MICRO STRUCTURE BULLETIN

Newsletter for Swedish Micro Structure Technology No.3 Aug 1994

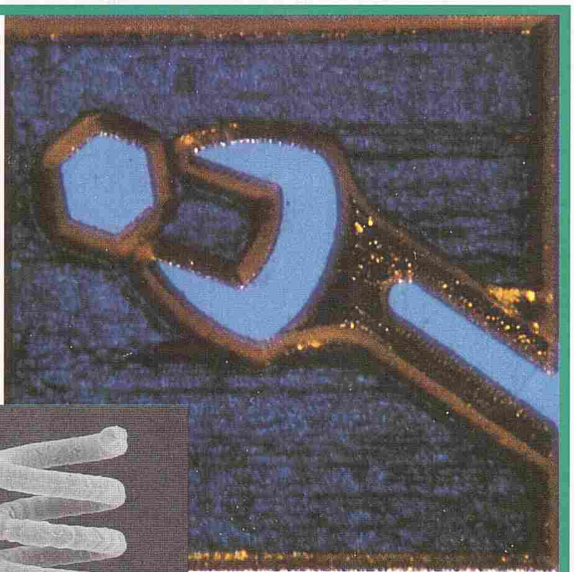
Optics in Micro Structure Technology

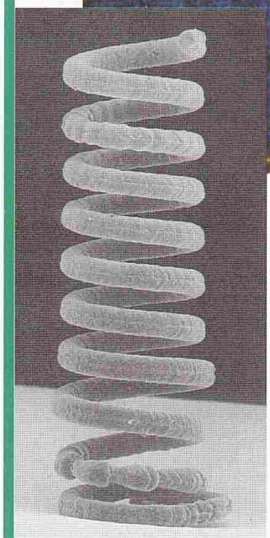
A striking thing with the title is that it is sort of a palindrome. The title could as well be "Micro Structure Technology in Optics" and it still would be an equally interesting subject. On the one hand, guiding photons often takes optical components with mechanical tolerances in the order of a mm or smaller. This implies the natural need for manufacturing technologies which specialize in minute details. Photons, on the other hand, are equally useful to define and, as will be later explained, sometimes also directly create the shape of mechanical structures.

A second duality offered by optics is the possibility to both machine and deposit material. It is well-known that light can be used to remove material. A less known mechanism is that material can be deposited in areas illuminated by a laser. These two possibilities are illustrated by the figures of this page.

The obvious example of optics in MST is in different types of lithography, where light is used to transfer information in the shape of a mask to an object. To simplify: Optics needs MST and MST needs optics.

The subject is too large to be covered in a few pages, so this issue will concentrate on a few examples with an emphasis on telecommunication. Many obvious applications, for example fiber-optic sensors based on micromechanical transducers, have been covered in past or will be covered in future issues of *MSB*.





Structures formed by removing (nut and wrench) and depositing (helix) material with the help of a laser. The 80 µm diamond nut and wrench was formed by ablation (Potomac Photonics, MD, U.S.A.), and the 300 µm boron helix was formed with laser assisted chemical vapor deposition (Uppsala University).

Center for Surface and Microstructure Engineering

The Swedish National Board for Industrial and Technical Development, NUTEK, has approved of the joint proposal from Uppsala University and the Royal Institute of Technology for an industrial competence center in Surface and Microstructure Engineering. NUTEK recommends the center to "focus on Microstructure Engineering with a center of gravity in Uppsala". More details will appear in next issue of *MSB*.

CONTENTS

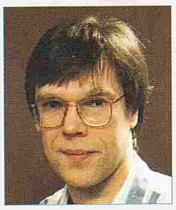
EDITOR'S NOTE

A regional industrial network in the area of small instruments for analytic chemistry and biotechnology has been formed, partly as a consequence of the workshop *MSW '94*. Why not form networks in other areas? Start by ordering one of the remaining copies of the proceedings from *MSW '94* (*see MSB 94:2*).

The multi-faceted saying "The whole is greater than the sum of the parts" can be applied as well to devices as to the importance of collaboration. Superior performance is achieved only if all components function together. Often production of the micromachined chip is simple, while packaging takes up most of the development resources. I therefore invite the reader to contribute to a future issue of *MSB* dedicated to packaging in MST.

One issue a year will describe MST development in the nordic countries, starting with Norway in the next issue. This will follow up the increase in nordic interest of *MSB*.

Despite the positive reception of *MSB*, some names were removed from the mailing list. To avoid this to happening to you, check the symbol that preceeds your name on the address label.



Jan Söderkvist

Micro Structure Technology for Telecom Applications

Information technology, IT, is a very rapidly growing industrial area. Telecommunication companies, such as Ericsson, will hold a central part in the development and use of new technologies that can improve performance and decrease the cost of the components needed in the "information technology society".

