Reducing MEMS product development and commercialization time

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Introduction

Micro-electromechanical systems (MEMS) incorporate miniature electro-mechanical components fabricated with processing techniques and equipment originally developed in the semiconductor industry. Combining traditional silicon processing techniques, bonding technologies and a number of non-traditional processing techniques, MEMS are being developed for a variety of applications. While existing MEMS sensors and actuators have enabled automotive crash sensors, ink jet printer nozzles and catheter tip pressure sensors, new market opportunities for MEMS technology abound in the telecommunication, biomedical, semiconductor, and aerospace industries.

Description of MEMS

MEMS is best described as an enabling manufacturing technology as opposed to an industry. Because many of the processes employed for MEMS manufacturing originated in the semiconductor industry, silicon is typically utilized for MEMS substrates. However, non-silicon materials such as glass, quartz, ceramic, plastic and metal substrates are also emerging in microfabrication. The process technologies normally employed in silicon MEMS manufacturing include: surface micromachining, bulk micromachining and high aspect ratio micromachining.

Bulk micromachining refers to processing in which the silicon substrate acts as the mechanical constituent of the devices. Applications of bulk micromachining include pressure sensors, ink jet nozzles and many high precision acceleration sensors.

Surface micromachining incorporates processes in which thin films on the substrate surface act as the mechanical constituent while the substrate acts solely as support. Air bag acceleration sensors are an example of surface micromachining.

Non-traditional lithographic processing for the fabrication of tall, high aspect features are generally referred to as HARMS (high aspect ratio micromachining). HARMS processes include high intensity exposure (using x-rays as a source) and deep vertical etching of substrates.

Areas of high growth

The adaptation of MEMS technology to a variety of new products offers tremendous market potential. The market for MEMS based systems is projected to be $38 billion by the year 2002 by the European commissioned NEXUS Task Force. Further studies by

System Planning Corporation in the United States project a market opportunity of $11.5 billion in 2003 and compounded annual growth of 20%-30%. Figure 1 illustrates System Planning Corporation's projection for 2003 dollar sales by application.

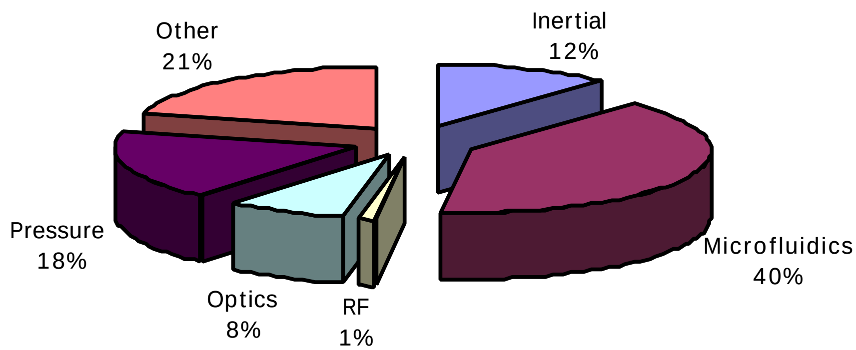

Figure 1 2003 Projected Dollar Sales by Technology Area[1]

Market segments expected to outpace the collective MEMS market growth include optical MEMS, bio-MEMS and RF devices. These high growth technologies will be driven by telecommunication and biomedical market segments. Products include optical switches and tunable optical components applied to fiber based communication networks. Within the biomedical market, MEMS enabled products are anticipated for drug delivery and drug discovery.

Commercialization challenge

Rapid growth and commercialization of MEMS requires equally rapid product development. While tremendous market opportunities exist for a variety of MEMS devices, rapid development has become a leading commercialization challenge.

In a study conducted by IntelliSense Corporation, senior executives and key technologists of major US companies were questioned on MEMS development and commercialization challenges within their organizations. They indicated the most critical challenge to

[1] System Planning Corporation, 1999, MEMS 1999 Emerging Applications and Markets

MEMS product commercialization was the length of product development. The median time to develop prototype devices at these companies was 3.2 years with some developments requiring 8 years. Following prototype development, additional development time is required as prototype designs are converted into products. On average, the time to transition from prototype to product was 2.2 years; many programs exceeded this with some respondents referencing programs lasting 6 years.

Reasons for the lengthy development time include a historic MEMS technology push, a lack of process expertise, and manufacturing obstacles. In the IntelliSense study, almost as many companies were involved in MEMS because of the technology excitement (41%) as for the business opportunities (46%). Involvement in MEMS technology for technical excitement versus commercial potential may explain lengthy development as technology development leads application identification. The consequences of the MEMS technology push are evident in the fact that 45% of companies surveyed indicated that current research does not compliment industry needs. Product development led by a MEMS technology push as opposed to a market pull contributes to lengthy product development.

