MICRO STRUCTURE BULLETIN

Newsletter for Nordic Micro Structure Technology, Vol.6, No.1, Feb 1998

NORMIC is the new, Nordic Microsystems manufacturing cluster within EUROPRACTICE. SensoNor (Norway) is the program coordinator and will, together with the institutes VTT, IMC, MIC, CNM and SINTEF, offer feasibility studies, design, production, packaging and testing of microsystems. Through NORMIC, SensoNor is setting up a foundry service on silicon bulk micromachining which is targeted towards European customers. NORMIC receives financial support through the EUROPRACTICE initiative for a two years period starting on October 1st 1997.

Customers of the foundry services are expected to include companies that are experienced users of microsystems technology, as well as first time users. NORMIC will offer a complete service ranging from design to mass production of microsystems within a framework where each customer can freely choose the level of assistance. The institutes will primarily serve the role as design centers, being the customer's interface to the industrial foundry services. Already at this stage customers are invited to contact the cluster for assistance and for the processing of devices.

Each NORMIC partner has been given the responsibility for the co-ordination of specific tasks contributing to the establishment of the manufacturing cluster. Information dissemination and customer contact are important in this start-up phase and is co-ordinated by CNM in Spain.

SensoNor will offer two bulk micromachining processes through NORMIC. These are currently used in their production of piezoresistive pressure sensors and accelerometers. Other devices can also be designed using these processes, and the customers will be allowed to vary some process parameters. By supplying foundry service based on well-established industrial processes, the quality assurance required for industrial use is secured.

NORMIC will offer one-customer production runs as well as MPW (Multi Project Wafer) services. One process with all process parameters fixed will be chosen for the MPW service based upon the input from a market survey conducted by IMC. A design kit, containing design rules, process parameters, and an element library, will be developed by SINTEF. Flip-chip bonding design rules and the development of an MST-specific ASIC interface will be the responsibilities of VTT in Finland. In Denmark, DELTA (a subcontractor of MIC) prepares guidelines for the testing of microsystems and will provide a service for testing.

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CONTENTS

EDITOR'S NOTE

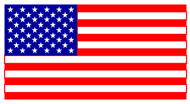
This issue of *MSB* covers some MST-related activities taking place in Finland. This collection of articles reveals a fruitful collaboration between developers, suppliers, producers and end-users. This is a good example of the advantage of teamwork. A single company does not need to deal with all of the technical and financial questions themselves.

I take this opportunity to welcome you all to an exciting *MSW '98*. Personally, I especially look forward to the discussions that will follow the presentations addressing industrialization aspects. When a development project is brought into production, academia and industry are forced to view each other's perspective. The academic must learn about yield, cost, reliability, and the unspeakable word, 'deadlines'. Industry must learn the importance each individual brings to the project, and that not all tasks can be specified in advance regarding necessary time and resources.

A successful development does not only required resources, teamwork and understanding. It is also important to believe in yourself and that the goal can be reached. When you are completely exhausted and wish to quit, someone that believes in you may encouragingly say "You can do it". Suddenly you will hear yourself saying "I can do it, I can do it". The struggle has suddenly become easier. Thanks to all of you who were spectators at NYCM.

Jan Söderkvist

MEMS in the U.S.A.



The development of Micro Electro Mechanical Systems (MEMS, the most commonly used term in the U.S.A. for what is called MST in Europe) in the U.S.A. started in the late 1980's with the design and manufacturing tool set developed for VLSI (very large-scale integration). Since then, MEMS are progressing toward smaller sizes, higher speeds, and greater functionality.

Today about 80 companies in the U.S.A. work in the field of MEMS. Out of these, about 60 are small businesses with less than USD 10 million each in annual sales. The remaining 20 companies are large corporations situated in different industry sectors with varying degrees of research activities and products in MEMS.

Market Situation

Many American market research institutes have surveyed the field of MEMS worldwide and have attempted to predict its course. The value of these surveys vary substantially, so it is mainly the general trends and statements that are valuable. Projections began to appear in the early 1990's when a Battelle survey predicted a market of about USD 8 million in the commonly quoted target year of 2000. Other predictions of the market have been between USD 12 and 14 million.

In 1994, SEMI (an international trade association for the semiconductor industry) conducted a market survey that predicted that the world market in the year 2000 will be USD 14 million, of which medical and transportation applications for pressure sensing could provide about 30 percent of the total. According to this survey, major markets will be in inertial sensors, including accelerometers for auto safety systems, auto suspension and braking systems, munitions, cardiac pacemakers, and machine control and monitoring. MEMS areas targeted for strong growth are fluid regulation and control, optical switching and routing, mass-data storage, displays, and analytical instruments.