The future telecom products will be focused both towards increased mobility (mobile and personal telephones) and the introduction of new types of services (multimedia communication, video-on-demand, etc.). This increases the need for high bandwidth in the transport networks and switches. High performance products, such as high speed ATM switches (2.5 and 10 GBit/s) and optical transmission links (10 and 40 GBit/s), will require new types of packaging and equipment technologies to fully utilize the improved performance of new semiconductor components. The limitation on system performance given by the electronic building practice can be overcome by an increased packaging density, i.e. putting the chips closer together or increasing the use of optical interconnects. Part of the solution can be achieved by the use of Micro Structure Technology (MST).

Even higher demands on new MST will occur if the use of multimedia services explodes. High volume production of opto-electrical modules will require MST in order to achieve both low cost and high performance. However, it is more uncertain if we really need MBit/s of information sent directly to our homes. Improved coding algorithms can enable an acceptable quality of video signals on copper cables. On the other hand, if the components can be made at an affordable cost there will be an increased use of optical fibers in the customer access network (FITL, fiber-in-the-loop, FTTC, fiber-to-the-curb, FTTH, fiber-to-the-home, etc.). Perhaps it will be possible with geometrical alignment in the sub-µm area at a cost of a few cents?

Opto-Electrical Modules

Although there has been much research aimed at developing entirely optical computers and switches it is unlikely that these products will be available in the foreseeable future. The current vision is more like that of "electrical islands in an optical sea". Data handling, some switching, etc. will be done in the electrical domain. Even an InP optical switch is guided by electrical signals. There will evidently be a need for modules that convert electrical into optical signals and vice versa. These modules will be used in high volumes, and the price must be low.

Opto-electrical modules for transmission systems (e.g. single-mode, SM, transmission with 2.5 GBit/s at 1.3 or 1.55 µm) are very expensive with packaging and alignment as a major part of the cost. Nevertheless, it is possible to make opto-electrical modules at very low cost. The total cost of equipment and packaging for 0.8 µm lasers for CD players is a few dollars, but the reliability of these short wavelength lasers is not currently adequate.

Extensive research is proceeding in order to create a low cost alignment between fibers, wave guides and optical components with SM performance. Active alignment technologies are presently in usage. The component or the fiber is moved until an optimal signal is achieved. The goal is to develop inexpensive passive alignment technologies with a sub-µm precision. One solution is to use multi-mode, MM, optical components and fibers (figure 1). In this case, alignment within a few µm is sufficient. This type of opto-electrical system can be used for internal optical communications but not for FTTH applications, since only relatively short distances can be covered. This means that the problem of achieving low-cost alignment with SM performance still remains to be solved.

MST offers several solutions that can be used for high precision alignment. The clas-

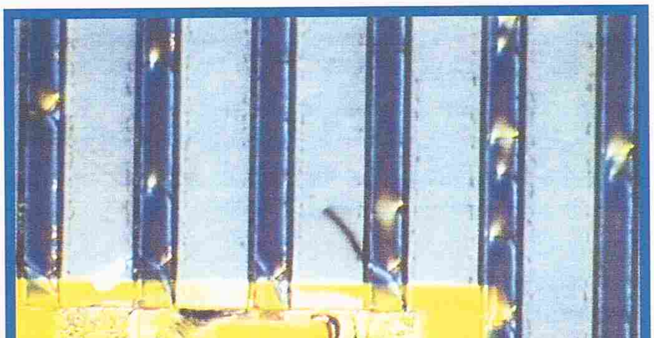


Figure 1. Multi-mode (MM) alignment between a polyimide wave guide and a laser diode (photo G. Palmskog).

