MICRO STRUCTURE BULLETIN

Newsletter for Nordic Micro Structure Technology, Vol.6, No.4, Nov 1998

1st Nordic Summit

The trend is to focus on regions instead of on individual countries, and small countries must cooperate to strengthen their international competitiveness.

The 4th *World Micromachine Summit* was held in Australia in April (see page 7). Delegates from various countries/regions discussed critical issues and driving forces for micromachine development in a local and global perspective. The Nordic delegates concluded that intra-Nordic collaboration would benefit from a Nordic meeting series similar to the World Summits.

As a result, the first strategic Nordic Summit on Microsystems was held in Copenhagen from October 5–6. Thirty key decision makers from academia and industry met to discuss how best to strengthen Nordic MST-related activities in both industry and academia.

The first meeting focused on education and university-industry collaboration. Four presentations related to these issues were given each day followed by intense discussion. In addition, J.C. Eloy was invited to present the NEXUS market analysis presented on page 2.

Topics addressed in the discussions included overviews of major national initiatives in MST, Nordic research collaboration, student recruitment and mobility, sharing courses, prototyping and foundry services, and MST computer modeling resources.

The meeting resulted in the formation of several initiatives. A homepage covering all Nordic MST-related courses will be developed. An action group will be established to coordinate educational courses and workshops, as well as to stimulate student mobility between the Nordic countries. Another action group will look into the possibility of coordinating MST-related computer modeling activities in the Nordic region. The success of the meeting will be judged on whether these initiatives gather significant momentum in the coming months.

Perhaps the most important take-home message from the meeting was that, even in the age of the internet, geography matters. As one industry delegate frankly put it, bilateral collaborations between neighboring countries are often far more effective than multilateral collaborations spanning a continent, let alone the globe. So, the Nordic region is not an irrelevant concept, even in a high-tech field like MST. The Summit also seemed to fill a genuine need for decision makers in MST to learn more about what is going on in the other Nordic countries. The Summit, therefore, seems certain to become a regular event.

Jan Söderkvist, Colibri
François Grey, MIC

The economical impact of the MST market is estimated to be largest for IT applications (see page 2). Ink jet printer heads and read/write heads for data storage dominate this application area (courtesy of Modular Ink Technology (MIT), Sweden).

CONTENTS

EDITOR'S NOTE

I sincerely apologize for this issue reaching you later than scheduled. Sometimes it takes longer than planned to edit *MSB* and to adjust the length of its articles. I am working on finding a solution that will reduce the risk of future delays while further strengthening *MSB* and its Nordic profile.

This could mean changes. Your suggestions and comments are important, e.g. regarding improvements, criticism, *MSB*'s focus, type and length of articles, number of pages and issues per year, choice of language, subscription fees, etc. Comments can be submitted also via *MSB*'s new homepage: www.mst.material.uu.se (heading '*MSB*-Contact the Editor-in-Chief'). Please, include your country and whether you come from industry or academia with your comments. Thank you all in advance.

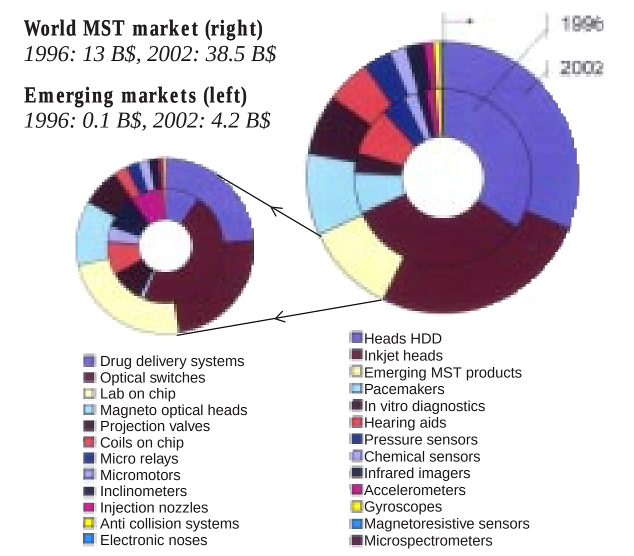
Finally, I wish to share the saying: "*A good scientist is a person with original ideas. A good engineer is a person who makes a design that works with as few original ideas as possible.*" (Freeman Dyson, 1923 –). To me, this saying contains much truth and highlights a natural difference between industry and academia. Industry's customers require reliable components, while researchers often are satisfied with one working device per wafer provided that it includes novelties or demonstrates strange but explainable results.

