MEMs - The Tiny Giant

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Ever thinking to have a comb a hundred times thinner than your hair, a motor smaller than your blood vessel, and a mirror barely the size of several of your red blood cell? Well, all these micron-sized things are no more wondrous you can only find in science fiction book or movie. An emerging micro-scaled technology, known as microelectromechanical system, or simply MEMs, is making the production of these tiny machines a reality.

MEMs devices are fabricated in a way very much alike how all our Pentiums, Athlons, or 74LS00, are made. In other words, they utilize the silicon integrated circuit fabrication process. By having a controlled interleaving process of thin film deposition-etching-deposition ….bla bla bla, we can have the micro-structure we want. Take a look on figure 1 for a clearer illustration, and [1] for the the fabrication process available.

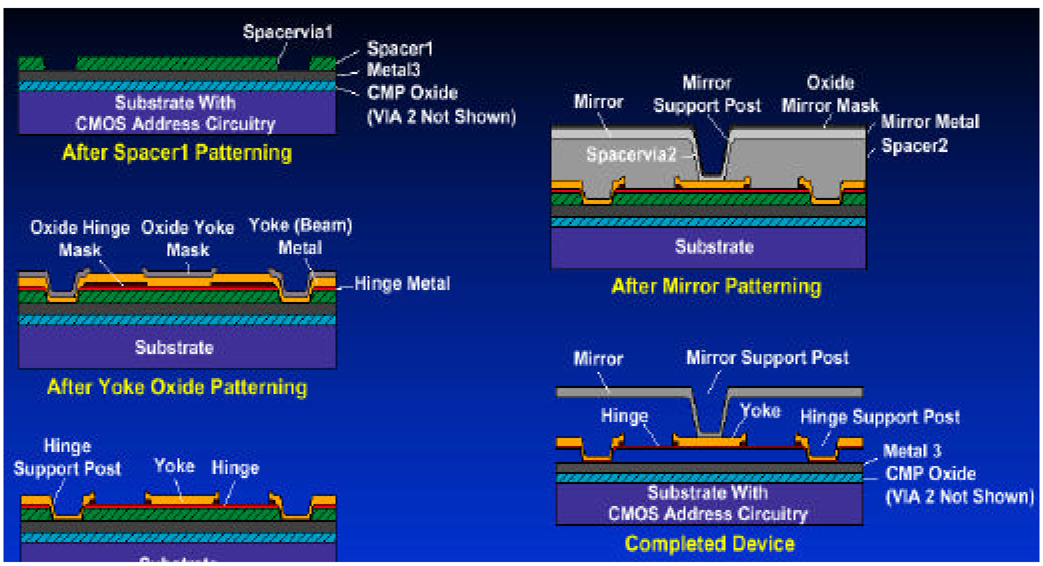

Figure 1 The silicon surface micromachining process used to fabricate TI's DMD

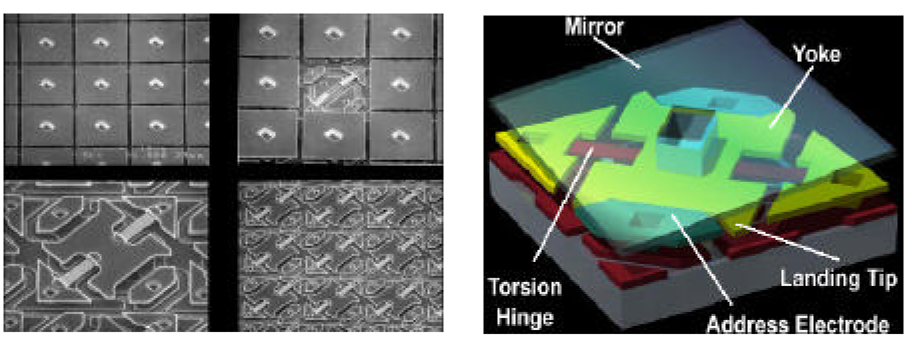

Figure 2 TI's DMD

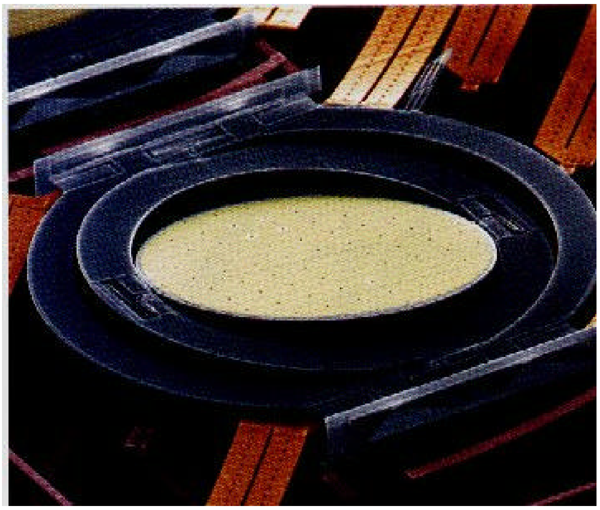

Figure 3 Micro-mirror

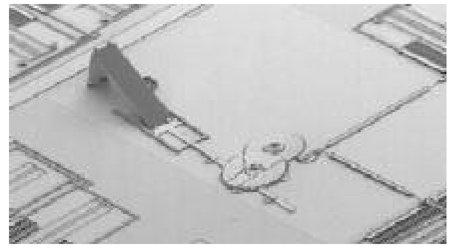

Figure 4 Actuated pop up structure

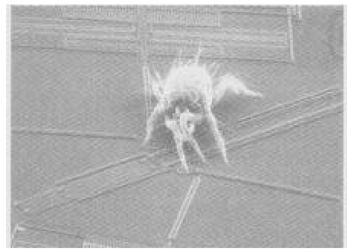

Figure 5 A spider mite walking on a MEMs

At this stage, I should give the definition of what actually is MEMs. Technically, MEMs is defined to be a micro-sized electrically controlled movable structure. It can be actuated thermally, magnetically, electrostastically, or through the effect of piezoelectricity. Anyhow, MEMs may still be actuated in brilliant ways yet to be designed or discovered in future. May be we will have MEMs actuated by sunlight, your voice, or who knows, your thoughts.