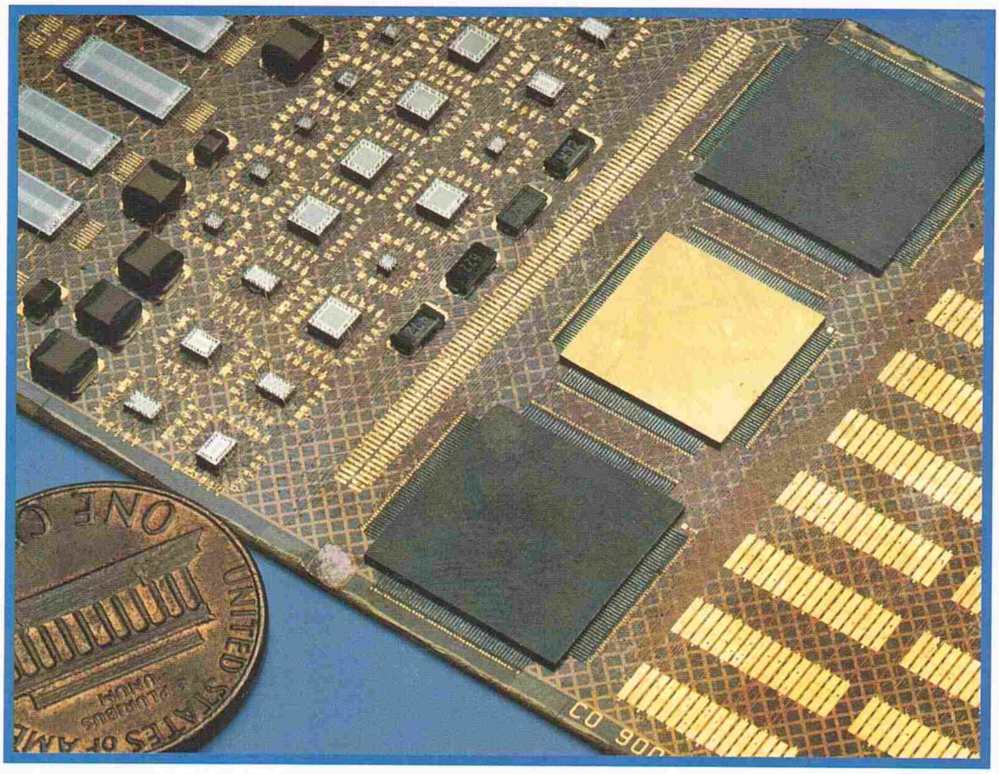


Figure 2. A multi chip module (MCM; many chips assembled on the same substrate) for a RISC processor application (Ericsson Telecom). Note the penny to the lower left.

sical method is the silicon workbench. Alignment between fibers and opto-components can be achieved by high precision etching of V-grooves in the silicon and by flip-chip mounting of the components. Modified flip-chip assembly gives a precision of approximately 1 µm. New development will be necessary to achieve SM performance.

Another way of decreasing the cost of the opto-electric modules is to use wave guides of polymeric materials on a silicon substrate. This decreases the number of process steps. The wave guides are patterned in a photolithographic process. A relatively new material, BCB (benzo cyclo butene) shows very promising results.

The ultimate low-cost technology might be to use polymeric materials also as the substrate. A process similar to the manufacturing of CD discs may be used to form wave-guides, mirrors and gratings in termoplastic materials. These polymeric MST solutions are under study within the BRO project (see separate note).

With the increasing use of optical interconnects, there will be a need for optical wave guides directly on PCBs (printed circuit boards). Polymeric wave guides might also be a solution in this case. Materials with low loss (0.1 dB/cm suffices for a polymeric wave guide on a PCB; typical losses for an optical fiber is 0.2 dB/km) have to be developed. Raoul Stubbe discusses various methods of alignment between wave guides and optical components on page 4.

Multi Chip Modules

The improvement in electrical performance obtained with increasing packaging density can be achieved with the multi chip module (MCM) technology. Silicon substrates with flip-chip assembly can be used for MCMs with excellent performance at very high speed (2–10 GHz).

Micro bumps for connecting chips to a substrate is a typical example of MST for MCM. In addition, the bonding of different types of semiconductor materials is useful in decreasing the thermal resistance. Ultimately, three dimensional high density packaging technologies, partly based on MST, will be developed. The limited space in MSB prevents a more detailed treatment of micro packaging.

Ongoing Research

Within Ericsson, we have traditionally not used the term Micro Structure Technology. However, there are many R&D activities that would fit into this definition.

Ericsson's activities for R&D in micro electronics have been concentrated to Kista in Stockholm and will be handled by the newly formed Ericsson Core Unit Micro Electronic System Technology (MEST). This unit includes a department with developmental activities for multi chip modules and opto-electrical modules. There are also two research centers within MEST involved in MST: Micro Interconnect Research Center and Fiber Optic Research Center. The sub-µm IC factory will also be included in MEST.

There are also activities concerning MCM within Ericsson Telecom in Älvsjö and within Ericsson Radar Electronics in Mölndal.

Kåre Gustafsson ■
Micro Interconnect Research Center
Ericsson Components AB

MST NEEDS

Telecom applications needs MST solutions that combines good performance (high signal speed, very good geometrical tolerances, low optical losses, etc.) at a very low price. Is this a possible combination? More research will be needed to find the answer.