Federal Support

Three main federal institutions in the U.S.A. provide substantial support for MEMS development. These are DARPA (Defense Advanced Research Projects Agency) at about USD 45 million per year, NSF (National Science Foundation) at USD 5 million per year, and NIST (National Institute of Standards and Technology) at USD 3 million per year. NIST is considering creating a new, special program solely for the funding of MEMS, which most likely would increase the amount of financial support from NIST.

DARPA predominately sponsors industrial and applied projects. NSF sponsors basic research, mostly at universities. NIST sponsors industries which are important to the economic benefit of the whole country.

International Roadmaps

A meeting during SEMICON West in July 1997 in San Francisco inaugurated an effort to establish an international MEMS/Microsystems Technology Roadmap. This project is led by SEMI, the organization that also organizes the SEMICON conferences. The goal is to have the document ready during the year 2000. Before then, many meetings will be scheduled in which the progress of the roadmaps will be discussed. These meetings will predominately take place at the SEMICON conferences during 1998–2000.

The objective of the roadmaps is to obtain a worldwide (mainly the U.S.A., Europe, Japan and Korea) perspective of the efforts in MEMS technology today, to define where the industry wants to be in the future, both for R&D and for commercial products, and to suggest how to get there.

A set of benchmarking metrics will be developed for each of the four technology sectors: sensing, actuating and process/control devices, and passive structures. Areas that are considered important are simulation/modeling, design/CAD, fabrication methods, metrology, packaging, testing and reliability, IC circuit design integration, materials, prototyping, environmental issues, and cost models.

Presently, it is necessary to find people in different parts of the world who are interested in the field of MEMS, have contacts both within industry and academia, and are willing to work on this project. In Particular, SEMI is looking for qualified people within Scandinavia. If you are interested, contact Ron Horwath at SEMI at phone +1-415-940-7994, fax +1-415-967-5375, or e-mail rhorwath@semi.org.

More About MEMS in the U.S.A.

If you want to find out more about MEMS in the U.S.A., a report will be available from the Swedish Technical Attaché System during the spring of 1998. The report, titled "MEMS i USA", is written by M.Sc. Eva Guterres, Assistant Technical Attaché in Washington, D.C. The report is about 40 pages long, written in Swedish, and can be ordered at phone number +46-(0)8-787 64 00.

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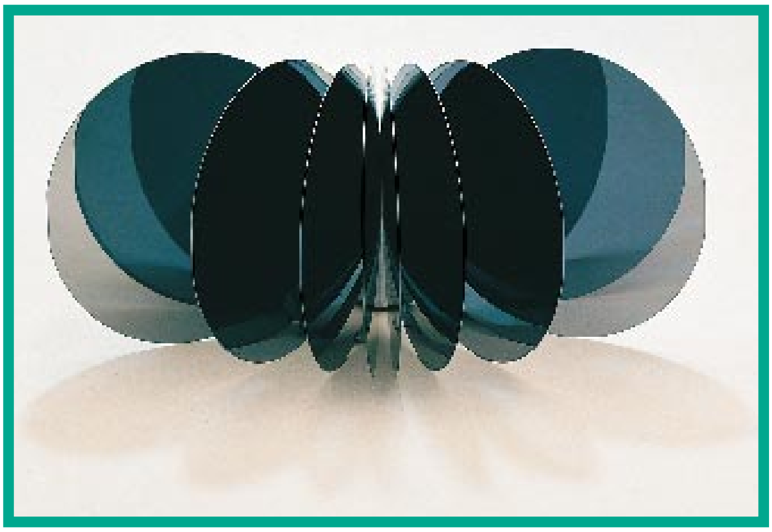
TURNOVER

It may come as a surprise that the automotive area is not the dominating application area for MST-products, neither regarding quantities nor turnover. It contributed with only 2% of the total MST-turnover in 1996. Six other areas were larger, e.g. IT-peripherals (70%) and medical and biomedical products (15%). Noteworthy is that hearing aids are responsible for more than half of the turnover for the rapidly growing medical area. More information will be presented in forthcoming issues of MSB.

Silicon for MEMS Applications

Commercial high-quality silicon wafers are produced in Finland at Okmetic Ltd. This production is the outcome of intensive R&D that started in early 70's with a feasibility study at Helsinki University of Technology. This study was followed by a pilot project in the 80's that was supported by the Finish companies Outokumpu and Nokia.



