Microelectromechanical Systems (MEMS) and Microfabrication Technologies---A Key Area for LSU IT Initiative

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1. Rationale---What is MEMS and How It Is Related to IT Technologies?

In the past 10 years, the field of microelectromechanical systems (MEMS) has quickly developed from pure research into wide spread industrial applications. Especially in the last few years, MEMS has significantly impacted the fast developing fields of information technologies (IT), the biomedical and biological industries, and becomes one of the strong pushing force behind industrial automations. The following is quoted from a US National Research Council report:

"To many of those working in the field of Microelectromechanical Systems (MEMS), there is a strong sense that a revolution is underway. As MEMS begin to permeate an increasingly wide scope of industrial procedures, not only engineering, but also society as a whole will be strongly affected. MEMS will provide a new design technology having an impact on society that rivals and even surpasses the dizzy effects of integrated circuits."

It should be noted that MEMS is not simply "minaturization of engineering systems." What is new and revolutionary in MEMS is its fast adaptation to new purposes of the advanced, productive IC technology. Built on the huge amount of investment and research efforts around the world over the past thirty years in silicon IC batch fabrication, MEMS technologies now pose to have major waves of impacts on our everyday life and industries in the same large scale as IC industries have done in the past decades.

The MEMS revolution arises from utilizing the knowledge and technologies develoiped for IC industries to build microcmechanical and microelectronic elements into engineering microsystems. The scope of MEMS is multidisciplinary, providing challenges and opportunities to electrical, mechanical, chemical, and biomedical engineering, and extending beyond engineering to physics, biology, and chemistry.

Some of the commercial areas in which includes:

1) Broadband communication. MEMS sits right in the cores of optical systems where new actuated mirror- and lens- systems are being exploited for display and for fiber-optic communication systems.

The future in broadband communications lies in optical network. In the past, optical systems tend to have large physical sizes and require complicated, time-consuming alignment, adjustment, and very expensive to produce and maintain. However, in the recent year, as the development of new technologies such as DWDM and other smart optics, optical network has become the main backbone for the next generation network and infrastructures of information technologies. As the IT industries develop, more and more bandwidth is required. We will eventually see the door to door optical connection and achieve the ultimate broadband connection for the whole society. In the past two decades, it is the IC chip and primarily the computational power (fast microprocessors and DRAMs and larger storage capacity). It is widely expected that the next wave of IT revolution will mainly be network and broadband communication. After all it is the information flowing on the network, not the individual computers that caused the IT revolution.

To reduce the costs and sizes of optical network systems and overcome the difficulties of alignment and maintenance, the optical communications have been quickly moving to integrated and micro-sized systems. MEMS technologies are playing a major rule in achieving these goals. Currently, one of the fastest developing sub-areas in MEMS is the microelectro-optic-mechanical systems (MEOMS).

Already, key systems such micro optical switches, micro-lenses, micro-lasers, micro DWDM systems, and MEMS switches and relays for signals and power controls. <u>These MEMS switches and relays are have huge potentials in both the wired and wireless systems</u> because of their lower power consumption, lower "On" resistance, infinite "Off" resistance and excellent responses speed.

2) Information storage in which much increased density (expected are 100-fold and greater storage-capacity increases) at increased speed and reduced cost. This is another key area in which MEMS may have huge impact. Various devices and systems are being developed now.

3) Interfacing Technologies between the network and physical world we live in. Various microsensors and miroactuators are being developed for physical, chemical, biological, medical applications. for example, implanted or carrying on devices may be developed to monitor patient conditions and then wireless communicate to the monitoring centers so that doctors and hospitals have real time insitu-information about the patients. So called lab-on chips or total analysis systems are being developed for such applications. Biological sensors are being developed so that soldiers or citizens may carry to detect biological agents. Such types of systems may be extremely useful in our war against terrorists.

4) In other industries. In the automotive industry, MEMS are in production for sensing applications, particularly for pressure and acceleration, and also for fuel-injection systems; printers, where ink-jet technology is revolutionizing a booming field ($3B worldwide market growing at nearly 20% per year).

