At the core of our "knowledge society"

On 27 April 2010, a full-day symposium on microsystems and innovation was held at DIMES, the Delft Institute of Microsystems and Nanoelectronics. The purpose was to offer an overview of the recent achievements in microsystems and the technological challenges that will have to be addressed in the near future. Also, attention was paid to the role that R&D on microsystems can play in industrial innovation and the development of the "knowledge society". The audience consisted of delegates from the academic and industrial communities, as well as of public authorities.

• ***Lina Sarro, Mart Graef and Paddy French*** •

Presentations were given by members of the academia and by representatives of large industries and SMEs. They provided the audience with a good overview of the field, the relevance and the impact microsystems are having and will have in many sectors of industry and society, ranging from health monitoring to automotive, and from diagnostics to equipment manufacturing. A panel discussion, which focused on the question how the various stakeholders (large and small industries, institutes and universities, government) can cooperate on microsystems-enabled innovation, followed. During the breaks posters highlighting the microsystems research activities at DIMES were shown. Both during the presentations, the poster sessions and the panel discussion, lively interactions between participants took place.

Switzerland and Germany

Keynote speaker Oliver Paul, professor at IMTEK (Institute of Microsystem Technology at the University of Freiburg, Germany), gave a clear overview of the research activities in Switzerland and Germany, pointing out where strong research groups are located. He touched upon the

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types and mechanisms of available funding in both countries, and the link to innovation: the “return on investment”. He stated that you never know where innovation is coming from, but you have to be ready when it arrives.
Then he moved on to the microsystems activity at his department. He gave specific examples of research in his group [1]. Interestingly enough, he showed how highly unexpected, but successful applications derived from some basic technological developments and some fundamental studies on 3D silicon structuring and microneedle fabrication his group was engaged in, in the early days. In particularly, he zoomed in on the CMOS-integrated 3D force sensor for coordinate measurements of micro-components (collaboration with Carl Zeiss IMT) and some recent developments in multifunctional probe arrays for brain research (EU project NeuroProbe).

From ICs to MEMS, from MEMS to ICs

The semiconductor industry has been traditionally driven by cost reduction: more transistors per unit area (Moore’s law), which basically meant more calculations, faster calculations. For microsystems, as pointed out by Reinout Woltjer (NXP), the increase in functionality, the “better” as opposed to “faster”, is the driving force, moving from the “production era” to the “value added era”. The added value is in making life better, providing dedicated functionality. NXP is pursuing MEMS opportunities and focusing research on three types of MEMS devices: oscillators (for timing devices), microphones (mostly for speakers in mobile phones) and galvanic switches (for phones, car networks and radar systems, large data communication).

ASML is, as we all know, market leader in lithography equipment. Lithography is the “heart” of IC manufacturing, the key to smaller and more powerful chips. Innovation is crucial to maintaining such leading position. Maybe surprisingly to some, but less to the microsystems/MEMS researchers, MEMS devices are at the heart of the new lithographic systems. Robert Kazinczi, from ASML, introduced the FlexRay design concept, a fully programmable illuminator for high-NA (numerical aperture) immersion systems; see Figure 1. Illumination source shapes can be generated on demand, by manipulating a large array of MEMS mirrors with electrostatic actuation, instead of the traditional way of inserting optical elements and changing lens positions. The tiny mirrors can be individually tilted, thus optimizing the light path and offering a large flexibility. FlexRay provides on demand (freeform) source availability which allows for reduction in R&D cycle time and device shrink. Moreover, better machine-to-machine matching is obtained through unlimited tuning. This innovative concept which allows scaling down to sub-22nm nodes, has been recently introduced to the semiconductor industry [2], placing once again ASML one step ahead of the competition.

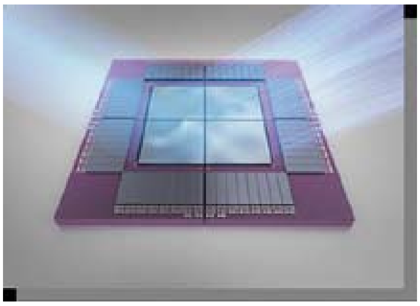

Figure 1. The FlexRay offers flexibility by controllable micromirrors. (Courtesy of ASML)

Microsystems for automotive

Environmental concerns are becoming a major factor in the development trends in the automotive industry. As illustrated by Paul Gennissen of Sensata Technologies emission legislation and energy availability/climate change dictate both mid- and long-term trends in automotive nowadays. For the long term, alternative fuels and electrical propulsion are the main objectives, while for the mid term the focus is on cleaner diesel, more efficient petrol consumption and more efficient transmission. A giant leap in fuel efficiency can be achieved when the automotive industry converts to closed-loop combustion control where the combustion process is measured by a cylinder pressure sensor. Sensata has been the first to develop a sensor that is affordable and reliable enough to be applied in mass-produced combustion engines. The sensor enables to monitor and correct the combustion process in individual cylinders of both diesel and petrol engines [3]; see Figure 2. In this way engine efficiency is increased and car pollution reduced. The heart of the sensor is a MEMS silicon strain gauge, but the success of the product is in the microsystem approach, i.e. the combination of sensor, dedicated signal processing and clever packaging design. This example once more

