CHANCES OF MICROSYSTEMS

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TUTORIAL INVITED PAPER
MIDEM´99 CONFERENCE - Workshop on MICROSYSTEMS
13.10.99 - 15.10.99, Ljubljana, Slovenia

Keywords: microsystems, MST technology, MicroSystem Technologies, increased functionality, cost efficiency, mass production, technology overview, industrial process control, automobiles, medicine, consumer articles, miniaturization, microelectronics

Abstract: Microsystem technologies offer new possibilities to increase functionality, utilize cost efficient mass production technology and thus explore new applications. These technologies combine electronic, mechanical, optical and chemical elements and use several physical effects. Applications can be found in industrial process control, automobiles, medicine, and consumer articles. The multidisciplinary requirements offer chances especially for innovative companies and networks. This presentation gives an overview of technologies and applications with emphasis on some outstanding examples.

Mikrosistemi in njihova priložnost

Ključne besede: mikrosistemi, MST tehnologije mikrosistemske, funkcionalnost povečana, uspešnost cenovna, proizvodnja množična, pregled tehnologij, vodenje procesov industrijskih, avtomobili, medicina, predmeti potrošniški, miniaturizacija, mikroelektronika

Izvleček: Tehnologije mikrosistemov ponujajo nove možnosti za povečanje funkcionalnosti, izrabljajo že obstoječo cenovno in stroškovno učinkovito masovno proizvodno tehnologijo in tako ponujajo možnosti novim aplikacijam. Te tehnologije kombinirajo elektronske, mehanske, optične in kemične elemente in izrabljajo nekatere fizikalne efekte. Uporabo mikrosistemov lahko najdemo na področju industrijske procesne kontrole, avtoelektronike, medicine in široke potrošnje. Zahteva po multidisciplinarnosti ponuja nove možnosti predvsem inovativnim firmam. V prispevku podajam pregled tehnologij in aplikacij mikrosistemov s poudarkom na nekaterih izjemno uspešnih primerih.

1. Introduction

Microelectronics, in the past two decades, has developed into one of the biggest industries of the world. Almost all goods of normal life could be penetrated by semiconductors with new functionality, better performance, higher userfriendlyness and other benefits at low cost levels. This has been made possible, as we know, by submicron CMOS and related IC technologies, mass production of 8 inch silicon wafers and a globalized, highly competitive semiconductor industry.

Today integrated circuits (IC´s) perform computational and signal processing tasks, run telecommunication networks, store large amounts of digital information. Analog signals can be processed by audio-, ZF- and RF-circuits, A/D- and D/A-converters, while dedicated Smart Power ASIC´s and Power Components like IGBT´s open the door to new power supply concepts and advanced drive systems for actuators.

The tremendous price/performance development has been made possible by four main factors:

- Continuous advances in lithography down to 0,25 μm and below.
- Wafer batch processing with growing wafer diameters.
- Silicon CMOS as nearly optimal „flagship" technology
- Standardizations in process technology, equipment, CAD engineering.

Microelectronics, however, is confined to the world of electrical units and electronic signals. Interfacing to the environment requires sensors and actuators in order to obtain a complete system. As a consequence sensors and actuators very often turned out to be the most costly and less reliable part of the system. Microsystems is the way to integrate also non-electronic components and functions into microelectronic systems while maintaining their benefits. Several efforts in partly overlapping directions have been made in the past years leading to names like MST (Microsystem technologies), MEMS (Micro-Electro-Mechanical Systems) or MOEMS (Micro-Opto-Electro-Mechanical Systems).

Mechanical systems play an important role in most microsystems. A new dimension of MST thus can be created by combining the requirements of precision engineering with microtechniques, as shown in fig.1. Microsystem technologies are therefore characterized by the combination of mechanical, optical and electrical functions in which the functional elements have microdimension and are suited for batch production. Additional applications may include chemical and biological microsystems.

MST makes it possible to realize complete miniaturized systems with new functionality, either on a silicon chip or in a hybrid combination. For that reason it is regarded as a breakthrough or „disruptive" technology, allowing unparalleled synergism between hitherto unrelated fields of endeavor such as biology and microelectronics. Many new MST applications will emerge, expanding beyond what is currently identified or well-known.

