セッション3

MEMS: From Development to Production

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Micro Electro Mechanical Systems (MEMS) are in the phase of transition from research to industry. This paper intends to describe this process from the point of view of a European R&D institution. The R&D activities at HSG-IMIT in Germany are described. The last chapter outlines the cooperation between the R&D institution and industry, in particular with local German small and medium sized enterprises.

1. Introduction

The technological development has to perform a very important and difficult task within the next decades: Improving the lifestyle worldwide should be achieved and the consumption of natural resources ought to be reduced at the same time. To meet this challenge, technical systems with high efficiency have to be developed. The important features are: Low consumption of resources and energy, highly efficient operation, dispersed local intelligence, easy disposal, high reliability and low cost. For these systems a large number of small but powerful and cheap sensors, actuators and systems are required.

An important method to fabricate MEMS is the application of micromachining technology. This technology has been an R&D topic for more than 20 years. A number of devices have been produced for industrial application, starting with pressure transducers, followed by accelerometers, thermal infrared detectors, inkjet print heads and magnetic read/write heads. At the moment, MEMS are in the state of transition from R&D to production and practical application. Technology investigators and market forecasters expect an important market in the MEMS field in the near future [Mic97, Bry96, Lan98]. The values for the MEMS market in the year 2000 range between US$ 5 and 25 billion. On the average, the expected turnover of MEMS devices amounts to roughly US$ 10 billion in the year 2000. A share of approximately US$ 4 Billion will be related to microsensors. MEMS deliver a core of systems and the market for these systems is forecast to reach roughly US$ 30 billion.

A recent analysis presented by F. Kodama predicts a total micromachine market of US$ 35 billion for the year 2015. Key players will be the IT equipment and infrastructure sector (10,5 billion $), automotive (10,4 billion $) and medical -biotech (5,4 billion $). For new, emerging areas (e. g. virtual reality, portable PC's, drug delivery) an optimistic forecast calculates another 23 billion $ [Kod00].

In this paper we would like to discuss the part of a European R&D institution supporting Small and Medium Sized Enterprises (SMEs) in MEMS applications. An increasing number of companies wants to apply MEMS for their products. In which way can an institute support these companies in order to develop new products for a market success? In the first chapter the activities of our institution are shortly reviewed. Then, we would like to discuss the opportunities and the problems of market access for SMEs.

2. The products and services supplied by HSG-IMIT

The Institute for Micromachining and Information Technology of the Hahn-Schickard Society (HSG-IMIT) is an R&D institution. It is a non-profit organization dedicated to support industry, especially small and medium sized enterprises in the region of the "Black-Forest" in the Southwestern part of Germany near the borders to France and Switzerland. The econo-

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my of this region has a long industrial tradition: Due to clock manufacturing, the Black Forest has been one of the first industrialized areas in Germany at the beginning of the 19th century. Today, the clock industry has lost its importance but the know-how paved the road to a precision mechanical industry based on a large number of medium sized local companies. For these companies, the transition from precision engineering to MEMS technology is an economically promising option. This is the reason why the Hahn-Schickard Society founded the institute in 1988 with the mission to spread out this new technology among the regional industry. Some selected activities are described in the following:

Inertial sensors:

An angular rate sensor has been developed [Gei97,Gei98]. Fig. 1 shows a SEM of the sensor structure. The technology is surface micromachining using a thick polysilicon layer. The sensor is structured to allow angular oscillation about the central axis. Upon rotation, the coriolis force induces another oscillatory mode which is recorded by an electrostatic capacitor. The device has a yaw rate resolution of 0.1°/s. Silicon technology is carried out within the foundry process of Robert Bosch GmbH, Reutlingen, Germany [Bos95]. At the moment, a new generation of sensors using SOI technology is being developed which will later on be produced by X-FAB GmbH, Germany.

