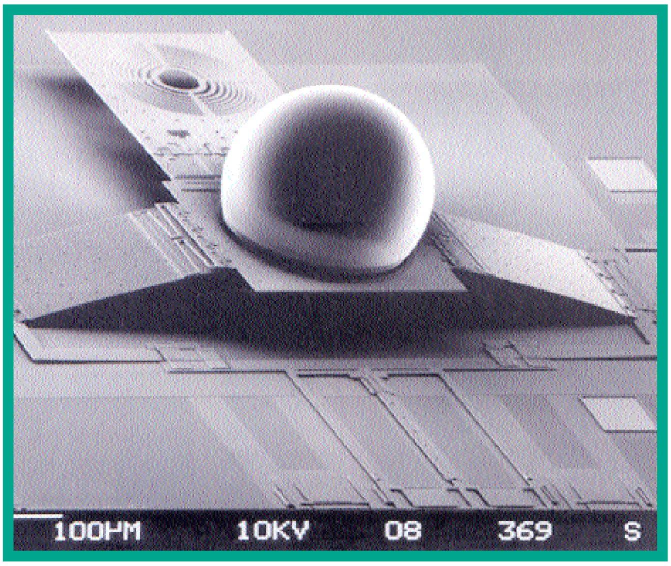
MICRO STRUCTURE BULLETIN

Newsletter for Nordic Micro Structure Technology, Vol.6, No.2, May 1998

MSW '98



SEM micrograph of a self-assembled micro-XYZ stage with a micro-ball lens for optical scanning and alignment. This MSW-related photo illustrates the theme of this MSB-issue: optics. Courtesy to Li Fan and Ming C. Wu, Dept. Electrical Engineering, UCLA, U.S.A.

Micromachining was introduced in Scandinavia over 15 years ago in both industry and research. Thereafter, the research activities have expanded steadily and several centers and programs related to micromachining now exist.

For industry in general, micromachining is still considered as a novelty. Yet, SensoNor and VTI Hamlin are two success stories which show that it is possible to base an industry upon micromachining. In addition, there are a limited number of smaller companies that use micromachined parts as key components in some of their products, but the quantities are too small for them to perform the micromachining themselves.

With this in mind, it has been very stimulating to see the increased industrial interest at the *Micro Structure Workshops* that are held in Uppsala every other year. At *MSW '94*, industry participated predominantly as observers. At the recently held *MSW '98*, the industrial participation was noticeably more dynamic, accounting for 41% of the 117 participants while 45% came from universities. In addition, industry co-authored 13 of the 27 oral presentations. There is a clear trend that industry now is taking the step from observers to users of micromachining.

MSW '98 was very well received by the participants. The possibilities to form new contacts, to learn who is who, and the informal atmosphere were well appreciated elements. The program was well balanced, containing presentations ranging from overviews to project presentations, from process steps to devices, and from multiple applications including medical, automotive and space. The three invited speakers, H. Baltes (ETH Zürich, Switzerland), A. Boisen (MIC, Denmark), and H. Kuisma (VTI Hamlin, Finland), all included industrialization aspects in their presentations. Questions from the attendees also showed that there was a notable interest in how to successfully industrialize micromachining.

Several speakers pointed out that it is possible to enter the field of micromachining without having your own micromachining lab. Concentrating on system aspects, electronics and packaging while outsourcing the micromachining can be a very attractive approach.

Two posters were awarded: Arvi Kruusing *et al* from Tallinn Technical University, Estonia, presenting magnetic microdevices, and Thierry Corman *et al* from KTH discussing encapsulation aspects of resonant structures.

More information can be found in the workshop proceedings (see page 7). The fourth *Micro Structure Workshop* will be held in the end of March in the year 2000. Also, look out for *MSW*-related activities held before then. See you at the next *MSW*.

Jan Söderkvist
Coordinator MSW

CONTENTS

EDITOR'S NOTE

MSB is targeted at readers in all Nordic countries. It is important that you, as a reader, feel that *MSB* addresses your interests independent of if you live in Denmark, Finland, Norway or Sweden. A major change in the editorial board has been made to better cover MST-related activities in all four countries. Welcome Siebe Bouwstra, Anders Hanneborg and Ari Lehto.

It was a pleasure to be responsible for *MSW '98*. I have very much appreciated the many positive comments from the record number of participants. Without the invited speakers, regular speakers and poster presenters it would not have been possible to create *MSW*. Thank you all.

The large interest in *MSW* has triggered discussions of how *MSW* better can function in a Nordic perspective. The target is to further stimulate the establishment of contact networks between the MST-actors in our countries without *MSW* loosing its local profile. This initiative follows the trend that the MST-area is becoming very international.

