MICRO STRUCTURE BULLETIN

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Miniaturized Pressure Sensor

For the past 14 years RADI Medical Systems in Uppsala, Sweden has been working to produce a miniaturized pressure sensor that can be integrated into a medical guidewire. The application for such a product is the measurement of pressure in the coronary arteries of humans, for example during balloon dilatation. Information gained from the measurements can help determine treatment for a patient suffering from coronary artery disease.

Demands from the market are that the sensor needs to be tiny, and that it should have a high frequency response. The guidewire should be comparable to non-sensing guidewires physicians use, and be disconnectable for rapid exchanges of the balloon catheters used with the guidewires. As a result, a first generation was developed:

- 1985: RADI contacted the Uppsala University. A research program was initiated.
- 1990: RADI launched a fiber optic sensor Pressure Guide^{TM}, with ∅0.018”.

Manufacturing fiber optic sensors proved to be a time-consuming process and the market demanded:

1. Faster production.
2. A detachable wire.

There was a need for a new sensor generation:

- 1994: Research program initiated with KTH in Stockholm. Development of electronic sensor starts.
- 1995: Reduced fiber optic sensor size to ∅0.014”.
- 1996: Product development in cooperation with IMC in Stockholm.
- 1997: RADI launched a finished product, PressureWire^{TM}, a solid state micro pressure sensor.

The guidewire-mounted pressure sensor element is manufactured manually under microscope.

This sensor is piezoresistive with a Wheatstone bridge; AAMI BP22-1994 signals, 0–1000Hz bandwidth, 10ms time response. The guidewire is detachable, total length 175cm; ∅0.014”, Teflon-coated shaft. Today, RADI is able to produce a product that meets market expectations, and can keep up with the growing demand for stock.

Sensor production consists of approximately 20 people who work in self-led groups. Production is divided into operator-led operations. Everyone gets a feeling for logistics and the importance of steady flow. Internal groups are responsible for quality and effectivity. Matrix grouping works well and gives the operators a sense of responsibility and an overview of the entire process. Manufacturing is mainly performed manually, under a microscope. The final and most critical operations take place in a cleanroom.

Product development continues to be a priority. Other projects are to further improve quality and reduce costs. The focus of the quality project is to analyze returned-goods statistics, increase yield, specify process variables, improve tests and study handling of the product by end users. The focus of the cost reduction project is to identify work and material costs as they occur and use this to optimize flow. There is also an investigation into how to increase yield and reduce costs for direct and indirect material.

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EDITOR'S NOTE

A component's price is controlled by several factors, including packaging, handling, testing and qualification. These factors are often forgotten in the initial development phase although they contribute, directly and indirectly, to a substantial part of the total cost. The sensor element itself usually influences the cost much less than first is believed. Nevertheless, the sensor element enables the device which could explain why universities often focus only on this part (bottom-up view). Industry has to look at the entire system (top-down view).

Packaging is normally not considered an interesting research area for a university, partly due to the difficulty of setting up general research programs that cover but small aspects of the packaging area. For industry, packaging is a challenging area that can be a major cost driver. Production disturbances are, to a non-negligible level, related to this area, and often require emergency actions. Unfortunately, it is difficult in advance to specify what type of problems that might occur, but it can be agreed upon that it usually is very time consuming to pinpoint their cause and to come up with reliable work-arounds. The detective work involved often is worth to be considered as 'research'.

Summer is here; flowers and leaves have 'unpacked' and warm jogging clothes are packed away.

Have a nice summer
Jan Söderkvist

Protective Coatings for MST

Packaging of microsystems contributes around 50 percent to the price of the entire system. Packaging concepts for sensors exposed to harsh environments may be even more expensive. To protect the silicon sensor chip the package frequently becomes bulky and requires manual assembly at the chip level.

A protective coating may enable the direct exposure of the sensor chip to harsh environments, such as alkaline solution at an elevated temperature. Moreover, such coatings may be applied at the wafer level and reduce the packaging and assembly requirements. In a collaboration between Grundfos A/S, Danfoss A/S, and Mikroelektronik Centret (MIC) such packaging schemes are under development.