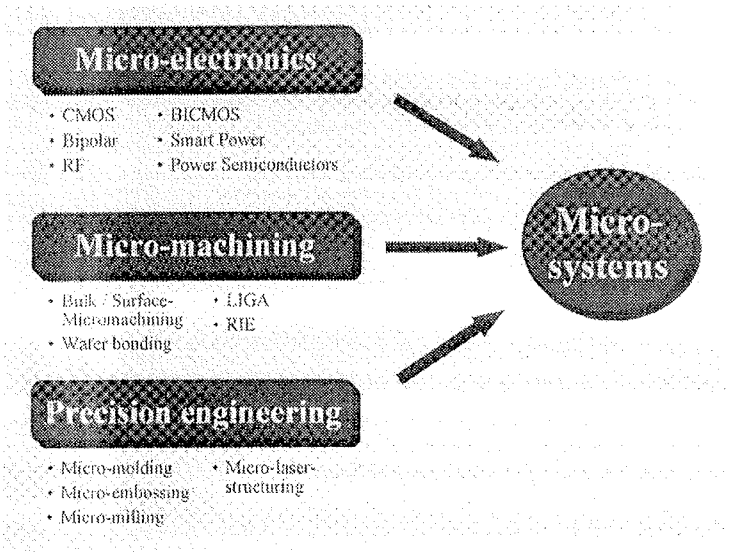

Fig. 1: Microsystems by combining technologies

2. MST – a „disruptive" technology

Basic research in microsystem technologies started in the 1970s, mainly in the research labs of huge companies like IBM or Bell Labs and at some universities. In the 1980s, in Germany the LIGA technology, originally intended for separation nozzles for the nuclear industry, was developed. In addition first microelectronic companies like Analog Devices became aware of the chances of fully integrated micromaching technologies e.g. for accelerometers. In the 1990s first attempts to commercialize MST products as well as coordinating efforts in the US and in Europe like NEXUS or the IVAM Microstructure Initiative NRW were made. These coordinating initiatives proved to be most useful in building up networks of SME´s, R&D institutes and universities. First market studies and summary data have been collected, standardization and roadmap activities have been started. Also application-oriented r&d institutes like the IMS of the Fraunhofer society concentrated on the realization of microsystems.

In 1996 the worldwide industrial activity in microsystems was evaluated at 12 bio US$ (7"2 in US, 3"2 in JP and 1"5 in EU), based on the employment of 60.000 people in this field (40.000 in US, 15.000 in Asia and 5000 in EU) /1/. A high number of international conferences dedicated to MST takes place around world, as can be seen from the short collection of the current half year, shown in table 1.

The commercialization of microstructures today is already supported by:

- Networks of companies and research institutes offering design and manufacturing service taylored to specific MST-based product needs.
- First dedicated MST production equipment: Some semiconductor equipment manufacturers already

Table 1: International events for MEMS and microsystems

07.07.-10.07.99	Dortmund	Commercialization of Microsystems
30.08.-01.09.99	Mainz	3rd Conference on Micro Opto Electro Mechanical Systems
20.09.-22.09.99	Santa Clara	SPIE´s 1999, Micromachining and Microfabrication
29.09.-01.10.99	Stuttgart	MicroEngineering´99, Fair and Congress for Microsystems and Precision Engineering
27.09.-02.09.99	Gif-sur-Yvette	MME´99 – Micromechanics Europe
27.10.-29.10.99	Tokyo	MICROMACHINE´99
27.10.-29.10.99	Queensland (AUS)	International Symposium on Microelectronics and Micro Electro Mechanical Systems
01.11.-04.11.99	Boston	MEMS Technology Workshop
11.11.-19.11.99	Nashville	MEMS Symposia
23.01.-27.01.00	Miyazaki (JP)	MEMS´2000 Conference

offer machines specialized on MEMS-specific processes like wafer bonding, double-sided alignment of wafers or RIE for structures with high aspect ratios. New concepts like „scalable" equipment, where the same process and basic tools can be applied for prototype manufacturing up to fully automated volume production, help to overcome investment barriers.

- First CAD systems oriented on MEMS design requirements: These systems mainly integrate 3D-modelling into IC design tools.
- MEMS foundry services.

4. Applications and markets for microsystems

Microsystems very often are embedded in products or bigger systems, the applications are highly diversified due to the versatile structure of MST. This makes it very hard to

1. define, what a „microsystem" is
2. determine and predict application areas, markets and volumes

The first comprehensive market study for MST based products has been published by the NEXUS consortium this year. Fig. 2 shows the projected market development for MST products with an 18% average growth rate. The contribution coming from new or unknown products (in 1996), which is relatively small for a new technology, reflects the situation, that big steps still have to be overcome regarding production and reliability related issues in commercialization. Fig. 3 shows the main applications for MST products. It can be seen, that the mass storage and inkjet printer market today and also in the next years will dominate significantly the MST arena, applications in the medical and biomedical field are the most promising candidates for the future of MST.

It can also be seen that MST products will penetrate applications in nearly all fields like IT-peripherals, medical / biomedical, telecommunication, industry and process control, automotive, environmental monitoring and facility control.