The next *MSB* issue will feature two new series of articles. Application areas will be presented from the user's point of view, and process equipment used for micromachining will be presented. Your input is highly appreciated.

Jan Söderkvist

VTI Hamlin Growing, From Lab to Fab

VTI Hamlin's new factory, FAB 2, in Vantaa, Finland was completed just before the end of 1997. At present, the needed equipment has been hooked up and installed and the 6” process ramp up has been started.

VTI Hamlin's new FAB 2 is a unique sensor FAB, that has been designed for the optimum processing of micromachined silicon capacitive sensors. The total area of the FAB 2 building is 11,700 m^2 of which 3,000 m^2 is cleanroom. The infrastructure and facilities have been planned to support 6” wafer manufacturing with production up to 50 million acceleration, pressure or yaw rate sensing elements annually. By the end of the first phase in September 1998, FAB 2 will be equipped with sufficient process equipment to support an annual production of 10 million sensing elements.

Even the building resembles a capacitive silicon sensing element.

The factory planning started in the summer of 1996, and the formal decision to build a greenfield factory was taken by BREED Technologies, Inc. in October 1996. An extremely hectic phase with parallel detailed planning and implementation of the factory infrastructure and process followed. Despite a very tight schedule, or perhaps because of it, the factory project has been on schedule and within budget. It is successfully marching to meet the ultimate goal of validated sensing element production by September 1st, 1998.

Substantial emphasis has been put on the manufacturing simulation of the process. This is mainly for two reasons: first to have a good holistic understanding of the complex production system before implementation, and second to have a visual model which makes it possible to benefit from existing operator experience and know-how to support optimum factory design.

The basis for the factory planning and layout was to simplify the complicated cyclical flow of the semiconductor processes and to maximize the visual control of production. This resulted in the world's first octagonal class 10 lithography area surrounded by class 100 process and class 100 000 grey areas.

The air flow is from a suspended plenum, through the lithography and processing areas, and returned back to the air handling units via the grey area. To support the simple flow target an abundance of feed-through cabinets have been installed in the octagonal walls. To support visibility, the maximum amount of glass has been used in the clean room walls. As an outcome of these goals, the superior new clean room structure supports short throughput times, which allows for rapid learning leading to excellent yields and good productivity.

With the new FAB 2 factory, VTI Hamlin Oy, and its 180 employees are ready to meet the challenges of the 21st century and become one of the leading producers of silicon capacitive sensors.

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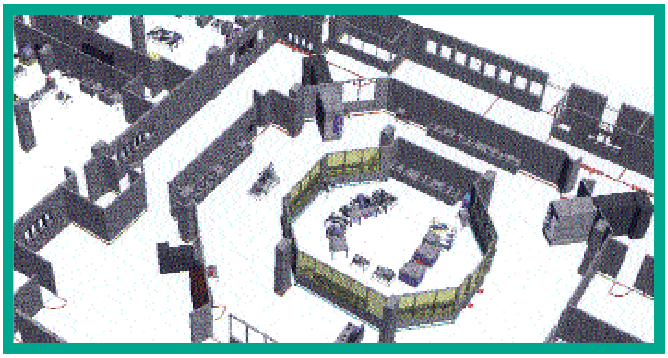
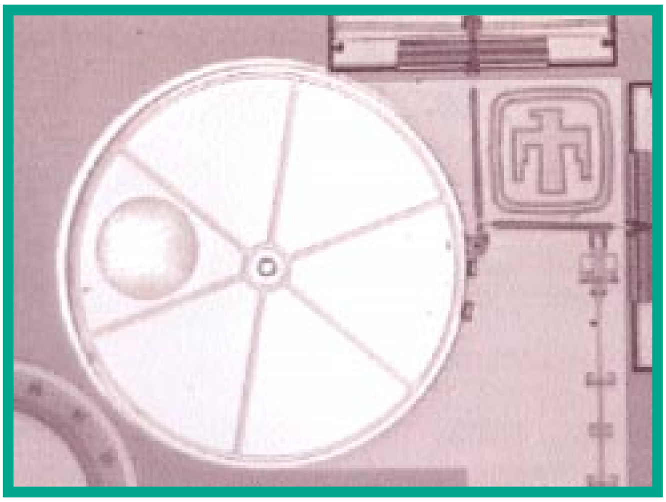


Part of VTI Hamlin's FAB 2 with the octagonal class 10 lithographic station in the center.

Micromachining Basics Part 11:

Micro Opto Electro Mechanical Systems

Micro opto electro mechanical systems (MOEMS) is a rapidly evolving branch of the microstructure technology tree.
It involves optical MEMS in various applications, such as communication networks, interconnections, displays, scanning probe microscopy and sensors.