Okay, may be I have gone a little bit too far. Now, what is the use of all these tiny things? You certainly don't use a mirror as wide as your hair for making-up, right? The answer to this question is…. actually, the application is as far as your mind can imagine. A designer can build a micro actuator, micro wheel, micro stick, micro……bla bla bla. However, MEMs already finds applications in automobile, biotechnology, industrial sensor, video imaging and telecommunication, with devices ranging from simple actuator, tiny bio-station, sensor, accelerometer, switches, printer head, to complex device like DMD(Digital Mirror Array) from Texas Instruments. The fact that MEMs is fabricated using semiconductor-alike process enables the entire digital or analog electronic control circuitry to be integrated onto the same silicon wafer, at a cost much lower than other technologies. All these are making MEMs a lucrative options for future smart devices.

Allow me to elaborate a little more on the mentioned devices. MEMs accelerometer can be used in car, as airbag sensor, to trigger the airbag. Computer read/write heads and inkjet nozzles is another place where MEMs is found. In the medical biotechnology world, people are pushing towards the design of MEMs based labs-on-a-chip[2], where an entire range of equipments used to test, say a blood sample, can be integrated onto a chip. The result is that it not only saves space, but also expensive chemical and most important, it is fast and easier to handle.

Looking at all those examples and possibilities, we can conclude that there is certainly a guaranteed huge market out there for the tiny MEMs. However, what really makes MEMs shines lies in an even bigger field, an ultra-huge play ground---the worldwide telecommunication market. With a little twitch around, MEMs technology is turned into optical MEMs (or MOEMs) . Already, there are optical switches, routers, tunable wavelength filter, all built using MEMs technology. For example, Agilent Technologies has a novel 32X32 bubble based MEMs optical switch.

