MICRO STRUCTURE BULLETIN

Newsletter for Nordic Micro Structure Technology, Vol.7, No.1, Feb 1999

Automotive Opportunities

Don't we all rely on our car to always take us wherever we wish to go. Nevertheless, it is amazing that our cars do not break down more often considering the harsh environment that its systems are exposed to. The entire automotive industry is under extreme pressure in order to reach the required ppm, and even ppb, failure rates of the sub-systems at an affordable price.

Cost pressure means large quantities and, therefore, few suppliers. Also, the demanding requirements for quality restricts the number of suppliers since it takes time to establish a high quality level, and it takes high quantities to keep the quality there. For example, only a handful of suppliers worldwide are active in the airbag and ABS-systems fields.

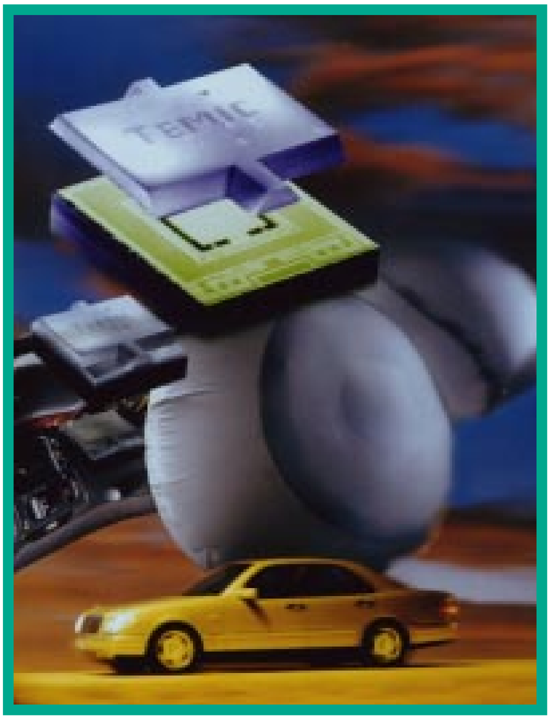
This makes it difficult for a newcomer to enter the field. Universities often severely underestimate the developmental efforts and investment needed for taking a project from one working sample in the laboratory to a high-quality, low-cost, high-volume production. In fact, large companies also have difficulties entering the automotive area, even if they are well established in other application areas.

Fortunately, technological change offers more clear market openings for new actors. SensoNor and VTI Hamlin are two companies that were successful in establishing a strong market position when the MST-technology was still fairly new to the established automotive suppliers.

Although the number of MST-based components in a car will continue to grow (see page 4), the automotive MST-field is slowly settling, with a resulting increase in competition and price pressure. Today, one either needs much patience and resources to create the necessary quality and survivability reputation, or one should enter into a cooperation with an established supplier. Established MST-suppliers also team up with system-suppliers, as in VTI Hamlin and BREED. In fact, the automotive industry is a very representative example of a 'buyers market'.

From the MST point of view, automotive applications were the MST leaders in the early 1990s, but the economical MST-focus is now shifting towards IT peripherals and biomedical uses (see *MSB 98:4*). Nevertheless, the automotive field is still a strong driver at universities, and success stories can still be found where suppliers base new products on university MST-projects, but only after a costly re-development to reach reliability and producability.

Jan Söderkvist, Colibri



Today, micromachined components, such as accelerometers for airbags, are a natural part of automobiles (courtesy of Temic, Germany).

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EDITOR'S NOTE

Four of the countries in the Nordic region have noteworthy activities in the MST area. Denmark has a strong, young research institute that has established close collaborations with smaller industries, while Sweden concentrates on university-like MST-R&D. Finland and Norway both have strong MEMS industries and industrial-oriented research institutes; Finland focuses more on capacitive and Norway on piezoresistive detection. From Iceland, I still wait for the first *MSB* subscriber.

I expect there to be several untried opportunities for collaboration over the national boundaries because of the complementing nature of these activities. The foundry service Normic is one possibility, provided that their technology suits your application. Future changes of *MSB* and the expansion of related activities aim in part at promoting Nordic collaboration.

In the latest issue of *MSB* I asked for input on how to further promote the filed of MST in our region. Unexpectedly few comments reached me (none!). One reason could be an error in *MSB*'s and Uppsala University's new homepage (www.mst.material.uu.se) that made it impossible to send comments via the internet. I sincerely apologize for this. The error is now corrected (hopefully). Suggestions as to how you would like *MSB* and related activities to develop are always welcome.