Merry Christmas
Jan Söderkvist

Market Analysis for MST

An interesting evaluation of the world MST market and the position of Europe to meet it has been compiled by Microparts, LETI and Yole Développement in the NEXUS Market *Analysis MST* task force (see page 4 for ordering information). The aim is a realistic evaluation of the 1996 world MST market, and a prognosis for the market of 2002. The study comprises existing, as well as emerging markets, and is based on 200 worldwide, in-depth interviews from Europe, USA and Asia.

To avoid misunderstandings, the investigators have applied rather strict definitions for the concepts of "microsystem" and "microsystem market volume". For a microsystem, multi-functionality provided by two or more microcomponents, or technical functionality provided by the shape of the microstructure is required. For the market volume, a minimum definition is applied: for an airbag system only the packaged accelerometer is counted, and for an aerospace air data module only the sensor with electronics is counted. Hence, the "leverage effect" of the microsystem on the overall system/product is neglected. This leverage effect is estimated to be a factor of 10 to 50, depending on the application.



The list of existing markets includes sensors for pressure, inertia, matrix imaging, magnetic effects and chemical analyses, as well as drug delivery systems, ink jet printer heads and hard disc driver (HDD) heads. Quartz resonators, including watch crystals, are not included. The list of emerging MST markets comprises some twenty items, including microfluidic components, micromotors, various analytical instruments, micro-optics, and biochips. The world MST market is forecasted to increase by a factor of 3 from 13 B$ in 1996 to 38.5 B$ in 2002. The main part of this increase is expected to be due to ink jet heads and read/write heads for HDD. Only a small part is predicted to be due to emerging markets, which are expected to increase from 0.1 B$ in 1996 to 4.2 B$ in 2002, i.e. only 11 % of the total increase. However, the emerging markets will expand more rapidly than the existing markets (more than a factor of 10 as compared to a factor of 3).

The evaluators pointed out that the MST markets might appear small (13 B$ in 1996) in comparison to the world semiconductor market, which was 140 B$ in 1996. However, taking into account a leverage factor of roughly 30, the overall MST-induced markets are estimated to expand from 400 B$ in 1996 to 1000 B$ in 2002.

USA and Japan are dominant in the existing markets, due to their extensive consumption of ink jet printer heads and magnetic read/write heads. Excluding these devices, the position of Europe is quite similar to that of the USA and Japan, i.e. around 1 B$ in 1996. Today, more than 150 European companies manufacture microsystems, employing over 6000 persons with a turnover of 1.5 B$. In the opinion of the evaluators, microsystems are well on the way towards becoming an established industrial field in Europe. Several manufacturers are already active in the field, which is increasingly supported by new start-up companies and new CAD and simulation tools.

The present author's opinion is that most previously published forecasts concerning the development of MST markets have been strongly over optimistic, and sometimes they have induced a sense of mistrust of the field when the forecasts have not been realized. The NEXUS study presented here, however, seems to represent a serious attempt to be more realistic and to avoid overselling the field.

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MPW, 1ST RUN

NORMIC offers a Multi Purpose Wafer service including support for device design and testing. Silicon processing will be made at SensoNor asa. Deadline for reservation of chip area is March 1, 1999.

For more information, please contact
MPW-coordinator
Edvard Kälvesten
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Challenges in MEMS Packaging

Micro electromechanical systems (MEMS) have experienced an increasing interest over the last decade, and the future for this product group seems bright. So far, packaging, or protection of the system, has not been a key issue since most customers would accept a high price for a product that solved their specific needs. Since the special product market is limited, some companies have introduced MEMS technology to volume markets such as the automotive market.