Other challenges in R&D and manufacturing contribute to extended product development. Process expertise and material control were identified by 87% of companies as the major obstacles in MEMS research and development. Manufacturing obstacles include packaging (33%) and process control (25%). To achieve MEMS market potential technology commercialization strategies and programs that resolve prolonged development are required.

Successful commercialization

Successful MEMS commercialization addresses many of the challenges currently producing lengthy development cycles through 1) collaboration between MEMS experts and industry experts, 2) utilization of MEMS infrastructure, and 3) established MEMS foundries.

Collaborative development

As evident in the responses from leading executives, successful commercialization requires the application of technology to identified market opportunities. This necessitates an intimate understanding of product opportunities and expertise in MEMS process technology. However, product companies may not fully realize the complexities of MEMS processing and process experts are not often established in specific product markets.

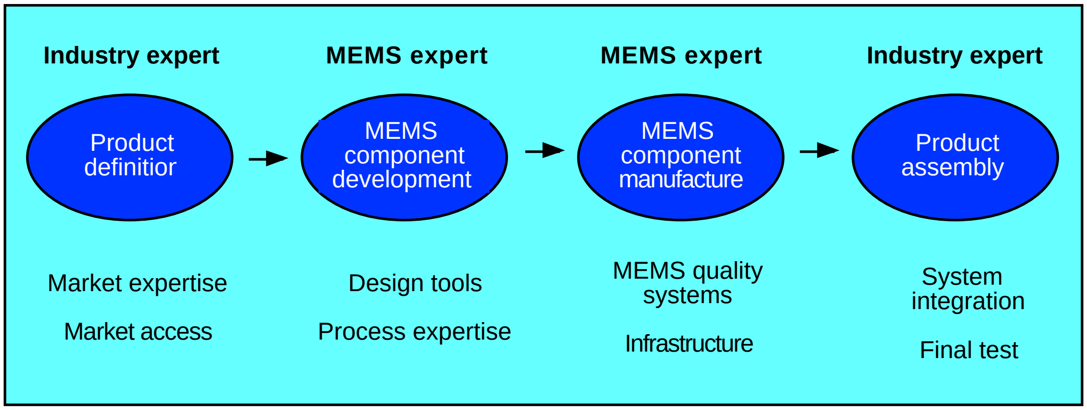

Figure 2 Collaborative development activities

Collaboration between companies with process expertise and those with market expertise (Figure 2) can lead to successful, rapid MEMS product development. IntelliSense has participated in 28 product development programs with industry experts in aerospace, biomedical, telecommunication, semiconductor, and consumer markets. An example includes the NASA sponsored development of a silicon micromachined recuperator for cryogenic applications involving IntelliSense Corporation and Creare Incorporated. Combining the product expertise at Creare and the MEMS expertise of IntelliSense, MEMS component development was completed in 4 months. Dr. Bob Kline-Schoder of Creare estimates that the collaboration on the MEMS component reduced product development time by 50%.

With a core competency in MEMS and a portfolio of process technologies that can be directly applied to design programs, IntelliSense is assisting partners in bringing products to market faster. Design tools and fabrication infrastructure also contribute to reduced time to market for MEMS programs.

Development infrastructure

MEMS design tools are now being successfully employed to reduce MEMS component development time. According to the IntelliSense survey, only 20% of MEMS development time was allocated to up-front design, while 60% was required for prototype fabrication iterations, and 20% for testing. Performing design simulations instead of fabrication iterations reduces development time and cost. IntelliSuite™ design tools by IntelliSense for example combine process based model generation and thin film material properties with device and package analysis to enable simulations that accurately predict device performance and reduce fabrication iterations.

Leading MEMS developers such as Bell Labs, Lucent[2], US Air Force[3] and Raytheon[4] incorporate MEMS modeling in product development. Raytheon successfully used

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[2] Published for the Symposium on Design, Test, and Microfabrication of MEMS and MOEMS, March-April 1999, Paris, France

[3] W. D. Cowan, V. M. Bright, A. A. Elvin, and D. A. Koester, :Modeling of stress-induced curvature in surface-micromachined devices.

IntelliSuite™ to design a communications RF switch (Figure 3). According to Dr. Shea Chen, Principal Mechanical Engineer, "From the beginning we knew that an electromechanical solution tool was essential for R&D. We had a couple of different membrane designs before a capable simulation tool was available. All of them had been built, tested, and discarded."

