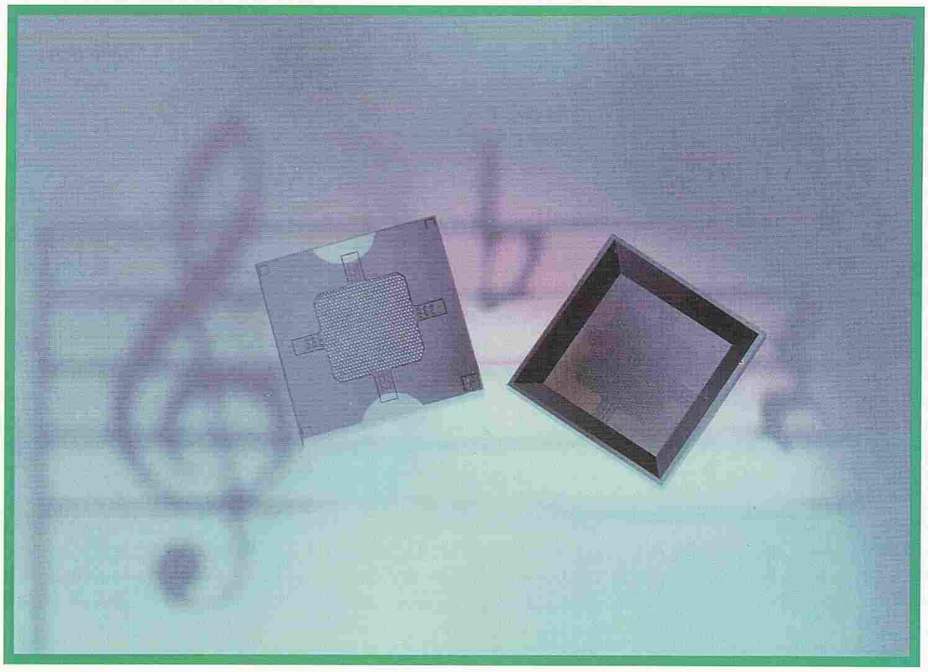
MICRO STRUCTURE BULLETIN

Newsletter for Swedish Micro Structure Technology No.2 May 1994

MSW '94



The front and back side of a 2x2 mm silicon microphone sensor presented at MSW '94. The structure was developed at CSEM in Switzerland by Johan Bergqvist. It constitutes one part of the doctoral thesis he recently presented at Uppsala University.

Micromechanics / Micro Structure Technology (MST) is today not only a research area. It is, since a few years, also of increasing industrial interest. This has created a need for an informal biennial workshop at which industry and university can meet.

The first *Micro Structure Workshop* (*MSW*) was held in Uppsala (Eklundshof) on March 24-25. The purpose was to stimulate the use of Micro Structure Technology (MST) and to bring together in an informal way those in Scandinavia interested in MST. *MSW* is thereby a complement to scientific conferences which are primarily forums for the latest scientific results.

MSW '94 focused on development projects, academic/industrial MST-activities, and the future use of MST. Half of the thirty presentations came from industry.

The content of several of the presentations has been, or will be, presented in the *Micro Structure Bulletin* (*MSB*). Information for those who want their personal copy of the proceedings can be found on page 7.

Seventy participants from both industry and university attended *MSW '94*. The mix was well-balanced:

- industry: 36%
- university: 43%
- research institutes: 8%
- other: 13%.

Comments from the participants showed that the two-day workshop was well received and that many new contacts were formed. Also, the informal atmosphere and the food were well appreciated.

The positive response motivates making *MSW* a recurring biennial event. The major international MST-conference, *Transducers*, takes place in the years that the *MSW* is not held. Remember that Sweden will host next year's *Transducers-Eurosensors*.

In addition, a biennial MST-course aimed at industry will be held starting next year.
See you at *MSW '96*.

Jan Söderkvist ■

CONTENTS

EDITOR'S NOTE

This issue features a brief summary of the first Nordic workshop on MST/ micromechanics *(MSW '94)*. The workshop received very positive comments, both from industry and from researchers. The impression is further improved by the higher than expected number of participants. I would like to take this opportunity to express my appreciation to all the speakers and for all the positive and stimulating comments.

In order to affect the physical environment properly it is essential to be able to detect its state. This means that detection methods suited for small devices are important for MST. Hence, the series of articles on micromachining basics continues with mechanical detection methods.

The contents of coming issues of *MSB* are already in the planning stage. Space will be made available for contributions from the readers. Thus, you are invited to make suggestions. The theme for the next issue is optics; following issues will deal with devices used in chemical analysis, and MST in Scandinavia. The third issue next year will focus on the *Transducers-Eurosensors* conference in Stockholm.

This issue's saying describes a possible consequence of micromachining: "The solution to a problem changes the nature of the problem" (Peer's law).

