MICRO STRUCTURE BULLETIN

Newsletter for Nordic Micro Structure Technology No.1 Feb 1996

summit

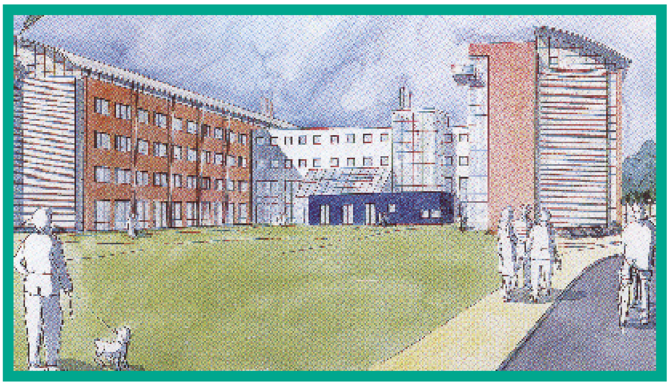
SURFACE & MICRO STRUCTURE TECHNOLOGY

CONTENTS

The Center for Surface and Micro Structure Technology – *SUMMIT* – was recently launched and its first project activities are currently being initiated. *SUMMIT* is an "industry-relevant competence center" financed equally by NUTEK, industry and academia. *SUMMIT* is located at Uppsala University and is headed by Professor Jan-Åke Schweitz. The Royal Institute of Technology (KTH) and the Industrial Microelectronics Center (IMC) are closely affiliated.

The main objectives of *SUMMIT* are to establish and uphold an internationally leading position within surface and micro structure technology (MST), and to facilitate and broaden the implementation of these emerging technologies within Swedish industry. The needs and requirements of the industry will constitute guidelines for activities in the center. A good footing in fundamental science is ensured by its location in a strong university environment.

Companies which plan to make R&D efforts within this field will hopefully find a qualified partner in the center. Perhaps a joint effort with *SUMMIT* will enable R&D which otherwise would be impossible due to the company's lack of sufficient capacity or knowledge. It is an explicit ambition of *SUMMIT* to offer increased possibilities for development and renewal on reasonable terms for industry.



Uppsala University's new Center for Materials Science, the Ångström Laboratory, will be inaugurated during 1996 and includes SUMMIT and other MST-related research and education activities.

The R&D activities in the center will initially be oriented toward five main fields of MST applications: replication, fluidics, optics, sensors and actuators. The activities also include a basic block of "generic MST", which is aimed at more fundamental problems of common interest to two or more of the applied blocks. Some examples of devices and problems which may be addressed are found on page 3.

SUMMIT will also include programs for education and information, a special graduate program for research students, and programs for the exchange of researchers with Swedish industry and with the international scientific community.

SUMMIT comprises three research groups at Uppsala University, two at KTH and one at IMC. During the first contract period of two years, nine companies are included: Ericsson, Sandvik Coromant, CelsiusTech Electronics, Siemens Elema, Engström Medical, Telaire Europe, Quartz Pro, Radi Medical Systems, and Swema Instruments.

The center will receive financial support from NUTEK for a period of ten years. When in full operation, *SUMMIT* is planned to have 20–25 active researchers and an annual budget of 18–24 MSEK.

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EDITOR'S NOTE

This issue features several organizations that work in the area between pure research and industry. Such organizations increase the possibilities for industries not already involved in MST to get familiar with MST before committing extensive resources towards their own MST-activities. Industrial involvement can vary along a spectrum from observing and learning to new collaborative projects aimed at production.

If you are interested in finding out the direction of Nordic MST, in making new contacts, or in getting stimulated, then attend the second *Micro Structure Workshop, MSW '96*. It is still possible to add a few posters. Use this opportunity to facilitate making new contacts by presenting your company's MST activities or your MST needs in your application area. Contact the me if you are interested.

The first issue of MSB was produced in 1993. Despite the fact that this is our fourth year, the list of topics to be discussed in MSB continues to increase.

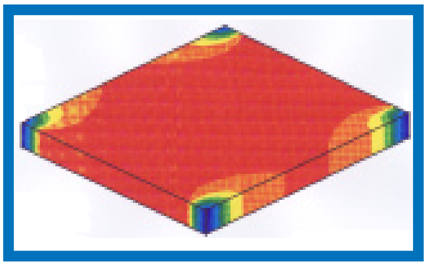
The current issue was prepared in December as a (micro-)member to the editor's family was born in early January. If she wants to, she will contribute to the development of *MSB* in her own way.