Okmetic

Okmetic Ltd. was established in 1985, and production started in 1987 in Espoo near Helsinki. Since then, the company has had an annual growth rate of 30% to 50%. The Espoo plant now has about 230 employees and operates 7 days a week. Okmetic's wafers are sold globally.

Double-sided polished wafers for micromechanical applications were delivered already during the pilot project. The product range of the Espoo plant now includes 100 to 150 mm diameter IC wafers, double-sided polished micromechanical wafers, and epitaxial wafers both for IC and MEMS applications.

Skyrocketing Wafer Demand

In the 90's the demand for wafers 'exploded', partly due to the rapid expansion of the silicon based MEMS industry. A major expansion in production capacity was necessary, and a new factory for 150 and 200 mm wafers was built in 1996–97.

The new plant in Vantaa, also near Helsinki, started operations ahead of target in November 97, with first customer shipments in early December. In full operation, the new plant will more than triple Okmetic's production capacity. The number of employees is currently about 150 people, and is rapidly increasing with the ramp-up of production volumes.

The factory design is modern: the 2,000 m^2 clean room is realized with raised floor and filter fan technologies, providing the maximum flexibility to upgrade the environment if needed. Today, the final wafer processing is done in a Class 1 environment.

Wafers for MEMS

A special product group is silicon for MEMS applications. Here, Okmetic provides double-sided polished wafers in 100 to 150 mm diameter ranges with or without an epitaxial layer, and with common dopants and resistivity levels. A very good flatness combined with a tight thickness distribution is unique in these wafers. Customers typically specify non-standard wafer thickness. Okmetic has gained a good market share in this sector, after long development in process technology with customer-specific products.

MEMS applications place unique requirements for wafers, in addition to those placed by the IC-industry. For example, crystalline defects formed during thermal treatments prior to the deep etching of cavities and membranes can interfere with etching selectivity. Okmetic has developed advanced crystal growth techniques, yielding very homogenous silicon material with minimum defect formation during heat treatments. Nevertheless, the strong material resistance against slipping during subsequent heat treatments is not sacrificed.

R&D and Quality

It is essential to have accurate control over the produced material. For example, oxygen, metal and surface particle contents, epitaxial layer thickness, and surface topography must be monitored and controlled. Electric parameters, such as the carrier concentration, generation lifetime and CV-measurements, must also be checked. A variety of measuring techniques and tools are, therefore, used in both production and R&D.

Simulations complement the experiments, and are especially important for parameters that are difficult to measure. For instance, computer modeling of crystal growth enables realistic calculations of melt flow in the crystal growth crucible. These simulations can be checked using furnaces for thermal process simulations.

Okmetic invests heavily in R&D as well as in process and product development. In addition, the research is supported by alliances with local research laboratories. The past history has shown the success of this activity. Continued development will result in new types of MEMS wafer products, including SOI and other etch-stop structures. Company scientists readily share the strong know-how base of silicon material with the customers.

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PUBLICATIONS

Some MST-related papers during the last few months:

- A Silicon Microsystem-Miniaturised Infrared Spectrometer; M. Blomberg, O. Rusanen, K. Keranen and A. Lehto (VTT Electronics, Finland), *Proc. Transducers '97*, Chicago, June 1997, 1257–1258.
- Fourier Transform Infrared Detection in Miniaturized Total Analysis Systems for Sucrose Analysis; B. Lendl, R. Schindler, J. Frank, R. Kellner (Vienna Univ. of Techn, Austria), J. Drott and T. Laurell (LTH); Analytical Chemistry, 69 (1997) 2877–2881.
- Porous Silicon – An Enzyme Coupling Matrix for Micromachined Reactors; J. Drott (LTH); Doctoral thesis, ISRN LUTEDX/ TEEM – 1062 – SE.
- Silicon Microphone for Hearing Aid Applications; J. Bay (Mictronic A/S / MIC, Denmark); Doctoral thesis, ISBN 87-89935-12-8 (1997).

VAISALA

Vaisala Oy develops, manufactures and markets electronic measurement systems and equipment for meteorology, the environmental sciences, traffic safety and industry. Vaisala's core customer groups are meteorological organizations, research institutes, defense forces, air and traffic authorities, and industry. The main part of the production takes place in Vantaa near Helsinki in Finland.

The *Upper Air Division* targets weather observation in the upper atmosphere, with products including radiosondes. The products of the *Surface Weather Division* include meteorological sensors and measurement systems to improve weather observations, and air and road traffic safety. The *Sensor Systems Division* focuses on transmitters and instruments for the measurement of relative humidity, barometric pressure and carbon dioxide content.