Low Cost/High Volumes

Volume markets require cheap, easy to use standard components with good reliability. In an inexpensive product you have to use a standardized production system, cheap and easily available materials, and as little manpower as possible. Possible solutions can be found in the IC-industry. The following conclusions are quite obvious:

Injection molding (or similar process) of a polymer, preferably an epoxy, is well known, efficient and easy to automate.

Lead frame based technology is also well known, and is compatible with the molding technology.

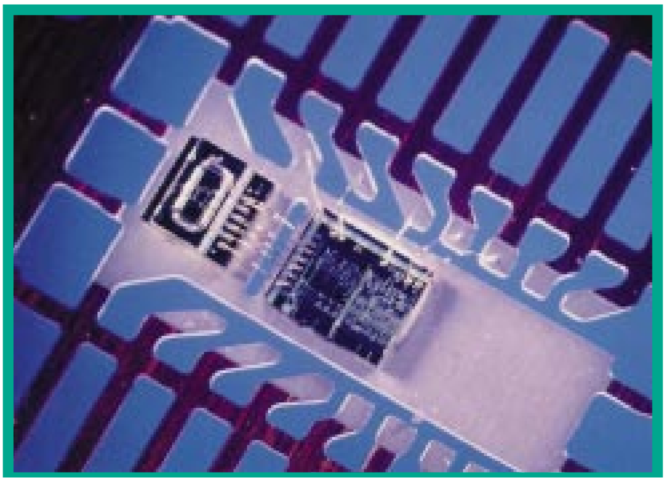
The sensor element and any signal-processing chip have to be attached to the lead frame automatically, and preferably by using an inexpensive material.

Tough Environments

Micro system components will be placed in an increasing number of applications where the surrounding environment is tough. Typical environments might be:

- Relatively high temperatures (120–200°C) in a humid atmosphere
- High temperatures (>200°C)
- Abrasive or erosive environments
- Corrosive liquids or gases
- Low temperatures

A typical example regards pressure sensors. All pressure sensors have to be open to the surrounding environment unless a shielding membrane is used. Such membranes often results in a more complex design and a higher cost. If the sensor element is open to the environment it will interact with any particles, liquids or gas present in the surroundings and in the sensor, including the die attach material. Nearly all adhesives are sensitive to humidity at temperatures close to and above T_g (the glass transition temperature).



Typical pressure sensor system with a sensor die and ASIC mounted on a lead frame.

Sensitive Sensor Elements

Nearly all sensor elements are more or less sensitive to mechanical stress introduced by the molding or encapsulation material, materials used in the joining of components, and even stress introduced by temperature cycling.

The most common sensitivity problems are probably related to die attach and molding as long as the molding material is in direct contact with the sensor element, as in injection molding processes. The main reasons for such sensitivity problems are shrinkage and structural transitions occurring during hardening and cooling of the molded parts. The most common solution is to cover the sensitive element with a soft material (glob-top) that is able to absorb most of the stress.

The bonding of dies to a lead frame or substrate will normally also affect the sensor element. A low stress adhesive is often recommended. A typical low stress adhesive contains one or more additives that reduce the resistance towards humidity.

Compact Solutions

There is a significant drive towards the integration of an increasing number of functions into a single package, such as a FM transmitter, a micro switch, an energy source, and so on. Either more functions must be integrated into one die or the different dies must be stacked and connected without the use of wire bonding. Preferably, one should be able to use the same types of simple polymer packages as introduced in our SP13 tire pressure sensor.

Time to Market/ Product Life Time

The time available for product development is steadily decreasing as the lifetime of a product is often limited to a few years. A shortened development time requires good tools for sensor design as well as for packaging. Results and information must be made available throughout the whole chain of development.

In the area of sensor design, reasonably good modeling and simulation tools are available. Most modeling and simulation tools for assembly and packaging are focused on IC components, which are fairly simple compared to most micro systems. A typical example is injection molding simulation, in which wire sweep and paddle shift are treated in detail while mechanical stress on the sensor die is omitted. A sensor die is far more sensitive to mechanical and thermal stress than is a memory die. Another important issue is the resistance to mechanical shock, both in production and later in handling.