Jan Söderkvist

Micromachining Basics Part 7:

Excitation Methods

Excitation methods (EM) are of increasing importance for micromachined structures. Sensors that previously only had a detection function are now often required to have a self test ability. Additional cases for which EM are important include energy converters, e.g. pumps and ultrasound generators, resonant sensors and resonators.



Piezoelectric field intensity in the cross-section of a beam.

Exciting Vibrations

Vibrations can be excited by modulating the excitation force. Mechanical resonance frequencies can be excited if the resulting deflection is monitored. The rapid phase change between the force and the resulting amplitude at resonance can be used to track automatically the resonance frequencies in closed-loop "self-oscillating" operation. This criterion is more reliable than using the sometimes dramatic increase in amplitude at resonance.

Choosing the location of the excitation and detection properly makes it possible to enhance or suppress selected vibration modes.

The complexity of combining excitation and detection in micromachined structures stresses the importance of including both methods early in the design phase. Using "macroscopic" methods in prototype production is deferring difficulties to the future in an undesired way.

Internal vs. External Methods

Excitation can be divided into internal (IEM) and external (EEM) excitation methods. The former relies on forces within the material, i.e. a deformation is generated, while the latter generates displacements via forces between the material and external surfaces. Thus, IEM is most efficient where the deformation-induced stress, and EEM where the displacement, is largest.

IEM usually gives more reproducible characteristics. Examples of error sources are degradation of the material parameters and temperature dependent mounting stress. For EEM, the influence of the surrounding surfaces must also be considered.

Piezoelectric IEM

An electric field pulls negative and positive charges in opposite direction, with a resulting deformation if the material structure is sufficiently asymmetrical. Piezoelectric crystals, such as quartz and $LiTaO_3$, are well suited for micromachining. Non-piezoelectric materials, such as silicon, can be excited by depositing thin films of piezoelectric material, e.g. AlN, PZT and ZnO.

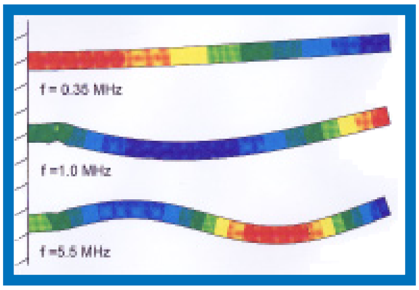
The piezoelectric effect is reversible, which makes it ideal for resonator applications. Piezoelectric low frequency resonators, consisting of a micromachined quartz tuning fork, are found in almost all watches. Applying an AC signal of a few volts generates a resonant vibration with an amplitude sufficient for the material to fracture. The strong anisotropy makes it equally easy to excite shear vibrations piezoelectrically, a concept used in many high-Q resonators intended for frequency control in the MHz-range for telecommunications and computers.

Thermal IEM

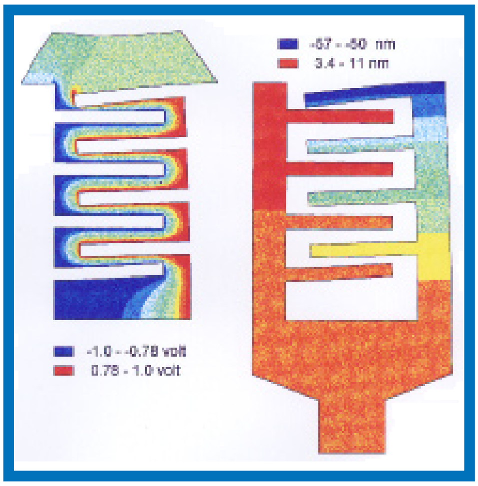
Deformations can be introduced thermally either by varying the thermal expansion coefficient across the material or by creating thermal gradients. The former option is suitable for thin structures of bimorph type while the latter is most efficient for thicker structures. Thermal energy can be introduced in several ways, for instance by an electrical resistance or a laser.

Thermal excitation can be used to excite mechanical vibrations. Small dimensions enable the excitation of MHz frequencies. Recently, SensoNor has announced a new accelerometer based on thermal excitation of a vibrating micromachined silicon beam. They use the piezoresistive effect to locate the desired resonance frequency.

A limitation could be that the mean temperature of the structure is increased due to the added heat energy, with a resulting drift in performance.



Thermally excitation of a 10 µm thick beam as a function of thermal frequency.



Electrostatic excitation of a comb-shaped tuning fork. The electrostatic field is shown to the left and the resulting mechanical deflection to the right.

However, very little heat energy is needed to excite resonant vibrations of small structures.

For semiconductors, strain can also be created by laser-generated electron-hole pairs. This strain can dominate over direct thermal strain at high frequencies.

