxide (PSG), e.g. deposited in an LPCVP process, is a common choice when the structural material is poly-silicon. Some other material combinations are: silicon – porous silicon, silicon nitride – poly-silicon, polyimide – aluminum, and gold – titanium. A growing trend is the development of SM in non-silicon compatible materials, i.e. in GaAs and InP-based III-V materials (see e.g. *MSB 96:3*).

The sacrificial etchant, e.g. HF, can penetrate far into narrow gaps if its selectivity is good. Nevertheless, holes are often introduced in the structure to facilitate the entrance of the etchant. Sometimes part of the sacrificial layer is left unetched, which increases the design possibilities.

Etching can be used also to shape the structural layers. For instance, the 10 µm thick and 1–2 µm wide poly-silicon comb-fingers shown in *MSB 95:3* were formed using a high-aspect ratio dry RIE (reactive ion etching) process. Another common alternative used for poly-silicon is wet etching by KOH which does not attack PSG.

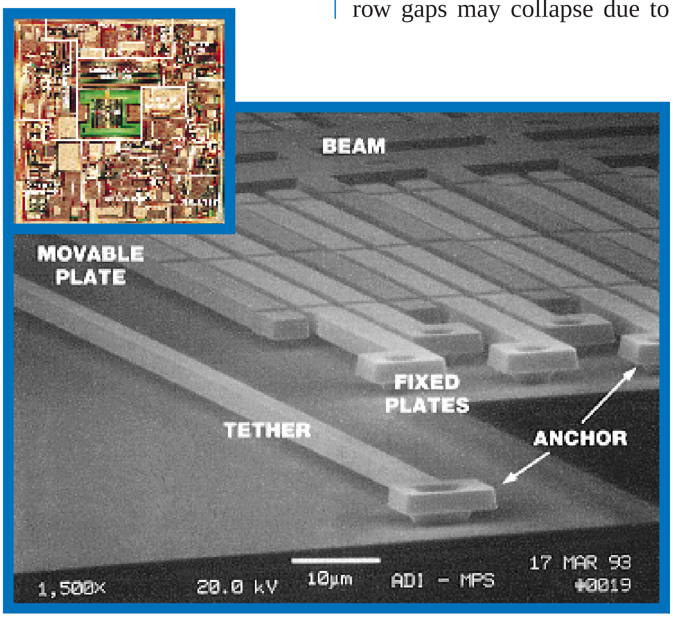
The layers are sometimes pre-patterned during the deposition phase, for instance with photoresist masks. A standard etchant that dissolves the photoresist is thereafter used in this 'lift-off' process.

Sputtering or evaporating electrodes onto the created movable structures makes it possible to electrostatically excite and capacitively detect the movement.

Limitations

Achieving poly-silicon layers as thick as 10 µm requires state-of-the-art technology. The useful thickness also depends on the lateral dimensions of the structure since the mechanical stress built into the layers noticeably can bend and buckle large structures.

During the sacrificial etching and cleaning processes, narrow gaps may collapse due to

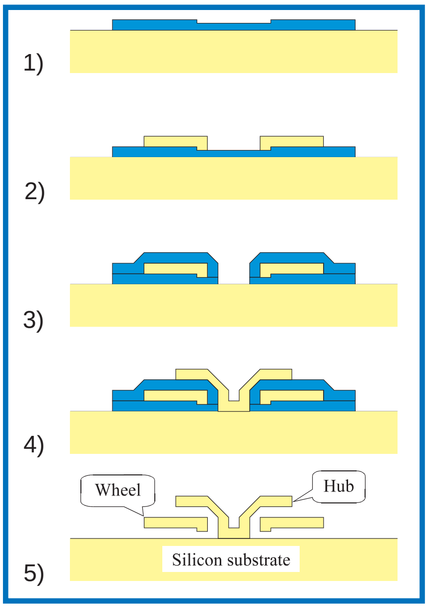


Close-up view of a surface micromachined ADXL50-accelerometer from Analog Devices, Inc., U.S.A.

WWWs

The informative web site of the European MST-network, NEXUS, was recently relocated to *http://www.nexus-emsto.com*. The MST magazine, **mst news**, can be downloaded from there, and the Japanese MST magazine, **Micromachine**, from *http://www.iijnet.or.jp/MMC*.