Jan Söderkvist

Absolute Pressure Sensors – Low Cost and High Reliability

Media compatibility is a key issue for most silicon pressure sensors because of the very delicate structures on the electrical interconnection side of the sensor chip. An additional diaphragm or other extra protection is often used in sensors for measuring the pressure of humid and contaminated gas media, thus adding cost and reducing accuracy as well as adding new failure modes.

SensoNor is developing new families of calibrated pressure sensing micro-systems designed to meet customers requirements for robustness, low cost, high reliability and automatic assembly on PCB. No external components are needed for signal conditioning and calibration. The technology consists of a transfer-molded two-chip solution with an internal signal conditioning ASIC and a unique triple stack sensor element.

Sensor Element

The micro-structured pressure diaphragm with piezoresistive sensor elements (full Wheatstone bridge) is sandwiched between two glass parts.

A vacuum cavity is created by anodically bonding the silicon chip to a micro-structured top glass. The quality of the enclosed vacuum inside the cavity has been monitored for different bonding conditions in order to optimize the process toward achieving the minimal residual gas pressure.

By using diffused, buried conductors, the piezoresistors and the interconnection leads are placed on the same side of the sensor element as is the vacuum cavity. The figure shows the special, patented feed-through method of isolated *p*-type diffused conductors. An *n*-epi layer is grown on the surface in order to bury the conductors. Highly boron doped layers are implanted and diffused through the epitaxial layer in order to contact the buried conductors.

The pressure inlet is through an opening in the bottom glass layer, which is also attached to the silicon layer by the same anodic bonding process as is used to make the vacuum cavity. One great advantage of this technique is the resulting improved media compatibility obtained by having the pressure inlet port on the backside of the silicon diaphragm versus the much more corrosion and moisture sensitive front side containing the metal conductors, piezoresistors and electrical interconnections. The result is a sensor element with excellent media compatibility.

The diaphragm thickness is defined via a pn-junction etch-stop process using a 4-electrode configuration. Very good thickness control is obtained by using this method. A diaphragm thickness of 20 microns can be controlled with a 4-sigma variation of +/- 5%.

The tripple-stack pressure sensor die showing the feed-through connections.

Signal Conditioning

A state-of-the-art VLSI ASIC with a digital core provides signal conditioning and enables temperature compensated output over a wide temperature range. No additional trimming, filtering or software offset is required. Each sensor is individually calibrated using the specially developed compensation algorithms in the automated test line. Individual calibration data is stored in OTPROM cells in the ASIC.

Automatic Pick and Place

The two chips are positioned on a common lead frame, interconnected by chip-to-chip wire bonding and molded into a surface mount package. The pressure inlet port is made as part of this molding operation. Placing the opening in the bottom side of the package leaves the top side smooth for automatic pick and place. The pressure sensors are shipped in standard blister tape ready for automatic assembly machines.

Products and Services

The following products already have been developed and offered based on this new technology platform: the SP10 Tire Pressure Sensor Family, the SP15 General Purpose Pressure Sensor and the SP16 MAP/BAP Sensor. The production technology used for the pressure sensor elements and packaging is also offered as a foundry service supported by the European Commission under the ESPRIT IV Programme of DGIII.

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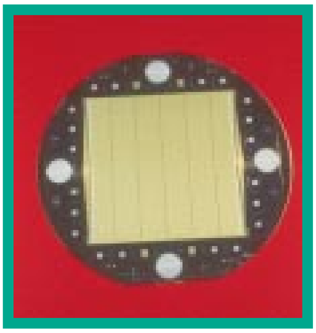
Silicon Radiation Sensors

The Department of Microsystems at SINTEF Electronics and Cybernetics has been working with radiation sensors made in silicon since the middle of the 1980's. These radiation sensors consist of segmented p^+-type implants in high resistivity n-type silicon. Position resolution is obtained by connecting read-out electronics separately to each segment.

The most typical position sensitive radiation sensor is the micro strip detector. It consists of a large number of long parallel lines of p^+ implants. Typical implant width is 5–25 µm, and the pitch (center to center distance of strips) between the implants is 25–100 µm. The position resolution is approximately pitch/3.5. These sensors are usually large, there is often only one sensor on each 100 mm silicon wafer.