Tough Requirements

The figure below shows a typical cross-section of a coated differential pressure sensor with a piezoresistive read-out. For a successful coating several requirements need to be met. These requirements include, but are not limited to: a high chemical stability against the media of interest, a limited thickness to minimize the mechanical impact on the membrane, a low pinhole density, coverage of anisotropically etched cavities, and sufficient step-coverage, e.g., of interconnects. Furthermore, patternability of the coating is desirable, among others reasons to provide access to bond pads.

Our investigations show that amorphicity of the coating material is essential. All polycrystalline materials tested failed within days when exposed to localized etching, presumably through grain boundaries. In addition, several types of polymers, such as polyimid and Parylene C, were tested. These films failed through delamination, typically after one month of exposure to alkaline solutions at elevated temperatures.

Arrhenius plot of several etch rates of several thin films in alkaline solutions (pH 11). Arrows indicate upper limits.

The diagram shows etch rates of several materials in alkaline solutions (pH 11). The green region denotes the application area and is characterized by a critical value of 0.1 Å/h at 125 °C. This corresponds to an approximate expected life time of 10 years for a coating with a thickness of 1 µm. The etch rates were determined by measuring film thicknesses using ellipsometry before and after exposure to the alkaline solutions in a "pressure cooker". It is observed that the etch rate of conventional materials such as silicon dioxide and silicon nitride is several orders of magnitude too high for our application.

SiC and Ta–O

SiC (commercially available from FhG-IMT, Munich, Germany) deposited in a PECVD process exhibits excellent step coverage and low etch rates. An improved deposition process brings the etch rate below the critical point at 125 °C set by the application area. In the diagram this material is marked SiC (II).

Schematic cross-section of a differential pressure sensor with piezoresistive detection. The protective coating (in red) is applied at both sides of the sensor chip.

For Ta–O films, we could not detect any etching after exposure to aqueous solutions with pH values in the range of 2–11. The Ta–O films were deposited at room temperature by reactive sputtering. After several months of exposure an upper limit of the etch rate of less than 0.008 Å/h was found! Etching in concentrated hydrofluoric acid may be used to pattern Ta–O in a batch process. Moreover, pinholes can easily be revealed by a short exposure to buffered hydrofluoric acid. Typically, the pinhole density is less than 3 per cm^2, which is sufficiently low. The step coverage of the sputtered Ta–O is slightly limited.

Application Examples

Several differential pressure sensors were successfully fabricated by gluing a coated chip into a simple metal housing. These sensors are evaluated during online exposure to alkaline environments. Resistance against saline environments, wear, and hardness of the coatings are also under investigation.

Deposited at room temperature, Ta–O was also used successfully as an etch mask for anisotropic etching of Si in a 28 wt% KOH solution at 60 °C.

We expect that this type of protective coating not only will meet the packaging constraints of the type of sensors mentioned here, but also can be applied to implantable and/or blood-compatible microsystems since both Ta–O and SiC are biocompatible.

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Piezo Printheads – Produced in Sweden

Due to the common usage of inkjet printers it may be easily forgotten that the key element to this technique is a microactuator which is packed inside the printhead. Such printheads represent a huge fraction of the overall volume of manufactured microsystems.

At XaarJet AB (former MIT Inkjet) in Järfälla, Sweden, printheads are produced. The technology applied is the piezo shear mode / shared wall concept which was developed by Xaar (UK).

The Actuator

The basic components of a printhead are the actuator and the electronic driver chip. The actuator itself consists of a channeled base and a cover plate, both made of PZT, a piezoceramic material. The channels, filled with ink, are surrounded by PZT and, at the front end side, by the nozzle plate.

The key for the actuation is the shear motion of the PZT walls, as shown in the figure of the cross-section through the actuator. The material has a permanent electrical polarization in the vertical direction. If an electric field is applied across the channel walls, e.g. using two parallel electrodes on the wall surfaces, a shear motion is generated.