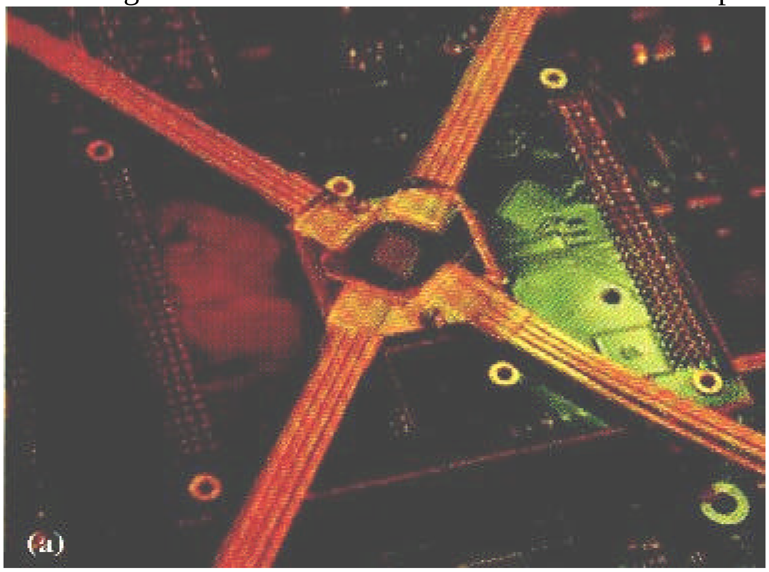

Figure 6 Agilent Technologies's 32X32 optical switch

We are looking at a promising technology in its infancy, which windows of opportunity is lucrative. Almost every major players in the telecommunication field is in the race to board this "MEMs express" train. Telecommunications giant is fastly acquiring startups with MEMs capabilities. In March 2000, Nortel Networks spent USD$1.43 billion to acquire CoreTek, a maker of MEMs-based detectors. In April, JDS Uniphase acquired Cronos Integrated Microsystems, a silicon surface micromachining fabrication process service provider, for USD$750 million. In June, Corning acquired IntelliSense, a MOEMs fabrication process service provider and also MEMs modelling software provider. Giants like Lucent Technologies, Agilent Technogies a whole bunch of telecommunication players, have come-up with optical switches or routers, all based on MEMs technology.

What is behind all this optical MEMs super-race? The answer lies in figure. In 1996, all-optical MEMs based switches accounted for USD$10 million in a USD$2 billion market[3]. Industrial market analyst like System Planning Corp and Cahners Instat Group project that optical switches alone will be a USD$700 million market by 2003, and a whelming USD$1 billion by 2004.

All this is due is due to the explosion of demand for bandwidth created by the internet. Existing electronic switches represent the bottleneck on the information superhighway. Whereas the demand for bandwidth should reach Tbps in near future, electronic based technologies, even the expensive GaAs based circuitry, have a speed limit at 40Gbps. Optical switching is the only workaround to eliminate this problem, with virtually no speed limit, irrespective of data format, polarization independence, almost no crosstalk and low loss (less than 1dB). We call this sort of switching as all optical switching, or photonic switching.

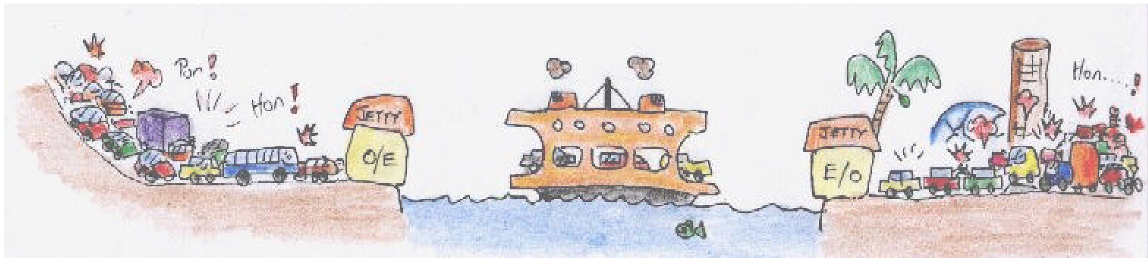

Figure 7 An analogy to traffic bottleneck for optical network: Penang before 1985

Figure 8 An analogy to the smooth traffic offered by all optical switching: Penang Bridge