Micromachine-based components, such as pressure and carbon dioxide sensors, constitute key components in some of the measurement systems, such as in the Barocap and Carbocap sensors. Vaisala works closely with research institutes and industry in the development and manufacturing of MST components.

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Sensor elements used in Vaisala's products for the measurement of humidity and pressure.

CO_2 Detection with CARBOCAP

Numerous techniques for measuring gas concentration have been developed over the years. The list includes chemical sensors, ceramic sensors, pellistors and various types of electrochemical sensors. Each one, however, is only suitable for a limited number of applications.

Chemical sensors are difficult to develop, and they often have a short service life. Indirect measurement methods tend to suffer from poor sensitivity, cross sensitivity with other gases, low accuracy and drift. Frequent recalibration is not a realistic option for most users, especially for high volume or low-end applications.

NDIR Gas Detection

High price has been the problem with optical devices due to their increased complexity relative to chemical sensors. With high production volumes, however, these prices can be decreased with integration and miniaturization. One subset of optical measurement systems, Non-Dispersive Infrared (NDIR) methods, has been of special interest to Vaisala due to its ability to function accurately for long periods of time.

NDIR is based on the principle that each gas absorbs light of different wavelengths (4.26 µm for CO_2). The amount of light reaching the detectors depends on the amount of gas in the measurement cell. Filters are used to remove unwanted wavelengths.

NDIR Detection Types

A single-beam, single wavelength device (see the figure) offers the poorest performance. Aging of the lamp and contamination or other changes in the reflecting surfaces degrade performance. Using two wavelengths, one of which is used for calibration, improves performance. The simplest solution is to use two optical channels, interference filters, and detectors. A complication is that the filters and detectors must be closely matched in regards to temperature and aging.

Better yet, is to use a single optical channel with switching between the two wavelengths. This switching is usually done with a rotating interference filter wheel. Unfortunately, the wheel solution is bulky and difficult to protect from dust, and the wheel motor must be changed periodically. This makes for an expensive solution.

Electrically Tunable Filters

In Vaisala's new optical carbon dioxide sensor, CARBOCAP, the rotating wheel is replaced with a micromachined electrically tunable Fabry-Perot interferometer (FPI). This makes it possible to overcome most of the disadvantages of the conventional single-beam dual-wavelength solution since it enables a virtually solid-state solution.

The FPI modulates the incoming infrared light such that only one wavelength passes at a time. This enables measurement at both the absorption and reference wavelengths. The ratio between the detected signal at these wavelengths indicates the degree of light absorption, and thus the gas concentration.

CARBOCAP® based transmitters.

The FPI has been developed in close cooperation with the Technical Research Center in Finland (see next page).

System Performance

The measurement system can be truly miniaturized when the mechanically rotating filters in the traditional method are replaced by a small silicon FPI. Experiments show that the new sensor is very insensitive to any deterioration of the optical transmission. This enables excellent drift characteristics over both time and temperature. In fact, the recently launched CO_2 transmitter have a recommended calibration interval of five years.

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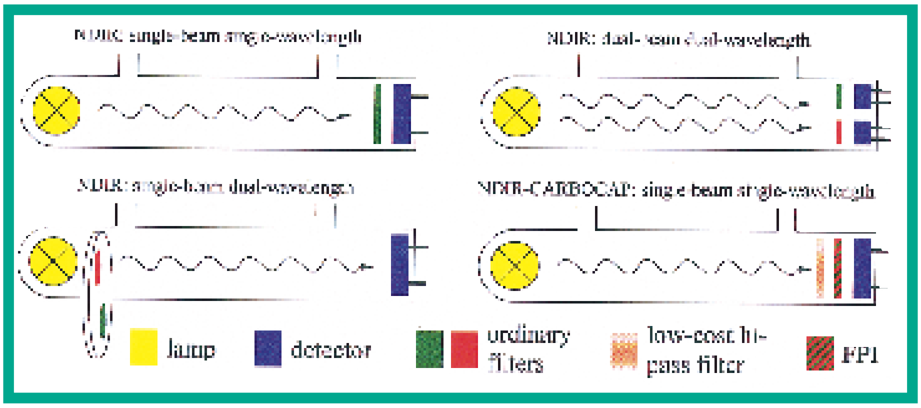


MEMS Research at VTT Electronics

VTT (Technical Research Center of Finland) is a multidisciplinary research institute with approximately 2800 employees. VTT Electronics is one of its divisions, employing 270 persons at two locations, Oulu and Espoo (near Helsinki). The Microelectronics Center, MIC, is located in Espoo and has just moved to a new laboratory building.

