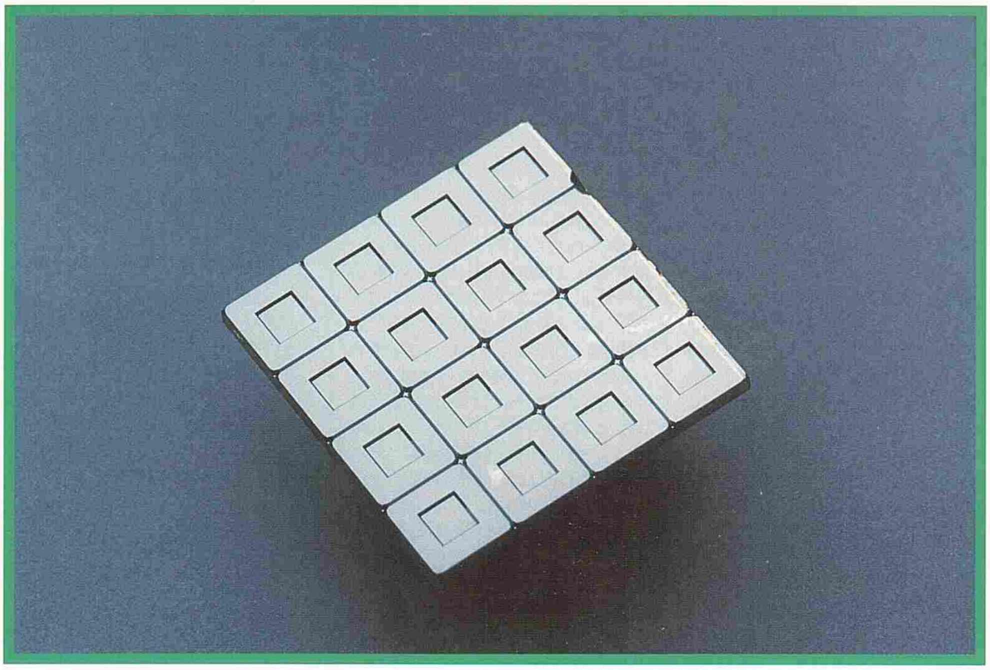
MICRO STRUCTURE BULLETIN

Newsletter for Scandinavian Micro Structure Technology No.1 Feb 1995

Solid State Bonding



Device samples of the Samba Interference Sensor.

Bonding techniques of different kinds are essential in micromachining. Bonding not only makes 3D-structures possible, but also makes complex microsystems possible by enabling the integration of micromechanical devices such as sensors, actuators, and CMOS logic.

For microelectronics applications, the driving force for bonding research has been the fabrication of Silicon-On-Insulator (SOI) materials, allowing for smaller, faster, and cheaper integrated circuits. With modern chemical mechanical polishing (CMP) techniques, bonding techniques can also be used in standard IC-processing. This opens the possibility of integrating previously incompatible processes.

An interesting new field of applications is in Opto Electronic Integrated Circuits (OEIC), where bonding of III-V semiconductors to each other or to silicon, is a needed processing step.

One of many micromachined sensors for which bonding is an essential fabrication step is the Samba Interferometer Sensor, shown above. Two silicon wafers are joined by thermal bonding via a patterned thermal oxide. The depth of the created cavity is determined by the thickness of the oxide and can be accurately controlled. Light penetrating the structure perpendicular to the bonded interface is subject to interference if the depth of the cavity is correctly chosen relative the wavelength of the incoming light. Changing the depth, for example by applying an external pressure, changes the interference conditions and the intensity of light reflected by the cavity; hence a pressure sensor is obtained.

CONTENTS

EDITOR'S NOTE

Two of the most important micromachining processes are etching and bonding. Etching was introduced in the first issue last year (*MSB 94:1*). This issue will focus on bonding. Both techniques are based on refined methods used for microelectronics. Further articles describing these processes will follow.

Most of our readers should have already received the announcements for *MSK* (March 28–29) and *Etching Technology* (April 25–26). Information regarding the NEXUS workshop, *Accelerometers*, to be held in Uppsala immediately prior to *Transducers '95• Eurosensors IX*, will soon be available. It is worth noting that the number of registrations to *MSK* in the first days following its announcement indicates that the number of participants may exceed the assigned maximum number of participants.

The use of MST-based devices is limited only by the imagination. Exploring life will reveal many new possibilities, as summarized by Sören Kierkegaard, "Life is not a problem that should be solved, it is a reality that should be experienced". This saying applies also to my Christmas tree at home. It has started to grow, exactly as last year's tree. Why not leave it and enjoy the wonders of nature instead of throwing it out on a specific date.