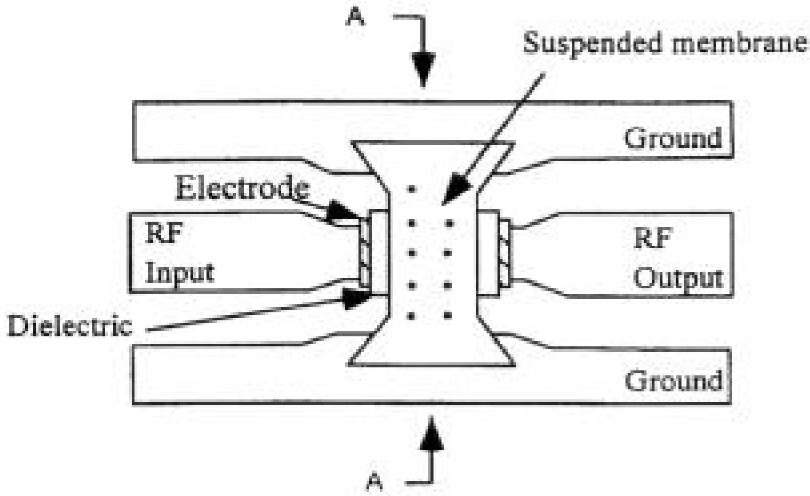

Figure 3 Schematic view Raytheon's RF switch

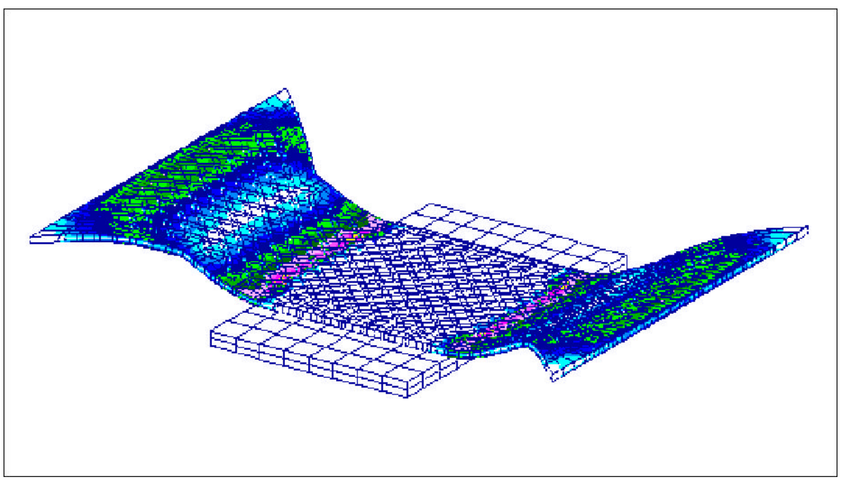

Figure 4 IntelliSuite™ analysis results

Using IntelliSuite™, engineers at Raytheon were able to accurately model the complex geometry and contact analysis for this highly nonlinear problem (Figure 4). IntelliSuite™ simulation iterations were also used to model the membrane and spacer elements. By

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[4] Z. J. Yao, S. Chen, S. Eshelman, D. Denniston, C. Goldsmith, "Micromachined Low-Loss Microwave Switches," IEEE Journal of Microelectromechanical Systems, Vol. 8, No. 2, June 1999.

modeling many design alternatives and selecting designs with the highest potential, fewer fabrication iterations were required.

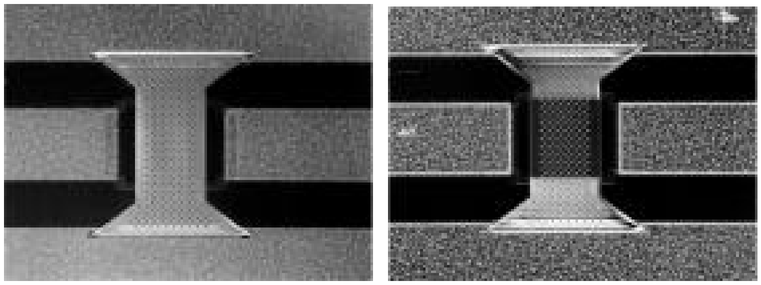

Figure 5 SEM image of the up (left) and down (right) switch positions

Having achieved a commercially successful design, Raytheon now relies on software tools to reduce product development time. Chen says, “When we create new membranes, IntelliSuite is always employed to identify possible mechanical/electrical problems and to optimize designs.”