An alternative web address to that given in *MSB 96:4* (*http://www.uspto.gov*) for those that wish to search for US patent documents is: *http://patent.womplex.ibm.com*.



A schematic process sequence for the creation of a surface micro-machined rotatable wheel. Membranes and laterally movable comb-structures can be equally well fabricated.

1) Growth and patterning in two steps of a sacrificial layer (blue) that later will be etched away in order to free the wheel.
2) The 'raw-material' (structural material) for the wheel (yellow) is created by growing and patterning a layer with the desired thickness.
3) A second sacrificial layer is added and patterned so that the wheel can be freed from the hub.
4) A second structural layer is grown and patterned to define the hub.
5) The sacrificial layers are removed with etching. What remains in this cross-section view is the substrate wafer, the hub and a freely rotatable wheel.

capillary forces that arise when liquids evaporate. These gaps might remain closed due to atomic 'bonding' forces. The severity of this 'stiction' can be reduced by increasing the mechanical stiffness of the structure, making the surfaces less flat (bumps), or by using freeze drying sublimation techniques.

Another limitation is that the high temperatures used in the deposition and annealing steps during SM stress the thermal budget (extensive use of high temperatures are not allowed).

Electronics Compatibility

SM is more similar to IC fabrication than BM. Therefore, it is easier to include, for instance, preamplifiers and signal conditioning if SM is used. Nevertheless, great care must be taken when deciding on the process sequence in this case. For example, contamination issues prohibit the use of some microelectronics equipment if the wafer has been exposed to certain chemicals commonly used in SM, e.g. KOH.

	Lateral	Thickness
SM	100:s of µm	a few µm
BM	several mm	100:s of µm

Typically maximum dimensions for SM and BM.

Surface or Bulk ?

SM and BM complement instead of compete with one another. The choice depends on the device, application area and available equipment. Nevertheless, those working with BM often mistrust the films used in SM and feel that BM is inherently more reliable. In return, the SM camp looks upon BM-formed structures as being bulky and 'old fashioned'. A positive consequence is that this rivalry challenges development in both areas.

In general, SM is more compatible with electronics, enables freely movable structures, and generates small 2D-structures (see the table), but involves more complex and expensive process steps.

Jan Söderkvist

MICROCAR

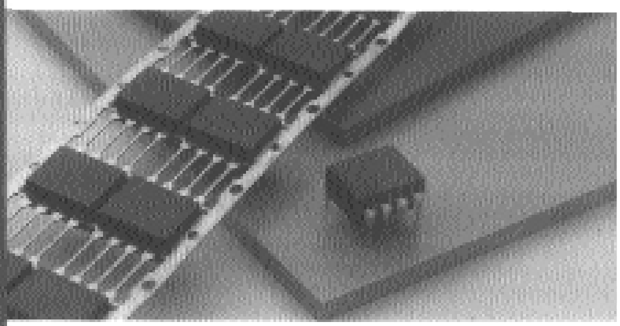
The 4.8 mm car shown on the front page is an excellent example of what can be accomplished with micro-fabrication technologies. It was manufactured by DENSO Corporation in Japan as a demonstrator of their capabilities, and is the smallest wheel driven mechanism in the world.

Its body consists of a 30 µm thick nickel film that was formed by non-electrolysis plating of an NC machined aluminum mold. Electro-discharge machining removed the unwanted nickel parts and a KOH sacrificial etch the Al-mold. The body was plated with gold to protect it from oxidization.

The chassis and the wheels are made of stainless steel with NC machining and the bumpers with electro-discharge machining. Wet etching of aluminum coated glass was used for the registration plate and the emblem. A 250 µm bearing hole was drilled in the chassis for the zirconia wheel shaft. A cyanoacrylate adhesive and a micro-manipulator for cell handling were used when assembling the parts.

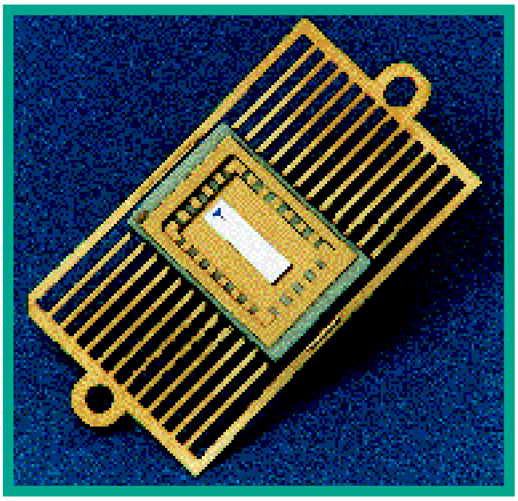
A stepping motor drives the car electromagnetically. The tube shaped barium ferrite rotor, formed using grinding, was permanently magnetized with a special tool. In its present version, the microcar is powered via two 25 µm copper wires.