Electrostatic EEM

The attractive force between electrodes of different voltages becomes stronger if the distance between the electrodes is reduced, which is favorable for MST dimensions. A rule of thumb is that the electrode distance should be below 10 µm.

The force increases with the electrode area. Large electrodes can be created by using plate-shaped or comb-shaped structures. The latter alternative can be used to generate displacements parallel to the electrodes, i.e. displacements not limited by the electrode distance.

Electrostatic excitation has drawbacks due to the inverse dependence of the force on the electrode distance. An avalanche process, electrostatic collapse, can occur since the electrostatic force increases as this force reduces the electrode distance. In addition, the electrostatic force contributes to the mechanical spring constant. A consequence is a sometimes substantial reduction of the mechanical resonance frequencies. For large vibration amplitudes, this reduction depends on the vibration amplitude, i.e. sinusoidal vibrations are distorted.

The electrostatic force is proportional to the dielectric constant. Applying an electric field to a material with a high dielectric constant causes the dielectric material to be squeezed between the electrodes, with a resultant shrinkage in the direction of the field and expansion perpendicular to it. Dielectrics in bimorph structures enable the creation of bending motions.

Magnetic EEM

A magnetic field can generate forces on metals. This is of greatest interest for micromachined structures produced by processes such as electroplating and LIGA.

A magnetic force can also be created by an electric current flowing in a magnetic field. The resulting Lorentz force is more suitable for non-metallic materials, such as silicon. The Lorentz force is perpendicular to the field and the current.

A third way of creating deformations magnetically is to use magnetostrictive alloys. They can expand up to 0.2% in a strong magnetic field. However, such materials are difficult to micromachine. Also, the technology for creating the necessary magnetic field strengths needs to be further developed if a complete micro-solution is to be accomplished.

Trends

Electrostatic and thermal forces are currently the most frequently used means of exciting deflections and vibrations for non-piezoelectric micromachinable materials. Increased use of IEM and internal detection is a notable trend for commercial products. Resonating sensors are also of increasing interest since they usually result in better performance, but at the cost of a more complex design phase.

Jan Söderkvist

SUMMIT Fields of Activity

MICRO REPLICATION	**MICRO FLUIDICS**	**MICRO OPTICS**	**MICRO SENSORS**	**MICRO ACTUATORS**
Matrix fabrication	Channels	Mirrors	Pressure	Positioning
Injection molding	Pumps	Lattices	Flow	Gripping
Electro deposition	Valves	Wave guides	Acceleration	Manipulation
	Nozzles	Lasers	Force	Motors
	Connects	LEDs	Torque	Robotics
		Connects	Temperature	

GENERIC MST	New materials	New sensor and actuator principles
	New technology	Analytical modeling
	New metrology	Numerical simulation

AWARDS

Micro Structure Bulletin is proud to present the following. Congratulations!

IVA

Bertil Hök, an adjoint professor of the micromechanics group at Uppsala University, has been awarded membership in the Royal Swedish Academy of Engineering Sciences (IVA). He will participate in IVA's division on Basic and Interdisciplinary Engineering Sciences, which, for instance, is concerned with questions related to the future of Swedish research. Bertil Hök's involvement in Swedish micromechanics has been, and still is, of great importance to the development of this area.

Innovation Cup

Each year, *Dagens Industri* and *Skandia* organizes an invention contest between university employed researchers in Sweden. In December 1995, Ylva Bäcklund and Carola Strandman, both at Uppsala University, were appointed as winners of the eastern region which includes Uppsala, Stockholm and Linköping. They were awarded for their innovative method of fixing optical fibers in micromachined silicon V-groves with the help of thin etched beams (patent pending). In January, the national winner of the 1995 award will be selected.

MST-based projects from Uppsala University have been awarded before in this competition. In 1989, Bertil Hök and Lars Tenerz were awarded for the intravascular pressure sensor described in *MSB 93:1* and *95:4*, and Lars Tenerz and Jonas Tirén for a micromachined valve.

MEMS at IMC

IMC's activities in the field of micro electro mechanical systems (MEMS) started with the development of a gas flow sensor back in 1989 (then at IM). Since then, these activities have continuously expanded. A MEMS-group was formally established in 1992 and the current size of the group is eight persons.

During the years, the following fields of specialization have crystallized:

- Microsensors and microfluid systems for biotechnical applications
- Fiber optical precision interconnect techniques
- Polymeric microstructures and replication techniques

Usually, the group's projects are carried out on a contract basis together with external industrial customers. In some cases, such projects have resulted in commercial products which have then been produced in small scale by IMC. One example is the gas flow sensor (see *MSB 94:2*), which was manufactured for Swema AB.