Jan Söderkvist

Micromechanics at the Department of Solid State Electronics Chalmers University of Technology

The research activities at the Department of Solid State Electronics are specialized in devices and circuits composed of silicon and silicon related materials. Within these parameters, research is performed in a wide spectrum ranging from basics to applied.

Some of the topics recently studied are the thermodynamic properties of charge carriers in semiconductors, gold-hydrogen impurity complexes, ultrathin oxides, electronic properties of the interfaces between dielectrics and silicon, remote-plasma-CVD-dielectrics, thermal bonding of oxide, AlN and diamond on silicon, micromechanical sensors and parameter extraction methods for MOSFETs. Micromechanical projects includes optical structures with microcavities (the Samba Sensor), accelerometers and thermal detectors.

Recently a new project, named *Chalmers Kiseldesign*, was initiated with the aim to create novel possibilities for interaction between the department and small and medium-sized enterprises (SMEs) within the silicon technology field. In addition, a spin-off company, Samba Sensors AB, was founded based on original device ideas from the department.

For the future development of micromechanics, the concept of MecMOS is being introduced within Chalmers Kiseldesign. Thus, the circuit design facilities of the department are applied towards CMOS processing at a commercial producer followed by micromechanical post-processing in the laboratory for silicon technology in order to prepare circuit structures with mechanical and electrical components contained on the same chip.

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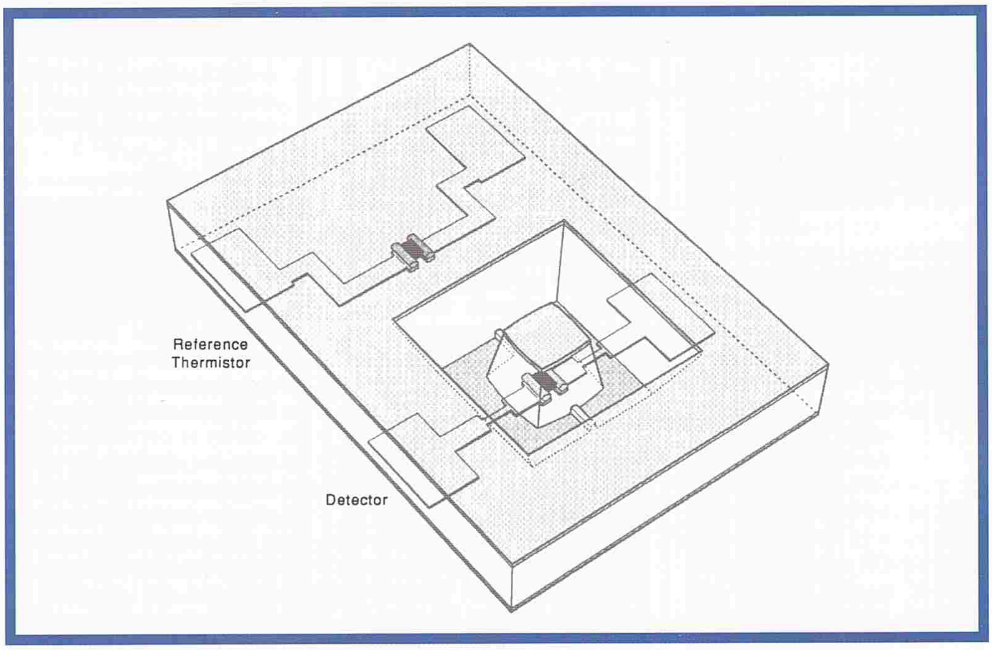
Activities in silicon wafer bondning

Research within the field of silicon wafer bonding has been going on at the department for about 7 years. A large number of basic investigations into the electronic properties of silicon-related bonded interfaces have been performed in order to increase understanding of their use in device applications.

A model for unipolar n-n and p-p junctions has been created together with a survey of the properties of p-n junctions and oxide interfaces. The charge properties of the latter structures are of considerable importance in the preparation of Silicon-on-Oxide (SOI) materials by silicon wafer bonding. The conditions for the charging of oxide to oxide interfaces have recently been investigated in detail by combining optical and electrical methods.

In the search for new insulating materials in SOI technol-



A schematic view of the thermal detector-based bolometer.

ogy, the possibility of using diamond or aluminum nitride is being investigated due to their high thermal conduction coefficients. This work is carried out in collaboration with Uppsala University. Bonding conditions and electrical properties have been also studied in this collaboration.

Recently, measurements performed by atomic force microscopy have been used to find a parameter correlated with the bonding strength. A relationship between the Fourier-transformed characteristics of surface roughness and the strength of bonding between different materials has been observed.

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A thermal detector for single quanta of radiation

As part of a program aimed at the development of thermal quantum detectors, a bolometer has been developed in collaboration with the Department of Physics at Chalmers. A schematic view of the device is shown below.