Unfortunately, lubrication has drawbacks for micro-systems including high viscosity and adhesive effects. The wear on the bearings is, therefore, a limiting factor. Despite this, the car can run as fast as 100 mm/sec, which is quite fast at this scale.



MST at Chalmers KiselDesign

In *MSB 96:1*, Chalmers Silicon Design (In Swedish: Chalmers KiselDesign, CKD) was presented. The aim of CKD is to encourage cooperation and technology transfer between industry and Chalmers University of Technology. In order to do so, CKD is involved with a number of projects, most of which began as proposals from small and medium-sized enterprises (SME:s) that are linked in the network of CKD. Additional projects have been initiated by the Department of Solid State Electronics at Chalmers University. These projects are used as "tools" for CKD to apply towards other projects. Examples include anodic bonding with new materials, such as sputtered silicon dioxide, sputtered silicon nitride, VAPOX and LPCVD deposited silicon nitride, and aluminum nitride. Another tool is MecMOS. Examples of some CKD projects are presented below.



IR-detector manufactured by CKD and mounted in a test package by Bofors Missiles.

IR-sensor with Aperture

CKD has developed an IR-detector in cooperation with Bofors which will be put into an optical measurement system. For increased performance in signal conditioning an etched aluminum aperture has been added directly on the active surface. The Department of Solid State Electronics has been responsible for the silicon processing. Bofors has defined the aperture and has also performed the packaging of the chip.

Differential Pressure Sensor

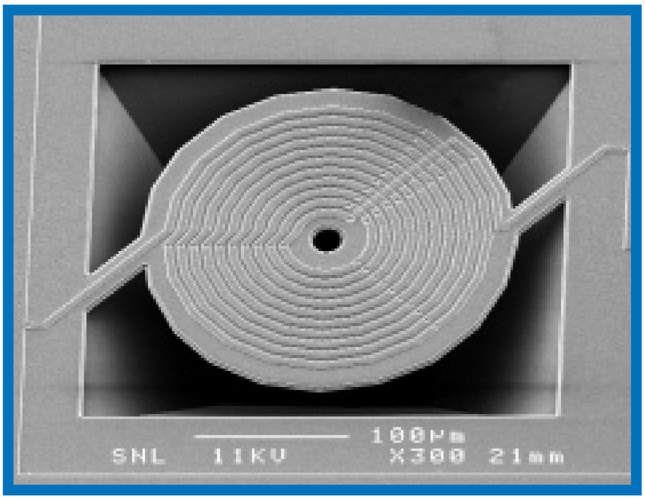
One member of CKD, Samba Sensors, has developed an optical differential pressure sensor. In its previous design, the sensor was intended for absolute high pressure measurements (about 100 bars). If accurate measurements at lower pressures are desirable, a differential sensor has advantageous. CKD has performed the manufacturing of the prototypes. The goal was to investigate the performance of different geometries of the capillary from the ambient to the buried cavity.

Actuators in Silicon

This project has focused on how the design of some critical structures affect the dynamic behavior of components in a micro fluid system. New processes will be developed for deep silicon etching. In the next step, different geometries will be evaluated. CKD will also investigate how the silicon specification affects the dynamic characteristics. When the design is optimized the structures will be bonded to piezo electric ceramics, resulting in a very compact fluid actuator. The main potential application would be in a medical dosage equipment, and the test structures manufactured in CKD are intended for this application.

MecMOS

MecMOS is the mixture of micro mechanics and CMOS technology. Surface micro machined structures can be achieved by sacrificial etching of various different materials on the surface. This work was coordinated with the Phisical Electronics Laboratory at ETH, Zurich (where the acronym IMEMS is used instead of MecMOS). At CKD, a number of test structures were realized, including beams and bridges. These were manufactured in a variety of materials, such as silicon, polysilicon, silicon dioxide, silicon nitride and aluminum. These were all available in the standard CMOS-process of AMS in Austria. After the initial work, MecMOS was transferred to the Department of Solid State Electronics where it formed the basis of a PhD work (see next page).