Top view of a metallized shutter with a VCSEL beam visible through a hole in the shutter. Complements to Sandia National Laboratories, Intelligent Micromachine Department, NM, U.S.A. (http://www.mdl.sandia.gov/Micromachine).

MOEMS vs. MEMS

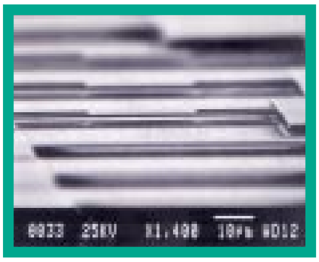
I personally use the more 'fundamentalistic' definition that MEMS include mechanically active microstructures. Therefore, I do not include microstructures like lenses, diffractive optics, microstructured carriers for passive alignment, and integrated optoelectronics *if* these structures are not integrated with micromechanically active parts. However, for many people microstructures for passive alignment and assembly is the largest field of MOEMS. For more information on mechanically non-active microstructures for micro optics, see *MSB 94:3, 94:4, 96:3, 97:5,* and *98:1*.

The special design and technology issues in MOEMS compared to MEMS are obviously the optical qualities of the microstructure, e.g., regarding surfaces and transmittive layers. MOEMS micromachining can often be adopted directly from microoptics and optoelectronics, for example, from the micromachining of disc lasers or diffractive optics. The step from optoelectronics and microoptics to MOEMS is, in general, much smaller than from silicon based IC electronics to MEMS.

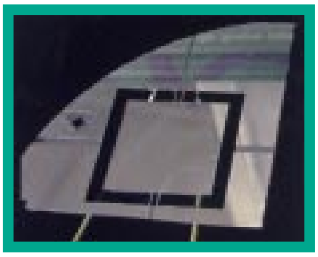
The recent progress in the mechanical characterization and modeling of CMOS-build surface micromachined structures has resulted in useful tools that enables a rapid progress in MOEMS. This is especially true for high precision micro-opto-mechanics, as indicated below. As an example, ETH in Zürich, Switzerland, is very active in this area.

III-V Based MOEMS

For optoelectronics such as lasers and photodiodes, III-V semiconductors are currently dominating due to their direct bandgap, and the development of the excellent substrate materials GaAs and InP. When optoelectronics are integrated with optical MEMS, III-V based MOEMS have a good chance of enabling low-cost alternatives to the currently dominating III-V hybrids based on silicon technology.



Tunable flexural membrane of InP for a WDM filter. It is made within the ESPRIT 'MOEMS' project in collaboration with the Dept. of Electronics, KTH. The suspended mirror plate is 30 x 20 µm.



Resonant piezoelectrically driven large mirror for distributed image projection from a linear scanner directly to the eye. The project was a collaboration between Uppsala University and Celsius Tech Electronics AB, within SUMMIT.

Uppsala University (UU) is participating in a European ESPRIT project called *MOEMS*. The goal is to develop a highly selective Fabry-Perot monochromator integrated monolithically with an InP based photo diode. UU is now developing advanced mechanical characterization methods and opto-electro-mechanical models to enable precision design. The results are experimentally verified using techniques such as residual stress distributions and Weibull statistics on mechanical strengths. The surface micromachined optical cavity of the monochromator sets requirements in the Ångström range for the bending, positioning and parallelity of the surrounding mirrors. Modeling and mechanical characterization have shown to be of absolute necessity.

MOEMS Trends

Recently, a new workshop series was initiated on MOEMS with biannual meetings at the *LEOS Summer Topical Meetings* in the U.S.A. and biannual workshops hosted by Europe and Asia. The latest meeting, *MOEMS'97*, was held in Nara, Japan on Nov. 18–21, 1997. With close to 200 participants, the workshop had a pleasant atmosphere and a large number of the world leading groups represented.

At *MOEMS'97*, I particularly noted the new generation of digital pixel chips for projection screens, long distance strong micro actuators for auto focusing, and the many telecom switches. Marvels of technology shown include the 3D structured xyz-table for ball lenses shown on the front page, and the optical lock fabricated by four-layer surface micromachining shown on this page. The next meeting will be held at the *LEOS Summer Topical Meetings* in Monterey, CA from July 20–24, 1998.

As is the case with structured carriers for passive alignment, the largest part of research and manufacturing for bulk silicon technology is related to MOEMS. A good example of a successful new study in this field is the piezoelectrically resonant driven, large optical mirror made at UU within SUMMIT which was recently presented in Uppsala at *MSW '98*. In this project, mechanical modeling has once again been used to enable precision design.