This effect can be used to increase, as in the cross-section figure, or to decrease the volume of ink in an actuator channel. A rapid volume decrease and the reflection of pressure waves lead to the ejection of an inkjet droplet through the nozzle.

A XaarJet printhead with 128 channels.

Manufacturing

The printheads are completely manufactured in the Järfälla facility. In a manufacturing line it is of highest importance that the product be produced with high quality and tight tolerances, as well as with a reasonable yield and low cost. For this, it is advantageous to organize as many process steps as possible on a wafer scale. As an example, the ink channels are formed by sawing into plain PZT wafers.

Moreover, many production steps for the actuator have their origin in silicon technology and take place in a cleanroom. Examples are the metallization and passivation of the channels and the wire bonding between the actuator and the driver chips. The remaining manufacturing mainly consists of assembly steps and packaging, where placement accuracy and tightness play an important role.

The resulting piezo printhead has outstanding features, e.g. good control of the inkjet ejection by means of optimized drive pulses, high flexibility in the choice of fluids, and an extremely long lifetime. This defines the range of applications for the printheads.

Application Range

The focus clearly lies in printing. For good results, an optimized combination of printhead, ink and media is required. The company's strategy is to deliver printheads, inks, and cartridges to OEMs (original equipment manufacturers), who will develop the printer application and often provide the media.

Present work fields of printers equipped with XaarJet AB printheads are, at one side, industrial marking, ticketing, and labeling. On the other side are wide-format printers for poster size media in which there is a high quality demand on the printhead, as well as grand-format applications with up to five meter wide printers.

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Basic printhead components

Cross-section through the actuator, perpendicular to the channels.

Low Cost Modules for Single Mode Fiber Access Applications

Electronic communication and information transfer is rapidly becoming part of our lives. Means for increasing the communication speed are constantly sought. Here, optical fiber is an interesting replacement to the 'good old faithful' copper wire.

For the majority of consumers to benefit from the increased capacity of the fibers, it is necessary to extend them all the way out to their homes. In the past, components for these kinds of access applications have been too expensive for commercial use.

Key issues when linking the electric and optic domains include packaging and fiber alignment, areas where MST offers interesting possibilities. For example, for the production of the 4-channel transmitter/receiver module in the figure an MST-fabricated silicon optical bench is used for laser soldering and passive aligning of the fibers. This allows for the highly parallel and automatic production of high volumes at low cost.

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From a Research Lab to a MEMS Fab

Many companies and research organizations have started research on MEMS. A few have succeeded in turning their developments into industry. What has been important for the success? What has been difficult? What are the lessons learnt? Some answers to these questions may be found below with the case of Vaisala-VTI Hamlin as an example.

Start-up of a MEMS Activity

Companies producing MEMS may have very different histories and motivations for starting. University spin-offs, corporate research within large organizations, and technology upgrades of existing sensor and system companies can be found. When starting MEMS activity Vaisala was, and is still today, a well-established instrument and system company focusing on environmental measurement. Vaisala did not get started in MEMS for the purpose of upgrading the old, but for creating new business. The aim was to diversify to new areas. The automotive industry was referred to in its earliest documents almost 20 years ago.

Today VTI Hamlin, the spin-off from Vaisala's MEMS activity, is part of the Breed Technologies Corporation. It is the leading company producing accelerometers for automotive applications excluding airbags. VTI has recently brought to full speed a new clean room facility in Vantaa, Finland with 10 M/ year capacity on 150 mm wafers, expandable to 50 M/ year.

DFM

With today's rapid product cycles it is essential to '*design for manufacturability*'. Competition usually does not allow for modifications and re-takes at a later stage, especially considering re-qualification times and re-investments in production equipment. In fact, development might contribute directly to 5% of a product's cost, while its indirect influence of the product's cost can be more than 70%.

Total Commitment

Whatever the history and motivation for starting the MEMS activity, all successful cases share the enthusiasm among the pioneers of the technology. But what is often missing is the total and long term commitment of the upper management and the owners. The management has to be prepared to defend and protect the starting technology years before it is going to make the first small contribution to the revenues of the company. It will take even longer before the start-up will become profitable. The time span required is ten to fifteen years, which is much longer than the planning period of most companies.