Jan Söderkvist

Micromachining Basics Part 3:

Mechanical Detection Methods

Most commercialized micromachined devices are found in sensors, resonators and actuators. Applications which use micromachined mechanical details have appeared only recently.

An actuator is often combined with a sensing function for optimization of performance. Also resonators include a sensing function to ensure that the vibration occurs at resonance.

In conclusion, the knowledge of various detection principles is an essential part of MST. This article summarizes the most commonly used mechanical detection methods.

Overview

The detection methods (DMs) can be grouped according to whether they are based on internal or on external properties. The two best-known internal DMs in MST are piezoresistivity and piezoelectricity. Both link internal strain to changes in electric properties. The best examples of external DMs are capacitive detection and some optical methods. Both measure the displacement of a surface. The material affects the choice of internal DM. For instance, silicon is piezoresistive while quartz is piezoelectric. The choice of external DM can also be affected by the material properties, for instance via the transparency and electric conductivity.

Piezoresistivity

The piezoresistive effect is commonly used in micromachined silicon sensors as a strain gauge, for instance, in pressure sensors and accelerometers. It is fairly simple to implement and gives sufficient performance for many applications.

Piezoresistivity means that the resistivity depends on the stress in the material. In silicon, the effect is mainly due to a direction-dependent change of the electron mobility. Other semiconductors, like GaAs, have other physical mechanisms that affect the freedom of the electrons. Not all anisotropic materials, e.g. quartz, possess a piezoresistive effect

The relative change in resistivity equals a constant, π_{jk}, times the mechanical stress. For silicon, the relative change can exceed the resulting strain by a factor of about 50. The importance of the electron mobility means that π_{jk} depends on the doping.

The piezoresistive effect can be used to detect both static and dynamic stress. However, the somewhat limited resolution makes it less suited in accurate resonators. Also, it does not possess a reverse actuating effect.

A long-term drift of the zero-point can be expected, especially at elevated temperatures. It is therefore common to use four resistors connected in a Wheatstone bridge.

Advantages with piezoresistivity are its compatibility with IC-technology and that very little external electronics is needed. Drawbacks are the limitations on the stability, signal noise and dynamic range of piezoresistivity.

Piezoelectricity

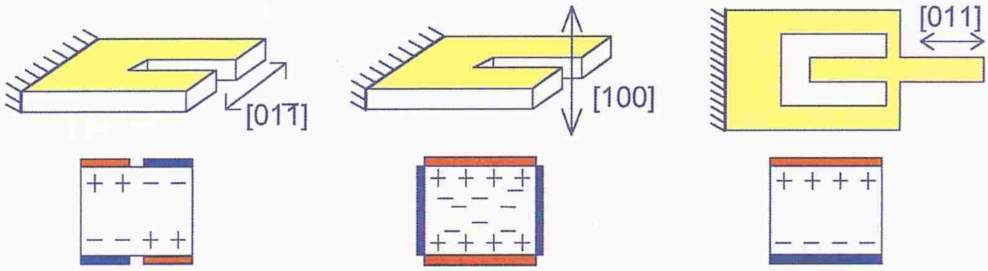
Commercial piezoelectric devices are found mainly in resonators. Every computer and most watches contain one or more piezoelectrically activated resonators. The frequent use of quartz in resonators is due to its extreme stability and low temperature coefficient.

Piezoelectricity is due to the dipole structure of materials whose crystallographic structure lacks inversion symmetry. A mechanical stress can move the dipoles so that free charges are attracted to the electrodes. Changing the stress generates a current at the electrodes. The electrodes can be shaped so as to be sensitive to only one specific deflection direction due to the piezoelectric anisotropy.

A current is more easily detected than charges. Therefore, piezoelectric detection is best suited for resonators and for dynamic detection. Measurements on static loads can be performed either by using an accurate charge amplifier or by making a mechanical resonance

MECHANICAL DETECTION METHODS — ADVANTAGES AND DISADVANTAGES

PIEZORESISTIVITY	PIEZOELECTRICITY
+ simple + IC-compatible - dynamic range - stability	+ stability (quartz) + can be used both for detection and activation - not silicon - primarily dynamic
CAPACITIVE DETECTION	**OPTICAL DETECTION**
+ stability + almost any material - stray signals - needs electronics	+ low sensitivity to electric interference + galvanic isolation - normally expencive - not fully IC-compatible



The bound piezoelectric charge distribution and suitable electrode configurations (red:positive, blue:negative) in the cross-section of a GaAs [011]-beam, for three vibration directions.

frequency sensitive to the desired load. For instance, extremely small changes in mass can be detected by monitoring the resonance frequency.

Vibration amplitudes smaller than an atomic radius may be detected piezoelectrically. This results in a sufficiently large dynamic range for almost any application. The resolution is mainly limited by stray impedances. It is best to use a high quality pre-amplifier located near the electrodes as well as a shielding enclosure.