Typical applications involving MST include:

- Opto-electrical modules
  - Low cost alignment between components and wave guides
  - Low cost packaging of the modules
  - Low cost connectors
- Multi chip modules
  - Low cost modules with high integration
  - High performance modules for high speed and high integration
  - Microwave modules
  - Testing of high density modules

6TH ANSYS CONFERENCE

Approximately 100 scientific presentations, covering various simulation capabilities and application areas, were given to the 400 participants in Pittsburgh on May 2–6. Clearly, finite element analysis (FEA) is no longer a complicated tool used only for certain applications. Modern FEA programs are even user-friendly. Simulations will be important for MST due to the small size of the components and a fast industrial development. If requested, Colibri Pro Development and Anker-Zemer Engineering will organize a tutorial aimed at simulation possibilities in MST and/or piezoelectricity. In the next issue, *Micromachining Basics* will cover simulations.

Jan Söderkvist

Micromachining Basics P

Optics in M

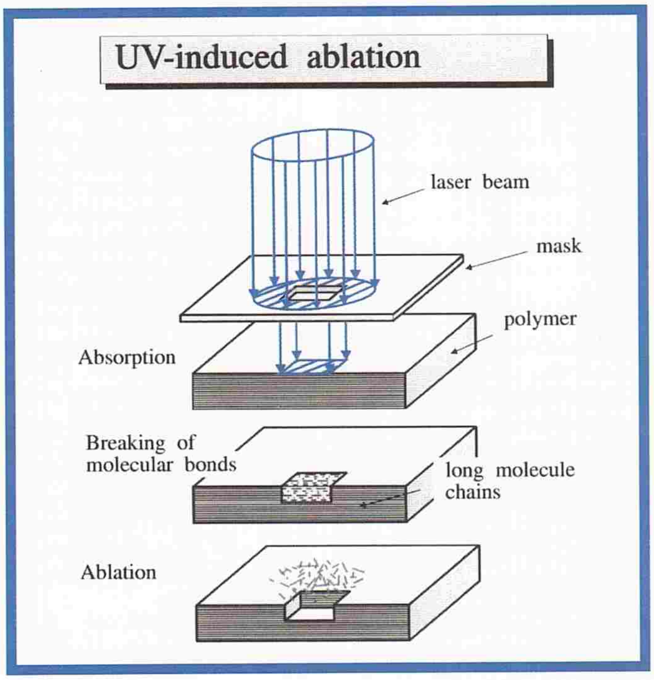
The most powerful principle for transmitting information known today, without much debate, is optical communication. The information bandwidth is theoretically several TBit/s when transmitted serially and can indeed be improved further if sent in parallel. How do we then make use of this, seemingly infinite capacity?

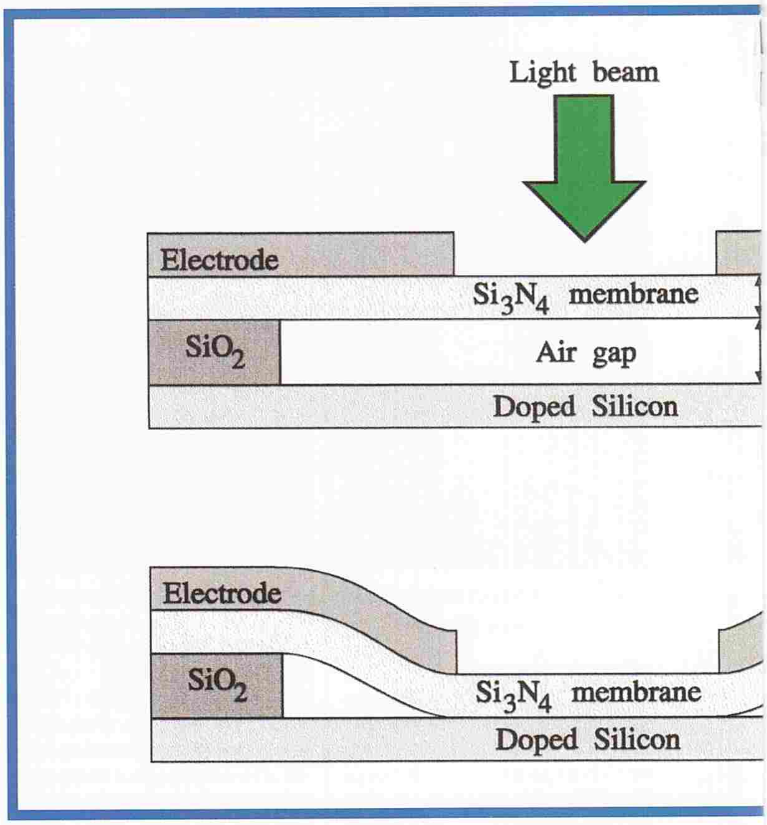
Fiber Communication

Over longer distances the obvious choice is to use optical fibers. Fibers guide light with extremely low attenuation (less than 0.2 dB/km) and can be bent to radius less than a few cm without significant losses. The TBit/s regime is still far beyond reach, but with so called single-mode fiber, today's best commercial systems show capabilities in the order of 5,000 GBit km/s, ie 2.5 GBit over 200 km without repeaters. Although these are impressive figures, (1 GBit/s corresponds to about 15,000 phone calls or 15 uncompressed TV-channels), applications like videophone, "video on demand", and interactive television, will push the demand for capacity even further. It is believed the next step (the so called sixth generation) will be in the use of several wavelengths. Optical fibers now carry only pulses of light with one color, much like a one lane highway. Using an array with lasers, each producing light with a slightly different wavelength, "lanes" in the order of hundreds can be achieved with a single fiber.