Microsensors and Microfluid Systems for Biotechnical Applications

Starting in 1991, IMC has been a supplier of contract R&D in the field of microsensor and microfluid systems to Pharmacia Biotech's exploratory research group. The main theme has been to use design and processing methods borrowed from microelectronics fabrication technology, in order to create chip-based measurement systems for biotechnical analysis.

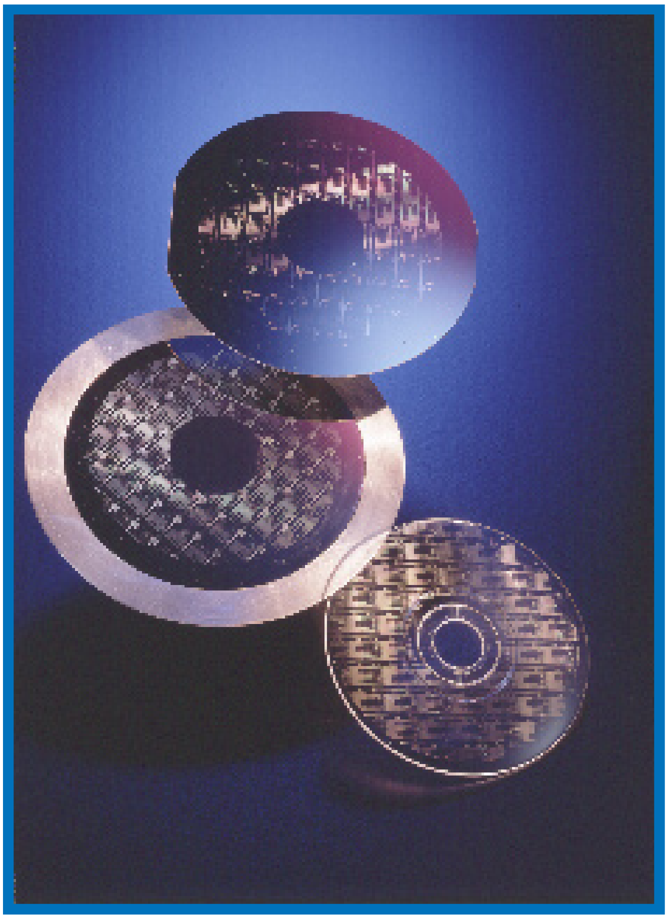
In addition to the accumulation of strategic knowledge at both Pharmacia and IMC, the different projects have resulted in a number of device prototypes such as:

- a microcapillary flow system
- a glucose sensor
- microelectrodes for electrochemistry
- a fluid flow sensor
- a calorimetric microbiosensor
- a refractive index detector
- a microvalve system
- a combination sensor for liquid chromatography applications

The trend is to increase the number of sensors integrated in the same microsystem. A good example is the currently running combination sensor project. The latest version of this micro-analysis system includes sensors for the measurement of seven physical/chemical parameters (pressure, temperature, fluid flow rate, conductivity, pH, UV-absorption and fluorescence) in a single detector cell (see figure).

An unusual feature of many of the sensor chips developed at IMC is that they are made on quartz glass wafers, as opposed to the customary silicon wafers. The UV-transparency of quartz is one advantage as UV-absorption is one of the most important detection principles in biotechnology. Another advantage is the low thermal conductivity of quartz glass which increases the performance of thermally based sensors.

In a recently started project, IMC is developing microstructures to handle samples for rapid DNA sequencing based on single-molecule detection. This project is being carried out in cooperation with the department of Medical Biophysics at Karolinska Institutet.



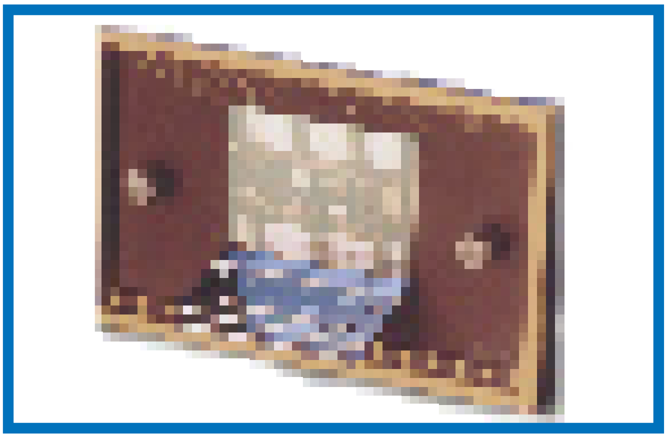
Low cost production process for fabrication of polymeric microstructures (Silicon-Nickel-Polymer). Plastic substrates with waveguide channels for fabrication of 1:4 optical power splitters were injection molded in a state-of-the-art production equipment for CDs (Cycle time about 10 seconds.) The technique is developed in co-operation between IMC and Toolex Alpha.