Legislation

All materials that are regarded as carcinogenic will sooner or later be banned in all kinds of products, even in the processing of products. Restrictions or regulations will also be put on materials that are poisonous or may trigger allergic or asthmatic reactions. Typical examples are lead, flame retardants, and some types of epoxy based materials. Naturally, this will also influence the electronics and MEMS industries.

Conclusion

A range of exiting and challenging problems will face the micro system industry in the years to come. Assembly and packaging will be important areas to focus on if successful micro-systems are going to be produced in high volumes in the future.

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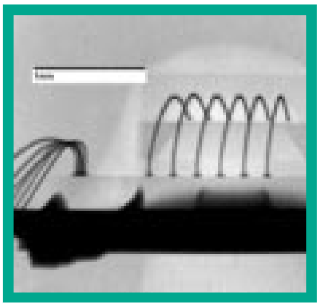


CT-image of a molded component. The sensor die, ASIC, wires, adhesive and glob-top are easily visible.

Thin Silicon Radiation Detectors

As well as developing MEMS technology and components, SINTEF Electronics and Cybernetics has a substantial activity in developing and producing silicon radiation detectors. The challenge of producing very thin detectors has been to combine etching technology from the field of micromechanics with a radiation detection process. SINTEF has succeeded in making p-i-n diodes in etched membranes of 10 µm thickness surrounded by supporting frames.

These detectors are now being installed in the "CHICSi" detector system for the Celsius target chamber at the Svedberg Laboratory in Uppsala. Thin silicon detectors are used as ΔE-detectors in ΔE-E telescopes (ΔE=energy loss). Such telescopes provide isotope identification and energy determination (i.e. for fragments from nuclear collisions).

The thickness of the ΔE-detector should be minimized to the lowest size practical with respect to thickness variations. To achieve acceptable energy resolution with a 10 µm detector, the thickness variations should be within 0.5 µm.

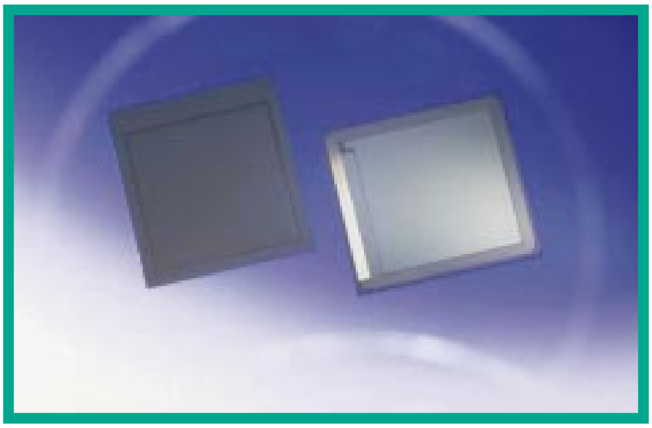
Etching of Thin Detectors

The etching process has to meet three requirements to be useful for detector fabrication:

- It must be possible to etch membranes with a controlled thickness.
- The increase of thickness non-uniformity during the etching process has to be minimized.
- The etching should not increase short-range surface microroughness.

These requirements have been met by an etching process using a tetramethylammonium hydroxide (TMAH) solution. The quality of the etched surface can be very good at high TMAH concentrations (above 25 wt%). Measurements of etch depth with a profilometer show that the etch depth variation is as low as ± 0.1 µm per detector. The values of the surface microroughness, R_a, were in the range of 2–4 nm, which is comparable to that of polished surfaces.

Consequently, the most important parameter determining the uniformity was the thickness uniformity of the starting wafer. At a controlled temperature and with a sufficient volume of etching solution, the etch rate is stable enough to etch with time control to obtain the target membrane thickness.



Back and front sides of the 10 µm thick "CHICSi" detector.

Design and Processing

The active area of the ΔE-detectors is a 10.0 mm × 10.0 mm p-n junction on a membrane of n-type doped float zone silicon. The distance from the membrane border to the edge of the device is set at 1.1 mm in order to have a robust frame.