Optical communication, however, is not without its own share of problems. To guide a photon, in a controlled manner, from one point to another is by far more difficult than with the rivaling carrier, the electron. One may argue that the optical fiber performs this task perfectly and that is true once the task of coupling the light into the fiber has been painfully achieved. Yet there are many functions required by telecom, like for example routing the signals, that have to be accomplished outside the fiber.

High transmission rates call for single-mode fibers. Such fibers have a core (the light guiding part of the fiber) with a radius of only a few µm. This is where the problem starts since this means that all the mechanics used to position fibers, light-sources, detectors, and integrated optical circuits, requires an alignment precision significantly better than 1 µm. If not, unacceptable loss will result. Micromachined silicon devices is one out of very few technologies that actually can meet these mechanical tolerances. The fact that silicon based MST is well-suited for massfabrication makes it an even more interesting candidate for optical interconnect technology.





A micromechanical membrane-based optical switch.

Micromechanical Switching

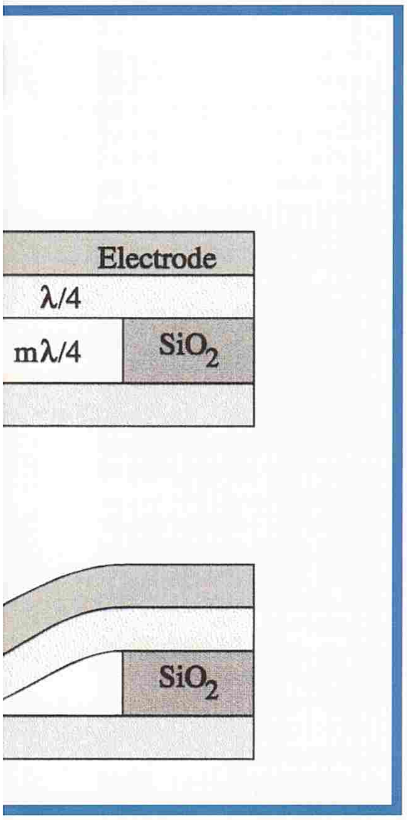
Although switching speeds in the fastest communication systems soon will exceed 10 GHz, there is room for switching devices considerably slower, especially if they are cheap. At the Optical Fiber Communications (OFC'94) conference, scientists at AT&T Bell Laboratories presented a micromechanical switch that was fabricated on silicon using a standard microelectronic technique. The switch (see figure) shows a contrast better than 20dB for operation within the impressively large wavelength region 1.3 to 1.55 µm and the switching speed of the device well exceeds 1 MHz.

The modulator is made by suspending a silicon nitride thin film membrane a controlled distance over the substrate. Applied electrostatic forces deflect the membrane toward the substrate and by bringing them in contact a reflection mirror is transformed into an antireflection mirror. The cost of the device is estimated to only 1$.

UV-light Creates Microstructures

In some applications, especially when organic materials are concerned, a more immediate way than chemical lithography to form the material is possible. UV-light is characterized by high photon energies. The light from an KrF-based excimer laser has a wavelength of 248 nm which corresponds to a photon energy of 5.1 eV. This is enough to break bonds in large molecules and chains of molecules and to activate chemical reactions. If a sufficient number of bonds are broken within a small volume, the material may disintegrate into small molecules that evaporate. This material art 4:

ST



removal or etching phenomenon is called ablative photodecomposition or just ablation (see figure). Because polymers consist of long organic molecular chains, they are well suited for ablation. When the bonds are broken to a sufficient extent, molecules like H_2O, CO, CO_2, and CN, are formed.

Processing materials with lasers is far from new, but what distinguishes UV-laser ablation from other types of laser material processing, and in many cases yields a greater advantage, is that there is very little or no heat involved.

Another virtue of UV-light is its short wave-length. Images with well below 1 µm line spacing can be produced. Also, the ablation process only occurs within a few tenths of a micrometer. Hence it becomes possible to create very minute three-dimensional structures with this technology.