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Fiber Optic Sensors

Over the last two decades fiber optic sensors have demonstrated an almost explosive growth in the number of published papers. The possibility of combining integrated optics and micromechanics contribute to the increased interest.

Fiber optic sensors are known to have many advantageous features, including:

- immunity to electromagnetic interference (EMI)
- light weight, low loss (< 0.2 dB/km) transmission lines
- large bandwidth
- electrical isolation
- no spark or fire hazards

Despite these advantages, only a few fiber optical sensors have made their way from ideas and feasibility projects to commercially available products. Some complications are cost, alignment requirements for optical fibers, and temperature and vibration induced intensity and phase noise.

Modulated Optic Sensors

Fiber optic sensors are often categorized as based either on intensity or on phase modulation (see Figure 1). Generally, the first type is based on the measured parameter affecting the optic transmission or the coupling losses. These sensors are usually associated with simplicity and low cost.

Phase modulated sensors, on the other hand, are generally based on interferometry. This often results in high accuracy and a large dynamic range at the expense of a higher cost since more complex electronics is needed.

For accelerometers, TAKAOKA, Japan, is the only supplier utilizing fiber optics, to our best knowledge. Their accelerometers, originally developed by ASEA (see *MSB 94:3*), are based on intensity modulation. The general principle of intensity modulated accelerometers is illustrated in Figure 1a. The amount of light coupled between the two waveguides will change when a seismic mass moves in response to an acceleration perpendicular to the substrate.

Figure 1b shows a high resolution phase modulated accelerometer based on a Fabry-Perot interferometer. The interferometer consists of two mirrors separated by a small air gap.

The two accelerometer designs shown in Figure 1 are similar to designs used in silicon electrical accelerometers. By incorporating strain sensing resistors into the bending beams, typical piezoresistive accelerometers are created. Replacing the two parallel mirrors in Figure 1b with electrodes transforms this sensor into a capacitive accelerometer.

Bragg Gratings

New techniques for the direct writing of Bragg gratings in optical waveguides using interfering UV laser beams will have a great impact on both high-bandwidth communications and distributed sensing. Bragg gratings used in wavelength-division multiplexers, demultiplexers, dispersion compensating elements, fiber lasers and optical sensors are believed to likely play a key role in the formation of multibillion-dollar markets within the next 5–10 years.

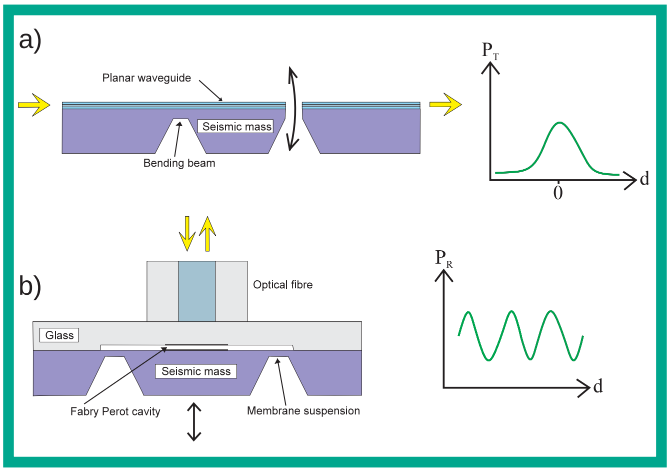

Fig. 1. Optomechanical accelerometers based on a) intensity and b) phase modulation. P_T and P_R represent the variation in intensity of transmitted and reflected optical light, respectively, as a function of deflection, d, of a seismic mass.

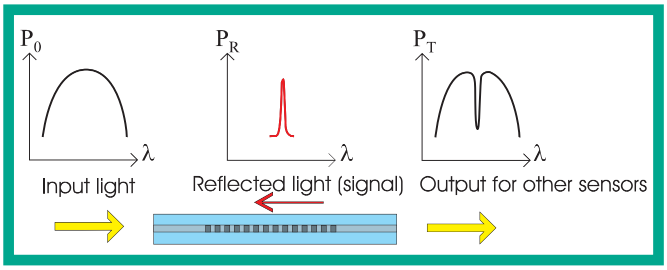

Fig. 2. Operation of a Bragg grating wavelength filter written in an optical waveguide.

The operation of a Bragg grating wavelength filter is shown in Figure 2. The grating reflects light with a wavelength equal to twice the grating period times the refractive index of the waveguide. Mechanical compression and stretching of the waveguide will modulate the filter wavelength. Sensors sensitive to longitudinal strain can thereby be developed.

The major advantage of wavelength encoding sensors is that the signal, being a wavelength (a color), is insensitive to typical intensity and phase noise. New decoding systems capable of measuring dynamic wavelength shifts with surprisingly high resolution are making Bragg grating sensors even more attractive.