Vaisala had enough foresight in the early 80's. They built a clean room facility in 1980. ICs for internal use were initially manufactured as a basic load. But from the beginning the idea was to create new sensors for new applications and markets.

Creativity and Freedom

An enthusiastic spirit prevailed in the new Vaisala start-up. Creativity and originality were highly valued. 'Me-too' was an often referred to ugly word. That's how the Vaisala MEMS acquired it's unique features far from the safe main stream. Unconventional ways to do things were tried out when striving for uncompromized excellence. From retrospect this is a success factor.

There were no barriers. Even if separate production and R&D responsibilities were defined everybody acted for the benefit of the whole. When new sensors finally, five years after the start-up, were brought into production no transfer was needed. The same people who were involved in the development continued solving the production problems and controlling the processes on the same equipment initially used in the R&D phase.

Being a high volume manufacturer doesn't stop creativity. Anisotropic wet etching of silicon can produce amazing shapes. This picture shows the proof mass and springs of an angular rate sensor designed by Anssi Blomqvist at VTI Hamlin.

Time to Grow Up

After years of medium volume production of the highest accuracy pressure sensors an opportunity was opened in the automotive industry. Large volumes of accelerometers were needed starting in the early 90's for airbag and chassis control. Vaisala got a foothold on the latter.

The accelerometer was brought from prototype to 0.5 M/year volumes in less than two years. This period was extremely painful with severe problems in design, processes and quality. Interconnections failed, the proof masses were sticking to the counter electrodes and the cantilever beam springs were breaking. Anodic bonding process failed due to shorting. Self-made equipment were a bottleneck in expanding the capacity. The operation procedure, which had been adequate for controlling the R&D and the small volume laboratory type production, failed badly.

These almost simultaneous problems were solved in the manner inherited from the early days of R&D. A few key individuals understood the product and processes thoroughly. They found solutions by being creative, bold and self-confident. Changes to the design and processes were implemented on a running basis without complete validation tests. The automotive customer was forced to accept them, against all quality rules.

The latest VTI sensors utilize the earliest and most original features of the company's technology. A unique technique of manufacturing horizontal and vertical glass isolating layers enables to obtain multiple feed throughs to a vacuum space.

After the problems were solved and the yield was stabilized at a high level it was clear that the old ways couldn't be continued. A new discipline was needed. The operation couldn't be run as a laboratory any more. Stopping a car line was too frightening a vision.

The Automotive Industry

The new model of operations was borrowed from the automotive industry, which seemed to be a complete opposite to the former ways. Inflexible attitude to changes, strict documents control and formal quality procedures were now required instead of the former relative freedom to change things as the situation required.

Operators had to be taught to perform according to instructions (which had to be written first, of course). No variation from time to time and operator to operator would henceforth be allowed. Changes were implemented only by a formal change request procedure, which often led up to the end customer for sign-off. Even small design changes could be implemented only for the coming model years, after a validation procedure taking at least three months. The design had to be frozen two years before the production start-up, with the processes frozen at about one year.

A number of previously unheard of analyses and documents had to be completed and taken into active use: DFMEA, PFMEA, DFA, DOE, Control Plan, PPAP, DV, PV, SPC, Cpk. A new language (or jargon) and a new way of thinking had to be learnt. It was no more a question about creativity, original designs and unique technology. Now it was about quality, reliability, repeatability and control of the smallest detail. Now it was real industry.

The change didn't happen overnight. The first Design Failure Modes and Effects Analysis (DFMEA) was completed indeed overnight: the customer was coming the next day and requested an explanation in the format given. Six years later the team, which was planning the design and process changes for the new clean room, started an FMEA for themselves in order to decrease the risk of causing something unexpected. Now it was a real quality tool, not just a forced add-on.

Is it Fun any More?

Does the new environment and operation procedure offer satisfaction to the individual comparable to the old ways emphasizing creativity and freedom? The answer is yes, but in a different way. First, the persons who have stayed through the history of the company strongly felt the need for a more disciplined way to operate, having seen where an uncontrolled manner of operation may lead. There was a motivation for change.