Micro Structures in Optical Interconnects

As current communication and computing systems grow faster, efficient and secure routing of information between such elements as gates, chips, boards and networks become increasingly important. At present day, the short-distance data transfer at the board-to-board, chip-to-chip, and gate-to-gate levels are performed solely by electronic interconnects, a technology that is approaching its limits. In fact, the communication at the board-to-board level, presently performed electronically, is already considered to be at a severe bottleneck.

Optical interconnects have been proposed as a viable alternative and for example fibers and passive integrated optical circuits (IOCs) are believed to gradually replace the electrical connections at increasingly lower hierarchical layers. The switching itself however, at least at high frequencies, will probably also in the future be achieved in the pure electrical domain.

An important concern when developing new technologies that would replace the electrical interconnects is of course cost. The components used have to be easy to manufacture and a type of IOC technology that has attracted much interest mainly for this reason is polymeric waveguides. Waveguides share the abovementioned problem with fibers, i.e. the difficulty in coupling light in a controlled manner.

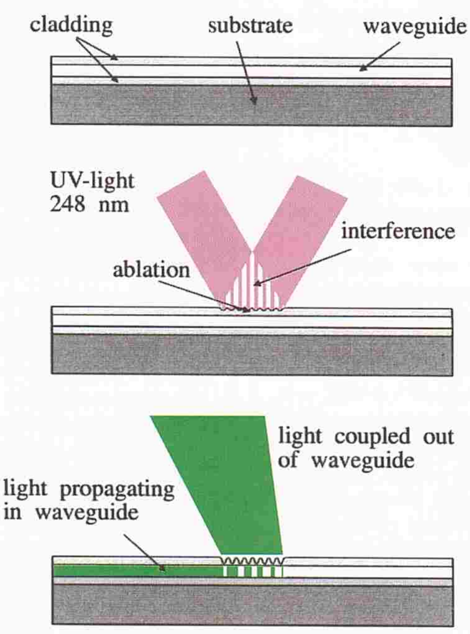
At the Institute of Optical Research we have used ablation to create two types of coupling units that could be used to perform coupling to polymeric waveguides, one wavelength dependent, the other wavelength independent. The first is based on the grating approach. If the upper surface or the upper cladding layer is locally corrugated, light propagating in the waveguide will be coupled out in a direction which depends on the wavelength of the light and the period of the corrugation. And due to reprocity of light, a reversed path is equally possible.

We have accomplished this structure by letting two beams from our UV-laser interfere on the surface of the polymeric waveguide (see figure). The periodic intensity distribution by means of the ablation process imparts a grating structure or corrugation on the waveguide.

The achieved periodicity of some of the gratings has been less than 0.5 µm, which indicates that it is possible to create submicrometer three-dimensional structures with ablation. The results are very promising but much work still remains to attain reproducible gratings that could be used commercially.

The second approach, which has also had some promising results involves creating a 45° mirror. By simply exposing the waveguide with a focused UV-light beam incident on the waveguide surface in the desired angle, material is removed so as to form a slit of air through the waveguide. Light propagating through the waveguide will be totally internally reflected by the waveguide-to-air slit surface. An important difference is that with this approach all wavelengths are coupled out at the same angle.

Fabrication of grating couplers by UV-ablation



Micromechanics Formed with Excimer Lasers

Excimer laser ablation can also be used to create micromechanical devices. Interesting to note is that this technique gives access to other materials than the more conventional silicon. The example above was based on polymers, yet another interesting material that has been processed is diamond. Developers at Potomac Photonics in Maryland have for example created the hexagonal nut and wrench onto the surface of bulk diamond depicted on the front page.

Raoul Stubbe,
Institute of Optical Research

SMEs

In Europe, the overall potential of small and medium-sized enterprises (SMEs) oriented toward the production of MST includes some 10,000 to 15,000 enterprises. A much larger number of SMEs are involved if the variety of application fields is considered.

Europe's share of the world market in the field of MST is currently about 40%, which is expected to decrease to about 35% in the year 2002. Nevertheless, the absolute volume is expected to increase significantly.

BRO

A Swedish national cooperative project, BRO (Building practice Research for Opto and micro electronics), supported by NUTEK, is focused towards the development of technologies for low cost internal optical communication links. It includes the development of polymeric wave guides, methods for the passive alignment between opto-components and wave guides, as well as MST solutions for the shaping and joining of semiconductor materials.

The University participants are Uppsala University, the Institute of Optical Research, KTH, and the IMC in Stockholm and Linköping. The industrial partners that take an active part in the research are Ericsson, Pharmacia and Toolex Alfa. Additional members in the industrial reference group are: Combitech Electronics, ABB HAFO and Siemens-Elema

The Institute of Optical Research

The Institute of Optical Research (I.O.F.) is one of about twenty independent research institutes in Sweden. It sees its mission as filling industry's need for R&D, gatekeeping, technology transfer, training, and providing other services in modern optics. An important ingredient is collaboration with universities, institutes, and industry in Sweden and abroad.