LHC – CERN

In collaboration with the Semiconductor Tracker (SCT) group in the ATLAS Collaboration at CERN, SINTEF is designing and producing detectors for the new Large Hadron Collider (LHC) at CERN. These detectors are now in the prototype and testing phase, while production is expected to start in late 1999 or in 2000. The inner detectors in use in the LHC experiments will experience very large radiation levels during their 10 year lifetime. Fluence levels of neutrons, protons and pions above $2 \cdot 10^{14}$ cm^{-2} are expected.



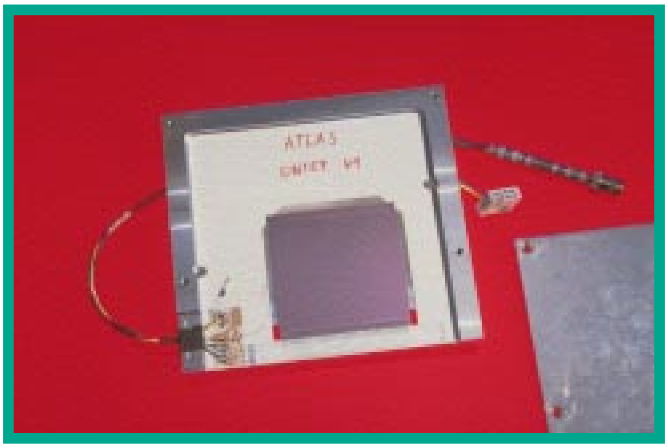
The STAR detector.

At fluence levels above a few times 10^{13} cm^{-2}, type inversion of the bulk material occurs when the initial n-type material starts to behave as p-type material due to radiation induced acceptors close to the mid-bandgap. This behavior is not yet fully explained on the microscopic level, but the issue is being addressed by an international R&D collaboration at CERN. This effort has resulted in significant progress during the past two years. SINTEF is participating in this collaboration together with more than 40 universities and institutes.

ATLAS – CERN

The ATLAS SCT detector is a single sided strip detector, 63.6 mm x 64.0 mm in size. It has 640 strips consisting of p^+-type implants in n-type wafers. The strips are 20 µm wide and the strip pitch is 80 µm. The strips are biased from a common bias line via 1 MΩ polysilicon resistors.

The electrical signal from the detector is capacitively coupled to individual electronic channels via an integrated coupling capacitor located on top of each strip. The prototype wafers have a resistivity in the order of 6000 Ωcm and the detectors are fully depleted around 50 volts before irradiation. Each incoming charge particle generates approximately 30.000 electron hole pairs.



The ATLAS detector.

STAR

SINTEF produces a different kind of silicon detector for the STAR collaboration. The STAR drift chamber has p-type implanted strips on both sides of the detector. By applying high voltage to the strips in the middle of the detector and low voltage to those strips close to the edge, the electric field can be shaped such that the radiation-generated electrons in the detector drift laterally towards the n-type implanted anodes along the edge. There are implanted resistors between each strip in order to make the electric field uniform. This detector can resolve the position two-dimensionally due to the segmented anodes and the drift time of the electrons in the field.

The advantages of silicon drift detectors is the position resolution obtained with a limited number of electronic channels, and the low capacitive load. The disadvantage is the relatively long read-out time compared to single or double sided strip detectors.

The STAR collaboration will assemble 216 drift chambers forming a barrel detector that will be used to search for quark-gluon plasma in the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratories in the US.

Outlook

The examples described here are applications of radiation sensors in high energy physics experiments. These sensors also have large market potential in commercial applications where position sensitivity is an issue. One example is digital radiography within various medical applications.

SINTEF is in charge of the Europractice Competence Center 6a (CC6a). The purpose of CC6a is to promote the use of silicon radiation detectors in industrial, medical and scientific applications within Europe.

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MEMS '99

The last *IEEE MEMS* conference of this millennium was held in Orlando, USA, in January this year. Almost 500 participants enjoyed a workshop atmosphere and 122 oral and poster presentations. The presentations covered a broad spectrum of results, ideas and applications.

Previous *MEMS* events were arranged as workshops, but the large number of participants and submitted abstracts has made it difficult to retain the workshop spirit. Still, the single-session format has been maintained.

The best overview of the scientific contents of *MEMS '99*, including the four contributions from the Nordic countries, can be obtainedby browsing through the proceedings. This 655 pages thick book is available also on CD-ROM. The IEEE catalog number is CH36291, and the ISBNs are 0-7803-5194-0 (softbound paper edition) and 0-7803-5197-5 (CD-ROM), respectively.