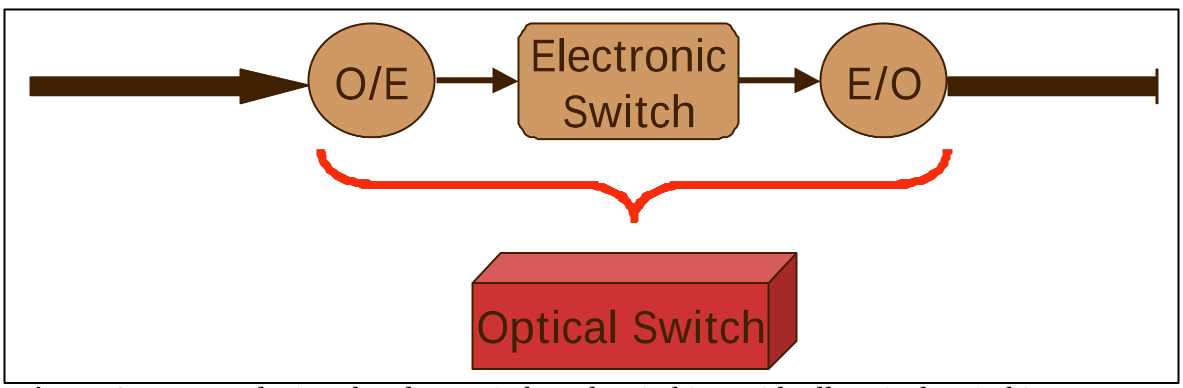

Figure 9 Replacing the electronic based switching with all optical switching

Also, all optical switching gives a tremendous cost savings to manufacturers. For example, standard electronic switches used in fiberoptics can cost up to USD$1000 per channel. Let say a thousand channels are needed, the cost will be USD$1000 X 1000 = USD$1 000000 !!! Using MEMs technology, a thousand mirrors can be built onto a single silicon wafer, with all the control circuitry embedded into the chip, at a manufacturing cost for barely a few dollars. Other than optical switches, several other MEMs devices can be and are being developed for the optical networks, such as attenuators, filters and tunable laser.

Actually, there are other competing technologies been developed for optical switching besides MEMs, like liquid crystal switches, thermal-optical mediums that conduct light, acousto-optical switches, waveguide based switches, and low-density bubble switches that are an adaptation of ink-jet technology. However, industry experts say competing against MEMs is like trying to stop a runaway bullet train. MEMs have advantage that they are backed by the trillion dollar investment of the past 30 years in microelectronic manufacturing technology. MEMs is most likely to win because of the momentum in this huge knowledge base.

Anyway, MEMs does not come without weakness. The fact that all MEMs relies on a electrically controlled movable part means that their speed is slower than that achievable by other technologies. For example, the fastest MEMs optical switch ever reported is in the range of hundreds of microseconds, whereas switches based on waveguide have speed in the range of nanoseconds. However, owing to its overwhelming advantages as discussed, and that microseconds switching speed is still acceptable, MEMs is still one of the best options available. With careful design and optimization, and backed by the sheer number of researchers involved in the development of tomorrow MEMs based switches, it is most likely that MEMs will be gaining access into a even faster speed realm, perfecting its technology.

To end this article, I would like to call upon the reader's attention that MEMs is still in its infancy. We are looking at a technology just like how semiconductor technology is 30 years ago (at that time, who ever thought of integrating a few millions transistors onto a tiny silicon wafer, who ever thought of how the introduction of the microprocessor has changed the world so tremendously). Industrial giants as well as tiny startups, and also university researches around the world, are taking steps to share this fortune making cake. Our neighbour Singapore government is funding its university as well as polytechnic for researches in biotechnology MEMs. There is a great window of opportunity lying ahead of us, and our local universities have the same qualities and ability to embrace this research as the rest of the world. For a clearer example, we can design the switch, and send it for fabrication in commercial foundry. And that is one the project on-going for the Photonic Research Group of UTM. With effort and blessing of God, we can make this tiny stuff into a giant.

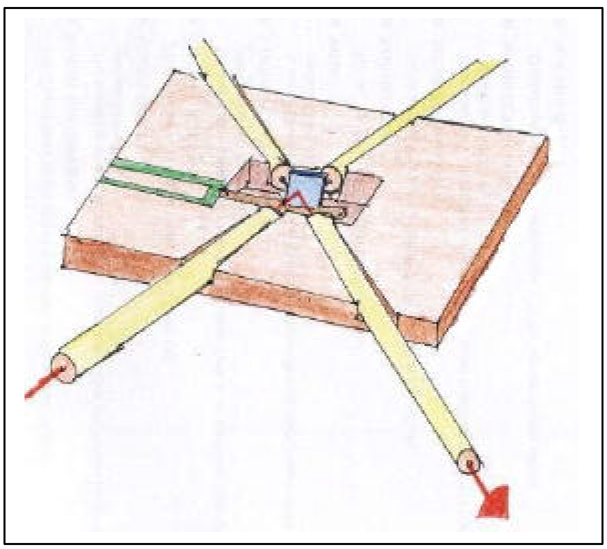

Figure 10
A 2X2 optical switch under development

REFERENCE

[1] Ming C. Wu, "Micromachining for Optical and Optoelectronic Systems", *Proceedings of The IEEE, vol. 85, No.11*, November 1997.

[2] Stuart F. Brown, "Good-bye Test Tubes Hello Labs-on-a-Chip", *Fortune*, 11 October 1999.

[3] Valerie C. Coffey, "The Market: Tiny tools are changing the rules", *Laser Focus World*, pg.133, January 2001.