The first process step was to etch membranes in double-sided polished wafers with a 25 wt% solution of TMAH in water. The membranes were defined with an oxide mask on the back side of the wafers. The wafers were 280 µm thick and were (100) oriented. The processing is completed with a standard detector process using boron and phosphorus implants followed by aluminum metallization.

Evaluation

A prototype ΔE-E detector telescope using 12 µm think ΔE-detectors and 280 µm thick E-detectors has been tested in the Celsius target chamber. In one test, a beam of protons impinged on a Kr gas target. Collision fragments with atomic numbers up to Z=7 were observed. The resolution was sufficient to separate ^{6}Li from ^{7}Li, and ^{7}Be from ^{9,10}Be. Fragments with atomic numbers up to Z=16 have been observed in other experiments.

SINTEF detectors:
www.oslo.sintef.no/ecy/7230/silicon.html

CHICSi detector system:
www3.tsl.uu.se/~chic/chicsi.html

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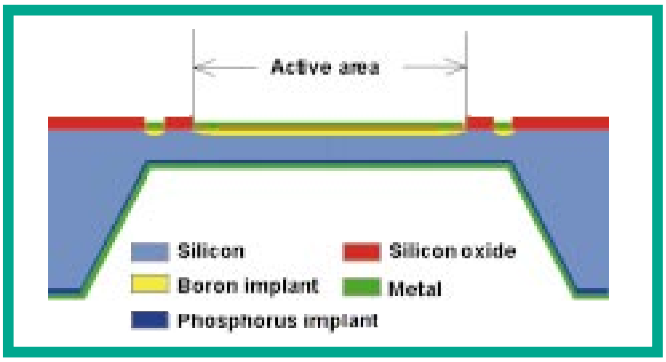

Schematic cross section of a detector.

PUBLICATIONS

Some MST-related results presented during the last few months:

- Advanced packaging technologies for differential pressure sensors exposed to aggressive media; C. Christensen (MIC); Doctoral thesis, MIC/DTU, Lyngby, Denmark.
- An Analytical Analysis of a Compressed Bistable Buckled Beam; M. Vangbo (UU); *Sensors and Actuators A*, **69** (1998) 212–216.
- Integrated Bio/Chemical Microsystems Employing Optical Detection: The Clip-On; O. Leistiko and P.F Jensen (MIC); *J. Micromech. Microeng.*, **8**(2) (1998) 148–150.
- New CO_2 Filters Fabricated by Anodic Bonding at Overpressure in CO_2 Atmosphere; T. Corman, E. Kälvesten (KTH), M. Huiku, K. Weckström, P. Meriläinen (Datex Engström, Finland) and G. Stemme (KTH); *Sensors and Actuators A*, **69** (1998) 166–171.
- New Small Radius Joints Based on Thermal Shrinkage of Polyimide in V-grooves for Robust Self-assembly 3-D Microstructures; T. Ebefors, E. Kävesten and G. Stemme (KTH); *J. Micromech. Microeng.*, **8**(3) (1998) 188– 194
- Valve-less Diffuser Micropumps; A. Olsson (KTH); *Doctoral thesis*, TRITA-ILA-9803, ISSN 0281-2878 (1998).

NEXUS IV Launched

Phase 4 of the EU-collaboration "Network of Excellence in Multifunctional Microsystems" (NEXUS) was launched in June and will run for 2 years. The network is funded by DG III and will continue to consolidate the pan-European microsystem network created over the past years by NEXUS.

The NEXUS network facilitates co-operation throughout Europe among users and producers of microsystems, manufacturers of MST materials and production equipment, and R&D groups associated with this technology.

Its predecessor, NEXUS III, established an industrial lead for microsystems technologies (MST) in Europe and accomplished the following:

- Increased *membership* to nearly 300 corporate members, including 120 industries, 95 research institutes and 85 universities.
- Enhanced integration and collaboration between NEXUS and microsystem activities in Central and Eastern Europe through *NEXUSPAN*.
- *User-Supplier Clubs* have proven to be an efficient means for the transfer of microsystems technologies between manufacturers and users. Four USCs are now operational.
- Organization of specific *workshops*, such as the CAD tools workshop held in Heidelberg in January 1998.
- Dissemination of *market information*. A report is available from the NEXUS office at a price of 400 ECU for non Nexus members and 200 ECU for Nexus members.
- A *benchmarking mission* to the USA was arranged in November 1997 and assessed a wide range of application fields. The mission report is available to NEXUS members.