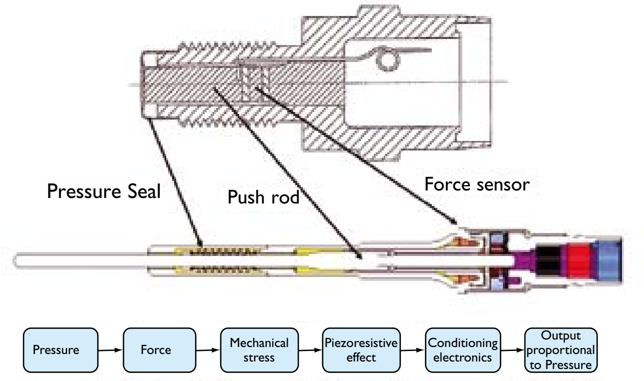

Figure 2. Evolution into a combined cylinder pressure sensor/glow plug. (Courtesy of Sensata Technologies)

underlines the importance of a (micro) system approach, focusing on the "product" that is needed.

Health: prevention, diagnostics, care

A very interesting parallel between microelectronics and microfluidics was drawn by Albert van den Berg, professor at the University of Twente, to introduce the relevance and potential of the now well-known lab-on-a-chip. As the electronic switch, the transistor, also the "liquid" switch needs to be integrated on a chip to be able to do the necessary complex liquid manipulation at very small scale, down to pico/femtoliter. These manipulations are essential to develop new drugs, to assist in disease diagnostics, in the point-of-care market. The lab-on-a-chip is a technology platform for a number of measurement instruments for the point-of-care segment. Examples include monitoring of ions in liquids, such as lithium content in blood, sodium content in urine, etc. [4] Accurate and easy measurements can help chronic patients to monitor their health, but also to spot and possibly prevent infections.

Cees van Rijn, professor at Wageningen University, pointed out that diagnostics are quite relevant also in the food and beverage industry. His company Aquamarijn Microfiltration [5] develops, fabricates and implements membrane technology for bulk filtration (milk fractionation, beer clarification, etc.) and microanalysis for fast and simple on-line diagnostic applications, based on nano- and microsystems technologies.
As smaller and smaller samples need to be analyzed, membranes with tailored porosity are required. Miniaturized systems which have the advantage of small dead volume and thus hardly any loss of sample, provide a much improved detection limit for cells and bacteria (10 ml^{-1} vs 10,000 ml^{-1}). The Aquamarijn microsieves are particularly suited for these analytical applications. Thanks to the high flux, narrow pore size distribution, and smooth pores, a large amount of fluid can be checked on the presence of cells and bacteria.

The fluid under study is concentrated on a small, optically flat surface, suitable for microscopic scanning and fluorescent counting methods. Research in this area deals with the proper material choice for the microsieves (including strength, biocompatibility, possibly "disposable" for some applications); the design of the complete analysis module; improved lab testing methods. Also the automation for continuous filtration systems, for example for drinking water equipment, requires analytical methods to be able to guarantee the reliability of the filtration.

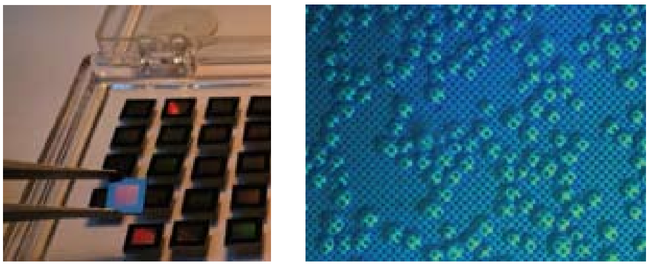

Figure 3. Microsieves, with on the right a close-up of a microsieve with yeast cells. (Courtesy of Aquamarijn Microfiltration).

The Delft perspective

In his presentation, prof. French showed how microsystems technology started in Delft under the leadership of professor Simon Middelhoek, and which initiatives were taken since then to put Delft on the world map of the field. The start of the STW Technology Foundation was an important step in stimulating applied research in this field in the Netherlands, leading to many successful developments. Since the early days, Delft has seen the importance of having a cleanroom to validate new concepts, ideas and devices. Through these developments, Delft became a major player on the microsystems world stage. A second important step was replacing the initial small cleanroom with a new facility, DIMES. DIMES has since expanded into a large research school encompassing four faculties.
A wide range of microsystems developed in DIMES were presented to illustrate the Delft approach: increased functionality, system integration and new measurement concepts, etc. These included medical research performed in collaboration with a number of major hospitals, fundamental materials studies, environmental and industrial applications along with the technologies specifically developed to support these applications. The goal of