More importantly, there are now many more people involved. The scope for each individual has narrowed, but the new discipline has integrated the individuals into teams. In the old laboratory environment a few key individuals acted to solve a crisis situation and the rest were wondering what had happened. The start-up of VTI's new clean room proved that now the information, responsibilities and actions are shared by a large number of employees. Creative ideas by individuals are still needed, but they are implemented in a controlled manner which keeps all aware of what's happening.

In spite of the automotive industry's seemingly negative attitude to change, continuous improvements and new products are actually expected. An improvement has to be made whenever possible. It might not be possible in the middle of a model year but certainly there will come a time to introduce it. Continuous improvement is the only way to keep the product competitive in the long run. This keeps the R&D people enthusiastic and busy, if in a well controlled manner.

But R&D is not the most important area of the company any more. A continuous effort is needed to maintain what was already achieved: the yield high and spotless quality. The main emphasis of an industrial MEMS company, once the products are the right ones, is not in R&D but in the process control and quality.

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Encapsulation of Silicon Resonators

In the field of micromachining, microsensor packaging is one of the less investigated, although one of the most important and challenging, technology areas. The package is at least as important as the sensing element itself. It provides mechanical support and protection from the external environment.

In the case of silicon resonant structures the encapsulation requirements are particularly demanding. The high performance of a resonant structure is, in principal, based on its high mechanical quality factor since this leads to high resolution and low power dissipation, and makes high short-term stability possible. When encapsulating the device, special attention should be paid to maintaining a high quality factor. To achieve this, the resonant structure can be housed inside a low pressure cavity to reduce the gas squeeze-film damping that appears in the narrow gaps between the mechanically oscillating structure and, for example, the electrodes used for excitation and detection.

A challenge in the realization of a low pressure encapsulation is to provide hermetically sealed electrical feedthrough conductors from the external environment to the internal cavity. Different solutions can be adopted to form a low pressure cavity. One way is to utilize a low pressure during anodic bonding. Another is to encapsulate the resonator inside a cavity leaving a small opening that later is sealed in a low pressure metal deposition or growth process. The use of a getter material which absorbs the residual gases inside the cavity is also an interesting alternative.

At the department of Signals, Sensors and Systems (S3) at KTH, the encapsulation of resonant silicon structures originally designed for density and Coriolis mass flow sensing of liquids has been realized. The encapsulation is made by anodically bonding, inside a vacuum chamber, the silicon structures to two recessed glass lids. Lateral feed-through metal conductors are used for attaining electrical contact with the excitation and detection electrodes inside the cavity.

The entire fabrication is performed at the wafer level using only batch-fabrication techniques. The resulting pressure inside the hermetically sealed cavity is 1 mbar with proven long-term stability. Low power consumption can be achieved and a voltage of 5 V_{RMS} is sufficient for the excitation.

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Silicon resonators encapsulated at the wafer level between two glass lids with electrical feedthrough conductors for electrostatic excitation and capacitive detection.

SIMULATIONS

On January 28, the Finish conference *Microsystem Modeling* was held in Helsinki. The large number of participants (90) proved that there is substantial interest in MST-modeling in Finland and that further collaboration is needed. The organizers received much positive feedback.

The program included three invited presentations (Stephen Senturia, MIT/USA, Jan Söderkvist, Colibri/Sweden, and Mark G. da Silva, Microcosm/USA) followed by five presentations from Finland (Jorma Kivilahti, Heikki Haario, Jari Järvinen, Timo Veijola and Kimmo Kaski) and a poster session. The final discussion, led by Heikki Kuisma, VTI Hamlin, summarized the day's topics well. The event was organized jointly by CSC and Tekes.

DELTA Danish Electronics, Light & Acoustics has a long experience with the packaging and testing of electronics. Its activities within microelectronics provide a strong basis for its extended activities in microsystems. DELTA has offered services within microsystems for almost a decade, for example in *environmental testing, packaging, materials* and *failure analyses*. New services include interconnection technology (flip-chip assembly, etc) and *testing at the wafer level* to select Known Good Dies (KGD) (soon also with non-electrical stimuli and detection). Other services are *ASIC design* and production, and *EMC* measurements and shielding.