2. Economical Benefits for State of Louisiana and Advanced Research in LSU

Louisiana missed the opportunity in the early wave of the information technologies, such as the IC industry, the computer and related software industries. Most of the high tech industries have been located in east and west coastal areas as well as Texas. There are many reasons for this. However, one of the major reasons should be that the state did not invest enough at the early stage of the silicon revolution, especially in the advanced research and higher education in the related fields, and instead, depended mostly on natural resources such as oil and gas.

1) Louisiana Has the Opportunity to Catch the Next Wave in IT Industry

However, in the MEMS area, Louisiana has invested significantly and the state has placed itself in a position not too much behind other states. With federal and state funds, LSU has established the Center for Advanced Microstructures & Devices (CAMD), a well know research facility in the field. In the past 7-9 years, LSU have recruited some excellent faculty and researchers in the field and have developed excellent research programs in the field. Therefore, this time we have the opportunity to catch the next wave of development in IT industry and benefit economically in the technological revolution.

It is well known that advanced research facility and excellent higher education can help to nature new industries. New start-up companies tend to locate in these places because of the readily available well-educated labor sources and knowledge bases. This is the reason that most of the high tech companies have concentrated in area where good research universities are located. With the significant research efforts in MEMS on LSU campus, eventually we will see significant economic benefits for the state.

2) MEMS Research Efforts in LSU and Excellent Funding Records

Significant resources have been committed to this vital field in establishing the state-of-the-art synchrotron source at CAMD and supporting the development of the Microsystems Engineering Team (μSET) in College of Engineering at LSU, especially in the Department of Mechanical Engineering.

In 1993, the Department of Mechanical Engineering recruited three junior faculty members, Drs. W. Wang,, M. Murphy, and K. Kelly. At that time, all three of them did not have any experiences in the MEMS field. However, the group has quickly established itself as one of the best funded research group in LSU and made ME Department one of the strongest MEMS programs among the mechanical engineering departments nationwide. In the past 6-7 years, these three faculty members have brought in a total of research funds more than 6-7 millions dollars. Currently, there are more than 15 graduate students majoring in the MEMS area.

In addition to the micro-systems engineering team (μSET) in mechanical engineering, faculty members in Chemistry (Dr. S. Soper's group) and Chemical Engineering (Dr. E. Podlaha's group) also have very dynamic MEMS research programs. There are also MEMS programs in Electrical Engineering (Drs. P. Ajmera's group and m. Fieldman’s group).

3) Job Market for Students Specializing in MEMS

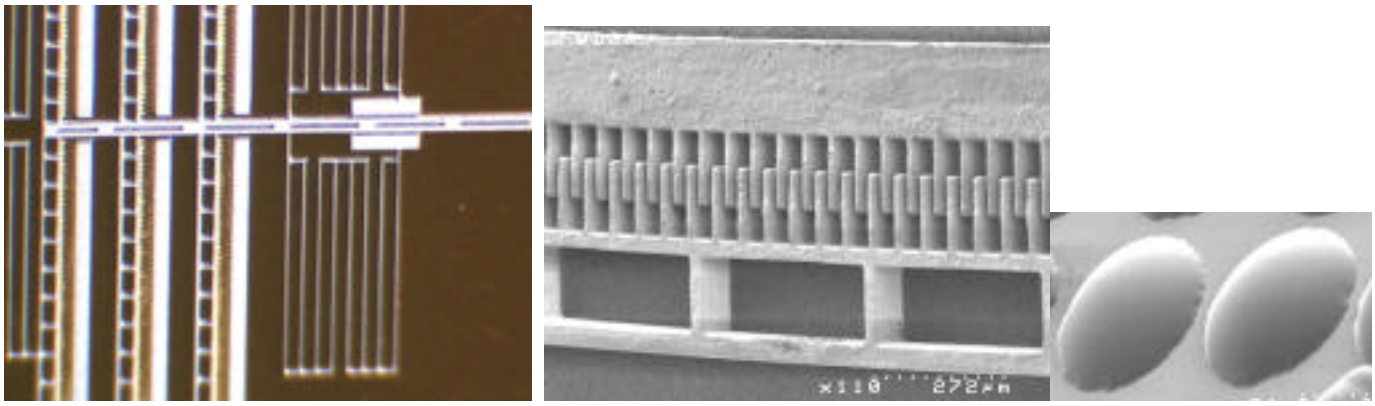
The job market in MEMS has been great so far and grows fast. Most of our graduate students received excellent job offers very quickly. This has also been true even for our international students. It seems that there is a short supply in MEMS field. Most of the graduate students have joined high tech companies, some in optical communication and other IT companies, and others in traditional industrial companies that are trying to utilize the MEMS for their purposes.