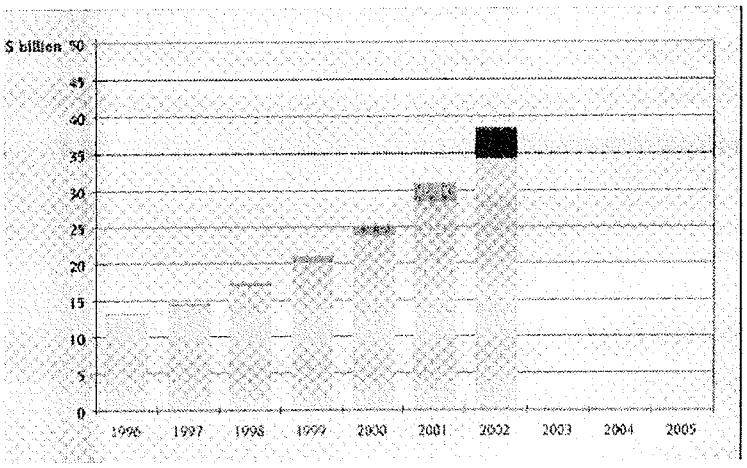

Fig. 2: MST market (source: NEXUS)

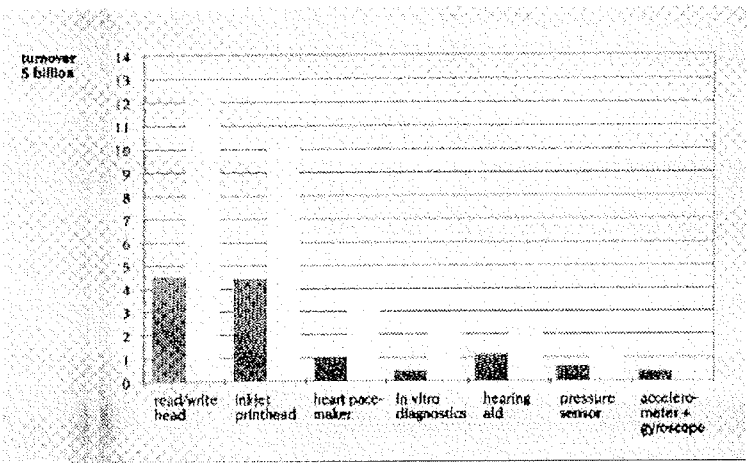

Fig.3: MST applications (source: NEXUS)

5. The complexity pitfall

As shown before, microsystems, as a breakthrough technology for system miniaturization for a broad range of applications, open up several new dimensions. Additional materials (e.g. PMMA, Ni,...) are involved, new processes required, specialized packages become necessary. Testing concepts and reliability issues have to be worked out and solved. Also the design process, especially in integrated solutions, becomes more complex. On the one hand all these factors create chances for exceptional new solutions, on the other hand they contribute to complexity. Standardization is far behind the level achieved in microelectronics and will never reach it. Therefore predictions on the progress of MST and commercializations are much more difficult than for microelectronics, where progress has been following „Moore´s law" for 20 years.

These situations require new and more flexible structures, that can provide and combine the required capabilities. Networks and clusters like IVAM or EMSIC /2/ have proved to be able to handle this complexity in an efficient way. While multinational companies deal with applications based on high volume and high potential like read-write heads for HDD or the „finger print sensor", the high diversity of microsystems opens chances not only for SME´s that concentrate on specific technologies, but also for r&d-organizations that act in an integrative way working on system design and system integration aspects as well as on standardization.

This situation will not change in the near future: the diversity will remain dominant, only a few applications will reach production volumes known in the IC world and will become interesting for large companies.

6. Promising application areas

Applications of microsystems can be divided into the following areas:

- Read-/write heads for hard-disk drives and printheads for inkjet printers. These, as they are driven by highly-dynamic EDP markets, are the dominating MST-applications today.

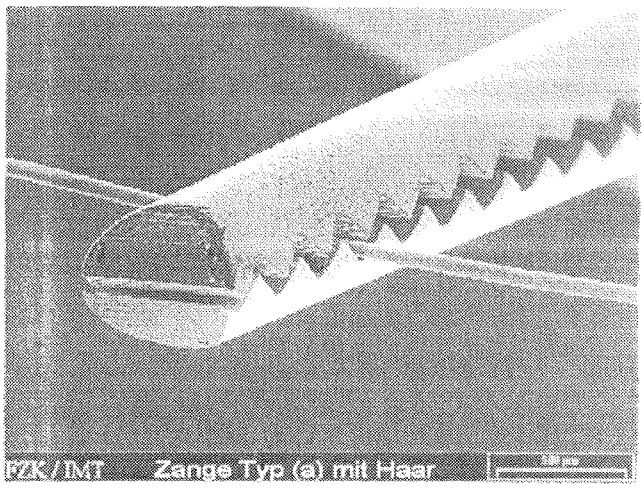

Fig. 4: Microsurgery: forceps with hair (source: Forschungszentrum Karlsruhe)