Fiber Optical Precision Interconnect Techniques

The alignment of small components is a general problem in all fiber optical applications. In single mode systems the needed alignment accuracy is in the order of 1 µm. The perfect silicon crystal offers the possibility to reach this accuracy.

Examples of devices developed at IMC are

- an alignment fixture for fiber fusion splicing
- a mechanical splice for ribbon fibers
- carriers for the passive



The multisensor measures temperature, pressure, flow, conductivity, UV-absorbance, fluorescence and pH.

IMC is supplier of a micromechanical key component in Ericsson's EC4 Fusion Splicer.

alignment of lasers or detectors to fibers

The fixture for fusion splicing has reached the stage of a commercial product and is now sold as part of a fusion splice equipment manufactured by Ericsson Cables (see figure).

Electro Discharge Machining (EDM) is a non-traditional microfabrication technique that is being investigated for fiber optical applications at IMC. EDM is based on the erosion of the material to be machined by means of a controlled electric discharge between an electrode and the material. Compared to conventional etching techniques, EDM makes it possible to achieve improved structures with complex shapes, arbitrary angles and high aspect ratios.

Polymeric Microstructures and Replication Techniques

A promising new technology is to use conventionally micromachined structures as masters for subsequent fabrication of polymeric replicas. In this technique, a metallic submaster is first formed by electroplating on a silicon microstructure. Replication can then be made by injection molding or hot embossing of e.g. polycarbonate, polystyrene or PMMA.

One obvious advantage is the very low cost that can be achieved by making devices in plastic. However, the optical and dielectrical properties of polymers can also be exploited.

At IMC, prototypes for optical alignment structures and waveguide channels for optical power splitters have been fabricated in polycarbonate. Surface smoothness, replication quality, shrinkage and thermo-mechanical properties have been investigated.

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LARGE WAFERS

An international standards working group has decided to set a new wafer standard larger than the current 6 and 8 inches. This joint effort is promoted by the fact that the transition to larger diameter wafers is too costly for one company to sponsor alone.

A likely sizes is 300 mm, but 400 mm has also been mentioned. Today, silicon suppliers are not in a position to produce the quantity of materials necessary for volume production of 300 mm wafers. This means that timing will be a critical issue for both chip manufacturers and the supplier infrastructure.

The advantage of batch processing is obvious since the surface area of a 300 mm wafer equals that of 17,700 2x2 mm^2 components. However, it is not likely that these large wafers will be used for MST-components in the near future. The investment cost in production equipment is motivated only for *extremely* large quantities.

IMC

Industrial Microelectronics Center, or *IMC*, is a young organization with an old history. The oldest employees can still remember the Institute of Microwave Technology (IM) which was situated in the abandoned, and somewhat run-down, premises of a former veterinary school. According to company legend, mice were frequently caught in the clean-room in those days.

In 1987 IM moved to the brand new Electrum building in Kista, Stockholm's high-tech industrial center. At the same time the name was changed to the Swedish Institute of Microelectronics. The new process laboratory in Kista houses a 1000 m^2 clean room which is Sweden's best equipped outside of industry.

In 1993 a large reorganization took place. IM's academically oriented research was mostly transferred to different departments at the Royal Institute of Technology (KTH). The process laboratory was established as a separate unit within KTH.

A large part of IM's staff chose to join the freshly created Industrial Microelectronics Center (IMC), with the mission to "carry out market-oriented, applied research, development, consultancy and small scale production in the field of microelectronics".

Included in the new IMC organization was also the former Center for Industrial Microelectronics and Material Technology (IMM) in Linköping.

At present, IMC is organized into the following application areas:

- Micromeasurement Components
- Advanced Communication Components
- Silicon Carbide Electronics
- Coatings Technology
- Microelectronic Systems
- Technology Transfer and SME

Micromeasurement Components and Advanced Communication Components are the two areas where the MEMS activities are concentrated.

Since its creation, IMC has actually been growing and the number of employees is approximately 60 today.