3 Additional Faculty Positions in MEMS Area for Mechanical Engineering

So far, the Department of Mechanical Engineering has the strongest MEMS research program and the highest amount of federal funds in this vital field in the past 6-7 years across the campus. As a matter of fact, the Department of Mechanical Engineering in LSU has one of the strongest MEMS programs among the ME departments nationwide. By adding new faculty positions for ME department in MEMS area, LSU may have a much better return on the limited investment based on our past performances. Additional faculty positions may make the program even stronger because of the existing strong bases.

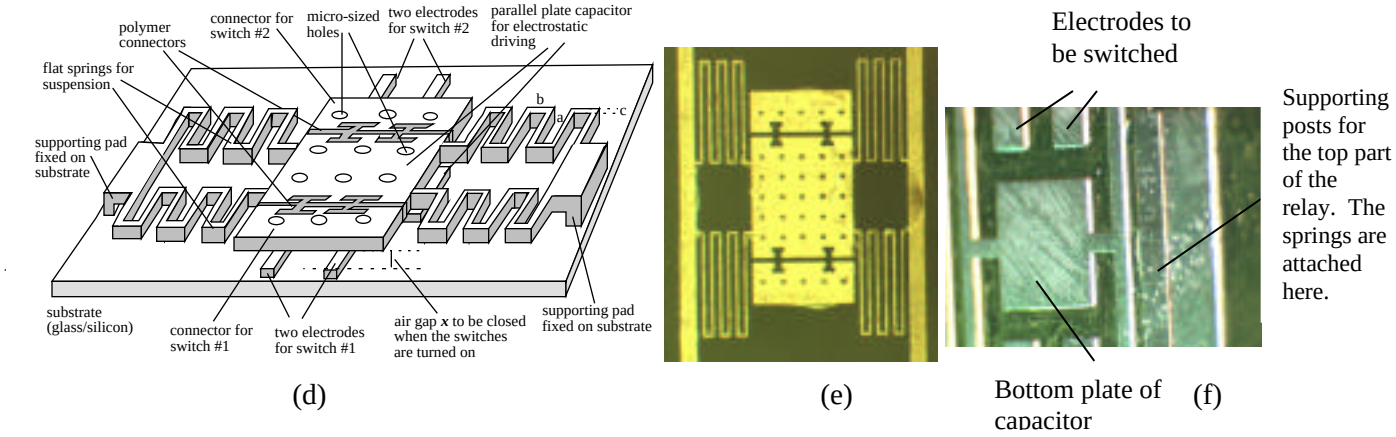
4 Some Example Current MEMS Projects (in IT Related Areas) at LSU

There are various MEMS research efforts going on in LSU. Because of the page limited, just some representative projects in Wang's group will be given as examples. In the following figures, pictures for an electrostaticaly actuated MEMS relay and an optical switch for IT applications are presented.



(a) (b) (c)

Figure (a) Photograph of MEMS optical switch under development in Wang's group; Figure (b) Comb Drive for the optical switch; Figure (c) Array of micro-lenses for integrated optical systems.



(d) (e) (f)

Figure (d) The schematic design diagram for the MEMS micro-relay for communication applications under develop in Wang's group (US patent pending); Figure (e) Microfabricated top layer of the MEMS relay; Figure (f) Photograph of the bottom part of the MEMS relay.