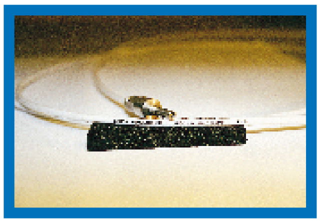
Suspended integrated coil for high frequency applications.

Future Projects

CKD has further projects in development which will be started during the fall of 1997. One example is a device to monitor the number of times a medical instrument has been sterilized in an autoclave. Another is the development of a 3D-accelerometer.

Conclusions

From the start, we at CKD noticed the difficulties with cooperative work between the academic and industrial hemispheres. There was a mutual effort to overcome the gap between these two areas of development. After some time, we all felt that the spirit of CKD was set and the projects started soon after.



A Sambasensor suited for in-cylinder combustion pressure measurements.

Most satisfying is the fact that many SMEs have come to CKD for assistance. Hence, a significant amount of technology transfer was obtained. On the other hand, an understanding for the conditions at a SME was gained at the department at Chalmers. Now all involved parties believe that the concept of CKD is productive and look forward to new challenges.

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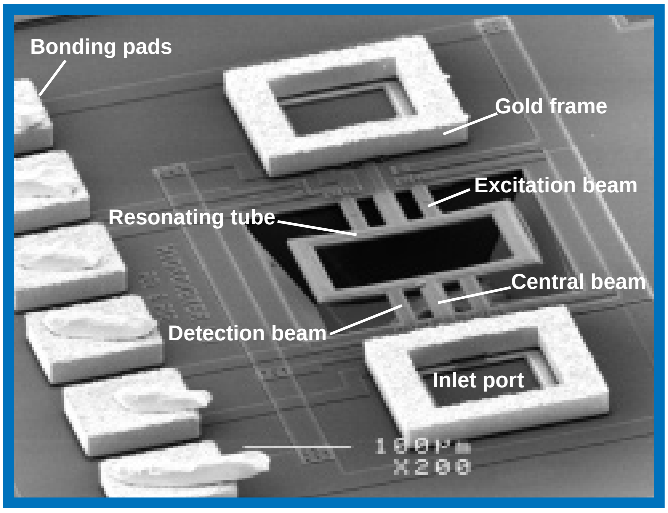
A CMOS-Compatible Densitometer; A Demonstrator of MecMOS

Micromachining can be performed with varying degrees of compatibility with standard integrated circuit (IC) fabrication. One philosophy is to use commercially available standard IC processes and materials as far as possible. Sensor and actuator effects can be achieved with minor deviations from customary electrical design rules combined with adding a few post-processing steps after completing the IC processing. Thus, the technique is especially suitable for small and medium sized companies since it requires a minimum of investment in equipment and know-how. At the Department of Solid State Electronics at Chalmers we have denoted this truly CMOS compatible technique as “MecMOS”.

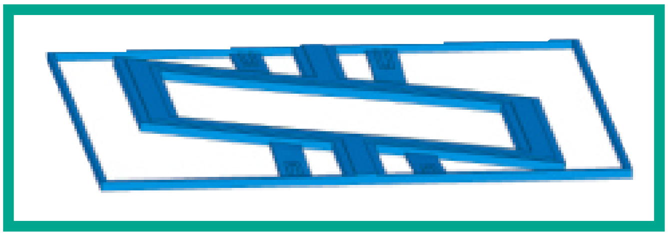
Typical post-processing techniques include sacrificial layer etching and anisotropic bulk micromachining. The two techniques have been combined in a demonstrator of MecMOS, a miniaturized resonant fluid density sensor.



SEM of the densitometer. The size of the etch pit is 250 by 250 µm. The resonating tube is 20 µm wide and 6 µm thick. The volume of the probed liquid is only 11 pl.

Operating Principle

The sensing element consists of a rectangular tube of dielectrics supported by two groups of beams. The two central beams form pipes connecting the rectangular tube to two inlet ports. For the device shown, the sample liquid is injected into one of the ports using a thin syringe. Due to capillary forces the liquid is drawn into the tube which is thermomechanically excited into torsional vibration by harmonically heating polysilicon resistors in two of the soft outer beams. The resonance frequency of the liquid-filled tube will then depend on the density of the liquid inside the tube. The mechanical vibration is piezoresistively detected using polysilicon resistors located in the other two outer beams.