MSW 98 FIN

The first Finnish MST seminar on microsystems was held in Vantaa (near Helsinki) on Tuesday, the 20th of October, and was organized by AEL. There were 41 participants including the speakers.

The key speaker was Prof. Simon Middelhoek from TU Delft who gave a comprehensive talk on the subject from the beginning to the future entitled "All since the beginning". This talk was followed by the introduction "What is MST/ MEMS?" by A. Lehto. The session then focused on microsystems technologies including talks on "Micromechanics" by A. Lehto, "Micro-optics" by M. Leppihalme, and "Sensors and their interface electronics" by H. Seppä. The last talk in this session, "Adaptive materials", was given by K. Ullakko and detailed new kinds of materials that exhibit magnetic shape memory with very large displacements.

The afternoon session was directed towards MST activities in Finland. The Technical University of Helsinki has established a Microelectronics Center, which was introduced by P. Kuivalainen and was followed by an introduction of the VTT Microelectronics Center by J. Heleskivi. "From a vision to products", a true experience, was described by H. Kuisma, and possible future implications of MST were considered by J. Mykkänen in his talk "Future possibility".

Tampere University of Technology has been successful in developing laser and super-bright LED's. This was discussed by M. Pessa in his talk "Optoelectronics". There is also silicon wafer manufacturing in Finland and M. Tilli gave a talk on "Silicon as MST-material", which was followed by H. Stubb's presentation on "Conducting and light emitting polymers". Packaging is always a critical issue in MST and current techniques were discussed by O. Rusanen. The somewhat different topic of "Applications of nanotechnology" was illustrated by M. Paalanen which highlighted two existing commercialized examples of nanodevices: a thermometer and a cooler. The telecommunication industry may offer great possibilities for MST, including MOEMS. This topic was discussed by H-O Scheck in his talk "The possibilities of MEMS in telecommunications". The final talk on MST was given by P. Piironen from the point of view of TEKES, the main technology development funding organization in Finland, in her talk "MEMS as seen from TEKES".

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Automotive A... a Challeng...

The number of electronic systems in passenger cars has increased with accelerating speed during the last ten years. Increasingly stringent restrictions are being placed on the amount of polluting gas allowed in a car's exhaust. This has put strong demands on engine control systems, including sensors. Customers also prefer cars with more functions.

Volvo PV 445 1957-58.

Sensors

The -50s and -60s Volvo Duett shown in the picture contained only a couple of simple sensors. There were at most about 30 sensors in the Volvo 850 in 1994. In a top luxury car, the amount was at that time between 50–60. The number of new features in cars is increasing rapidly as more powerful and inexpensive microprocessors and reliable sensors become available. Micromachined sensors are now used widely in automobiles. Of course, increasing the number of sensors in a car is not a goal in itself. Efficient use of existing sensors is necessary.

Customer satisfaction is very important. Reliability is a key word for survival. Comfort is increasing rapidly and climate control systems are becoming popular, even in non-luxury cars. Humidity and other air quality sensors are important for increasing their functionality. Also, seating comfort could benefit with sensing and adjustment systems. Road Traffic Information (RTI) systems need support from gyros since GPS positioning is not sufficiently accurate.

The new Volvo S80 has a multiplexed network in which 18 electronic nodes are connected into a distributed system. Most of the sensors are hardwired into the closest node, and the sensor signals are distributed to the other nodes via the multiplexed network.

The environment in cars is very harsh. Temperatures which cycle from –40°C to over +100°C in the engine bay, and vibrations in all directions, necessitate good design of all components. In addition, EMC must be taken into consideration as both the car itself and external sources radiate electromagnetic fields that can cause serious problems.

Volvo's strategy is to be a special car maker, focusing on some core values in which Volvo strives on being the leader in the automotive business, including:

- Safety
- Environmental care
- Quality

Safety

Volvo is well known for it's safe cars. Safety is divided into three areas:

- Passive safety
- Active safety
- Security (personal safety)

Passive safety systems need to be developed further to keep Volvo on the top of the industry. New sensors can help in the development of new generations of airbag controls. In addition, passenger seat occupancy sensing and roll over protection systems are strongly needed.

...pplications –
...ing Future

Within the area of *active safety*, active yaw control systems are entering the market with the first generation of automotive gyroscopes. The gyro's cost needs to be lowered and its performance needs to be improved. We can expect sophisticated chassis systems to be developed, maybe using three axis gyros and accelerometers that serve several systems in the car. Tire pressure sensing is also requested by customers. Driver vigilance needs to be detected in a reliable way. At present, there is no good single sensor for this purpose. In the long term, advanced sensors will be needed for new collision avoidance systems.