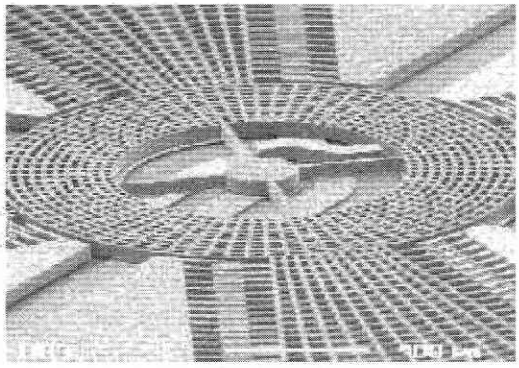

Fig. 1 Yaw rate sensor

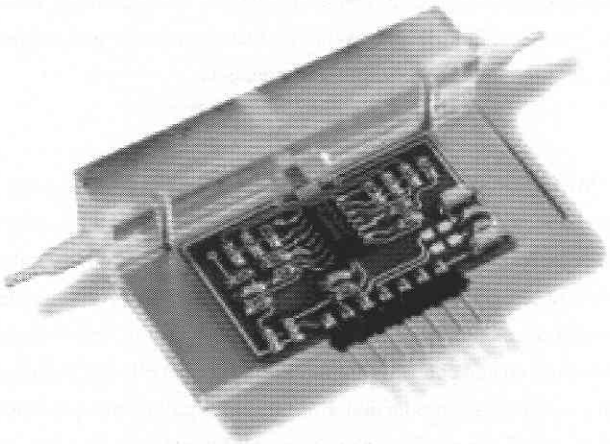

Fig. 2 Flow sensor

Flow sensors:

Thermal flow sensors are developed for air and for liquids. Applications for air flow sensors are automotive and pneumatic systems. Thermal sensors with thermocouples on membranes made of silicon nitride are especially useful for the measurement of very small flow volumes. HSG-IMIT developed a liquid microflow sensor which has a full measurement range of 10 to 1000 μl/h combined with a fast response time of 1 ms. This sensor is predominantly used in microdispensers for medicine and bioanalytical systems.

Top-Spot:

Microarrays may be considered as the ultimate step of miniaturization for the chemical laboratory. Instead of handling individual test-tubes, a variety of reagents are dotted in an equally spaced grid on a carrier slide. For typical volumes of a few nl or below, confinement of the droplets is provided by mere surface

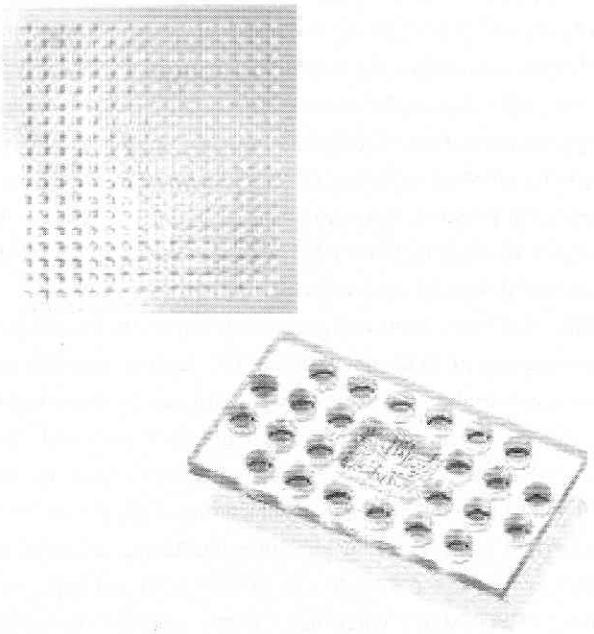

Fig. 3 (left) TopSpot print head. Our proprietary 24-nozzle chip is used for printing microarrays. (right) Example of a microarray printed with TopSpot.

tension. At grid constants of several 100 μm only, several 1000 reagents can be accommodated on a single chip offering a massively parallel analysis tool which is of great commercial interest for the pharmaceutical and chemical industry. In collaboration with the Freiburg (Germany) based GeneScan Europe AG, our institute has developed the TopSpot print head to manufacture such microarrays on an industrial scale [Duc00]. TopSpot technology will be integrated in three different commercial devices that are scheduled to enter the market by summer of 2000.