Modal shape of first resonance.

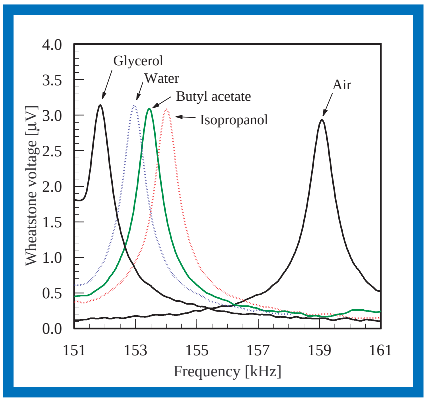
Fabrication

The sensor was fabricated by post-processing chips from a commercial 2 µm double-metal CMOS process. The tube was shaped already during the CMOS process by etching away all the dielectric layers exterior to the tube. This is made possible by combining contact to silicon, intermetallic via, and pad opening while omitting the metal layers. The interior of the tube is defined by patterning and integrating the two metal layers, i.e. combining them with a via. Gate polysilicon resistors are enclosed in the supporting outer beams, and are used for excitation and detection of the mechanical vibration.

After CMOS processing is completed, including electroplating of gold bumps, the first post-processing step is to sacrificially remove the metallization, mainly aluminum, inside the tube. The required channel length to be etched from each port is 325 µm. This can be completed in less than one hour using a strong solution of HCl and H_2O_2 at 35°C. During sacrificial etching, the gold bumps are protected by photoresist requiring one additional non-crucial photolithographic step. The second and final major post-processing step is to release the resonating structure from the substrate by anisotropic silicon etching.

Results

The sensor has been tested with air and four liquids of different densities. The measured resonance frequency for an air-filled structure at atmospheric pressure is typically 159 kHz with a quality factor of 215. The obtained frequency shift is close to 6 kHz if air in the tube is substituted with water. The resolution of density is better than 0.02 g/cm^3. However, the practical repeatability limit is currently higher, mainly caused by contamination problems due to the very simple packaging and liquid handling solutions used for the test device. The sampled volume is as small as 11 picoliters.



Frequency response of the sensor with the tube filled with air or one of four liquids with different densities.

Microsystems

This densitometer illustrates the feasibility of fabricating sensors by the MecMOS concept, i.e. post-processing of commercially processed wafers. The inherent compatibility with IC fabrication greatly simplifies integration of sensor elements and electronics into a single-chip microsystem.

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µ-tech and the Norwegian Microtechnology Center

One year ago, an initiative was passed in Norway to create a proposal for a national research program on microtechnology, known as *µ-tech*. The long-term objective of *µ-tech* is to create industrial growth based on competence within microtechnology. This should be accomplished through:

- Co-ordinated R&D activities at the University of Oslo (UoO), the University of Trondheim (NTNU), SINTEF, the Norwegian Defense Research Institute (NDRE), and Norwegian industry.
- Establishing microtechnology as a prioritized scientific area at NTNU and UoO.
- Investing in needed experimental facilities and scientific equipment in a Norwegian Microtechnology center.

The research program is planned to be launched with 19 Norwegian companies participating, all with specific interest in development and production related to the six prioritized research areas:

- MicroElectroMechanical Systems, MEMS
- MicroOptoElectronic Systems, MOES
- Fiber optic components and interface technology
- Application Specific ICs (ASICs) for microsystem applications
- Microsystem packaging and interconnects
- Functional materials and their applications

The focus in all areas should be application of knowledge into microsystem design and manufacturing.

The industries involved in *µ-tech* range from large established companies, such as the Kongsberg Group ASA, through successful high-tech companies, such as SensoNor and Tomra, to small start up companies with unique technology, such as IDE, ISP, and PreSens. Participating research institutes are SINTEF, Europe's fourth largest non profit research organization with industrial contract research as its main focus, and NDRE, which is engaged in fundamental and applied research in the areas defined and funded by the Ministry of Defense.