An incident radiation quantum is absorbed on a pure silicon body (absorber) where its kinetic energy is converted into heat. The absorber, with a volume of about 0.05 mm^3, is suspended by thin supporting bars of heavily doped silicon, on which aluminum heat leads are evaporated, and by a layer of silicon dioxide.

A thermistor is implanted on the back of the absorber to detect the temperature increase caused by the absorption of a quantum. A reference thermistor is positioned on the front surface. The leads connected to the absorber do not only serve to thermalize the absorber, they also serve as excellent electrical conductors to the thermistor, since aluminum goes into its superconducting state far above the working temperature of about 50 mK. The sensor has been tested with radiation from ^{109}Cd with results consistent with those predicted.

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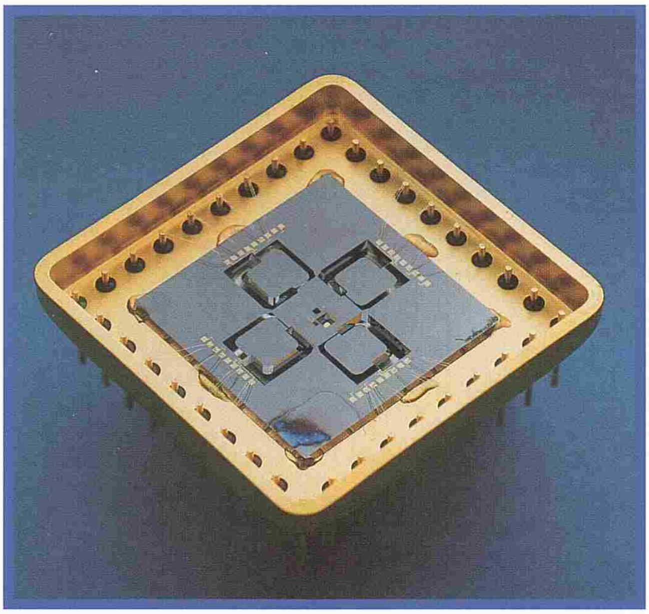
A Novel 3-axis monolithic silicon accelerometer



The 3-axis monolithic silicon accelerometer.

Working prototypes of a novel 3-axis monolithic silicon accelerometer have been manufactured at the department, in cooperation with Saab Combitech AB. The experience from the prototypes is most encouraging and has, almost beyond expectation, confirmed the theoretical predictions of negligible cross-axis sensitivity and high accuracy in the separation of an arbitrarily directed acceleration.

The accelerometer design has the possibility to accomplish sensibility for angular acceleration or velocity. Further, the present design has a good possibility for being developed into a low cost 3-axis accelerometer in the 0–2 g range with a resolution of about 10 mg due to the simple manufacturing process.

The 3-axes design of the accelerometer consists of four cantilever beams, with adhering masses of inertia (see schematic figure). The concept of the accelerometer design is that each cantilever beam is by purpose sensible to force components along two axes in a Cartesian system of coordinates, in contrast to conventional constructions where each sensing element is optimized to sense forces along just one axis. Here, the output signal from the cantilever beams is used in pairs or all together to calculate the acceleration along each of the three Cartesian axes. For instance, the inertia force in the x-direction is found by subtracting the response from beams 2 and 4 ($F_x=\{F_2-F_4\}/2\sin\alpha$), and in the z-direction by adding the response from all beams ($F_z=\{F_1+F_2+F_3+F_4\}/4\sin\alpha$).

To form the masses of inertia, each of which is symmetric with respect to the beam, and the cantilever beams inclined to the surface, (100)-oriented silicon wafers are used as a starting material. The cantilever beams that support the inertia masses are etched parallel to the (111)-planes with the well-defined angle α=54.73° to the (100)-planes in the silicon crystal, (see also *MSB 94:1*). A (100)-oriented silicon wafer gives the possibility to have four different (111)-beams oriented with an angle of 90° to each other.

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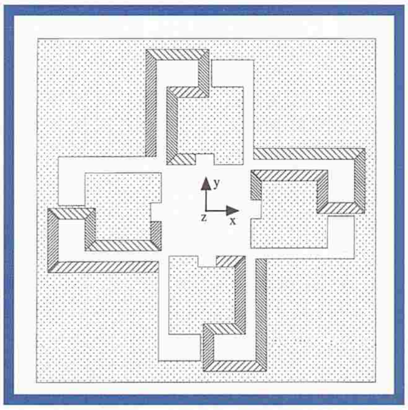
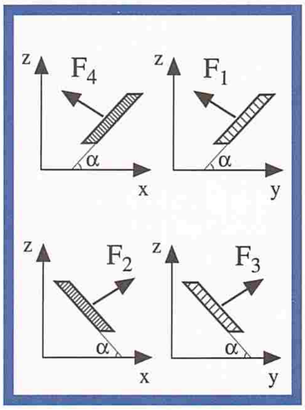