Bragg grating sensor elements can be connected in series if they have non-overlapping reflection wavelengths. Internal strain fields in aircraft wings and bridges can thereby be mapped with high localization and accuracy since optical fibers are easily embedded into materials such as composites and concrete.

Commercialization

Why do we see so few optical sensors on the market? In most cases it is not due to the market being conservative. Instead, the special benefits of optical devices will not be fully appreciated until price and performance are competitive to that of standard electrical devices.

Sensor systems based on Bragg gratings may change the situation. Light sources and systems for wavelength demodulation are continuously being improved, and we still have not seen the limits of this technology. Also, the telecommunications industry is working hard on finding cost-efficient ways of attaching optical fibers to waveguides.

The Bragg sensor elements' price would mainly be determined by packaging and fiber attachment if using batch fabrication. The system's price would be dominated by the light source and the wavelength demodulation devices. The price is expected to fall to a competitive level since the market for the needed sub-components is developing rapidly.

Conclusion

The combination of micromechanics and integrated optics enables precision fabrication of optomechanical sensors. The recent development of techniques for the direct UV writing of Bragg gratings in optical waveguides may result in the final breakthrough for optical sensors. From being limited to niche markets, the demand for optical sensors is predicted to intensify due to their unique performance at competitive prices.

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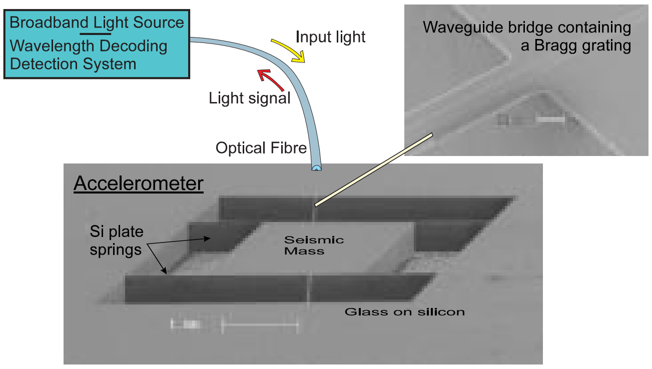
A Bragg Grating Based Accelerometer

Work on a new approach to fiber optic accelerometers has been carried out in a collaboration between Brüel & Kjær and the Microelectronics Center (MIC). Technologies for the fabrication of optomechanical accelerometers based on strain sensing Bragg gratings in planar waveguides were developed.

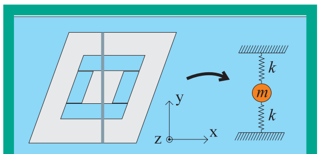
By anisotropic etching of (110) oriented silicon an accelerometer structure was obtained. A seismic mass (4 mg) is suspended by four thin plate springs providing a uniaxial accelerometer. On top of the structure a planar waveguide connects the seismic mass and the frame through 1 mm long bridges.



Accelerometer based on strain sensing by a Bragg grating in a planar waveguide. The skew shape of the frame and seismic mass is due to the use of (110) silicon wafers.

When the accelerometer is subjected to acceleration along the sensitive axis, the waveguide bridges experience compression and tension, respectively, in a push-pull mode. By locating a 0.8 mm long strain sensing Bragg grating into one of the bridges, an optomechanical accelerometer is created.

The necessary materials technology for producing the device included KOH etching of (110) oriented silicon and low tensile stress PECVD glasses for the fabrication of silica-on-silicon based planar waveguide bridges. For the waveguide core a new germanium and nitrogen doped photosensitive silica glass was developed. Using UV light, permanent Bragg gratings were written in planar waveguides based on the developed glasses. However, to realize a complete functioning device there still remains the task of writing a Bragg grating in an accelerometer structure and the attachment to an optical fiber. Our calculations indicate potential µg resolution and a dynamic range exceeding 130 dB. The weight of a packaged device is expected to be below one gram.



Modeling of accelerometer

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Center for Microinstruments @ DTU

At the Technical University of Denmark (DTU) in Lyngby, the Centre for Microinstruments (CfM) has recently been established. CfM is a collaboration between the Department of Information Technology and the Microelectronics Center (MIC), and is headed by professor Jørgen Staunstrup. CfM and its associated graduate school are supported by, among others, a range of Danish companies.

The research activities of CfM focus on:

- Computer Aided Engineering (CAE) for micromechanical transducers
- smart transducers: design of sensors and actuators with integrated signal processing
- low power design for digital signal processors

Tools and technologies developed will be demonstrated in two main applications:

- system level design of transducers, interfaces and digital circuitry for hearing aids
- topology optimized microactuators

Within the framework of CfM, the course ‘*CAD tools for Microsystems*’ is held in the second quarter of 1998, and a series of seminars ‘*Microinstruments*’ is given in early July. Responsible for these activities will be guest professors S. Crary and K. Najafi, respectively, both from the University of Michigan, U.S.A.