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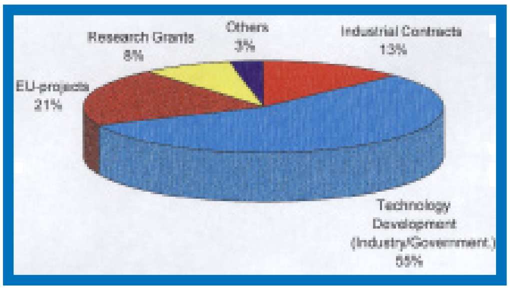
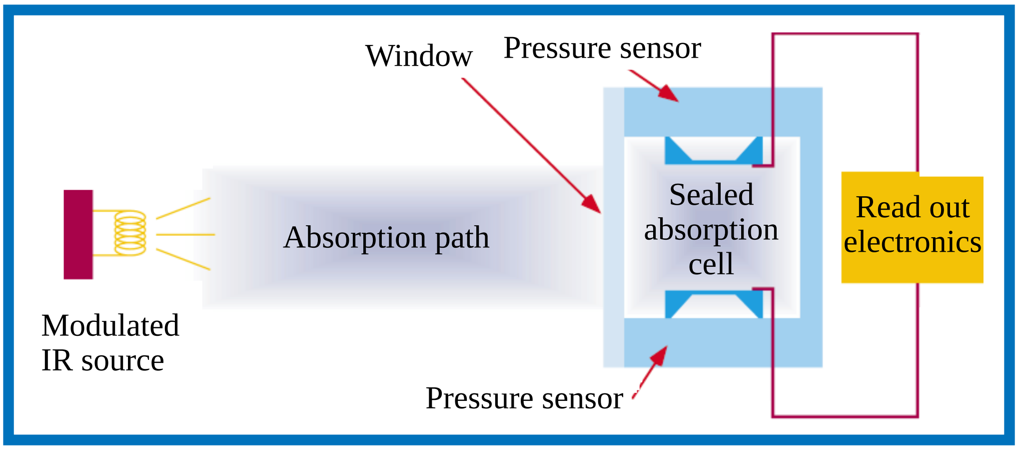


IMC's project structure.

TESS: Development of a Miniature Silicon Photoacoustic Gas Sensor at SINTEF



Schematic drawing of the operation principle of the photoacoustic gas sensor under development at SINTEF.

TESS (*T*otal *E*nvironmental *S*urveillance *S*ensors) is a collaborative project aimed at developing and exploiting advanced sensor technology to improve the competitiveness and environmental performance of European industry in the world marketplace. TESS is a 3 year 5 MECU project commissioned in June 1994 under the European Commission ESPRIT program.

TESS is investigating and developing three advanced sensor technologies which allow complementary aspects of environmental atmospheric monitoring to be addressed:

- OTIM uses an Optical Transform Image Modulation technique for a Gas Cloud Imagery Application
- Semiconductor gas sensors offer the opportunity to monitor gas emissions continuously at the source.
- Photoacoustic technology may be used in both selective point measurements and long path applications.

TESS partners are Capteur (UK), Chelsea Instruments (UK), Endress + Hauser Conducta (D), EDP (P), ICI (UK), Mentec (IRL), Sieger (UK), SINTEF Electronics and Cybernetics (N) and University College London (UK).

The miniature silicon photoacoustic gas sensor is developed at SINTEF Electronics and Cybernetics in Oslo, Norway.

The Photoacoustic Technique

The principle of a photoacoustic sensor is as follows: When a gas is irradiated with light, it absorbs incident light energy proportional to the concentration of the gas. The absorbed energy is immediately released as heat and this causes the pressure to rise. Each gas has a unique IR spectrum, and strong absorption takes place only at certain wavelengths. When the incident light is modulated at a given frequency, the pressure varies periodically at the modulation frequency. This pressure, or sound signal, is measured with a sensitive pressure sensor (microphone).

In a conventional photoacoustic sensor, the gas to be analyzed is pumped into an absorption cell that is sealed by mechanical valves. The cell is irradiated with modulated IR light at the wavelengths at which the gases of interest absorb strongly. This is accomplished by introducing an optical filter between the blackbody IR source and the optical entrance window of the absorption cell.

The TESS Photoacoustic Sensor Concept

A schematic drawing of the operating principle of the photoacoustic gas sensor developed at SINTEF is shown in the figure. Here, the absorption cell is prefilled with the actual target gas and sealed. When modulated IR light is passed into the absorption cell, a photoacoustic pressure signal is generated. If the target gas is introduced in the absorption path outside the cell, a reduction in pressure signal is observed. This reduction is proportional to the concentration of gas in the absorption path.

It is important to note that a pressure reduction is observed only if the gas in the absorption path outside the cell is absorbing light energy at the same wavelength as that inside the prefilled cell. In this way, a high selectivity can be obtained without the use of any additional optical filtering. The gas inside the absorption cell acts as a filter itself.