The most commonly used micromachined material, silicon, is not piezoelectric. The piezoelectric effect is therefore not frequently used in micromechanics. There are several piezoelectric materials that can be micromachined, for example, quartz and GaAs. Note that GaAs is a semiconductor which is both piezoelectric and piezoresistive.

Capacitive Detection

Deflections can be monitored by measuring the capacitance between the moving surface and a fixed surface. This technique is used commercially, for instance, in accelerometers for air-bags.

Capacitive DM can be used to measure both DC and AC movements. Published results show the possibility of measuring AC-changes in the order of one millionth of a typical micromechanical capacitance (1 pF), under ideal conditions. This makes it possible to detect vibration amplitudes below an atomic radius. The dynamic range is sufficient for most applications.

It is important that stray impedances are small and stable if a high resolution is needed. Therefore, the electronics must be located near the stimuli-sensitive capacitance, and the leads must not be allowed to move. It is therefore common to have the necessary detection electronics inside the enclosure. Most materials can be used for capacitive detection. However, using a material with a low resistivity may lead to degraded performance due to stray currents.

Micromachined structures are normally dimensionally stable. The long-term stability for capacitive detection is therefore expected to be high. The thermal dependence is mainly due to the material parameters.

The capacitance change is measured with an AC-signal. It is recommended that its frequency does not equal any mechanical resonance frequency, since there always exists an attractive electrostatic force between two electrodes. Improved performance can be reached with differential detection.

Optical Detection

Several optical DMs exist. The most fundamental are based on reflection of a beam of light on a deflecting surface. This method is well suited for systems in which optical fibers are used for information transfer.

More advanced methods use the change in bandgap of certain semiconductors, e.g., of GaAs. The response to external stimuli can be directly measured in terms of a wave-length shift of the photoluminescence, or as a change in refractive index.

Optical phase shifts are used in a few sensor applications. Some, e.g. those based on the Sagnac effect, can be explained only in conjunction with the general theory of relativity. It is also possible to activate resonators with a stimuli-sensitive resonance frequency thermally by directing a modulated beam of light on the relevant surface.

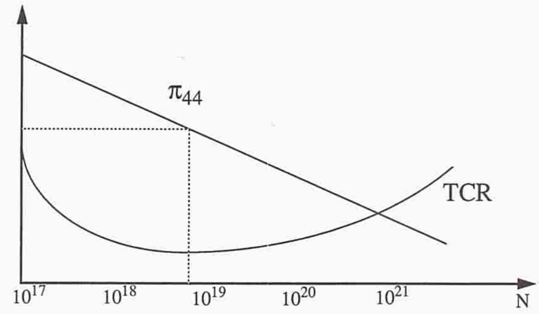
Magnetic Detection

Sensors based on electromagnetic detection are encountered in several macroscopic devices, for instance in microphones The use of magnetic detection methods in MST-devices is more limited. A disadvantage of magnetic detection is that both the cross-section area and the available space for the coil decrease when reducing the size of the device.

Another limiting factor is that magnetic materials are seldom compatible with traditional micromachining. The development of micromachining based on electroplating may resolve this dilemma.

Detection Systems

An ideal sensor responds only to the desired stimulus. Unfortunately, most DMs are sensitive to several stimuli, for instance: to pressure, acceleration or temperature. In addition, an internal DM may respond to undesired force components when Poisson's ratio is non-zero.



A typical dependence of the piezoresistive effect on the doping level, for silicon. Included is also the temperature dependence of the resistor.

A well-designed mechanical construction makes it possible to suppress irrelevent stimuli so that they do not reach the stimuli-sensitive part. For instance, unwanted force components may be prevented from reaching the stimuli-sensitive part in this way. This shows that the design of the entire sensor, including the enclosure, may be more important for performance than the DM and the stimuli-sensitive part itself.

Which DM to Choose?

Most applications allow a choice of DM. Experience shows that it is then often best to choose a DM that gives sufficient performance instead of choosing one that gives optimum performance. The underlying argument being: to optimize the available R&D time and financing resources.

The possibility to manufacture a device in a reproducible and cost-efficient way is often more restricting. Available manufacturing processes, materials and experience must suit the technical solution, including the requirements of the DM. Other factors that affect the choice of DM are, for instance, accuracy, stability and environmental requirements.

In conclusion, it is often more the strength of each company/university than the application that determines the choice of detection method.

Jan Söderkvist ■

MST Activities

The main research activity at the Instrumentation Laboratory (Elektrisk mätteknik) of the Department of Signals, Sensors & Systems (S^3) is focused on silicon sensors and actuators:

Silicon Sensors and Actuators

A new research field — applied sensor and actuator technology in silicon based on microelectronic fabrication techniques and micromachining of silicon — was established at the Instrumentation Laboratory at the Royal Institute of Technology (KTH) in December 1991 when Göran Stemme was appointed professor. Several new devices with promising performance have been fabricated despite the short time the group has existed. At the moment the group has four full-time and two external graduate students.