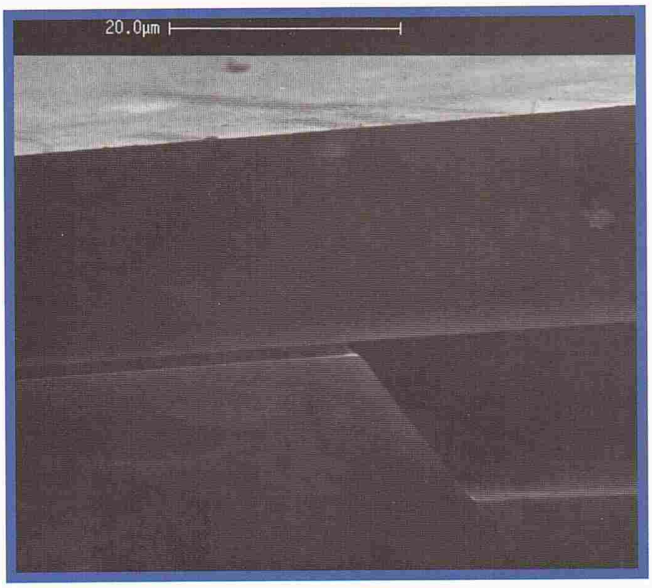
A schematic sketch showing one 3-axis accelerometer where the four differently oriented (111)-planes are inclined to the wafer plane with the angle of 54.73°. Each is marked with a different pattern.



The four smaller sketches show how an arbitrarily directed acceleration is separated into acceleration vectors.

Micromachining Basics Part 6:

Solid State Bonding



Cross sectional SEM photograph of a structure with a bonded SiO_2-Si interface. The oxide is 1 μm thick.

For silicon micromachining to be sufficiently versatile, methods not only to remove, but also to add material in a controlled manner are necessary. Adding material can be done chemically, by chemical vapor techniques or electroplating, or physically, by sputtering, epitaxial growth or solid state bonding.

When two flat and clean surfaces are brought into contact, a strong mutual adhesion appears. This phenomenon was described in the literature as early as 1936, by Lord Rayleigh, concerning polished glass slabs in "optical contact." Such a method for the joining of materials is attractive for combining monocrystalline semiconductors, in that neither glue nor external forces are needed. Bonding offers an alternative to epitaxially grown layers, and makes precise control of the joint thickness possible.

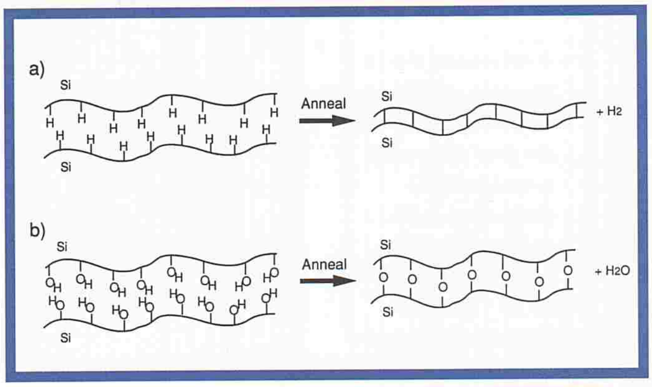
Silicon Direct Bonding

The first reports on direct bonding of silicon surfaces were presented in 1986, and since then there has been substantial research on this subject. Today's market offers very high quality silicon wafers with very flat surfaces and extremely low surface roughness. With highly developed cleaning processes, this allowes for bonding to become a key technology in micromechanics and microelectronics.

Electrical interconnects, such as ohmic contacts between different silicon layers and shallow pn-junctions, require clean and completely oxide-free interfaces between the silicon surfaces. Surface oxide is removed in an aqueous HF solution before bonding, making the surface not only oxide free, but also hydrophobic (Greek: *hydor* = water, *phobis* = fear, i.e. a drop of water does not wet the surface). When the wafers are put together, van der Waals forces between the outermost surface atoms cause surface adhesion. At elevated temperatures (400–600°C, N_2 ambient), dehydration takes place, and Si-Si bonds will be formed as illustrated in the schematic figure. Electrical contacts between different layers can also be accomplished by bonding with intermediate conductive films, e.g. metals that form silicides during annealing.

Silicon-to-Insulator Bonding

In many applications, an insulating layer of silicon dioxide between the silicon surfaces is necessary, insulating one structure from another, or as a sacrificial layer.



Schematic illustration of the proposed bonding mechanism for a) hydrophobic and b) hydrophilic silicon surfaces.