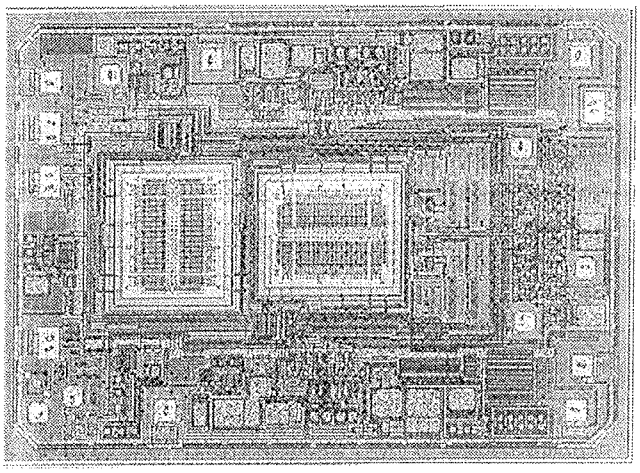

Fig.5: Monolithic accelerometer (source: Analog Devices)

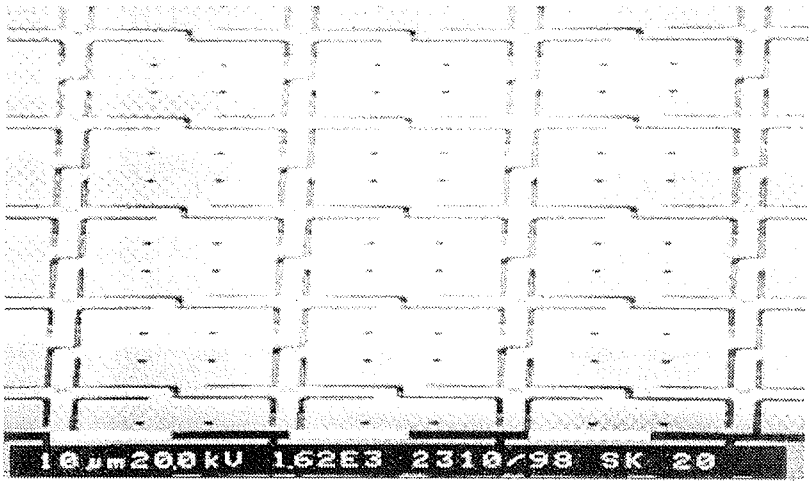

Fig. 6: Micromirror display (source: Fraunhofer Gesellschaft/ IMS)

- Interfaces for microelectronic systems. Microsensors and microactuators contribute the main part to these applications /3/.
- Micro resonators and filters. These devices may replace quartz oscillators or LC filters.
- High-precision or highly-miniaturized mechanical systems, based on MST technologies. Most promising examples can be found in medical areas, i.e. for micro-surgery (see fig. 4).
- Completely new application fields like MST for chemical analysis, providing complete micro-labs for complex analysis tasks, or bio-MEM´s, capable of identification and handling DNA structures. Both applications are in the field of medical and biotechnology.

Resonating devices, realized by surface-micromachining, offer an excellent opportunity to combine sophisticated mechanical structures with CMOS or BICMOS technologies monolithically. Accelerometers, gyroscopes, but also micro-resonators and filters can be built in this way (see fig. 5).

Very promising MST-devices can be found in applications that require large array configurations, e.g. for:

- identification („fingerprint")-sensors
- micromirror displays (see fig. 6).

Both applications can be realized by CMOS technology, combined with a MST surface structure containing the microsensor/microactuator function. Micromirror arrays seem very promising for large-scale projection displays, maskfree lithography or laser-printing.

7. Conclusion

Microsystems technologies offer new chances for further miniaturization and for the implementation of completely new systems in a broad variety of application fields. The technologies are just starting to emerge from experimental and research state into industrial commercialization. The large diversity of technologies prohibits or, at least, slows down standardization processes known from the microelectronics industry. This situation gives special chances to specialized organizations operating in well-organized networks.

The criteria for the success of microstructures lie in the ability of creative engineers to apply the well-known benefits of microelectronics batch production techniques to applications representing high production volumes.

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Prispelo (Arrived): 15.10.99 *Sprejeto (Accepted): 25.11.99*