This type of applied research requires access to advanced equipment and processes of the same type required for the fabrication of microelectronic components. The group fabricates its own silicon structures at the KTH microelectronic laboratory, located at Kista, 12 km outside of Stockholm. The laboratory comprises a 1000 m^2 clean-room area with facilities and equipment for the fabrication of small-scale microelectronics as well as for research and development of special purpose structures and components in silicon.

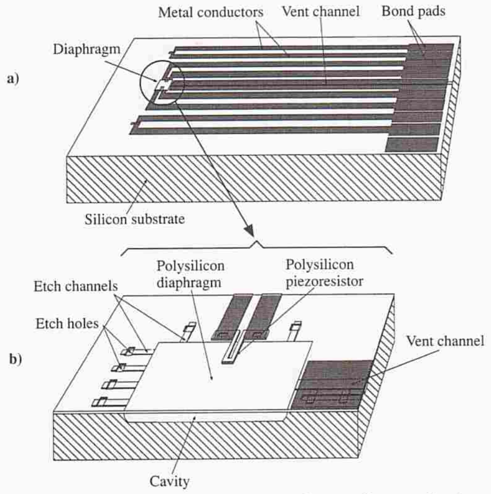
Presently the silicon sensor and actuator group are involved in the following major research projects, each run by a Ph.D.-student:

Pressure/Velocity Measurement in Turbulent Gas Flow

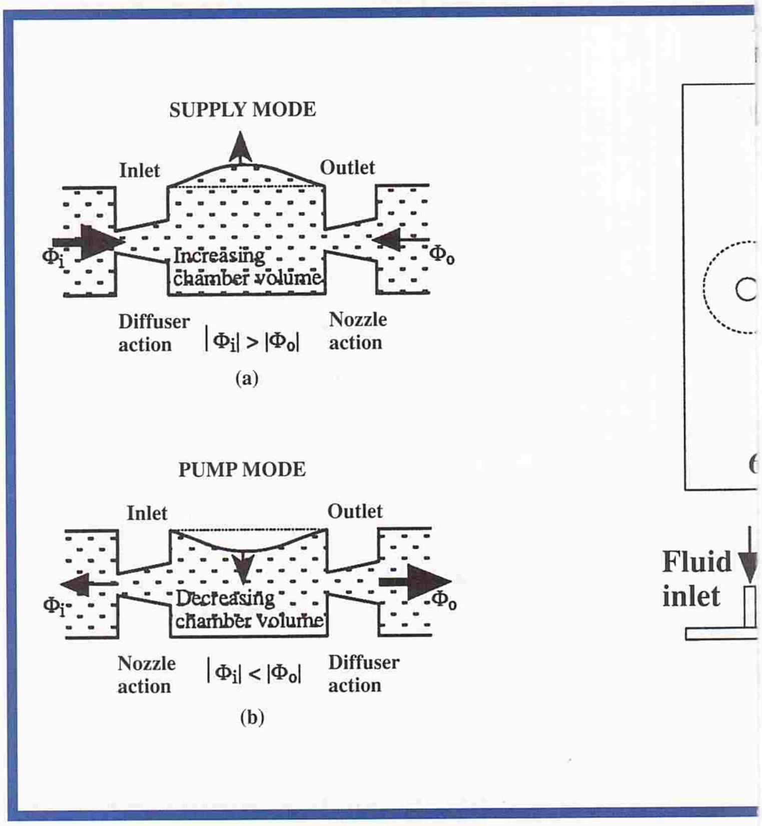
A fruitful interdisciplinary cooperation with the Department of Thermo and Fluid Dynamics, at Chalmers University of Technology in Gothenburg, has been going on for many years. The purpose of the research cooperation is to develop micromachined silicon sensors specially designed for the measurement of local pressure and gas velocity fluctuations in turbulent gas flow.

Recently, during 1993, we were able to fabricate an ultra-small silicon microphone with a small pressure-sensitive diaphragm. The small polysilicon diaphragm is only 0.1 x 0.1 mm squared and about 0.4 µm thick. Polysilicon piezoresistive strain gauges on the diaphragm make it possible to detect the smallest eddies in a turbulent flow. The sensor has a very flat frequency response curve, within ±2 dB between 10 Hz and 25 kHz, and an acoustical sensitivity of 0.9 µV/Pa for a supply voltage of 10 V.

The microphone design is shown in the figures below. The sensor is fabricated using the so called "surface micromachining" technique (see explaining text). In the figure to the right a SEM-photo of a cross-section of the diaphragm and the cavity is shown.



(a) A miniaturized microphone in silicon for turbulent flow measurements (chip size: 4 x 2 x 0.5 mm). (b) A close-up of the surface micromachined pressure sensitive diaphragm (diaphragm size: 100 x 100 x 0.4 µm).