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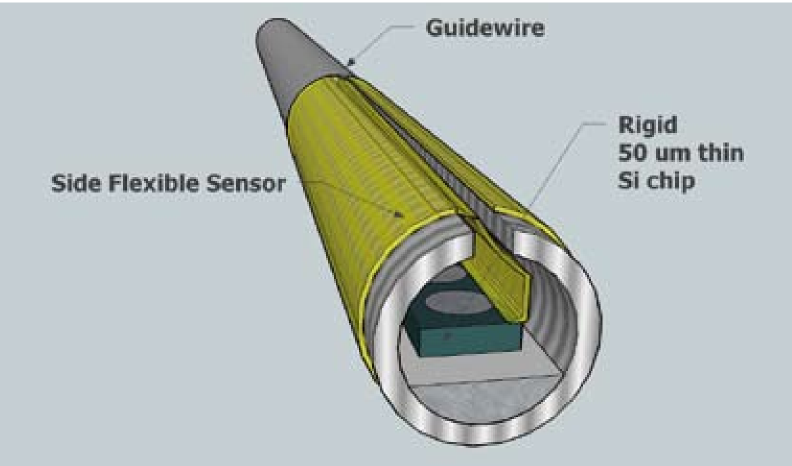

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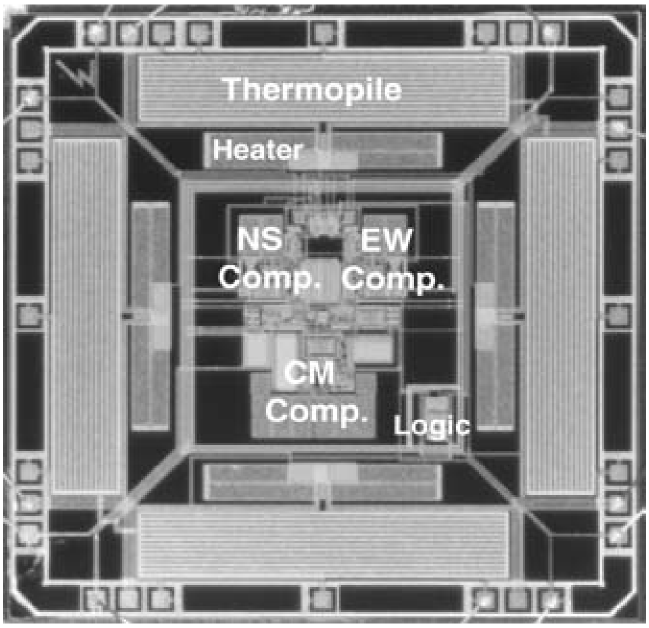

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Figure 4. Examples of DIMES devices.
(a) Blood impedance measurement system [6].
(b) Flexible blood pressure sensors for guide wires [7].
(c) A fully integrated thermal wind sensor [8].

increased functionality and the integral system approach continue to be the driving forces for future development in microsystems.

Panel discussion

Microsystems constitute the essential building blocks for virtually every domain that defines modern society, such as communication, transport, health care, energy management, safety and security. None of these domains would have developed as they have without the availability of reliable, sophisticated and affordable microsystems, enabled by nanotechnology. Consequently, nanotechnology is a strategic asset for industrial innovation and the knowledge-based society in general. It is clear that, within this landscape, important roles have to be played by large and small companies, universities, institutes and governmental organizations.

These considerations were the starting point for a panel discussion in which the following questions were addressed:

- What are the respective roles of industries, academia and government in the creation of a “nano-electronic ecosystem” in the Netherlands and in Europe?
- Are these roles subject to change? (e.g. industrial vs. academic research; role of SMEs for innovation)
- Which cooperative models would be most effective for the stimulation of innovation?
- Which application domains offer the best opportunities, in view of the Dutch and European capabilities and experience in nanotechnology?
- Are subsidies important? If so, how can these be allocated in the most efficient way? By whom?

The panel agreed that innovation in the emerging “More than Moore” domain strongly depends on cooperation between all partners in the supply chain. They have to provide the multidisciplinary expertise within the consortia, but they are also needed to generate the critical mass in order to bring the technology to the market. SMEs play an increasingly important role in these consortia, but the involvement of and guidance by large companies remains essential. Some people in the audience expressed their concern about the new financial models of various large companies, which could limit their long-term innovative capabilities.

The panel shared the opinion that innovation can not be planned, but that the ground can be prepared for it. In this respect, governments can help by stimulating cooperation and the exploration of technical frontiers. There were some critical remarks about the complexity of the (Dutch) subsidy system, which was judged to be insufficiently transparent. Some panelists expressed the view that the role of government in defining the innovation programme should be limited to the identification of key areas, rather than trying to control a comprehensive innovation process.

It was acknowledged by both the panelists and the audience that invention is still at the core of innovation. The multidisciplinary domain of microsystems offers a unique opportunity for the future of our “knowledge society”, and its importance for the preservation of the European competitiveness can hardly be underestimated.

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