CfM continuously has opportunities for guest students, grants for PhD education, and postdoctoral positions. For more information, contact:

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Stacking Technology for Smart Transducers

New packaging concepts allow for the tight integration of electronics, sensors and actuators

Microtronic A/S, Denmark, the leading European manufacturer of hearing instrument components, and Balteadisk SpA of the Olivetti group, Italy, the largest European ink jet print head manufacturer, are joining forces to promote silicon technology for smart sensors and actuators. The consortium, consisting of the two companies, the two research institutes MIC, Denmark, and CEA-LETI, France, the test and design house, DELTA, Denmark, and the silicon foundry CSEM, Switzerland, started the HISTACK project in November 1997. It is funded by EC through the ESPRIT program.

The objective is to develop a generic concept for integrating transducer functions, such as sensing sound and dispensing ink, and high-performance ASICs. The focus will be on the stacking of silicon chips, much like a multi-chip module (MCM) used in memory and telecommunication devices. The advantages of such a system are its minimum volume, which is important for a space-constrained system, and its high level of integration allowing the electronics to be close to the action in a smart system. Furthermore, the concept provides the possibility of combining different technologies and to protect the system more efficiently against harsh environmental conditions.

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Poling of Glass

Glass is a material known to man for thousands of years. Generally, glass and glass-based components are used in optics passively, for example for light transmission (i.e. fibers), redirecting beams (i.e. lenses), and the separation of spectral components (i.e. prisms).

New and surprising recent discoveries are bound to widen the use of glass in optics into active applications as well. In analogy with electronics where transistors and diodes are active components that allow for the switching and modulation of an applied electrical input, research is being carried out worldwide to make possible the use of glass and glass fibers as an optical modulator. This would have a great impact in telecommunications. The same properties as needed for modulation allows glass to be used for converting infrared radiation into visible light and other useful applications in displays, optical memories and laser technology.

Glass Made Non-amorphous

These new discoveries are based upon various ways of recording a strong permanent electric field in the glass material. The physics behind this recording is still under investigation in various laboratories, but under the influence of this electric field glass no longer behaves as an amorphous material, and can gain a strong optical nonlinearity.

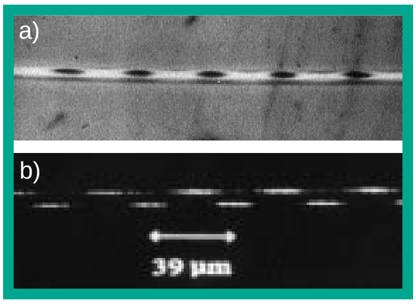
It is known that upon illumination with an optical beam that the movement of electrons in this nonlinear material is not symmetric and harmonic as is the input radiation. This make it possible, for instance, to double the frequency of the input light. By externally controlling the effect of the nonlinearity it is possible to switch and modulate light in an optical fiber.

Poling

It has been discovered unexpectedly that it is possible to record an electrical field as large as ~10^9 V/m by heating glass to ~300°C while applying a few kilovolts to the sample through a process called poling. Earlier, it was discovered fortuitously that even without the application of an external electric field that an optical fiber illuminated for minutes to hours by two very intense beams at frequencies ω and 2ω could be permanently modified to generate radiation at frequency 2ω when excited again only with frequency ω. Ultraviolet radiation has also been used as an excitation means for poling glass and optical fibers, so that an electric field is engraved.

While studying such systems it was further found that silica glass treated with hydrofluoric acid has an etching rate that is altered depending on the strength of the electric field present. Micro-features on fibers with a period of 39 µm have been seen, and could potentially be designed and patterned in glass disks using this selective etching technique.

Under the extreme electric fields recorded it is also likely that glass could suffer mechanical alterations such as compaction, and this too could perhaps one day lead to new applications.



Second-order nonlinear gratings in frequency-doubling fibers revealed by etching; a) phase-contrast optical micrograph, b) fiber showing alternating field polarity grating on the top and bottom of the fiber.

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Miniature Lasers and Micro-Structured Nonlinear Optics at KTH

The Physics Department at KTH in Stockholm has a research group headed by Fredrik Laurell which works on miniature lasers and micro-structured nonlinear optics. The typical minilaser consists of a 1 mm thick laser crystal placed together with one or more functional elements in a laser cavity with a total length of less than 3 cm. It is pumped with a diode laser and converts its rather incoherent low quality beam into a high quality Gaussian beam.