The operation of the diffuser based pump (single-chamber and single-d
At the right a top and side view of the new planar two-chamber pump.

The next step in this research project is to integrate the microphone on the same silicon chip as a gas flow velocity sensor that has been developed earlier by the researchers in the group (see separate article in this issue). The aim is to create a "multi-probe"-sensor for the simultaneous measurement of the pressure and gas velocity at a local "point" in a turbulent flow field. This sensor-probe will facilitate the determination of the pressure/velocity correlation parameter used in computer simulations of turbulent flow.

The design and fabrication process of the new multi probe-sensor started at the end of 1993. Person responsible: Edvard Kälvesten.

A Density Sensor for Liquids Based on Mechanical Resonance Vibration

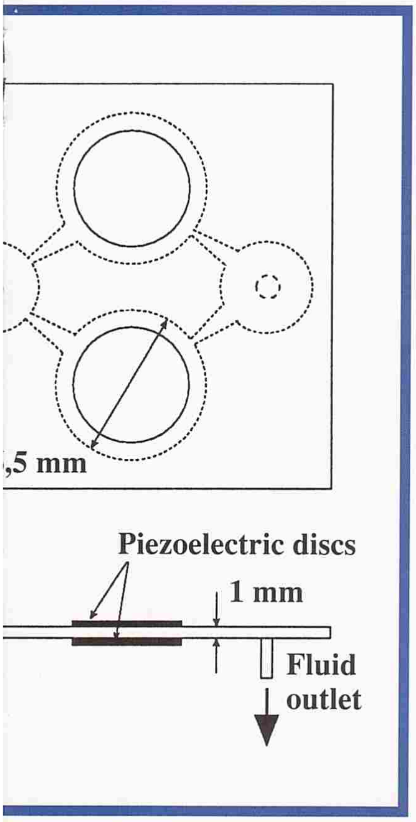
A new sensor to measure the density of liquid flow in a tube has been designed and fabricated. The sensor consists of a silicon tube system, which is oscillated in a selected mechanical resonance vibration mode.

A change in the density of the liquid flowing in the tube will, due to the change of mass, change the resonance frequency of the vibrating tube. Thus, the resonance frequency is a measure of the density of the liquid in the tube. It is the excellent mechanical properties of single-crystalline silicon, especially the high resonance vibration quality (Q-factor), which gives the sensor its good characteristics.

Preliminary measurements show that the sensor, i.e. the densitometer, has a high density sensitivity of more than 200 ppm/kgm^{-3}, high stability, small size, and a low temperature sensitivity in the order of a few tens of ppm/°C.

This type of densitometer, which is based on using small sample volumes and "on-line"

at KTH



aphragm).

measurements, can be used in different application fields, for example: in medical, chemical and bio-chemical analysis instruments.
Person responsible: Peter Enoksson

Valve-less Fluid Micro-pump

A valve-less fluid pump, based on a new concept, has been designed and evaluated. The pump consists of a chamber volume with two oppositely located fluid diffuser/nozzle-elements, as shown above. At least one of the walls of the chamber constitutes a piezoelectrically activated oscillating diaphragm. The vibrating diaphragm produces an oscillating chamber volume which, together with the two fluid flow rectifying diffuser/nozzle-elements, creates a one-way fluid flow.

Several micro-pump prototypes in metal have been built and tested. Among these is a planar pump with two pump chambers, four pump diaphragms, and four diffuser elements arranged as shown in the figure to the left. The piezoelectrically excited diaphragms of this pump are operating in a "push-pull" fashion. The measured maximum liquid flow rate was 12 ml/min and the maximum pump pressure was 1.6 m H_2O. The pump frequency was in the order of 530 Hz.

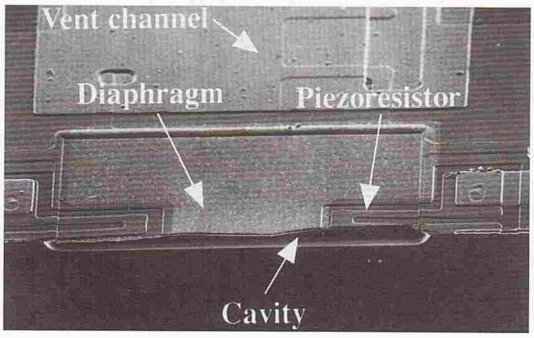
We are now making a micro-pump based on the planar double-chamber design shown to the left using micromachining of silicon.