Staff and Facilities

MIC has a current staff of 75 employees, and 1100 m^2 of clean room equipped for microelectronics and microsystems research. Bulk and surface micromachining are available, as well as micromechanical SOI technology with dry deep etching capability. In addition, special packaging techniques are available including flip-chip technology.

MEMS Research Areas at MIC

One area of research at MIC involves BiCMOS process development aiming at high frequency, low power IC's for mobile applications. Current features include a 0.8 µm line width and a 17 GHz cutoff frequency. A 0.5 µm process with a 25 GHz cutoff frequency is under development.

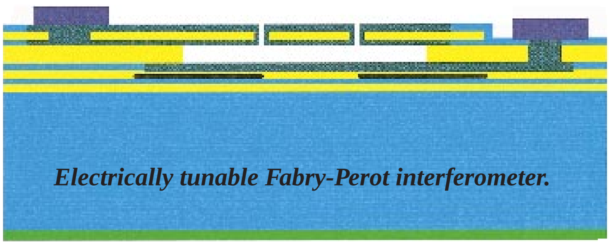
The integrated circuits design group concentrates on demanding analog circuits based on silicon technology. The design is based on an in depth knowledge of silicon processes and their characteristics. Application areas include RF telecommunication circuits, sensor interfaces and smart power circuits.

In photonics technology MIC contributes to the MEMS area with optical fiber, integrated optics and optical measuring technologies.

Micromechanics

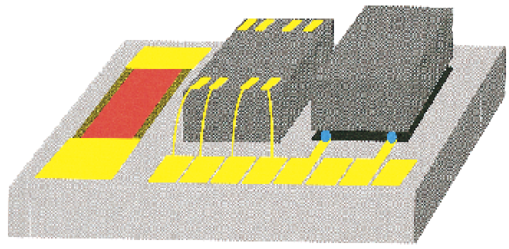
MIC's activities in silicon micromachining started in 1991 with the development of several silicon components. These included a capacitive differential pressure sensor and microphone, an electrically modulatable wide spectrum IR-source, IR-detectors of the bolometer and thermopile types, an electrically tunable Fabry-Perot interferometer (FPI), and a miniaturized IR-spectrometer.

The structure of the FPI is shown in the figure below. The device is silicon surface micromachined and can be tuned by applying a voltage between the two terminals. The maximum tuning voltage is typically 5–30 V, depending on the zero voltage wavelength. The tuning range is about 25% of the zero voltage wavelength. The first order interferometer has an aperture of 1 mm diameter and an FWHM of approximately 20 nm at a 1.5 µm wavelength using a three layer upper mirror. The FWHM can be narrowed by increasing the number of mirror layers and/or using higher orders. The interferometer has been commercialized by Vaisala Oy for CO_2 measurements (see page 4).



Electrically tunable Fabry-Perot interferometer.

The FPI, the wide spectrum IR-source, the IR-detector and an IC have been combined into the miniaturized IR-spectrometer shown in the upper figure. The light source and IR-detector have been integrated into the silicon substrate. The IC is normally die and wire bonded, and the FPI is flip-chipped on top of the detector. The whole spectrometer measures 5 by 12 mm^2 and is packaged in a ceramic DIL-package. The light source can be turned on and off in a matter of milliseconds. The maximum working temperature of the light source is 800°C in air.



Silicon micromachined miniaturized IR-spectrometer.

The latest research endeavor at MIC regards SOI components and their fabrication processes. Several components of different types are under development.

Integrated Optics

The development of photonics technologies at MIC proceeds in close proximity with silicon micromechanics. One aim is to develop photonic components fabricated using micromachining processes. In integrated optics, silicon based technology is today's method for the fabrication of optical waveguides and optohybrids for sensor and optical telecommunications applications. MIC's expertise consists of modeling, design, and different fabrication technologies of waveguides. Modified microelectronic deposition processes, especially low-pressure and plasma-enhanced CVD processes, result in phosphorous-doped silica and silicon nitride waveguides. MIC also has facilities for the component-level characterization of integrated optical components at various wavelengths.

Demonstrations include a 1.3/1.55 µm wavelength division multiplexer, a polarization splitter, a ring resonator, a thermo-optic phase shifter, and a process for the monolithic combining of waveguides, detectors and electronics. An infrastructure for the manufacture of prototype and pilot custom-designed optical integrated circuits on silicon is likewise available.

At present, much emphasis is also put into the development of Silicon On Insulator (SOI) waveguide techniques.