NEXUS IV will consolidate these activities and expand its network of co-operation by enhancing information dissemination, and by creating stronger links between industry and research and between the User-Supplier-Clubs. NEXUS will organize a number of strategic technology workshops, an interactive and more comprehensive electronic network (http://www.nexus-emsto.com), and strategic mission/visits to the Far East and other competitor nations. It will also provide better access to information. NEXUS IV will help guide Europe towards achieving and maintaining a world class lead in this future technology.

For further information please contact Hans-Christian Petzold at the NEXUS office: petzold@isit.fhg.de.

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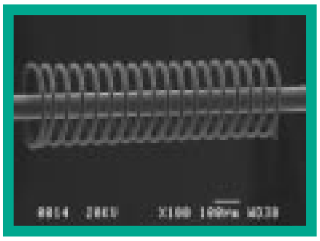
Micromachining Equipment Part 2:
Metal Forming

Metal structures are of increasing interest in MST. Several methods and process equipment can be used to create metal structures, some of which are:

Surface Layers

The deposition of thin layers (< a few 100 nm) of metal on structures (targets) has been mastered by the microelectronics industry:

Evaporation is done in a vacuum system in which a solid metal (source) is heated resistively or via an electron beam. The chamber pressure is often so low that evaporated metal atoms do not collide on their way from the source to the target. The linear path enables patterning of the deposited film via shadow masks.



Micro spring formed with LCVD (courtesy of Kajsa Larsson, UU).

Sputtering is based on the source being bombarded by heavy ions originating from a gas plasma (often argon). Knocked out metal ions are accelerated electrically towards the target. On the way they pass through the plasma, with numerous collisions as a result. Therefore, they will not reach the target with a well-defined angle, and patterning has to be done with conventional techniques, e.g. photolithography.

Chemical vapor deposition (CVD) is a third possibility. In CVD, a solid material is deposited from its vapor through a chemical reaction occurring on, or in the vicinity of, a substrate surface that normally is heated.

Bulk Metal

Thicker metal layers can be formed via 'conventional' techniques:

Electrochemical deposition (electroplating, see page 6) is done in a liquid electrolyte. Applying a voltage will create a current of metal ions moving from the source to the target, and metal is deposited on the target where there is a conducting seed layer. Patterning can be done by covering part of the seed layer with an insulating material, such as photoresist. It can also be done by using a seed layer having a 3D-topography (replication).

Casting, injection molding and *hot embossing* are techniques well-known in the macroworld. The development of corresponding process steps for micro-dimensions is progressing rapidly.

3D Metal Structures

Truly three-dimensional structures can also be formed:

Sacrificial etching can be used to create free-standing metal structures by etching away the material on which the metal is deposited (see *MSB 97:4*).

Laser-assisted CVD (LCVD) is based on the temperature dependence of deposition rates. A laser is used to locally heat a material, and thereby initiate a local deposition. This allows for direct writing without the need for masks. By moving the substrate relative to the laser focus, or vice versa, it is possible to form truly three-dimensional structures.

Copper leads inside a semiconductor made visible by etching away the silicon (courtesy of IBM).

Jan Söderkvist

DISSERTATIONS

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

Carsten Christensen, MIC
The main subject of his thesis, *Advanced Packaging Technologies for Differential Pressure Sensors Exposed to Aggressive Media*, is protective coatings and their characterization, and the development of accelerated tests. In particular, amorphous tantalum oxide was investigated.

It was shown that amorphous tantalum oxide is a very promising alternative, e.g. regarding corrosive rates in alkali solutions, pinhole density, step coverage, residual stress and dielectric properties.

The work was carried out together with the companies Grundfos and Danfoss within the industrial collaboration project "Materials for advanced micromechanical packaging".