Another important point is that in a conventional photoacoustic sensor the test gas has to be continuously pumped into and out of the absorption cell. In the concept developed in the TESS project no mechanical pumps or valves are required.

Using this principle, the TESS photoacoustic sensor concept should be easily adaptable by silicon technology, and hence suitable for miniaturization and low cost high volume production.

Current Status of the TESS Project at SINTEF

To test the detection principle, an experimental photoacoustic sensor has been created in stainless steel with conventional microphones to detect the pressure signal. The modulated IR light is generated by a silicon thin film IR source developed at SINTEF Electronics and Cybernetics (see *MSB 94:4*). This test sensor has been used to detect methane down to 5000 ppm and CO_2 down to 10 ppm.

The next step in the project will be to transform the 30 cm sized stainless steel sensor into a 5 mm × 5 mm area silicon chip.

One of the most challenging aspects of this work is the development of an extremely high sensitivity silicon piezoresistive pressure sensor. The pressure signal generated by the photoacoustic process is estimated to be in the order of 1 Pa. To achieve the specified detection limit of the proposed miniature silicon photoacoustic gas sensor (500 ppm for methane and 1 ppm for CO_2), a pressure resolution of 1 mPa is required.

The design, simulation and process documentation for the miniature silicon version of the photoacoustic gas sensor has been completed, and a test fabrication of the pressure sensor is currently running at the silicon laboratory at SINTEF in Oslo. The first prototypes will be ready in the beginning of April 1996.

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CHALMERS KISELDESIGN

Approximately one year ago, a project named *Chalmers Silicon Design* (in Swedish: Chalmers KiselDesign, CKD) was established at the Department of Solid State Electronics (FTE), Chalmers University of Technology. The main purpose of this project was to actively strengthen the possibilities of research, technical development and industrial exchange in connection with activities at FTE. Included are activities related to silicon and silicon-related materials in a broad sense. Consequently, several activities fall within the framework of CKD, ranging from the partial funding of relevant projects to the establishment of regular contacts between the involved companies.

By acting both as a technical and an economical catalyst for broadening the contact areas between the industry-university communities, research results and technical achievements can be made available more quickly. CKD is focusing its tasks primarily towards small and medium-sized enterprises (SME's), although large companies are participating as well.

Financing

The Swedish Board for Industrial and Technical Development (NUTEK) is funding the project for three years. This funding is intended to promote the activities of CKD, for example, a relevant joint industrial participant/FTE-project can be subsidized by this funding. The subsidized level is dependent upon the project, and is determined by the steering committee of CKD. The financing is normally shared on a on equal basis between the participant(s) and CKD.

Projects

During its first year, CKD-funded projects have been split into two main categories. The first category focuses on basic research of phenomena related to industrial applications. For example, anodic bonding of new unconventional bonding materials was investigated. Another example is MecMOS, an attempt to bring micromechanics and microelectronics (read CMOS technology) onto the same chip in an inexpensive way. The latter example is being performed in cooperation with ETH, Zurich, and others. These two projects were judged by the steering committee as being very comprehensive and applicable to a wide range of other projects. Hence, they were 100% financed by CKD.

Projects of the second category are defined in cooperation between one or more industrial participant(s) and CKD. Examples of common purposes are to create electrical and/or mechanical simulations, to produce prototypes or demonstrators of (micromechanical) components, or to improve special silicon processes (process development). In this category, an optical device was manufactured with the help of CKD in the FTE-SILab during the fall of '95. This device will most likely be in serial production during '96. Another example in this category is a process development project spanning over three years with the work split between FTE and ABB HAFO.

The Spirit of CKD

CKD is working in close cooperation with industrial participants and Chalmers in various projects involving silicon technology and related areas at FTE. This includes micromechanics as well as microelectronics. Within CKD, the participants are cooperating together instead of having the traditional customer-supplier relationship. As a result, several activities between industrial partners in areas outside CKD have started. CKD is truly a catalytic forum for increased cooperation.

In future issues of *MSB*, some of CKD's projects will be presented more in detail.

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DISSERTATIONS

MSB congratulates Peter Enoksson on successfully having defended his work for the degree of Licentiate of Engineering on December 14 at the Royal Institute of Technology (KTH). His work focused on the development of a micromachined density sensor for fluids, as suggested by the title of his thesis: *Fluid Density Sensor based on Resonance Vibration*. The principle of the sensor was presented in *MSB 95:2*. Reducing the size of conventional tube-based densitometers enables the sample volume to be reduced since the liquid whose density is to be measured is contained within the structure instead of surrounding it. Using mono-crystalline silicon enables a high Q-value and reduced manufacturing costs.