Security is becoming more important due to problems with crime in many countries. Better sensors for surveillance of the passenger compartment and the near outside area, with minimum power consumption, are on the wishlist. Smart keyless entry and immobilizer systems, and driver identification with the help of new sensing technologies are most likely to be available in the near future.

Environmental
Volvo takes *environmental care* very seriously. Reduced fuel consumption via more efficient engines requires accurate sensors with full performance during long service lives. Pressure sensors for the high temperature environment inside the engine cylinder and ionic current sensors are likely needed to ensure complete combustion. Alternative fuels are already in use. Sensors are required for gas flow and pressure measurements. Fuel cells are coming closer to product development, and there could be needs for new sensors to control the energy transfer.

Suppliers are required to avoid certain rare materials and chemical substances that are a threat to health or to environment, including during the production process. All substances used in the products, or in the production processes, must be declared. New systems will go through an environmental revision where the component weight, power consumption, as well as the use of energy during transport, product development and production will be investigated.

Business Opportunities
Suppliers have to adapt to the situation in the automotive business. The cost and quality demands and short development times place much pressure on them.

Volvo is interested also in small R&D companies with interesting technologies for potential use in Volvo cars and production processes. Therefore, the company Volvo Technological Transfer was founded which seeks and invests in interesting R&D projects. To help Volvo reach it's strategic goals, skilled R&D companies can play an important role.

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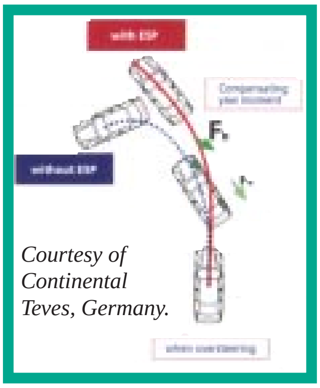
Vehicle Stabilization

BMW, Cadillac, and especially Mercedes' A-class have demonstrated that ESP (Electronic Stability Program) and similar systems are interactive safety systems that significantly can improve the stability of a vehicle. It is believed that millions of ESPs will have been installed soon after the turn of the century.

The ESP selectively brakes individual or several wheels to achieve vehicle stabilization before a dangerous skid occurs. The result is increased control under both regular and critical driving circumstances. For example, rapid turns during accident avoidance becomes safer and more controllable.

ESP is based on already familiar components, such as anti-lock brake systems (ABS), traction control systems (TCS), electronic brake power distribution (EBD), and engine drag torque control (EDC). ESP adds improved lateral (sideways) control of the vehicle via a more flexible control of the break system.



Courtesy of Continental Teves, Germany.

New sensors are needed, e.g. for measuring the steering wheel position and the angular velocity of the car (gyroscopes). Many of the sensors involved, such as accelerometers and gyroscopes, are micromachined. Today, this is a necessity, especially for gyroscopes, in order to reach an acceptable price-performance compromise.

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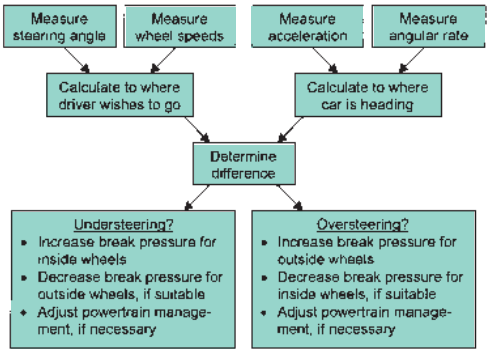


Block diagram of how Contineтal Teves' ESP system works.

PUBLICATIONS

- Mechanical Considerations in the Design of High-Precision Surface Micromachined Devices; S. Greek (UU); Doctoral thesis, *Acta Univ. Ups.* 409, ISBN 91-554-4343-5.
- Microprocessing at the Fingertips; G. Thornell and S. Johansson (UU); *J. Micromech. Microeng.*, **8**(4) (1998) 251–262.
- Pore Morphology Influence on Catalytic Turn-Over for Enzyme Activated Porous Silicon Matrices; J. Drott (LTH), L. Rosengren (UU), K. Lindström and T. Laurell (LTH); *Thin Solid Films*, **330** (1998) 161–166.
- Silicon Micromachining with Applications in Microoptics; C. Strandman (UU); Doctoral thesis, *Acta Univ. Ups.* 401, ISBN 91-554-4314-1.