Organization

The Institute rents space in the Physics building of the Royal Institute of Technology (KTH) in Stockholm, of which it is not a part. However, the Institute has very close collaboration with the Physics Department and other laboratories at KTH. Some employees of the Institute are also graduate students at KTH

A professor of physics is the director of the Institute. Industry is represented by the *Association for Optical Research in Sweden* (SSOF) comprising about thirty companies. The board of directors consists of four members appointed by SSOF, and four members and the chairman appointed by "The Swedish National Board for Industrial and Technical Development" (NUTEK).

On 31 December 1993 the Institute employed 27 people, ten of which held a Ph.D. degree in physics. The turnover in the fiscal year from July 1992 to June 1993 was 16.5 million Swedish crowns.

Project Policy

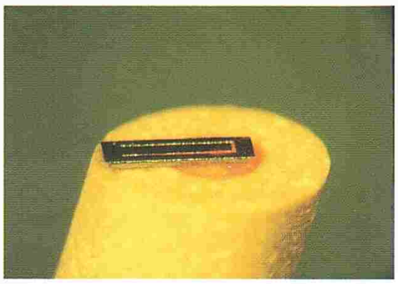
- Projects with partial support by government funds are open with the results published. The industrial partners have the benefit of setting priorities among projects and of monitoring their progress. They may be granted a non-exclusive license on any potential patents free of royalty.
- Projects and assignments without public funding are confidential with all results as the sole property of the customer.

Fields covered

The present policy of the Institute is to provide R&D services for industry in the following three fields:

- *Optical metrology and sensor technology:* Activities include interferometric and moiré methods, fiber optic sensors, signal processing techniques, evaluation of surface micro-roughness and defects by scattering, stylus measurements or Fourier methods, thin- film deposition, and ion-beam treatment of surfaces.
- *Image information:* Activities include image quality assessment of lenses, detector arrays, visual display units and spatial light modulators, aspects of image compression, and motion perception.
- *Photonics*: Activities include signal propagation in wave guides, technologies for preparing wave guide components and interconnects, active optical fibers, nonlinear effects in communication channels and for wavelength conversion, quantum well devices, and femtosecond laser pulse sources.

The Early Days of Swedish MST



Fiberoptic accelerometer with micromachined cantilever beam of GaAs-AlGaAs, designed and fabricated 1983 (courtesy of ABB Corporate Research).

The history of Swedish R&D in micromechanics and microstructure technology is short. An interesting fact is that the link to fiberoptics has been strong from the very beginning. In the early 80's, Ericsson Telecom developed a fiberoptic switch based on a silicon V-groove structure that was mounted in a conventional relay.

This was probably the first Swedish micromechanical product, and was used primarily to achieve redundancy in fiberoptic networks. Replacement of a blown-out laser diode was then a matter of milliseconds, and could be accomplished completely automatically.

At the same time, ASEA made a substantial R&D effort in fiberoptic sensors, which resulted in a family of systems for measuring temperature, vibration, pressure, current, voltage, magnetic fields, etc. A few of these sensors are still commercially available. One of the accelerometer designs used a cantilever beam of GaAs-AlGaAs fabricated by selective etching. The acceleration signal resulted from variations in reflectance, and photoluminescence due to band-band recombination in GaAs provided a reference signal.

Academic research started in 1984 as a cooperative effort between ASEA and Uppsala University. The two lines of research started included: investigations of the mechanical and thermal properties of micromechanical elements, and development of new speculative devices.

These initial projects resulted in two Ph.D. theses by Stefan Johansson and Kari Gustafsson which were defended in 1988. Highlights included the demonstration of the superior strength of silicon cantilever beams (14 GPa, more than ten times greater than steel), and high-speed fiberoptic multiplexing by means of a silicon scanning mirror.

Bertil Hök ■

DISSERTATIONS

MSB congratulates Lars Rosengren (Doctoral thesis, May 19) and Mats Bexell (Licentiate of Engineering thesis, May 27) on successfully having defended their work at Uppsala University.

Lars Rosengren
His thesis, *Silicon Microstructures for Biomedical Sensor Systems*, dealt mainly with the design and modeling of physical and chemical sensors, with two major applications in the medical field.

First, a system intended for continuous remote pressure sensing within the human body, in particular the eye, was presented. This system is based on a plate capacitor manufactured by micromachining techniques. Together with a coil, this sensor has a pressure dependent resonance frequency which can be detected wirelessly from outside the body. The system has been successfully tested in animal experiments.