The new micro-pump may be used in applications where small size and accurate flow volume control are essential. These are important characteristics in implanted medical delivery systems for applications such as chemotherapy, pain relief, and insulin dosage delivery to diabetics. Other applications are: chemical and biological analysis instruments, fluid delivery in engines, and pump-coolants and refrigerants in applications where there is a need for local cooling of electronics.
Person responsible: Anders Olsson

Thermal Infrared-detector Array

A new joint research project was launched in July 1993 consisting of the silicon sensor group at KTH, the Industrial Microelectronics Center (IMC) and AGEMA Infrared Systems AB. The goal is to design, fabricate and evaluate an infrared thermal detector array. The detector array will be integrated with readout electronics on the same chip. This means that the detector fabrication must be compatible with IC-fabrication. The first test structures are now being fabricated.
Person responsible: Pontus Eriksson

For more information please contact Prof. Göran Stemme, Tel: +46-8-790 77 87, Fax: +46-8-10 08 58, E-mail: stemme@instrlab.kth.se ■



An SEM-photo of a cross-section of the pressure sensitive diaphragm of the microphone.

Surface Micromachining

Contrary to bulk micromachining (when a geometrical structure is etched out of a bulk substrate such as a silicon wafer) surface micromachining means that a structure is etched out of a deposited surface layer. One common example is a polycrystalline silicon film deposited on the surface of an oxidized silicon wafer. The oxide interlayer serves as an etch-stop layer when the polysilicon top layer is locally etched. In a subsequent step the oxide layer can be removed using an etchant which selectively attacks the oxide but not the silicon. Under-etched polysilicon structures are thereby possible to create. A variety of free or suspended polysilicon structures can be formed with this procedure by a proper choice of masks and etch times.

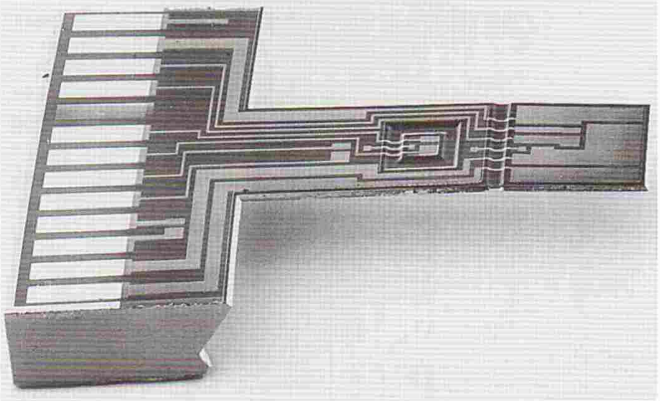
PUBLICATIONS

The following list shows some Swedish MST-related results published during the last months:

- Characterization of Gas Transport Through Micromachined Submicron Channels in Silicon; P. Norberg, L.-G. Petersson and I. Lundström (LiTH); *Vacuum*, 45(1) (1994) 139-144.
- Design of Microelectronic Thermal Detector for High Resolution Radiation Spectroscopy; S. Qutaishat, P. Davidsson, P. Delsing, B. Jonson, R. Kroc, M. Lindroos, S. Norrman, and G. Nyman (CTH); *Nuclear Instruments & Methods in Physics Research A*, 342 (1994) 504-508.
- Gallium Arsenide as a Mechanical Material; K. Hjort, J. Söderkvist and J.-Å. Schweitz (UU); *J. Micromech. Microeng.*, 4(1) (1994) 1-13.
- Modelling and Micromachining of Capacitive Microphones; J. Bergqvist (UU-CSEM); Doctoral thesis, Acta Univ. Ups. #27 (April 1994), ISBN 91-554-3252-2.
- Pressure Microsensor System Using a Closed-loop Configuration; B. Hök, L. Tenerz, S. Berg and A. Blückert (UU); *Sensors and Actuators A*, 41(1-3) (1994) 78-81.
- The Piezoelectric Effect of GaAs Used for Resonators and Resonant Sensors; J. Söderkvist and K. Hjort (UU); *J. Micromech. Micro-eng.*, 4(1) (1994) 28-34.
- New Concepts for Capillary Electrophoresis; Åsa Emmers (KTH); Doctoral thesis, Royal Institute of Technology (May 1994), ISBN 91-7170-869-3.

A Silicon Gas Flow Sensor –

Research, Development and Production



A micrograph of SWEMA's gas flow sensor fabricated at IMC.

One of the earliest works in Sweden in the area of micromachining of silicon resulted in 1985 in the publication of a new gas flow sensor based on the anemometer principle. The initial work was conducted at Chalmers University of Technology. An instrument containing a sensor developed from the original device is now on the market ten years later.

The Sensor as a Research Project

Within the frame of the research project a small gas flow velocity sensor of "hot-chip" type was designed. The hot part consisted of a 0.3 x 0.4 mm and 30 µm thin silicon chip placed at the end of an equally thin silicon beam.

A plastic material, polyimide, serves as a mechanical support as well as a thermal insulation between the chip and the beam. The chip is electrically connected to the supporting beam by four thin metal conductors on the beam and across the polyimide joint.