Micromachining Equipment Part 3:

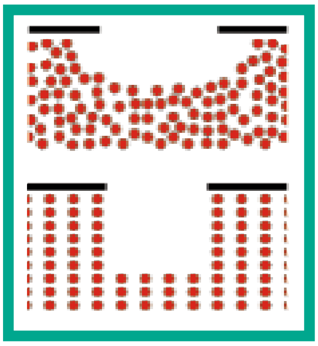
On Etching – Wet and Dry:

The word 'etching' is so established you can safely drop it in a conversation at a family gathering without causing confusion. Yet physicists and chemists almost get physical (eh!) while discussing silicon etching, which in fact has been practiced successfully for decades.

I like to think of etching as partly descending from man's fear combined with his vanity. As medieval metallurgists improved the toughness of armor beyond the tools of contemporary decorators, the idea was born of covering parts of the metal with wax, engraving the graceful, floral splendor into this much softer substance, and to let chemicals inscribe the pattern into the underlying metal.

A few hundred years later, man's laziness gave birth to photolithography. By using a light sensitive masking material and projecting an image on it, parts of this material could be removed selectively, much like developing a photograph. The subsequent pattern transfer to the substrate became much more precise and reproducible.

Today a two-step method is often used. First, a rather fancy polymer, a photoresist, is deposited evenly on the substrate, cured, exposed to UV-light through a template, and developed whereupon either the exposed or shadowed parts are dissolved. Next, this pattern is transferred by etching to a more stable, underlying masking material. This latter material is the result of either a surface modification, as in the case of oxidized silicon, or deposition, as in the case of gold evaporated on quartz. The light sensitive material is thereafter removed and the actual, bulk etching of the substrate begins.



Isotropic vs. anisotropic etching (size and color of atoms greatly exaggerated).

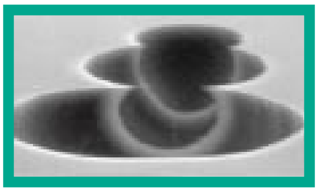
Depending chiefly on the material, but also on the etchant, the cross sectional profile of the engraved pattern will differ (see figure). For amorphous or polycrystalline materials, like glass, that appear essentially the same in all directions, the result is a rounded pit or trench. In ordered, single crystalline substrates, like silicon, with different atomic packing densities or different numbers of dangling bonds per atom in different directions (discerning a quarrel?), the result is a faceted cavity of a shape governed by the slowest etching crystallographic planes. These behaviors are referred to as isotropic and anisotropic, respectively. Should there be a mass transport limitation (due to poor agitation for instance), etching through small mask openings would proceed slower than that through large openings because of the depletion of reactive species.

In addition to the well-known virtual stopping on slow etching planes, there are other means of controlling the etch depth, e.g. with doping or an oxide layer sandwiched with silicon. Given all these features one wonders though why wet chemical etching sometimes is abandoned for the slower and far more expensive dry, or plasma based, etching. There might be several reasons for this, but most of them are probably based on the wish to create vertical, high aspect ratio structures in arbitrary crystallographic directions, either to reach higher packing densities of elements or just for the pure joy of beating nature.

If switching from wet to dry etching, one can replace the simple beaker on the hot plate and the pungent wet bench with thick-walled, stainless steel vacuum chambers. A positive side effect is a higher degree of cleanness and the avoiding of corrosion problems.

In its least ordered form, plasma based etching benefits from the dissociation or excitation of gases to more reactive species. One example is the ashing of organic materials (e.g. photoresist) in oxygen plasma. By increasing the physical part of the etching, i.e. allowing charged particles accelerated through the plasma's electric field to atomically blast, or sputter, the sample, a much more directional material consumption is promoted.

Starting at relatively high pressures (approx. 1 torr), the



Plasma etched silicon snowman with a neck of 5 µm diameter.

ordinary, chemical plasma etching (PE) shows great selectivity between mask and substrate material, as well as strong isotropy (figure). On the other hand, at a pressure of around 10^{-4} torr the mean free path of the plasma ions is long enough to constitute a physical ion beam etching regime (IBE) where mask selectivity almost vanishes and anisotropy is high. Using a pressure somewhere in between (10^{-3}–10^{-2} torr) results in the popular and compromising reactive ion etching (RIE) which relays not on sputtering, but merely on the disturbance of the surface caused by impinging particles. Contrary to sputtering with its quite complex dependence of yield on angle, full advantage can be taken here of the directionality of the ion bombardment, and the aspect ratio can be increased even more.