Also presented was a micromachined cavity, with a highly increased surface-to-volume ratio. The surface is enlarged by wet etching methods in order to maximize the quantity of immobilized enzymes on a small wafer. This device is intended for continuous glucose measurements in diabetics.

Finally, applications of anisotropic wet etching to passive optical devices, such as mirrors and beam-splitters, was presented.

Mats Bexell
His thesis, *Processing Techniques for the Fabrication of Micromechanical Systems*, contains a study of micro electro discharge machining (MEDM) in the micro-scale, both experimentally and as a literature review. Also, evaluated both experimentally and theoretically was an inch worm type of motor intended for a microrobotic arm. In addition, the thesis contained an investigation of eutectic bonding at a micro level.

Next:
On Sept. 16 Edvard Kälvesten, KTH, will present his Licentiate of Engineering thesis *A Silicon Microphone for Turbulence Measurements.*

PUBLICATIONS

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

- A Fiber Optical Voltage Sensor Prepared by Micromachining and Wafer Bonding; Z. Xiao, S. Norrman and O. Engström (CTH); *Sensors and Actuators A*, 41 (1994) 334–337.
- A System for Passive Implantable Pressure Sensors; L. Rosengren, P. Rangsten, Y. Bäcklund, B. Hök, B. Svedbergh (UU) and G. Selén (Pharmacia); *Sensors and Actuators A*, 43 (1994) 55–58.
- Characteristics of Quasi Buckling; J. Söderkvist and U. Lindberg (UU); *Sensors and Materials*, 6(5) (1994).
- Processing Techniques for the Fabrication of Micromechanical Systems; M. Bexell (UU); Licensiate thesis, *Uptec* (May 1994), ISSN 0346-8887.
- Silicon Microstructures for Biomedical Sensor Systems; Lars Rosengren (UU); Doctoral thesis, Acta Univ. Ups. #54 (May 1994), ISBN 91-554-3252-2.
- Wall Induced Effects in Gas Transport Through Micromachined Channels in Silicon; I. Lundström, P. Norberg and L.-G. Peterson (LiTH); *J. Appl. Phys.*, 76(1) (1994) 142–147.

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NEXT ISSUE

Some topics covered will be:

- MST at SensoNor and SINTEF
- MST in airbag sensors
- Simulations

TRANSDUCERS '95 • EUROSENSORS IX

Call for papers

Transducers '95 • Eurosensors IX will be held in Stockholm on June 25–29, 1995. Deadline for two-pages abstract is December 15, 1994. Further information: Congrex AB, Box 5619, S-114 86 Stockholm, Phone +46-8-612 69 00, Fax: +46-8-612 62 92.

Fiber-optic Gratings

Fiber-optic gratings have already shown their versatility in a broad spectrum of sensor applications. They are also expected to become an important component in telecom applications, such as dispersion compensation, network control, and WDM-based communication. A training course in Fiber-optic gratings will be given at the Institute of Optical Research on Dec. 1, 1994. To obtain further information please contact Lena Dörvaldt, Phone: +46-8-791 13 11, Fax: +46-8-789 66 72.

FUTURE EVENTS

Eurosensors VIII in Toulouse, France, Sept. 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, Jan. 29–Feb. 2, 1995. *Abstract deadline: October 3.* For information contact: Ms. J. Spierenburg, BASICS, Fax: +31-53 356 770.

Transducers '95 • Eurosensors IX, see separate note.

MME '95 (MicroMechanics Europe) in Copenhagen, Denmark, Sept. 4–5, 1995. For information contact: Prof. Otto Leistiko, Fax: +45-45 88 7762.

186th Meeting of the Elecrochemical Soc., Miami Beach, USA, Oct. 9–14, 1994.

Micro System Technologies '94, Berlin, Germany, Oct. 19–21, 1994.

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

THE AIM OF the *Micro Structure Bulletin* is to promote micromechanics and micro structure technology. It constitutes one part of Uppsala University's effort to share scientific and technological information.

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Editor-in-Chief:
Assoc. Prof. Jan Söderkvist, Colibri Pro Development AB
Phone: +46-8-510 116 49
Fax: +46-8-510 116 15
E-mail: jan.soderkvist @teknikum.uu.se

Industrial editor:
Hans Richert, Bofors AB / Chalmers Teknikpark
Phone: +46-31-772 41 46
Fax: +46-31-772 41 53

Scientific editor:
Prof. Jan-Åke Schweitz, Uppsala University
Phone: +46-18-18 30 89
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Assoc. Prof. Jan Söderkvist
Colibri Pro Development AB
Torgnyvägen 48
S-183 72 Täby, Sweden

Phone: +46-8-510 116 49
Fax: +46-8-510 116 15
E-mail: jan.soderkvist @teknikum.uu.se

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