MEMS foundry

Also critical to MEMS commercialization is the transition from prototype devices to production components. As cited in the IntelliSense survey, an average of 2.2 years has been required to transition from prototype to production. Often the reason for lengthy transition is the historically iterative prototype fabrication process for MEMS development. When the iterations are complete, a prototype is developed. However, processes used to develop prototypes do not necessarily scale to production. Designs that consider production processes and involve production engineers more often lead to commercial success.

IntelliSense’s MEMS foundry focuses its development efforts on commercial applications. Production and design engineers work collaboratively to identify not only the issues necessary to achieve prototype performance but those that will enable product manufacturing. This approach reduces time required to transition from a working prototype to a standard product.

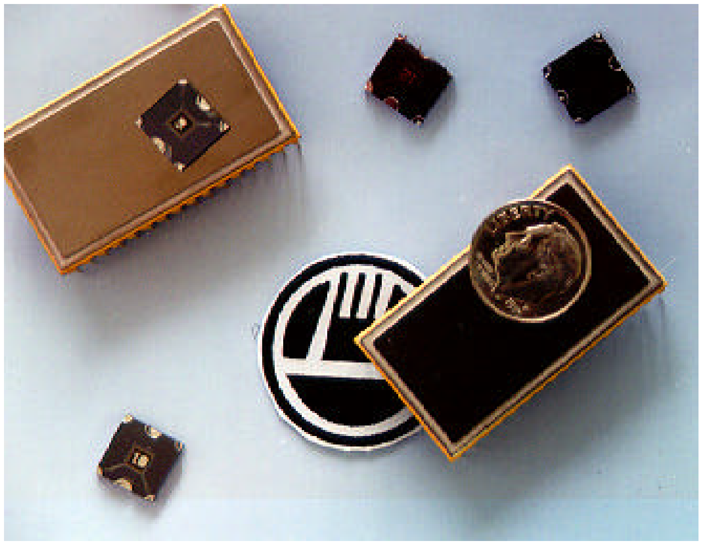

Figure 6 Microfabricated acceleration sensors

In addition to assisting with the transition from prototype to production, a MEMS foundry must also provide flexible processing. Unlike a standard CMOS foundry, which performs one or two standard processes, a MEMS foundry performs a wide variety of processes. MEMS components can incorporate an assortment of surface, bulk, and non-traditional processes. For nine years IntelliSense has developed custom processes for commercial customers for multiple applications, resulting in an extensive portfolio of established processes. These established processes and process development capabilities provide flexibility for MEMS fabrication.

MEMS is a technology that will be incorporated into an ever-increasing array of products and industries. However, technology alone will not lead to success. It results from identifying market opportunities and rapidly developing products to address the market needs. IntelliSense uniquely provides total MEMS solutions by offering software design tools, product development expertise, and manufacturing infrastructure necessary for rapid product development and increased commercial success.

Biographies

Fariborz Maseeh is the founder and President of IntelliSense Corporation. Prior to IntelliSense, Dr. Maseeh has led or been involved in the development of a number of silicon micromachined mechanical and biomedical sensors including: an ultra-sensitive silicon microaccelerometer, a fast-response silicon amperometric gas sensor and a non-invasive glucose sensor. Dr. Maseeh received a Sc.D. from MIT where he developed the initial CAD for MEMS. At IntelliSense Corporation, Dr. Maseeh has been involved in the development of a number of mechanical, optical and biomedical microfabricated devices. He also re-architected a new CAD for MEMS known as IntelliSuite™ which is used worldwide. His graduate work in the Microsystems Technology Laboratories of MIT led to several new fundamental discoveries, primarily in microelectronics design and fabrication.

Dr. Maseeh has over fifty scientific publications in fabrication technologies, design, CAD for MEMS and development of microstructures. He has been invited to chair sessions and to speak on microsensor design and development at a number of respected conferences and institutions.

Andrew Swiecki is the Director of Marketing and Sales at IntelliSense Corporation where he is responsible for marketing strategy, customer relationships, and business development. Mr. Swiecki has a MBA from the MIT Sloan School of Management where he focused on new venture and product development. He has a mechanical engineering degree from the University of Michigan. Mr. Swiecki publishes and speaks on MEMS design, manufacturing and micro-system technology.

Nora Finch is an Application Engineer at IntelliSense Corporation. She received a Master of Engineering in High Performance Structures as well as a Bachelor of Science from MIT. At IntelliSense, she focuses on IntelliSuite™ feature development and customer support.

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