Bringing it one step further, material can be redeposited on the vertical surfaces to increase the aspect ratio even further. A similar effect is obtained if a passivating reaction occurs simultaneously with the etching. For instance, with the addition of hydrogen to CF_4 on etching silicon, carbon starts to polymerise rapidly on all surfaces and only those constantly cleared by ion bombardment are etched.

While wet etching seems to have almost reached a state of perfection, dry etching currently seethes with activity. A major challenge is to achieve high plasma densities and low particle energies at low pressures.

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ELECTRONIC MSB MAILING

The paper version of *MSB* is distributed only by invitation outside the Nordic region. However, as a service to *all* our far-away readers, *MSB* will be distributed also electronically in the future. Two e-mail mailing lists have been set up:

List W: An e-mail will be sent to everyone on this list as soon as a new *MSB* issue becomes available for downloading at *MSB*'s web-site. At the web-site, PDF-versions of *MSB* both with (a few 100 kB) and without (50–100 kB) pictures will be available.

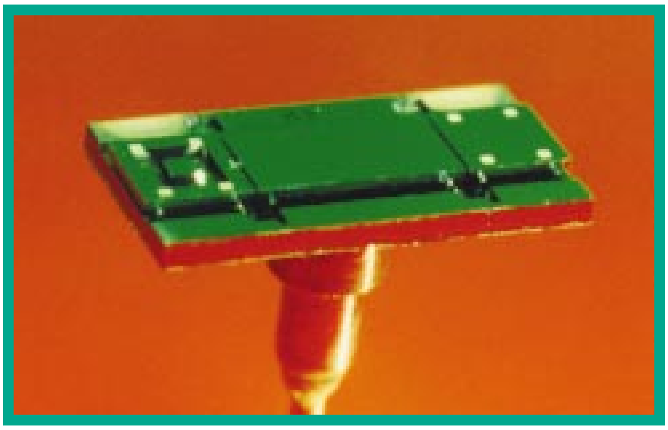
List P: The large PDF-file of each issue will be e-mailed directly to everyone on this list.

If you are interested in being included free of charge in either of these lists as an alternative to receiving the paper version of *MSB* please contact the Editor-in-Chief (address on page 8).

Pressure Sensor for Oil Reservoirs

During the last year, several SINTEF departments have been collaborating on developing a system for the measurement and inflow control of fluids in oil wells by collecting petroleum from several producing zones in the reservoir. The project is funded by the Norwegian Research Council together with Aker Maritime, Saga, Norsk Hydro, Enterprise and Shell.

The flow and fluid quality from each zone is monitored individually. The flow through the pipelines is measured by a modified Venturi tube principle. A silicon capacitive differential pressure sensor has been developed for this purpose. The sensor is designed to work in the extreme well environment of up to 1000 bar absolute pressure and 200ºC. Its differential pressure range is 0–1 bar, corresponding to an expected flow rate of 0–12 liters per second.



The sensor element illustrated is manufactured from three fusion bonded silicon wafers. A square bossed membrane (4 mm^2) has been defined by KOH etching in the top wafer. Together with the center wafer, the membrane forms the measuring capacitor. A second and equally sized capacitor, which is insensitive to the differential pressure, is also formed in the upper wafer. This enables compensation for capacitance change due to ambient temperature and pressure changes. The two capacitors are separated by sawing through the upper wafer of the fusion-bonded stack. The pressure inlet and channels that distribute the pressure to the capacitors are defined by KOH etching in the lower silicon wafer. The lower wafer allows for a minimized mechanical stress from the mounting. For electrical connections, aluminum is sputtered through a prebonded mechanical mask.

The capacitance change is converted to a frequency change by an in-house designed ASIC-circuit capable of sustaining a 200°C operation temperature. The first tests of the sensor element showed a sensitivity of 15 fF/mbar. The sensor element will be further tested with respect to long term drift and stability. Commercial system installations by Aker Maritime are planned starting in the year 2000 and onwards.

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DISSERTATIONS

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

Staffan Greek, UU
The main subject of his PhD thesis, *Mechanical Considerations in the Design of High-Precision Surface Micromachined Devices*, is the measurement and analysis of material properties, such as fracture strength and elasticity. Several surface micromachined material combinations were tested.