Oxidized silicon surfaces to be bonded are made hydrophilic (Greek: *philis* = friend, i.e. a drop of water will wet the surface), which is easily accomplished by a standard cleaning procedure. The opposing OH groups will attract each other, holding the wafers together at room temperature. By an annealing step, Si-O-Si bonds are formed, and at very high temperatures (above 1000°C) the bond is completely sealed by viscous flow of the oxide (see photo to the left).

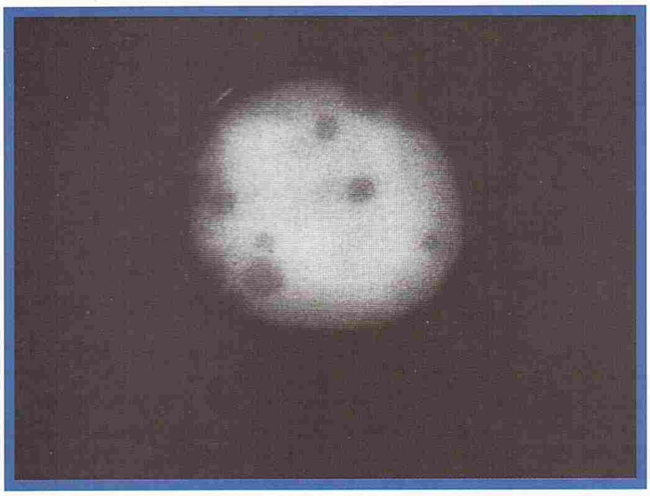
Bonding between silicon and quartz surfaces is desired in certain situations, such as between a quartz resonator and a silicon chip. The problem with interface stress due to the large mismatch in thermal expansion coefficients between the materials must be solved. Successful bonding by reducing the thickness of one of the materials, and keeping the bonding temperature at a minimum, has been reported.

A commonly used method for joining silicon and glass substrates is anodic bonding where heat and an applied voltage are used to electrostatically force the surfaces together. Thermal mismatch can cause marked stress, leading to fractures in the interface during cooling. Therefore, thermally matched Pyrex or Corning glass wafers are predominantly used for these purposes.

The bonding temperature is typically about 400°C, in which the glass is somewhat deformable. This will facilitate complete contact between the surfaces, even if they originally were not perfectly smooth. This method has an advantage over direct bonding in that a markedly lower temperature is needed.

Bonding of Silicon to III-V Semiconductors

Until recently, semiconductor lasers on silicon have been produced by heteroepitaxial



A bonded silicon wafer pair, as seen in transmitted infra-red light. Non-bonded areas are seen as dark spots.

growth. However, the materials suffer from a large lattice mismatch which gives rise to high dislocation densities. Direct bonding techniques are quite insensitive to lattice mismatch, and therefore they offer a unique approach to OEIC fabrication. The thermal mismatch between the two materials must still be considered, though. Several promising techniques have been presented. Some of them are quite similar to those used for direct bonding of silicon surfaces, but lower temperatures are used to overcome problems with thermal mismatch.

Epilogue

Already, there are many bonding techniques which are reproducible and has sufficient exactness to be used in micromechanics and microelectronics. There are other methods that must be further developed before gaining acceptance.

By using bonding with modern polishing and etching techniques, several new applications can be created including fully integrated, complex micro-systems and true 3-D devices.

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Bonding Elementary

The initial room temperature bonding process depends on several parameters which can be summarized in four main topics:

1. Surface topography, such as flatness and micro-roughness
2. Surface chemistry
3. Particle density and size
4. Material properties, such as hardness

Regarding its surface chemistry, silicon is a material offering a great many possibilities for modification. The “dangling bonds” of the surface atoms can be coupled with many different species, including OH, H, F or hydrocarbons, depending on their availability at the surface. This versatility allows for much freedom in the manipulation of silicon’s bonding properties.

TRANSDUCERS’95 • EUROSENSORS IX
June 25–29, 1995
Stockholm, Sweden

TRANSDUCERS’95 • EUROSENSORS IX is a joint meeting between the 8th International Conference on Solid-State Sensors and Actuators, and Eurosensors IX. Its main topics are: General and Theoretical, Materials and Technology, Mechanical Sensors, Physical Sensors, Chemical Sensors, Biosensors, Actuators, and Interface Electronics. More than 500 presentations will be given in oral and poster sessions, including prominent plenary and invites speakers. A special session on Industrialization of sensors will be organized.