An integrated resistor is used to heat the chip, while the chip temperature is measured with a diode integrated on the chip. A diode located on the "cold" part of the beam is used to compensate for changes in the gas temperature.

External control electronics applies a voltage over the heating resistor with a magnitude such that the temperature measured by the chip is kept constant, for instance at 50 °C higher than the gas temperature. The necessary heating power is a measure of the gas flow velocity.

The sensor shape and design simplify the mounting and give a minimal flow disturbance, since the sensor chip is mounted in parallel to the flow. Measurements have shown that the use of polyimide as the joint material between the chip and the beam significantly increases the flow sensitivity due to a decreased thermal conductivity to the mounting. Furthermore, the small mass of the chip gives the sensor a fast thermal response.

An integrated version of the sensor has also been fabricated and tested. The integrated electronics on this silicon structure was first fabricated in a standard CMOS process by ASEA-HAFO. After that, the sensors were formed using a double-sided silicon etching procedure followed by the polyimide isolation lithography. The electronics on the base plate controlled the temperature of the hot chip by pulsating the applied electric voltage over the heating resistor. Thus a "quasi-digital" output was achieved where the duty-cycle of the pulse period became a measure of the gas flow velocity.

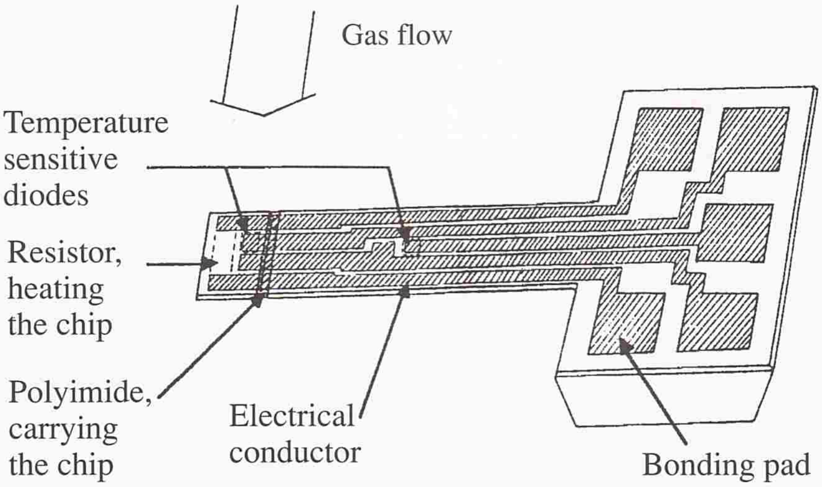
The research part of the sensor project was continued as a scientific cooperation between the Instrumentation Laboratory at KTH and the Department of Thermo and Fluid Dynamics at Chalmers University of Technology. The development was there primarily focused on sensors especially designed for turbulent gas flow measurements.

The Sensor as an Industrial Project

The project had an industrial continuation when the rights to the invention were transferred to SWEMA AB, a company at Farsta, a southern suburb of Stockholm. SWEMA is one of the leading suppliers of measurement instruments for ventilation ducts in Sweden. In order to be able to use the sensor in SWEMA's products it was necessary to develop the fabrication technology for higher yields and volumes and also to improve the sensor performance in terms of long-term stability. The major part of this work was conducted by the Institute of Microelectronics (IM, nowadays IMC — Industrial Microelectronics Center) in Kista, close to Stockholm. After an evaluation process by SWEMA, the company ordered a production batch from IM. The micrograph on this page shows the SWEMA gas flow sensor in silicon.

The sensor is now used in a hand-held instrument intended for measurement of air flow conditions in ventilation ducts. The instrument was introduced to the market in January 1994 and several instruments have already been sold.

Göran Stemme, KTH



A schematic view of the micromachined gas velocity sensor with polyimide as a thermal insulator between the heated chip and the support beam.

When It All Started

Micromechanics is older than most people think. One starting point was the discovery of the piezoresistive effect in the early 50's. Silicon sensors were fabricated ten years later. Around 1970, researchers at Westinghouse were using sacrificial layers to form capacitive sensors and electrostatic actuators.

A group at Stanford University, headed by Professor Jim Angell, probably had the greatest influence on the early development of micromechanics. The gas chromatograph on a single wafer, and other demonstrators, really pinpointed the potential of this new field. The achievements of Kurt Petersen, then at IBM, in designing and fabricating a number of innovative devices, also served as an inspiration source.

In Europe, Philips had a very early start in miniature pressure sensors. The predecessors of SensoNor in Norway were producing silicon cantilever beams for use in medical equipment on an industrial basis already in the early 70's. Unknown to many is that micromachining techniques for three-dimensional structures, such as the LIGA technology, can also be traced back to the 70's, and the research laboratories of Siemens.