3. Access to MEMS Technology for SMEs

Particularly sensors and actuators fall in the realm of the SMEs in Germany and Europe. In Germany, there are approximately 1200 companies which work in the field of MEMS. In order to maintain their competitiveness, numerous SMEs will depend on MEMS technology in the future. In contrast to conventional technology, these companies are unable to build up this technology in-house due to the high investment costs.

In Germany, SMEs have so far been restricted to developing prototypes by research institutes. Producing smaller volumes at institutes, problems emerge regarding warranty or liability. Manufacturing larger volumes exceeds the capability of the institutes and does not belong to their core business anyway. This is the reason why, at present, SMEs still cannot get access to innovative MEMS-products. MEMS technology therefore, is found almost exclusively in big industrial companies.

However, in order to secure and extend their markets, these SMEs depend on efficient service centers which are offering comprehensive support ranging from design to production of small as well as large volumes. The Southwestern German area possesses a very good starting point for establishing a MEMS-foundry. This is due to its industrial infrastructure extending from numerous customers and potential manufacturers (e.g. Bosch and TEMIC) to excellent research facilities (IMTEK - University of Freiburg, Karlsruhe Research Center and HSG-IMIT).

HSG-IMIT sees its main objective in the support of the industry from concept to commercialization. The institute provides an open-access facility where primarily physical sensors, microfluidic devices and systems can be developed, produced and tested. The HSG-IMIT offers concepts, simulation, process and device development, prototyping and manufacturing of devices and systems based on surface and bulk micromachining. In order to additionally enable the production of both small and large volumes, HSG-IMIT cooperate with various European manufacturers such as TIMA, X-FAB, Bosch and TEMIC. At present, HSG-IMIT is about to establish the MEMS-foundry service mentioned above. Based on product developments with customers, an adaptation to the manufacturer's technology is made in order to allow an easy transfer of the production for future customers. This means that HSG-IMIT do not only support their customers during the R&D phase but also during the process of market launch beginning with small numbers of units up to large volumes once the product has been established. Large quantities can be produced in cooperation with commercial manufacturers.

The cooperation of HSG-IMIT with manufacturers does not only provide access to production facilities to SMEs but at the same time it guarantees a minimum of development risk and short time to market by means of developing prototypes near to production. There is also a reduction of costs as well as giving a guarantee for a good quality of the product.

Moreover, the institute gives the guarantee that the customer's know-how will not be passed on to competitors or to the manufacturer. For the manufacturers involved, the greatest advantage of this cooperation lies in the second source at the institute and in the creation of an additional qualified R&D capacity by the institute. Further advantages are the improved utilization of their own line capacity and also the opening of new markets and getting new customers. HSG-IMIT benefits from cooperating in the area of qualification as well as from the industrial realisation of the products. All of this results in a considerable acceptance by the industry. Depending on the kind of technology, the cooperation with manufacturers may take place in different ways.

The technological compatibilities at HSG-IMIT are supplemented by its advanced metrological laboratory. In this facility, HSG-IMIT records sensor and fluidic element characteristics and conducts load and stability tests. A special focus is put on PC based measurement and quality control, which is offered by HSG-IMIT as a customer service.

HSG-IMIT also provides additional service in numerical analysis. Finite element analysis and system simulation are implemented to produce model calculations for mechanics, thermodynamics, fluidics, electronics and heterogeneous systems for MEMS and precise mechanical components.

4. Conclusion

MEMS represent one of the major technologies of the 21st century. SMEs however, still do not get access to this technology without support of a third party. HSG-IMIT considers the support of these companies as main objective. HSG-IMIT offers complete project development with design, modelling, layout, technology, construction and characterisation. We accompany SMEs from the idea until the final production. If larger series production quantities are required, we work together with well-known manufacturers to meet these requirements.

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