For further information, please contact:
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c/o Congrex AB
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PUBLICATIONS

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

- Assembling Three Dimensional Microstructures Using Gold-Silicon Eutectic Bonding; A.-L. Tiensuu, M. Bexell, J.-Å. Schweitz, L. Smith and S. Johansson (UU); *Sensors and Actuators A*, **45** (1994) 227–36.
- Characerization of an Inchworm Prototype Motor; M. Bexell, A.-L. Tiensuu, J.-Å. Schweitz, J. Söderkvist and S. Johansson (UU); *Sensors and Actuators A*, **45** (1994) 322–29.
- First Steps of μTAS in Latvia; A. Lusis *et al* (Riga), and A. Lloyd Spetz *et al* (LiTH); in *Micro Total Analysis Systems,* A. van den Berg and P. Bergveld (eds.), Kluwer Academic Publishers, The Netherlands (1995) 233–236.
- Gallium Arsenide Micromechanics – A Comparison to Silicon and Quartz; K. Hjort (UU); *Alta Requenza – Rivisita di Elettronica.*, **6** (1994) 48–54.
- Microanalysis Systems for Gases; I. Lundström, A. Lloyd Spetz, H. Sundgren and F. Winquist (LiTH); in *Micro Total Analysis Systems,* A. van den Berg and P. Bergveld (eds.), Kluwer Academic Publishers, The Netherlands (1995) 153–163.
- Micromechanical Fracture Strength of Semi-Insulating GaAs; K. Hjort, F. Ericson and J.-Å. Schweitz (UU); *Sensors and Materials*, **6** (1994) 359–367.
- Small Silicon Based Pressure Transducers for Measurements in Turbulent Boundary Layers; L. Löfdahl (CTH), E. Kälvesten and G. Stemme (KTH); *Experiments in Fluids*, **17** (1994) 24–31.

NEXUS

The European *Network of Excellence in Multifunctional Microsystems* (NEXUS) aims at bringing together European expertise with R&D resources in MST. The infrastructure created by NEXUS is intended to stimulate, support and coordinate interdisciplinary cooperation between MST laboratories and industry throughout Europe. It is recognized that no single company or country can cover the expenses and create the infrastructure required to develop MST technology.

NEXUS was formed in 1992 as a two year project financed by EU (ESPRIT III). A one year continuation has been granted after which a review of its achievements and a new application to EU is planned.

Organization

NEXUS is organized into various boards and committees supervised by a coordinating board. *General Assembly* meetings are held once a year (Note 1). Some important areas around which the working groups and task forces are formed are:

- *Communication Network:* Designed to improve synergism through better exchange between NEXUS partners, for example by encouraging the use of E-mail.
- *Core Projects:* Identify and promote "core research projects," and to encourage the formation of project consortia.
- *Industrial Links:* Promote and increase awareness and participation among small and medium-sized enterprises (SMEs).
- *Industry:* Define industrial needs and strategies in MST and ensure that the actions taken by the network are application and production oriented.
- *International Relations:* Provide an inventory of overseas MST activities, encourage the formation of corresponding networks in the U.S.A. and Japan, generate official platforms for international MST dialogues, and create a scientific basis for a worldwide dialogue on MST aiming at recommendations for future standardization.
- *Training and Education:* Promote MST-related education and training in Europe, organize workshops, subsidize COMETT courses, stimulate short rotations for technical training (Note 2), survey MST literature, and initiate the compilation of an MST textbook.

To stimulate the cooperation and the exchange of MST-related expertise, a catalogue "Who is Who in NEXUS" has been assembled. Various public relation activities have been also undertaken, including the production of a twelve minute video entitled "Microsystem Technology", a newsletter, and presentations at various exhibitions and conferences.

Partners

Membership in NEXUS is open to all European companies and institutions able to contribute expertise in areas relevant to MST. The expanding network consists of more than 155 partners from 15 countries. Roughly one third are in industry. Currently there are three Danish, one Finnish, two Norwegian and four Swedish partners. Uppsala University was one of the original twelve partners.

Other Networks

A network including partners from the eastern part of Europe is under development (NEXUSEAST). At present, NEXUSEAST has 13 partners from seven countries.

A similar network in the area of packaging, *Network in Microelectronics System Integration Technologies* (NETPACK), was recently formed. There is an informal exchange of information between the networks. These networks are all coordinated by Fraunhofer Institutes in Berlin.

Jan Söderkvist
NEXUS coordinator
at Uppsala University

- Note 1. The next NEXUS *General Assembly* is preliminarily scheduled to be held in Stockholm in conjunction with *Transducers '95• Eurosensors IX.*
- Note 2. Anita Lloyd Spetz from the University of Linköping will rotate February and March in Prof. Göpel's group at the University of Tüblingen, Germany. Anita will make surface analysis of very fast responding gas sensors, based on catalytic metal – oxide – silicon carbide.

MST in Biosystems
– Frontiers and Challenges

The joint conference *Nanofabrication and Biosystems: Frontiers and Challenges* was held in Kona, Hawaii, in May 1994. The conference was organized by the Engineering Foundation, U.S.A., with the objective to explore approaches of nano- and microfabrication as they apply to biology and engineering. A number of engineers and physical scientists met informally with biologists and biophysicists to discuss the materials and engineering aspect of micro- and nanofabrication, and how biologists have implemented such fabricated devices in their research.