Bertil Hök ■

MSW '94 - proceedings

Micro Structure Workshop was successfully held in Uppsala on March 24-25. Those interested in *MSW '94* can order the proceedings by depositing 160 SEK* on the "postgiro" account 69169-1 (Teknikum). Remember to write your name, address and "MSW'94-proceedings" on the "postgiro"-slip. The proceeding contains 148 pages and is mainly in Swedish.

*) Add 40 SEK sales tax if ordering from within Sweden (not applicable to universities).

DISSERTATIONS

MSB congratulates both Johan Bergqvist and Åsa Emmer on successfully having defended their theses. Bergqvist's dissertation took place at Uppsala University on April 22, and Emmer's at KTH on May 4.

Johan Bergqvist

His thesis, *Modelling and Micromachining of Capacitive Microphones*, comprises theoretical and experimental studies of capacitive microphones based on silicon technology. The work is stimulated by the growing demand for highly miniaturized microphones with high performance, particularly for applications in hearing aids. Several micromachining technologies are experimentally evaluated: dry and wet etching, pn-junction etch-stops, anodic and direct bonding, sacrificial layer technology, and metal electrodeposition. Measured values of the microphone devices include sensitivities up to 15 mV/Pa in combination with bandwidths of 17 kHz and a corresponding noise level of 30 dB(A).

The theoretical analysis is based on finite element analysis and on equivalent circuits. The simulations, which include the influence of thermal stress, electrostatic forces and air loading, are found to agree well with the measured results.

The work has mainly been carried out at Centre Suiss d'Electronique et de Microtechnique (CSEM).

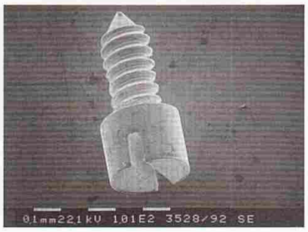
Åsa Emmer

Her thesis, *New Concepts for Capillary Electrophoresis*, describes new methods for separation and analysis by capillary electrophoresis, in particular for compounds like proteins. Miniaturization of separation system components is discussed. The fabrication and evaluation of a micromachined silicon non-return valve is presented as an example of miniaturization.

Coming Dissertations

Next dissertation in the MST-field is given on May 19 at Uppsala University. Lars Rosengren will then present his thesis *Silicon Microstructures for Biomedical Sensor Systems*.

Not Only Micromachining



It has for ages been possible to produce quite small components with traditional precision mechanics. This commercially produced M0.18 screw is an extreme example of this. Despite the small size (length 0.89 mm, pitch 0.05 mm and width of slot 0.05 mm) it is produced in volume at a very low cost. It represents the borderline between high precision mechanics and new MST.

Boo Johansson, Björkgren Mekanik AB

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MICRO STRUCTURE BULLETIN NO.2 MAY 1994

FUTURE EVENTS

MME'94 (MicroMechanics Europe) in Pisa, Italy, September 5-6, 1994. *Abstract deadline: June 15.* For information contact: Prof. Dario, Scuola Superiore S Anna, Pisa, Fax: +39-50-883 215.

Eurosensors VIII in Toulouse, France, September 25-28, 1994. For information contact: Eurosensors VIII Secretariat, CNRS/LAAS-7, Fax: +33-61 33 62 08.

MEMS '95 (Micro Electro Mechanical Systems) in Amsterdam, The Netherlands, January 30-February 2, 1995. *Abstract deadline: October 3.* For information contact: Ms. J. Spierenburg, BASICS, Fax: +31-53 356 770.

Transducers '95• Eurosensors IX in Stockholm, June 25-29, 1995. *Abstract deadline: December 15.* For information contact: Congrex, Fax: +46-8-612 62 92.

6e Int. ANSYS Conference in Pittsburg, USA, May 2-6, 1994.

Nanofabrication and Biosystems: Frontiers and Challanges, Hawaii, USA, May 8-12, 1994.

48th IEEE Int. Frequency Control Symposium, Boston, USA, June 1-3, 1994.

Actuator 94, Bremen, Germany, June 15-17, 1994.

5th Int. Meeting on Chemical Sensors, Rome, Italy, July 11-14, 1994.

µTAS (Workshop on Micro Total Analysis Systems), Enschede, The Netherlands, Nov. 21-22, 1994.

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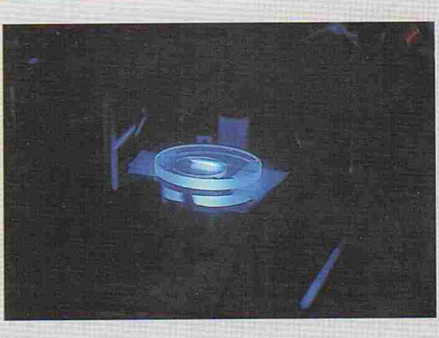
NEXT ISSUE

Some topics in the next issue will be:

- optics in MST
- MST for telecom applications
- The Institute of Optical Research (IOF)



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