The measurements were carried out *in situ* in a SEM using specially developed test structures. The results and effects were analyzed with finite element analysis (FEA). The fracture measurements were evaluated with Wiebull statistics. The work not only addressed test structures; an accelerometer and a Fabry-Perot filter were also studied.

Carola Strandman, UU
Her PhD thesis, *Silicon Micromachining with Applications in Microoptics*, covers bulk silicon micromachining used to make optical mirrors and assembly systems, based on flexible holding structures, for low cost optical devices. A fiber-optic pressure sensor for *in situ* blood pressure measurements is also presented.

In addition, several improved fabrication process are analyzed and described. Examples include etch studies on single crystalline silicon, such as a method for studying angular dependence during dry etching (RIE), and investigations of the influence of bond interfaces on the subsequent wet anisotropic etching of silicon.

Newcomers

Pangea Fiber Optics AB, based in Stockholm, is a recently formed spin-off company from the Institute of Optical Research. The business idea is to manufacture and sell custom designed components and systems based on fiber Bragg gratings, for the telecom, sensor and instrumentation industry (see *MSB 94:3*). The gratings are fabricated through holographical exposure of the optical fiber to ultraviolet radiation, using a certain step-and-repeat procedure. This unique and very flexible technique allows in-fiber filters of almost any spectral characteristics to be formed.

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Åmic AB is a newly established company, based in Uppsala, with the business mission to develop micromechanical, microoptical and microfluidical structures that are suitable for production in large quantities using replication techniques. Original components are manufactured by lithographic processes, laser machining, and other high precision methods. The originals are transferred to mold inserts via electro-plating. The replication step uses injection molding, casting or embossing (see *MSB 97:1*).

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MICRO STRUCTURE BULLETIN NO.1 FEB 1999

FUTURE EVENTS

MSM 99 (Modeling and Simulation of Microsystems), San Juan, Puerto Rico, U.S.A., April 19–21, 1999.
dmtwww.epfl.ch/MSM99

Solid-State Imaging Devices (course), Uppsala, Sweden, April 26–27, 1999.
For info.: FSRM
Fax: +41-32 720 09 90
www.fsrm.ch

Sensor'99, Nürnberg, Germany, 18–20 May 1999.
For info.: ACS Organisations GmbH
Fax: +49 5033-1056
www.sensor99.de/

Transducers '99, Sendai, Japan, June 7–10, 1999.
For info.: Transducers '99,
Attn.: J. Echizen
Fax: +81-3-3299-1361
www.com.cas.uec.ac.jp/trans99.html

Eurosensors XIII, The Hague, The Netherlands, Sept. 12–15, 1999. *Abstract deadline: March 8, 1999.*
For info.: R.F. Wolffenbuttel, Delft Univ. of Techn.
Fax: +31-15 278 5755
eurosensors.et.tudelft.nl

MME'99 (MicroMechanics Europe), Gif-sur-Yvette, France, Sept. 27–28, 1999. *Abstract deadline: May 15, 1999.* For info.: MME'99, Inst. d'Electronique Fondamentale
Fax: +33-1 6915 4080
www.ief.u-psud.fr/~mme99

AME - Centre for Advanced Microengineering

summit
SURFACE & MICROSTRUCTURE TECHNOLOGY

The Strategic Center AME
The Competence Center SUMMIT

The research activities of AME (Advanced Microengineering) and SUMMIT (Surface & Microstructure Technology) are mainly located in the new and multidisciplinary Ångström Laboratory at Uppsala University. SUMMIT works in close cooperation with KTH and has extensive collaborations with Swedish high-tech industry. AME comprises a four-year Graduate School with an annual admission of 10 PhD students. Important examples of research fields are: micro-optics, medical/bio applications, space applications and generic MST.

AME and SUMMIT invite persons with a genuine interest in MST to apply for PhD student positions. Suitable backgrounds are: BSc/MSc/Civ.ing. exam in physics, chemistry, medical/bio technology, materials, electronics, or other MST-oriented fields of engineering.

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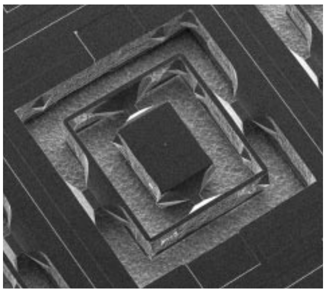
NEXT ISSUE



Some topics covered will be:

- Production aspects
- Packaging issues
- PZT printer head

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

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