The materials and physics research community has developed powerful and sophisticated methods of probing electronic, magnetic and mechanical properties of materials on a micro scale. These techniques are beginning to be employed for biological measurements. For example, devices have been fabricated to selectively orient neurones, to elucidate how both fungal and mammalian cells perceive topographical signals, to record action potentials non-invasively from individual cells, and to determine what surface features promote cell and tissue compatibility to biomedical implants.

From an engineering aspect there is a lot to be learned from the understanding of biological materials, how they self-assemble, their construction, and how solutions for, e.g., force achievement have been obtained by nature over geological time scales. The properties that have evolved are highly attractive in today's drive for new engineering materials.

These were the two complementary themes of the conference. The conference was divided into six sessions ranging from pure microfabrication techniques and devices, to direct applications of microfabrication in molecular biology. The sessions gradually included biology and medicine, e.g. how microfabricated instruments have been developed for biology and medicine purposes, studies of cell and tissue interaction with microfabricated surfaces, and biological processes as tools (and questions) applicable to nanofabrication.

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The Samba Interference Sensor

The Samba Interference Sensor consists of a silicon interferometer placed on the end surface of an optical fiber, as shown to the right. The sensor element used as a pressure sensor is briefly discussed on the front page. Light is emitted into the fiber from a light emitting diode, transmitted into the cavity of the sensor element, reflected back into the fiber, and detected by a photodiode. This design has advantages over standard types of pressure sensors in that it relies solely on the mechanical properties of silicon. Therefore, the sensor can withstand harsh environments, including high temperature and strong electrical perturbation. The Samba Sensor is well suited, for example, for the measurement of pressure inside motor cylinders in order to achieve highly efficient combustion conditions. Measurements of the cylinder pressure as a function of motor crank angle agree well with those obtined using a laboratory sensor.

As the sensor body is fabricated by silicon technology, it can be produced at very low cost and with high reproducibility. For automotive applications, the sensor has been developed in collaboration with Volvo Teknisk Utveckling AB.

The sensitivity of the Samba Sensor is determined by the relationship between the thickness of the cavity and the width of the pressure membrane separating the cavity from the outside world. Sensors for pressures ranging from mbar to 500 bar have been made.

A simple electrical based pressure sensor can be made by furnishing the two silicon parts with electrical contacts. Then by measuring the current through the structure when the external pressure is sufficient to force the parts in galvanic contact, a pressure relay function is obtained.

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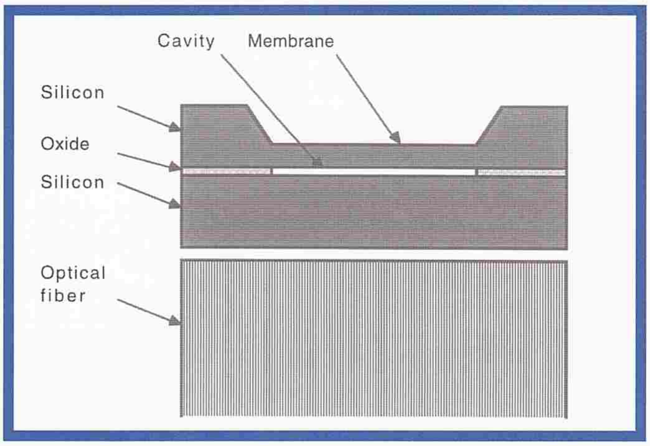

The Samba Interference Sensor placed on the end surface of an optical fiber.

A variation of the pressure sensor is obtained if the cavity is created at the interface between two bonded wafers with different doping types, thus forming a p-n junction as shown in the figure below. Using a very thin membrane (≈1μm) and applying a back bias to the p-n junction will bend the membrane due to the appearance of Coulombic forces inside the cavity. By placing this structure on the end surface of an optical fiber, as for the pressure sensor described above, gives the possibility to measure voltages on high potentials using the fiber as an electrically isolating medium.

Another interesting feature of the p-n structure shown below is its property to work as a photodiode and a voltage controlled interferometer simultaneously. Choosing the wavelength of the penetrating light, L1, subject to interference, such that there is a very low absorption by the silicon, and illuminating with a second light source, L2, with a wavelength such that the light is absorbed, a light controlled modulator is obtained. The light from L2 will create charge carriers in the back-biased p-n junction. Connecting the sensor body in series with a resistor to a constant voltage source, the light from L2 will change the voltage across the cavity and the degree of bending of the membrane, and thus the interference of L1 in the cavity. The geometrical conditions for optimal electrostatic conditions of the cavity are presently being studied by a Ph.D. student at the department.