A National Microtecnology Center has been suggested to provide the facilities needed to support *µ-tech*, and to provide support for a joint effort from education and fundamental research towards industrial production. The center will consist of three functional integrated units located in Trondheim, Oslo and Borre. Fundamental and applied research will be focused in Oslo and Trondheim where the universities and SINTEF are gathering their forces. Functional materials and micro-optics will be focused in Trondheim. A new Microtechnology Research Center is planned in Oslo, including new laboratory facilities located adjacent to an innovation center housing human resources from UoO, SINTEF and various start up companies. Industrial development and production, including a European foundry service for microsystems, will be established in the Microsystem Center located in SensoNor's proposed new facilities in Borre.

The research program, *µ-tech*, and detailed planning for the center is planning to commence in 1998. Hopefully all three centers will be in operation by the end of 2000.

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DISSERTATIONS

MSB *wishes to congratulate the following three individuals on successfully having presented their theses.*

Anja Boisen, MIC, Denmark
Her Doctoral Thesis, *Passive and Active AFM Probes – Design, Fabrication and Characterization*, was presented on May 23. The atomic force microscope (AFM) works as a miniaturized phonograph, as images are obtained by scanning the surface with a µm-sized sharp tipped probe mounted on a cantilever. The shape and sharpness of the AFM probe govern the obtainable resolution.

By successive reactive ion etching (RIE), novel high aspect ratio tip shapes have been produced. The shaft width and height can be adjusted without interfering with the definition of the tip apex. These rocket tips™ (see *MSB 96:3*) have proven very useful when imaging certain surfaces, for example, deep structures with steep side walls.

Furthermore, a novel method for the definition of high aspect ratio tip molds has been developed. Combining RIE and anisotropic wet etching yields pencil shaped tip holes. Electroplating a nickel layer on the silicon substrate results in conducting tips. An active probe with piezoresistive read-out has also been produced. Its novel processing utilizes special silicon-on-insulator (SOI) wafers with a buried boron etch stop layer.

Per Ericsson, Chalmers
His Doctoral Thesis, *The Buried Oxide of Silicon on Insulator Materials*, was presented on September 26. The performance of SOI-based electric circuitry is affected by defects in the buried SOI-oxide. It was shown that the amount of incorporated hydrogen in the oxide correlates with these defects for BSOI wafers (bonded SOI), and that the mechanical and electrical properties are strongly influenced by the pre-bonding cleaning procedure. This information is helpful in better understanding micromachined SOI-devices and the bonding process.

David Westberg, Chalmers
His Licentiate Thesis, *Micromachining by Sacrificial Aluminium Etching*, was presented on October 3. His work studied a new surface micromachining technique that is fully compatible with standard IC fabrication. It enables the use of standard IC materials and requires only a few post-processing steps after completed IC fabrication. Design freedom can be further improved by combining sacrificial etching technique with bulk micromachining. Two demonstrators are described, a densitometer and a nozzle array for inkjet and other applications.

MME

The 8th Micromechanics Europe workshop was organized in Southampton on September 1–2. It was a very successful event that featured 6 invited speakers and 50 poster presentations. The devices and technologies described ranged from the microscale of mechanical devices, such as pressure sensors, accelerometers and microphones, through microdevices in microfluid systems for bioengineering and reactors, to the nanoscale of scanning probe systems.

Due to the difficulty in selecting a few presentations to be highlighted here, only the three awarded posters will be listed: *Deep wet etching of borosilicate glass using an anodic bonded silicon substrate as mask* (T. Corman *et al*, KTH, Sweden), *Micromachining of <111> planes in <001> oriented silicon* (E. Berenscot *et al*, MESA, The Netherlands) and *Considerations on the characterization of a miniature silicon micromachined capacitive accelerometer* (R. Puers and S. Reyntjens, KU Leuven, Belgium).

The 9th *MME* will take place in Ulvik, on the shore of the Hardanger Fjord in Western Norway, on June 3–5, 1998. The scenic landscape, especially magnificent in this season, will help in creating the informal spirit that characterizes *MME*.

France will host *MME* in the year 1999. At the steering committee meeting in Southampton, it was decided that the *MME* workshop in the year 2000 will be hosted by Uppsala University.