The functional element can be a Q-switch crystal which inhibits lasing for some period of time during which pump energy is accumulated in the laser crystal. When the Q-switch changes into the transmitting state all of the accumulated energy is released in a short pulse with a very high peak power.

This system can also incorporate a nonlinear element which shifts the color of the laser. Of particular interest are the so called periodically poled crystals in which gratings of orthogonally oriented ferroelectric domains with periods of a few micrometers have been produced. The period of the grating is chosen to generate specific wavelengths of light. These new lasers can be tailored for applications such as range finders, environmental sensors, laser displays, materials processing, and many others.

The glass work is directed towards cheap active components primarily to be used in telecommunications and sensing, and is described in the article above.

The KTH-group deals with the following topics:

- *miniature lasers*
  - micro-chip lasers for range finder applications (2 industry PhD students)
  - quasi-three level lasers (1 PhD student)
  - eye-safe micro-chip lasers (1 PhD student, 1 post-doc)
- *micro-structured nonlinear materials*
  - periodically poled ferroelectrics with applications (2 PhD students)
  - poled glass- bulk, waveguides, and fibers (1 visiting professor)

The above work is done in close collaboration with the Institute of Optical Research (IOF).

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MEMS’98

Nordic Authors on the Front-Line

Five days of exiting news from the *MEMS* community. The most recent results, the bravest designs, promising new methods, and impressive video recordings competed to interest us. The occasion, of course, was the 11th annual international workshop on micro electro mechanical systems, or *MEMS’98*, held in Heidelberg, Germany, January 25–29 1998.

The single session format of this workshop helped to widen horizons. Fourteen sessions boasted fifteen topics, all within our main field of interest, *MEMS*. Out of 313 submitted abstracts, 117 were accepted, 51 for oral presentation and the remaining as posters. More than 600 attendants from all over the world made new contacts and experiences. This made *MEMS’98* a memorable event.

The Nordic presence in Heidelberg was apparent. Six prominent contributions to the proceedings were made by Nordic authors.

H. Björkman *et al*, Uppsala University, presented a new technology for the production of diamond replicas from silicon masters. A thick film of diamond is grown on microstructured silicon by hot filament chemical vapour deposition. The silicon is then sacrificially etched, leaving diamond of the desired shape. Suggested applications are microfluidics, building-sets and polymer molding.

T. Ebefors *et al*, KTH, presented a three-dimensional silicon triple-hot-wire anemometer for turbulent gas flow measurements. A polyimide joint is used for the out-of-plane wire which is perpendicular to the two others located in the wafer plane. This micro-joint is self assembled by thermal shrinkage of polyimide in V-groves.

M. Heschel (MIC) *et al* presented a stacking technology for the integrated packing of a transducer and an integrated circuit chip. The transducer and circuitry are stacked on top of each other, with the chip in between. The assembly is done by flip chip solder bump bonding and conductive adhesive bonding.

E. Kälvesten (KTH) *et al* presented a device for CO_2 concentration measurements. The sensor is based on the absorption of infrared light. It uses silicon IR-sources and has CO_2 chambers for calibration. The application is the measurement of respiratory gases during anaesthesia or intensive care.

E. Kälvesten (KTH) *et al* presented a sensor for blood pressure measurements. The device is micromachined from polysilicon and has a piezoresistive gauge. It is used clinically for intravascular pressure measurements in balloon angioplasty applications.

G. Thornell (Uppsala University) *et al* presented micromachining by ion track etching, MITE. This technology allows for the deep and vertical etching of insulating materials. It is accomplished by introducing damage in the material by swift heavy ions. This method eliminates the constraints of anisotropy in materials such as single crystalline quartz. It can also be used in materials lacking crystallinity, e.g. glass.

A notable trend over the last several years is that there has been an increasing interest in microstructures and their applications at the *MEMS* workshop. Thus, the next workshop will be an actual conference: the 12th annual International Conference on Micro Electro Mechanical Systems, *MEMS’99*. See you in Orlando, Florida!

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Dissertations

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

Arvi Kruusing, Tallinn Technical University, Estonia

In his Dr.Eng. thesis, *Magnetic Microdevices and Their Fabrication Methods*, the problems in theory and fabrication of some novel electromagnetic devices with permanent magnets, which are convenient for microfabrication, have been considered.

The first chapter presents the theory, design and experimental results of two novel permanent magnetic devices. The first one consists of a thin, flexible, permanent magnetic beam. If subject to an alternating magnetic field, the beam excercises oscillating deformations which are used for pumping fluid and fluid flow sensing. In the second device, grooves are formed into the surface of a permanent magnetic plate, which induces a lateral magnetic induction component at the surface. This device is used for force generation in a printed coil, which is wrapped into a box and mounted above the magnetic plate.

