

## **Position Paper: MEMS Perspectives from Industry, Education and Legislature**

**George P. Vakanas**<sup>1,2</sup>

<sup>1</sup> **Department of Mechanical Engineering, MC6106  
Arizona State University, AZ 85287**

<sup>2</sup> **Intel Mask Operations, Intel Corporation, IMO, SC2-12  
Santa Clara, California 95054**

**Introduction:** In reviewing the latest (1999) International Technology Roadmap for Semiconductors [1], it is not surprising to find a reference to MEMS under the all-inclusive “Performance System-on-Chip” (PSoC or SoC) new product category. For the MEMS industry, whose potential and success is oftentimes compared favorably to that of the Semiconductor/Microelectronics industry, MEMS applications either remain unhatched or, somehow they fall short of their market potential. Out of the many ingenious MEMS applications, only a few (e.g. the airbag sensor, inkjet nozzle and RF switches) seem to have achieved “economies of scale” and covered their expected market share and. What is it in these applications that helped them propel into the market? Have they provided cost-effective solutions to the consumer population? Have they enabled and leveraged existing technologies? Can specific and generic figures-of-merit (e.g. cost per function, device benefit-to-cost ratio) and technology pointers (e.g. limits, scaling and resolution of MEMS fabrication techniques) be identified and be used for future projections? With such diversity of MEMS applications, is a roadmap with a 10-year horizon possible? What is the role of legislature and governmental policy in the advancement of MEMS and nanotechnology?

**Lessons Learned from the Industry:** A linguistic examination of the “M.E.M.S.” acronym reveals the keywords of “micro” (demonstrating the advantages gained by size downscaling) and “electromechanical” (implying a potential for the integration of many functionalities) based on all-kinds of transduction combinations (chemical, mechanical, thermal, electrostatic, magnetic etc). In contrast to the semiconductor/microelectronics products, which fall in a well-organized hierarchy from logic, memory and ASIC devices to chipsets, systems and beyond, MEMS is identified by the 1999 SIA’s ITRS as a new SoC product category (as a system) with a yet emerging hierarchy of MEMS components and modules. The diversity of MEMS fabrication processes (e.g. LIGA/SLIGA, SUMMIT, HEXSIL, SCREAM, DRIE and laser, ion and e-beam Direct-Write) as opposed to CMOS is also raising concerns to workers in the field relating to process standardization and customization. Is this diversity in new non-silicon materials, hybrid devices, micro-systems and microfabrication techniques a problem or an opportunity? Do these trends impede progress or do they provide more choices and a competitive advantage? Is the MEMS community adopting an “all things for all people” strategy and thus spreading too thin? Or, is the MEMS Industry already bringing us new business and production working models and paradigms?

**Methodologies & Models from Development-to-Commercialization:** While the Semiconductor Industry is structured in a way that admittedly presents a “barrier-to-

entry” to potential new competitors in the Industry, the MEMS Industry is structured under a more distributed knowledge network and tele-working production and commercialization model. MEMS foundries already act as both consultants and fabrication service providers and, as such, they are forced to develop business expertise in rapid prototyping (RP) and medium-to-low volume manufacturing. Is the existence of diverse fabrication processes and low volumes a barrier to further development? Can such a distributed model be sustained in the long run? As opposed to the “mass-production” industrial model, MEMS have adopted and evolved into a more functional “customization” concept, more indicative of what the 21<sup>st</sup> century e-business and tele manufacturing will look like. A novel technology such as MEMS ought to manifest itself not only in terms of ingenious applications but also in terms of novel business models from development to commercialization. From a production point-of-view, the MEMS industry seems to be adopting an “agile manufacturing” concept by building modular solutions for “M.E.M.Systems” and by outsourcing fabrication to one-stop foundries. From a business perspective, MEMS seems to be adopting a value-added model with hybrid and miniaturized smart products. The dichotomy between “miniaturization” and “networking” (and distributed processing) does not present any performance issue in MEMS progress, which seems to be capable of achieving a “golden section” by harvesting the advantages of both worlds: downscaling and array/parallel operation [2,3]. Whether such MEMS qualities suffice to propel the technology further and sustain commercialization in the longrun, is still to be seen. Gap analyses, needs assessments and CAE methodologies could be of use in this effort.

**Human Resources and Education:** An often-assumed element in the product cycle of a novel technology is the uninterrupted supply of people capable and conversant in the new multi-disciplinary field. As our products get smaller and smaller, their complexity remains hidden from our senses and manifests itself as the need for more complex tools and processes, hence the importance of value-added education and JIT training. The “perceived distance” of designers and operators from the “tools” needs to be minimized and the topic of what constitutes “hands-on” experience for “in-tangible” technologies such as MEMS may need to be revisited, if we are to provide motivation and exciting learning experiences. Thus, we are in need for:

- Rich and rewarding interaction between multi-disciplinary teams from education/research and industry sector with expertise in engineering and business
- Rapid prototyping tools for MEMS [4,5] in which trainees and practitioners can see immediate results of their designs, in both software and hardware, for better and faster judgment and decision-making.

**Legislature:** An often-forgotten element of technological advancement is the drive and influence of legislature on technology. Although some optimists may think that technology drives new law making, in everyday work there are numerous demonstrations of the bilateral relation between the two. Just think of the impact on the airbag sensor commercialization if legislature was implemented requiring that the possibility for even a single fatality as a result of car collisions should be eliminated. How about the impact on bioMEMS sensor commercialization if a home-based, monthly medical testing system was to be implemented for every insured citizen? [6]. In a recent issue of the IEEE newsletter, it is reported that 20% of the Society’s revenues are spent for government

relations, policy communication and lobbying [7]. There are probably countless examples to demonstrate the way legislature and technological advancement interact. In the dawn of “re-inventing government” for the 21<sup>st</sup> century, engineers should probably be doing more in this direction.

**Conclusion:** A holistic outlook on the MEMS industry in relation and contrast to the semiconductor/microelectronics industry and in the context of education, industry, marketplace and legislature is discussed. It is argued that such a perspective is essential in analyzing emerging production and business models in order to synthesize meaningful strategies for widespread MEMS development and commercialization.

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