Jan Söderkvist

PUBLICATIONS

Some MST-related papers during the last few months:

- A Silicon Resonant Sensor Structure for Coriolis Mass-Flow Measurements; P. Enoksson, G. Stemme and E. Stemme (KTH); *J. Microelectromech. Systems*, **6**(2) (1997) 119–125.
- Design and Fabrication of Compliant Micromechanisms and Structures with Negative Poisson's Ratio; U.D. Larsen, O. Sigmund and S. Bouwstra (DTU/MIC); *J. Microelectromech. Systems*, **6**(2) (1997) 99–106.
- Micromachined Flat-Walled Valveless Diffuser Pumps; A. Olsson, P. Enoksson, G. Stemme and E. Stemme (KTH); *J. Microelectromech. Systems*, **6**(2) (1997) 161–166.
- Micromachining by Sacrificial Aluminium Etching; D. Westberg (CTH); Licentiate thesis, *Chalmers Technical Report no. 271L* (1997).
- Passive and Active AFM Probes – Design, Fabrication and Characterization; A. Boisen (DME A/S / MIC, Denmark); Doctoral thesis, ISBN 87-89935-06-3 (1997).
- The Buried Oxide of Silicon on Insulator Materials; P. Ericsson (CTH); Doctoral thesis, *Chalmers Technical Report no. 310*, ISBN 91-7197-541-1 (1997).
- Thin Detectors for the CHICSi DeltaE-E Telescope; L. Evensen *et al* (SINTEF, LU, UU, Univ. Oslo); *IEEE Trans. Nuclear Science*, **44** (1997) 629–634.

POSTTIDNING B

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MICRO STRUCTURE BULLETIN NO.4 NOV 1997

NEXT ISSUE

Some topics covered will be:

- MST in Finland
- MEMS in the US
- NORMIC, Nordic manufacturing cluster in EUROPRACTICE.

MSW '98 Call for Papers

The third Micro Structure Workshop will be held in Uppsala on March 24–25, 1998. Its purpose is to stimulate the use of Micro Structure Technology and to bring together in an informal way those in Scandinavia interested in MST. *MSW* is a complement to scientific conferences, which are primarily forums for the latest scientific results.

Ample time will be given for informal discussions, and a poster / exhibition session is planned. There will be many opportunities to form new and to strengthen old contacts. The target is to have a meeting as successful as *MSW '96*.

Invited speakers will be Prof. H. Baltes (ETH Zürich, Switzerland), A. Boisen (MIC, Denmark) and H. Kuisma (VTI Hamlin, Finland).

Participants from all countries are welcome although *MSW* is mainly aimed at participants within Scandinavia. Two thirds of the presentations at *MSW '96* were in English.

The creation of an interesting program relies on contributions from the participants. You are, therefore, encouraged to submit abstracts and suggestions for topics. Both industrial and academic contributions are welcome.

The abstract deadline is December 31, please see the editorial column for my address. I look forward to many interesting abstracts and to meeting you in Uppsala. As always, do not hesitate to contact me if questions arise.

Jan Söderkvist

MSB subscription (✉ or ✂)?

Please contact the Editor-in-Chief if you wish to receive *MSB* on a regular basis. In response, a ✉ sign will be included on your address label. A ✂ sign on your address label means that there is a risk of you being removed from the mailing list.

The editors also encourage you to put *MSB* on circulation, and to inform your friends and colleagues of its existence.

FUTURE EVENTS

MEMS 98 (Micro Electro Mechanical Systems), Heidelberg, Germany, Jan. 25–29, 1998. For info.: G. Stemme, KTH (Fax: +46-(0)8-10 08 58), CIS Heidelberg (Fax: +49-6221-181 019), or visit http://www.imit.uni-stuttgart.de/mems98.

Microsystems in Biomedical Engineering (course), Uppsala, Sweden, March 5–6, 1998. For info.: Y. Bäcklund, Uppsala University (Fax: +46-(0)18-55 50 95), FSRM (Fax: +41-32 720 09 90), or visit http://www.fsrm.ch/programm.htm.

MSW '98 (Micro Structure Workshop), Uppsala, Sweden, March 24–25, 1998. *Abstract deadline: Dec. 31.* See separate note.

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.

MME'98 (MicroMechanics Europe), Ulvik, Norway, June 3–5, 1998. *Abstract deadline: Feb. 1.* For info.: SINTEF Forum / MME'98, Fax: +47-22 06 73 50, or visit http://www.oslo.sintef.no/ecy/wshop/mme98.

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

Transducers '99, Sendai, Japan, June 6–10, 1999.

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