Contacts

The leaders of the IC-design and the IC-processing groups are Dr. Markku Åberg and Dr. Tapio Wiik, respectively. The packaging and materials activities are led by Dr. Ilkka Suni; MEMS is led by Dr. Matti Leppihalme. Their e-mail address is firstname.familyname@vtt.fi (first replace Å with A).

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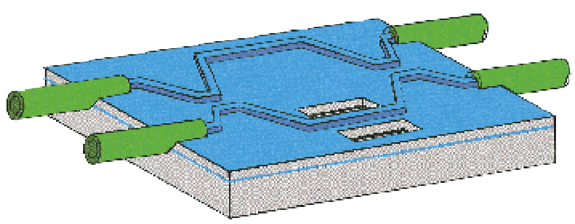

Schematic picture of micromechanically controlled Mach-Zehnder interferometer

EUROPRACTICE Microsystems Manufacturing Clusters

EUROPRACTICE is a large ESPRIT program that aims to facilitate access to component, subsystem and microsystem technologies. In other words, EUROPRACTICE supports selected activities that encourage European industry to utilize micro electronic technology. In October 1997, EUROPRACTICE entered its second two year phase after the first phase had been evaluated as successful.

The Microsystems activity is one of the EUROPRACTICE services. This activity focuses on reducing the risk and cost of including microsystems in commercial products. Within the Microsystems services, three Manufacturing clusters that were established during the first EUROPRACTICE phase continue to be supported in the second phase. Two new clusters have been added, among them is the Nordic cluster (NORMIC).

Manufacturing clusters offer design, prototyping, production and packaging of microsystems. Each cluster is co-ordinated by an industrial company that already has proven a high volume production of microsystems or related products. A number of research institutes are connected to each cluster and offer competence in design, prototyping, packaging and other microsystems services in collaboration with the industrial partner. The clusters are located in Germany (Bosch), France (Sextant), England (AEA), Switzerland/Holland (CSEM), and the Nordic countries/Spain (SensoNor). Experience from the first phase of the Manufacturing clusters shows that customers often prefer the local cluster. Because different clusters offer different products it may often be necessary to choose a more remote cluster for manufacturing. When more than one cluster offers similar processes the philosophy of EUROPRACTICE is to encourage competition in order to minimize the costs. Examples of micromechanic services that are offered within the microsystems Manufacturing clusters are surface micromachining, bulk micromachining, LIGA, and thin film deposition.

The design centers are the customer's interface to development and production within each cluster. The customer is guaranteed handling of their needs at all levels from design to packaging. The device cost is reduced by taking advantage of established processes and Multi Project Wafer Processing.

More information can be obtained at http://www.europractice.rl.ac.uk/mst.htm, or from the NORMIC contact person, Stein Ivar Hansen, at SensoNor, Fax: +47-33 03 51 05, e-mail: stein-ivar.hansen@sensonor.no.

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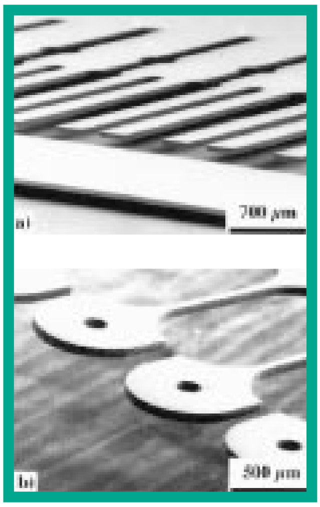
The Flexibility of Projection MITE

Micromachining by Ion Track Etching (MITE) was presented in *MSB 96:2*. The ion tracks are created by irradiation of heavy ions, such as Au, Pb and Xe, with energies between 10 and 15 MeV per nucleon and ion doses of 10^8–10^{10}/cm^2. Such ions can in quartz yield up to 100 µm long and 10 nm wide tracks. MITE relies on the merging of tracks etched into the pores of certain areas as defined either by a mask during etching, or by a projection masked ion beam during irradiation (see figure). Hence, in the first scheme we have latent tracks in the remaining micro structures, but not in the second scheme. The etch selectivity of the tracks is often much greater than the difference in etch rate encountered in different directions of a material. Therefore, a virtual etch anisotropy can be superimposed, or even induced, in an ordered or disordered material.



Structures made by projection MITE: (a) quartz tuning forks and (b) polycarbonate tensile test samples.