The second chapter contains a review of NdFeB magnet microfabrication technology with emphasis on laser processing methods, e.g. laser ablation deposited NdFeB films on silicon.

In the third chapter, some investigations using laser processing experiments are described.

Pelle Rangsten, UU

His Licentiate thesis, *Microstructure Technology in Quartz and Silicon*, summarizes the two most commonly used materials in microstructure technology (MST), quartz and silicon, from the authors point of view. Etching and bonding are two key technologies in their processing, and the thesis is therefore focused on these two microstructure fabrication techniques.

In addition to presenting several new results, the thesis also includes an introduction to the field of MST, a background of crystal structure and wafer fabrication, and a comparison of material properties for silicon and quartz.

MSW ’98 PROCEEDINGS

Did you miss the third *Micro Structure Workshop* that was held in Uppsala on March 24–25? There is a 190 page long proceedings in English. It covers all of the 27 oral presentations and four of the poster presentations. If you want your own copy, please contact Colibri at the address given on the next page. It can also be ordered directly by paying 240 SEK* per proceedings to the “postgiro” account 85 78 66-8 (Colibri Pro Development AB).

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FUTURE EVENTS

NANO '98, Stockholm, Sweden, June 14–19, 1998. For info.: NANO'98, KTH
Fax: +46-(0)8-790 90 72
www.kth.se/conferences/nano98

MMC/KTH Joint Seminar on Micromachines, KTH, Stockholm, June 15, 1998. For info.: P Enoksson, KTH
Fax: +46-(0)8-10 08 58
www.s3.kth.se/instrlab/seminar

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

Eurosensors XI, Southampton, United Kingdom, Sept. 13–16, 1998. For info.: Univ. Southampton
Fax: +44-1703-595791
diana.ecs.soton.ac.uk/~aht/EurosensorsXII/

The Challenges of Microsystems Technology (course), Copenhagen, Denmark, Sept. 17, 1998. For info.: FSRM
Fax: +41-32 720 09 90
www.fsrm.ch/

Micro Devices for Fluid Handling (course), Stockholm, Sweden, Sept. 28–29, 1998. For info: FSRM
Fax: +41-32 720 09 90
www.fsrm.ch/

MEMS '99 (Micro Electro Mechanical Systems), Orlando, U.S.A., Jan. 17–21, 1999. *Abstract deadline: Sept. 14.* For info.: Preferred Meeting Management, Inc.
Fax: +1-(619) 298-3459
www.eecs.umich.edu/mems

Transducers '99, Sendai, Japan, June 7–10, 1999. *Abstract deadline: Nov. 30.* For info.: Transducers '99, Attn.: J. Echizen
Fax: +81-3-3299-1361
www.com.cas.uec.ac.jp/trans99.html

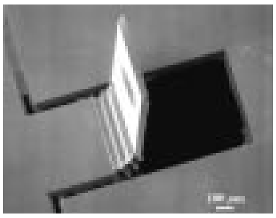
PUBLICATIONS

- A Lateral Symmetrically Bistable Buckled Beam; M. Vangbo and Y. Bäcklund (UU); *J. Micromech. Microeng.*, **8**(1) (1998) 29–32.
- Etch Rates of Crystallographic Planes in Z-cut Quartz – Experiments and Simulation; P. Rangsten, C. Hedlund, I.V. Katardjiev and Y. Bäcklund (UU); *J. Micromech. Microeng.*, **8**(1) (1998) 1–6.
- Low Pressure Encapsulated Resonant Structures with Integrated Electrodes for Electrostatic Excitation and Capacitive Detection; T. Corman, P. Enoksson and G. Stemme (KTH); *Sensors and Actuators A*, **66** (1998) 160–166.
- Magnetic Microdevices and their Fabrication Methods; A. Kruusing (Tallinn Techn. Univ., Estonia); *Doctoral thesis*, (Aug. 1997).
- Method for Fabrication of Microfluidic Systems in Glass; M. Stjernström and J. Roeraade (KTH); *J. Micromech. Microeng.*, **8**(1) (1998) 33–38.
- Microstructure Technology in Quartz and Silicon; P. Rangsten (UU); *Licentiate thesis*, (March 1998).
- Passive and Fixed Alignment of Devices Using Flexible Silicon Elements Formed by Selective Etching; C. Strandman and Y. Bäcklund (UU); *J. Micromech. Microeng.*, **8**(1) (1998) 39–44.

NEXT ISSUE

Some topics covered will be:

- Medical applications of microsystems
- Micro propulsion thrusters for space applications
- Microstructures based on polyimide joints



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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