Anders Olsson, KTH
His thesis, *Valve-less Diffuser Micropumps*, presents the results of his PhD work that was outlined in *MSB 94:2*. A diffuser pump is based on the flow-rate's channel shape-dependence, and does not include valves or rotating vanes. Connecting at least two diffuser channels of different shapes to a pump chamber makes it possible to control the direction of the flow.

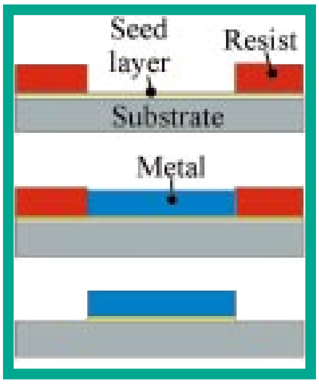
Pumps of different sizes for both liquids and gases have been fabricated in different materials using both conventional fabrication methods and micromachining technology. Measurement results and numerical simulations based on classical fluid mechanics have been used to understand the working principle, to improve the design, and to create a lumped-mass model.

Metal Microstructures on CMOS

Electrochemical deposition of metals (electroplating) has been widely used for corrosion protection and decorative finishing for more than 100 years. It was not until the development of LIGA (Lithographie, Galvanoformung, Abformung) that electroplating was used for the fabrication of microstructures.

As LIGA requires access to synchrotron X-rays for the exposure of the mold, it is a very expensive technology which is mostly used for the fabrication of replication masters. With the coming of new types of photoresists and polyimides that can be applied as very thick layers and exposed by UV-radiation, the technology has become much more accessible and versatile. This type of LIGA, which is often referred to as UV-LIGA, is a technology where the advantage of making very thick structures, as in bulk silicon micromachining, can be combined with the CMOS compatibility of surface micromachining.

SEM micrograph of released two layer metallic microstructures fabricated in high permeability NiFe.



Basic process steps of UV-LIGA.

In a smart sensor, the characteristics of the sensor is improved by integrating part of a signal-processing circuit. The integration of the mechanical and electrical components is performed using either monolithic or hybrid integration.

In most cases, monolithic integration is based on a CMOS process where the sensor is fabricated using the conventional CMOS layers combined with post processing etching. As the CMOS layers have not been developed for micromechanical components, the sensor signal usually has to be corrected by advanced signal processing.

In hybrid integration, the sensor and electronics are fabricated on separate substrates for optimum process freedom and performance. The integration is performed by bonding in the last step before packaging.

As only low temperature CMOS-compatible processes are required in UV-LIGA, monolithic integration by metal microstructure add-on is a powerful alternative to conventional types of integration. Here, the electronics can be fabricated in a state of the art CMOS foundry, and the sensor by UV-LIGA using the electronics wafer as a substrate.

Compared to silicon surface micromachining, the UV-LIGA technology offers an increased design freedom for the transducer structures. Film thicknesses up to several hundred micrometers can be achieved, and a wide selection of plateable metals and alloys with different physical and mechanical properties are available.

Successful fabrication of metallic microstructures requires precise control of the processing steps involved. The photoresist and the plating solution have to be compatible. The stress in the photoresist and in the plated metal layers has to be rather low. Uniform material distribution can be achieved by proper mask design and pulse plating.

When UV-LIGA is combined with sacrificial layer etch, released metal microstructures can be realized. Metals like copper or organic materials like photoresists can be used as a sacrificial material. All of the processing steps needed to form the released metal microstructures are low temperature steps, hence they are relatively easy to implement as post processing steps of a commercial CMOS process.

The add-on integration will most likely play an important role in future smart transducer applications.

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Schematic of metal microstructure on CMOS.

4th World Micromachine Summit

The 4th *World Micromachine Summit* was held at the Royal Melbourne Institute of Technology in Australia from April 29–May 1 of this year. Some 75 delegates from 13 countries/regions met to discuss critical issues and driving forces for micromachine development in a local and global perspective.

Tokyo, Montreux and Vancouver *(MSB 97:3)* hosted previous Summits. The Melbourne Summit was the first with participation of a full Nordic delegation, represented by Jan-Åke Schweitz, Sweden (chief delegate), Terje Kvisterøy, Norway, François Grey, Denmark, and Ari Lehto, Finland.