The primary advantage of projection MITE is that no latent tracks remain. Therefore, a thin film mask demanding good adhesion and chemical resistance during etching is not needed, and it is easier to structure samples of already high aspect ratios. However, this method is not appropriate for samples with low selectivity between the track and the non-irradiated material, or for samples with low ion track densities since the unprotected surface is also attacked. Projection MITE has been used to create structures in quartz (SEM photo a), glass, mica and polycarbonate (SEM photo b), employing a LIGA manufactured stencil mask.

MITE is certainly more flexible than many other processes when it comes to geometries and materials, and we hope that it will facilitate the introduction of new exciting material combinations and devices in microstructure technology.

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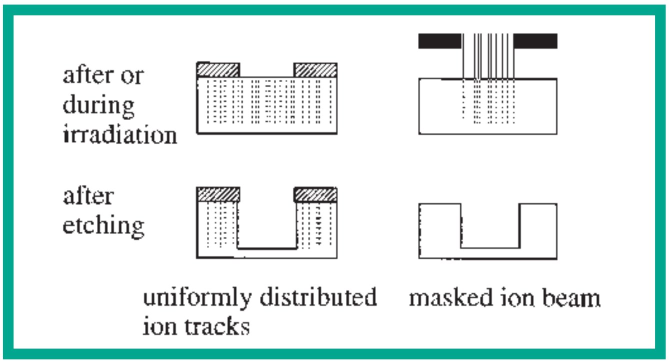

The two types of MITE. In the first, the ion tracks to be etched are defined by a lithographic mask. In the second, the ion beam is masked by a stencil mask (projection MITE).

Capacitive Pressure Sensors

Although VTI Hamlin is mainly an acceleration sensor producer the importance of pressure sensor development is growing. A significant effort has been put towards research to produce new, better and smaller pressure sensors to meet the needs of the market and to offer products for different demanding applications.

Capacitive Detection

VTI Hamlin's pressure sensing elements use the capacitive detection principle. A silicon diaphragm is deflected by a pressure difference which changes the width of the gap between the diaphragm and a fixed thin metal plate. The variation in gap size is detected as a change in the measured capacitance.

The thermal sensitivity and dynamics of capacitive elements are superior to that of piezoresistive capacitors. Thermal sensitivity is of the order of 100 ppp/°C (roughly 2000 ppm/°C for piezoresistive detection). This means that capacitive elements can be used in many applications without any thermal compensation.

In addition to low thermal sensitivity, capacitive elements are extremely stable over time. Full scale dynamic range is about 50% of the full scale capacitance (piezoresistive: ~ 1%), so very high resolution can be obtained. Capacitive technology is at its best when measuring low absolute (atmospheric) or low differential (1–100 mbar) pressures.

The capacitive detection principle calls for the usage of an AC-signal with a measurement frequency on the order of tens of kHz. For this purpose, VTI Hamlin has developed two ASICs, one designed for low power consumption and the other as a multipurpose circuit designed to function with every pressure sensing element in VTI Hamlin's product range.

VTI Hamlin's Pressure Sensing Elements

Absolute pressure elements consist of two wafers, a thin wafer with the diaphragm and the gap etched into it, and a glass coated thick silicon wafer with a deposited metal electrode.

The differential pressure elements contain a similar thin wafer, but with an additional support wafer fusion bonded on the diaphragm side. The thick wafer has additional vertical glass insulation which separates the element into four insulated blocks (see figure). These elements have an enormous overpressure tolerance, because the glass top surface acts as an overrange limit.

There are two types of absolute pressure sensing elements, APS1 and APS2. APS1 is a small, low cost solution intended for measurement applications where low power consumption is of high priority. It has a base capacitance in the order of 3 pF and a dynamic range larger than 1 pF. This element is easily scaled to full scale pressures up to 100 bar. Currently, versions exist for 4 bar and 75 bar absolute pressure. APS2 is a slightly larger element. It has a base capacitance and a dynamic range in the order of 9 pF and 7 pF, respectively, and a full scale of 1.1 bar. The response of this sensor element is highly linear (1/C vs. p) due to the thick and stiff center of its deflecting diaphragm (see photo on page 4). Application areas for both of these elements are limited only by their housing.

The differential pressure elements of VTI Hamlin have a unique structure with electrical contacts on the opposite side of both the measurement pressure port and the mechanical contacting surface. The measurement side can be in direct contact with any substance that is silicon compatible. On the reference side only dry non-corrosive media is recommended, although care has been taken in regards to protection against humidity. Current versions exist for 75 mbar and 400 mbar differential pressures. Present processing technology allows for pressures as low as 15 mbar, and in the near future full scale differential pressure may be as low as 1 mbar.