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Volume Production of MEMS at SensoNor

In *MSB 98:4* some challenges related to MEMS packaging were outlined and discussed. In this article we will provide some ideas on how SensoNor asa has met these challenges.

Cost effective volume production requires inexpensive, reliable packages and a fully automated, effective production system. Typical critical processes in the packaging of sensors and other MEMS devices are:

- Mounting of dies to a substrate.
- Achieving electrical contact (wire bonding, flip chip, etc)
- Encapsulating (molding, etc)
- Testing

To ensure the successful implementation of a MEMS product in volume production it is often wise to use well known technology. The main problem then is the modification and adjustment of existing production equipment.

Production Facilities at SensoNor

SA20, our first truly volume product, was put into production in 1992. Since then about 31 million sensors have been delivered to our customers world wide. In 1994, planning for the next generation of sensors and production technology started. A new fully automated back-end production line was created together with a new waferfab. The first new product, a pressure sensor named SP13, was put into production in the new back-end line in August 1997. A number of other new products, including SP11, SP14, SP12 and SA30, are scheduled for production starting in 1999 and 2000. The two operating back-end production lines are described below.

The SA20 Back-End Line

This production line is situated at Skoppum about 10 kilometers from Horten south of Oslo. The production line is partially automated and based on a reel to reel principle with pre-molded cavity capsules. The sensor chip is mounted in the pre-molded polymer capsule. Electrical contact is made by wire bonding, and welding a lid on the top closes the capsule. The cavity inside the capsule is filled with oil and is sealed off. Finally, the sensor unit is cut out from the copper band and all visible copper is plated with a tin-lead alloy by dipping. Before shipping all sensors are temperature (both high and low) and vibration tested, as well as tested for electrical connectivity.

The SA20 back-end production line is, as mentioned, partially automated and has a limited flexibility for changes in its products. A limited rebuilding of the production line based on the main components in the system may result in a more flexible and up to date production line.

The BELP (Bach-End Lead Frame Products) Line

The BELP production line was put into operation in the autumn of 1997. This line is fully automated within each production cluster and has a total capacity of about 15 million parts per year. In its current set up the capacity can be close to doubled by duplicating a number of production machines.

The assembly and packaging line consists of five free-standing, process-dedicated production / equipment clusters. The following processes are performed in the clusters:

- Assembly and electrical connecting
- Transfer molding
- Tin-lead solder plating
- Trimming and forming of leads
- Testing, sorting and packing

The assembly and electrical connection cluster, also named auto-line, contains the following operations connected by a robot:

- Die bonding
- Wire bonding
- Glob-topping
- Inspecting

Separation of these processes into different clusters ensures a very flexible assembly and packaging process.

Both the choice of a lead frame based production and a molded polymer package give reasonably good flexibility. For example, the internal design of the package allows both one and two chips solutions with chips of different sizes. We were able to develop a low number of packages into which a range of different sensor types, including accelerometers, pressure sensors and micro switches, can be designed to fit with few modifications.

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Back-end production line for SensoNor's SA20 airbag sensor.

Back-end lead frame based production line as currently organized.

NEXUS User-Supplier Clubs

As a primary activity towards promoting the industrial use of microsystems (MST), NEXUS, the European network on microsystems (www.nexus-emsto.com), brings together users and potential users of MST with suppliers of MST technologies and components. For this purpose, User-Supplier Clubs (USCs) have been established with the following missions:

– provide a forum for discussion between MST users and suppliers
– identify and assess markets where MST may provide a competitive edge
– identify the technologies, infrastructure, and co-operation structures necessary to access these markets
– promote the discussion on emerging standards
– provide early guidance to equipment manufacturers and materials suppliers on future requirements
– alert academia to new industrial requirements in order to stimulate future research
– disseminate information across industrial sectors via the NEXUS membership
– offer the industrial participants information from experts on new research trends and results

To date, four application specific USCs have been established, and a fifth one is under preparation:

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All companies and institutions involved with MST in one of the above application areas, either as a user or a supplier, are strongly encouraged to join NEXUS and the appropriate USC.