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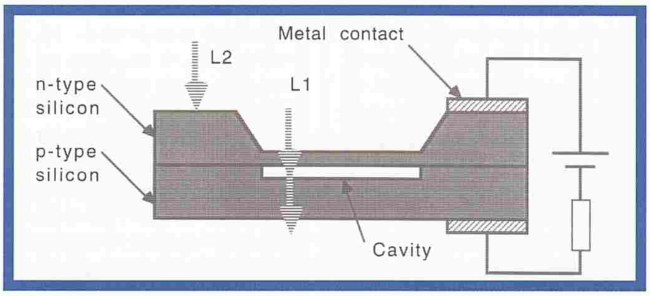

The combined photodiode and voltage controlled interferometer.

Samba Sensors

Samba Sensors AB was established in 1992 in order to finance a collaboration project between the Department of Solid State Electronics and AB Volvo. The founders were members of the department and Volvo. Later, in 1992, interest from new customers motivated a stock emission, the establishment of a professional board, and the search for an experienced company leader. Present company owners are CIT Synergo AB, Chalmers Innovation AB and the cofounders, each party holding 1/3 of the total stock. Currently, five individuals are involved in the development and production of electrooptical sensors based on variations of the Samba Interference Sensor.

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DISSERTATIONS

On January 20, Amir Baranzahi, Linköping University, presented his thesis, *Chemical Sensors Based on Catalytic Metal-Oxide-Silicon Carbide, MOSiC, Structures*, for the degree of Technical Licentiate. The sensors can been operated as detectors for hydrogen and hydrocarbons at temperatures up to 750°C.

On January 24, Gunner H. Larsen presented his thesis, *Implementation of Micromechanical Transducers for Acoustics and Vibration,* for the degree of Industrial Ph.D., at MIC, Lyngby, Denmark. His work contains studies of scaling and wet etching of borosilicate glass, and modeling and realization of a micromachined microphone.

MSB wishes to congratulate both.

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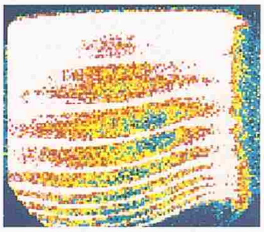
NEXT ISSUE



Some topics covered will be:

- MST at Linköping University
- MST and simulation in electrophoresis
- Flexible network creates new companies

MSK '95

Mikro Struktur Kurs is a two-day course to be held in Uppsala in March. The course is intended to give an insight into the possibilities and limitations of micromachining. Some topics covered are MST materials, fabrication techniques, sensors and actuator principles, industrial aspects, and the status of R&D. The official language is Swedish.

For more information, please contact Jan Söderkvist (Fax: +46-(0)8-510 116 15) or Karin Ljungberg, Uppsala University (Fax: +46-(0)18-18 30 20).

Etching Technology

This two-day course in Uppsala provides an understanding in the various etch techniques, such as wet or dry etching, isotropic or anisotropic etching. Participants will learn about the necessary equipment and the criteria for choosing one method rather than another. The official language is English.

For more information, please contact Annette Locher, FSRM (Switzerland, Fax: +41-38 24 71 45) or Jan Söderkvist (Fax: +46-(0)8 510 116 15).

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If your address labels start with a ✂-sign, then you will eventually be removed from the mailing list. For each issue of *MSB*, we randomly remove 20% of those whose address label starts with a ✂-sign.

FUTURE EVENTS

Transducers '95 • Eurosensors IX, Stockholm, Sweden, June 25–29, 1995. For information contact: Congrex AB, Fax: +46-(0)8-612 62 92.

MME '95 (MicroMechanics Europe), Copenhagen, Denmark, Sept. 3–5, 1995. *Abstract deadline: June 1.* For information contact: Prof. Otto Leistiko, Fax: +45-45 88 7762.

MicroSim '95, Southampton, UK, Sept. 26–28, 1995. For information contact: Sue Owen, Fax: +44-(0)1703 292853.

MSK '95 (Mikro Struktur Kurs – in Swedish), Uppsala, Sweden, March 28–29, 1995. For information contact: Jan Söderkvist, Fax: +46-(0)8 510 116 15.

Etching Technology (course), Uppsala, Sweden, April 25-26. For information contact: FSRM (Switzerland), Fax: +41-38 24 71 45, or Jan Söderkvist, Fax: +46-(0)8 510 116 15.

Sensor 95, Nürnberg, Germany, May 9–11, 1995.

49th IEEE Int. Frequency Control Symposium, San Francisco, USA, May 30–June 2, 1995.

MEMS '96 (Micro Electro Mechanical Systems) in San Diego, U.S.A., Feb. 11–15, 1996. For information contact: Preferred Meeting Management Inc., Fax: +1-(619) 298 3459.

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