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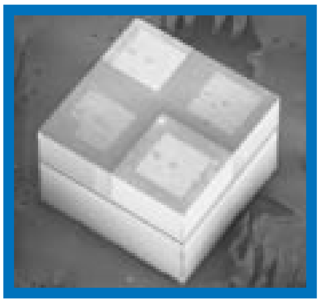

Differential pressure sensing element by VTI Hamlin.

DISSERTATIONS

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

Johan Drott, LTH

His thesis, Porous Silicon – an Enzyme Coupling Matrix for Micromachined Reactors, concerns enzyme reactors in micro total analysis systems (µTAS), with a focus on biomedical applications such as continuous glucose monitoring.

The thesis describes the miniaturization and silicon wafer integration of a micro enzyme reactor. To improve the catalytic efficiency and the long-term stability of the reactor, porous silicon was investigated and introduced as a surface enlarging enzyme carrier matrix in silicon microreactors. A porous silicon layer was applied to a high aspect ratio vertical channel type microreactor, yielding a 170-fold increase in enzyme activity compared to an identical reactor without the porous layer.

The versatility of enzymatic detection via microreactors was demonstrated by a porous high aspect ratio microreactor. It operated as a key component in a miniaturized fourier transform infrared (FTIR) spectroscopy system designed to measure the sucrose content of soft drinks.

To further improve the catalytic efficiency of porous silicon microreactors, the influence of pore morphology and matrix depth were also investigated in the thesis.

Jesper Bay, MIC, Denmark

His thesis, *Silicon Microphone for Hearing Aid Applications*, describes a prestudy for the development of micromachined microphones for use in hearing aids. Two new differential capacitive microphone structures are proposed and evaluated. A major part of the thesis deals with the general modeling of their behavior. Based on the modeling, the optimum backplate geometry is determined.

Various equivalent circuit models of conventional and differential capacitive microphones are presented. They are used in the calculation of sensitivity and frequency response, as well as the acoustic-mechanical noise. Process sequences for the fabrication of 'double backplate' and 'double diaphragm' differential capacitive microphone structures are also proposed.

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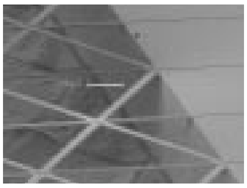
MICRO STRUCTURE BULLETIN NO.1 FEB 1998

NEXT ISSUE

Some topics covered will be:

- Micro Opto Electro Mechanical Systems (MOEMS)
- Optomechanical accelerometers
- Microstructures enabled by optical poling of glass



MSW '98

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 interested in MST. Ample time will be given for informal discussions inbetween the more than 40 oral and poster presentations.

Late news contributions are welcome as poster presentations on a first come basis. One late news contribution will be selected for an oral presentation.

Participants from all countries are welcome, although *MSW* is mainly aimed at Scandinavia. For more information, please contact Jan Söderkvist at the address given in the editorial column to the right. Welcome to *MSW '98*.

Advanced Micro Engineering at Uppsala University

PhD students are invited to participate in graduate studies and research within the fields of micro structure technology and micro engineering, with applications in sensor and actuator technology, micro optics, medical technology and space technology. One example of the research activities is given in the article on MITE in this issue. Candidates will work within two centers for research and training: AME (see *MSB 96:4*) and SUMMIT (see *MSB 96:1*). Both centers are located in the recently built and ultramodern Ångström Laboratory.

A suitable background would be MSc in Engineering (civilingenjör) or corresponding, with adequate specialization in the fields of physics, chemistry, materials or electronics.

Inquiries to Associate Professor Staffan Jacobson, Uppsala University, Box 534, SE-751 21 Uppsala, Sweden. Phone +46-(0)18-471 30 88, fax +46-(0)18-471 35 72, e-mail staffan.jacobson@angstrom.uu.se.

FUTURE EVENTS

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/.

MSW '98 (Micro Structure Workshop), Uppsala, Sweden, March 24–25, 1998. 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. 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. For info.: NANO'98, KTH, Fax: +46-(0)8-790 90 72, or visit http://www.kth.se/conferences/nano98.

Actuator 98, Bremen, Germany, June 17–19, 1998. For info.: Messe Bremen GmbH, Fax: +49-421-3505 340, or visit http://www.messe-bremen.de/actuator.

Eurosensors XI, Southampton, United Kingdom, Sept. 13–16, 1998. *Abstract deadline: March 2.* For info.: Intelligent Sensor Microsystems Group, University of Southampton, Fax: +44-1703-766207, or visit http://diana.ecs.soton.ac.uk/~aht/EurosensorsXII/.

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

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