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EURIMUS

The *European Initiative on Microsystems Usage* is a cluster project within EUREKA (www.eureka.be) with the goal of increasing the European MST market share. EURIMUS:

– Supports market-oriented R&D projects whose partners come from at least two EUREKA countries
– Aims for project selection in accordance to industrial criteria and confidentiality rules
– Helps in finding partners within industry and academia.

With a five year budget of 400 M Euro, the target is in excess of 100 industrial projects. If interested, contact:

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DISSERTATIONS

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

Christian Leth Petersen, MIC
His PhD thesis, *Microscopic Four-Point Probes*, addresses the design, fabrication and use of novel probes. On the surface of a crystal the topmost atomic layer will typically rearrange to form a surface superstructure. These films are well suited for studying the two-dimensionality of electronic properties.

A setup for measuring the oxidation of clean Si surfaces in ultra-high vacuum with a macroscopic four-point probe has been designed. Measurements show a clear dependence of the resistivity on the oxidation time and the doping of the Si crystals.

To increase the surface sensitivity of the measurements, novel microscopic four-point probes with electrode spacings down to 4 µm have been designed and fabricated (mm spacing for conventional probes). Measurements on microscopic features inside a SEM (scanning electron microscope) suggest that the surface state plays a significant role on this scale.

Mats Bergh, CTH
The main subject of his PhD thesis, *Wafer Bonding Problems and Possibilities*, is silicon on insulator (SOI) structures. By replacing the buried silicon dioxide layer with a polycrystalline diamond film the thermal properties of SOI structures can be improved. Buried aluminum nitride layers and semi-insulating substrates are also addressed.

The surface roughness can be related to the bondability of the material. Special surface requirements and various methods for measuring the surface roughness have, therefore, been investigated. The focus is placed on using atomic force microscopy (AFM) for determining the surface roughness. In addition, the use of bonding in various applications, such as in micromechanics and III–V materials, is discussed.

Timo Veijola, HUT
His PhD thesis, *Equivalent Circuit Models for Micromechanical Inertial Sensors*, discusses mainly numerical simulation models. These dynamic, nonlinear models include the contributions of electrical, mechanical, and fluidic energy domains by means of electrical equivalent circuits consisting of lumped, frequency-independent components.

Special attention is paid to modeling the rarefied gas flow in narrow air-gaps, including the effect of gas-surface interactions. The agreement between simulations and measurements for capacitive accelerometers and angular rate sensors is very good over a wide pressure range.

More information will be presented in the next issue of *MSB*.

Lars Wallman, LTH
His licentiate thesis, *Silicon Microstructured Sieve Electrodes for Neural Interfaces*, addresses the possibility of communicating electrically with nerves. One goal is to improve the quality of life for disabled persons by extending the limited functionality of today's hand prosthesis.

Special focus is set on sieve shaped neural interfaces, such as micromachined discs perforated with a large number of holes supplied with recording electrodes (see *MSB 97:2*). Transecting a nerve, inserting a sieve, and letting the nerve re-grow enables electrical monitoring and control of neuronal activities. An artificial neural network is used to control the data stream.

POSTTIDNING B

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FUTURE EVENTS

Transducers '99, Sendai, Japan, June 7–10, 1999.
For info.: Transducers '99,
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The Challenges of Microsystems Technology (course), Copenhagen, Denmark, Sept. 17, 1999.
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Eurosensors XIII, The Hague, The Netherlands, Sept. 12–15, 1999.
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Micro Devices for Fluid Handling (course), Stockholm, Sweden, Sept. 28–29, 1999.
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MME'99 (MicroMechanics Europe), Gif-sur-Yvette, France, Sept. 27–28, 1999.
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MEMS-2000 (Micro Electro Mechanical Systems), Miyazaki, Japan, Jan. 23–27, 2000. *Abstract deadline: Sept. 13, 1999.* For info.:
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www.mesago-jp.com/mems

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