PUBLICATIONS

Some MST-related results published during the last months:

- Equivalent-Circuit Model of the Squeezed Gas Film in a Silicon Accelerometer; T. Veijola (Helsinki U. of Techn.), H. Kuisma, J. Lahdenperä and T. Ryhänen (Vaisala Techn.); *Sensors and Actuators* A, **48**(3) (1995) 239–248.
- Fabrication of 45 degree Mirrors Together with Well-Defined V-Grooves Using Wet Anisotropic Etching of Silicon; C. Strandman, L. Rosengren (UU), H.G.A. Elderstig (IMC) and Y. Bäcklund (UU); *IEEE J. of Microelectromech. Systems*, **4**(4) (1995) 213–219.
- Fluid Density Sensor based on Resonance Vibration; P. Enoksson, G. Stemme (KTH) and E. Stemme (CTH); *Sensors and Actuators A*, **47** (1995) 327–331.
- Fluid Density Sensor based on Resonance Vibration; P. Enoksson (KTH); Licentiate thesis, *TRITA-ILA 95–02* (1995).
- Heavy Ion Induced Etch Anisotropy in Single Crystalline Quartz; K. Hjort, G. Thornell, R. Spohr, J.-Å. Schweitz (UU); *Accepted to the IEEE MEMS '96 Workshop*, San Diego, Feb. 11–15, 1996.
- Mikromekanik; J. Bay (MIC); *Kvant*, **6**(4) (1995) 15–22.
- Mikrosystemteknik – en översikt kring grunder och tillämpningar, L.-K. Sidén (IVA), *Framsteg inom Forskning och Teknik 1995*, Ingenjörsvetenskapsakademiens årsbok 1995, 7–25.
- Neural Networks and Abductive Networks for Chemical Sensor Signals: a Case Comparison; V. Sommer, P. Tobias, D. Kohl (IAP, Germany), H. Sundgren and I. Lundström (LiU); *Sensors and Actuators* B, **20**(3) (1995) 217–222

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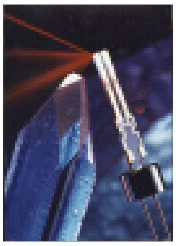
NEXT ISSUE

Some topics covered will be:

- The material quartz
- A quartz angular rate sensor (gyro)
- Quartz production at Quartz Pro AB



MSW '96
Call for Contributions

The second Nordic Micro Structure Workshop will be held in Uppsala on March 26–27, 1996. The purpose of *MSW* is to stimulate the use of Micro Structure Technology and to bring together informally those interested in MST. The aim is to make *MSW '96* as successful as *MSW '94* and *MSK '95*.

The program consists of 22 oral presentations and a poster session. Three of the presentations are given by the invited speakers Nicolaas F. de Rooij, Switzerland, Matthias Müllenborn, Denmark and Martin Nese, Norway.

Additional poster contributions are welcome until early March. One late news contribution will be accepted as oral presentation. For more information, please contact Jan Söderkvist (Fax and address listed in the editorial column).

MSB subscription (✉ or ✂)?

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FUTURE EVENTS

MSW '96 (Micro Structure Workshop), Uppsala, Sweden, March 26–27, 1996. See separate note.

Optical Microsystems for Telecommunication (course), Uppsala, Sweden, May 20–21, 1996. For information contact: FSRM, Fax: +41-38 200 990, or Ylva Bäcklund, Fax: +46-(0)18-55 50 95.

50th IEEE Int. Frequency Control Symposium, Honolulu, USA, June 5–7, 1996. For information contact: Synergistic Management Ink., Fax: +1-(908) 681-9314.

Actuator 96, Bremen, Germany, June 19–21, 1996. For information contact: Dr. H. Borgmann, Fax: +49-421-17 16 86.

Eurosensors X, Leuven, Belgium, September 8–11, 1996. *Abstract deadline: March 15, 1996.* For information contact: Timshel Conference Consultancy & Management, Fax: +32-16-29 05 10.

MME '96 (MicroMechanics Europe), Barcelona, Spain, October 21–22, 1996 (preliminary). For information contact: Dr. J.R. Morante, Fax: +34-3-402 11 48.

μTAS'96 (Micro Total Analysis Systems), Basel, Switzerland, November 20–22, 1996. *Abstract deadline: March 15, 1996.* For information contact: Mrs. E. Müller, Ciba Geigy Inc., Fax: +41-61 696 45 04.

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