Regional Reviews

The Summit was comprised of one session where the chief delegates presented reviews of the latest development in their respective regions, and six sessions on selected topics.

The regional reviews offered no real surprises, but rather provided evidence of steady ongoing progress. Most regional representatives expressed, with varying degrees of optimism and enthusiasm, the opinion that the MST field is gradually transforming from an academic technology-push area into a significant, market driven, industrial area.

The spectrum of MST applications is broadening, and many countries presented new or planned national MST centers or other national initiatives. The number of companies producing or using MST products is steadily increasing, and several examples of interesting start-up activities were given.

Special Sessions

One session was devoted to applications across major industries. In this session, Prof. G. Beardmore from Smiths Industries Aerospace suggested several possible reasons why aerospace MST applications are likely to be slow to evolve in the short term. For example, the aerospace industry is conservative by nature. Prof. R. Müller from Berkeley reviewed some recent progress in surface micromachining for microphotonics. Several beautiful “folded” silicon structures were illustrated, but Prof. Müller also noted that successful implementation in the micro-optics industry requires that the MEMS designs proceed beyond the “silicon optical bench” techniques.

Another session focused on market predictions (see e.g. page 2) and a third on global problem solutions. Dr. T. Shimoyama, chairman of Olympus Optical Co., discussed MST in future medicine, welfare and biotechnology. The development of endoscope was highlighted as one important example of the future direction of MST. An increasing proportion of elderly individuals in the industrialized countries was suggested as a major driving force for MST development in the healthcare sector.

In the session focused on educational issues, the present author was given the opportunity to present the emerging Graduate School in Advanced Microengineering at Uppsala University. Undergraduate engineering programs in MST are being started at universities in Freiburg, Germany, and Neuchâtel, Switzerland. Some concern was expressed about the educational capacity, and its capability to meet the demands of the expanding MST markets.

A final session devoted to improvements in daily lifestyle included two much appreciated presentations of ideas from Japanese and Australian school children for future micromachines. Many clever devices were suggested, e.g. a small fishbone removing machine, a small camera inside a ball to allow us to view sports events from the ball’s perspective, and a device which can maintain an area of clean air around one’s eyes and nose to prevent pollen allergy and hay fever.

Future

It was decided that the 5th *World Micromachine Summit* will take place in the spring of 1999 in Glasgow, Scotland.

In Melbourne, the Nordic delegates concluded that the intra-Nordic collaboration would benefit from a local meeting series similar to the World Summits (see front page).

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EUROSENSORS XII

The 12th *Eurosensors* conference was held in Southampton from 13–16 September. The sensor research area is maturing, and the movement from basic physical principles to more application-oriented fields is apparent. A strong inclination towards chemical sensors and biosensors was noted.

More than 300 oral and poster contributions were presented, mostly from academic institutes. Continuous support for contributors from Eastern Europe is beginning to bear fruit, both in terms of quantity and quality.

Among Nordic contributors, a plenary speech by S Leppävuori on piezoelectric actuators should be noted. Anke Weinert, Chalmers, received a bronze medal for her oral presentation of a low impedance sensing technique for vibrating structures. Microactuators were presented by T Ebefors *et al*, S3, KTH, Stockholm (see *MSB 98:3*, p6), and by J. Jonsmann *et al*, MIC, Lyngby. Multisensor systems from Linköping and Västerås were also presented.

Bertil Hök

POSTTIDNING B

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MICRO STRUCTURE BULLETIN NO.4 NOV 1998

FUTURE EVENTS

MEMS '99 (Micro Electro Mechanical Systems), Orlando, U.S.A., Jan. 17–21, 1999. For info.: Preferred Meeting Management, Inc.
Fax: +1-(619) 298-3459
www.eecs.umich.edu/mems

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

Sensor '99, Nürnberg, Germany, May 18–20, 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.
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.
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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www.summit.material.uu.se

NEXT ISSUE

Some topics covered will be:

- Automotive applications
- Pressure sensors
- Radiation detectors at SINTEF

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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