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Switches Raise Prospects for Tiny Technology

By BARNABY J. FEDER

Since the beginning of the Computer Age, microprocessors have been transforming mankind's machines, endowing them with memory, flexibility, precision and the ability to share information.

Now, miniaturized machines, reduced to microchip dimensions, are working alongside or in place of the processors.

Karen Tam for The New York Times

Robert L. Bratter, chief executive of Cronos Integrated Microsystems, in a Cronos plant where MEMS, or microelectromechanical systems, are made.

These tiny devices known as MEMS, for microelectromechanical systems, include valves, levers, motors and microphones. In the form of tiny sensors, millions of MEMS have already made their way into products like automotive air bags, ink-jet printers and disposable blood pressure analyzers.

These days, though, the MEMS spotlight is on minuscule mirrors and the

central role they may soon play in communications. Various companies are introducing MEMS-based switches to control the paths of lightwaves through the rapidly expanding networks of optical fiber cables that make up the Internet's backbone. By bouncing the lightwaves off MEMS mirrors instead of running them through electronic switches, networks could improve Internet efficiency.

"This could be the true validation of the technology," said Robert L. Bratter, president and chief executive of Cronos Integrated Microsystems, a designer and maker of MEMS components based in Morrisville, N.C.

JDS Uniphase, a rapidly growing telecommunications equipment supplier in Nepean, Ontario, near Ottawa, is certainly betting on it. In April, the company agreed to buy Cronos for $750 million in stock -- a rich price for a start-up with annual sales of only about $10 million.

Another MEMS player is Nortel Networks, one of North America's largest and oldest makers of telecommunications gear. Nortel agreed in March to pay $3.25 billion in stock for Xros Inc., a start-up in Sunnyvale, Calif. Although Xros has no sales yet, it does have a MEMS design for big network switches.

A week later, Nortel snapped up CoreTek, a start-up in Wilmington, Mass., that uses MEMS in the design of lasers that can be tuned to send signals of different wavelengths through optical networks. CoreTek investors will get up to $1.43 billion in Nortel shares if CoreTek meets certain development milestones.

Meanwhile, Nortel's main rival, Lucent Technologies -- North America's largest manufacturer of telecommunications equipment -- has announced commercial availability of its first large MEMS switch. Last month, Lucent signed Global Crossing as its first customer.

Success for MEMS in the optical communications market would finally dispel the aura of failed promise that settled over MEMS a decade ago after early missteps and a naivete about how fast the technology would take hold.

MEMS advocates recall a surge of interest in the 1980s, which they say brought a flood of publicity to brilliant, but useless, creations. For example, Nippondenso, a Japanese affiliate of Toyota, assembled several MEMS devices into a model car the size of a grain of rice.

Other heralded visions that have still not yielded real products include fuel cells on a chip; minuscule implant pumps for extremely accurate drug delivery; and battlefield surveillance systems small enough to drift around like dust particles.

But if some of the most dazzling visions have yet to materialize, many technology experts continue to foresee a revolutionary role for MEMS. MEMS have recently shown up in devices as diverse as movie

projectors, DNA analysis kits, braking systems and airspeed indicators.

"The field is diversifying very rapidly," said William Trimmer, vice president of technology for Standard MEMS, a MEMS maker in Burlington, Mass.

What is more, if manufacturers of MEMS switches show they have successfully met the telecommunications industry's demanding standards for reliability, programs to develop other MEMS products should encounter less skepticism, predicts David Honey, photonics program manager for the Defense Advanced Research Projects Agency of the Defense Department, which has been a major financer of MEMS research.

One big challenge for MEMS is that while the devices are often made with the same equipment and methods as are microprocessors, they have to be designed and packaged differently for every new application. As a result, most of the scores of products already on the market have been aimed at narrow niches. And only a handful are currently profitable, according to Roger H. Grace, a San Francisco consultant who has tracked MEMS businesses for more than a decade.

The bumpy path MEMS have taken from the laboratory to commerce might have been predictable. Lasers and robots -- two other inventions that inspired dreams of transforming the world -- took a similar route.

Even though lasers are now everywhere -- used in scanners, medical equipment and home entertainment devices like CD players -- only a handful of the companies that made lasers managed to grow into publicly held ventures, and none of them became household names among investors.

Robotics is commonplace today in industrial applications like assembly, welding, painting and packaging, but most of the major pioneers went bankrupt, or survive as small divisions or affiliates of companies like General Electric or ThyssenKrupp of Germany.

MEMS manufacturers see a potential home run in switches because fiber optics has become the backbone of modern communications networks, with pulses of light representing the off-and-on binary code of digital information.

Without MEMS, directing those light pulses toward their destination and balancing the traffic has required converting the light to electrons at network junctions, routing the electrons through switches, then translating them back into lightwaves to continue down their new path. The new MEMS devices can eliminate this double translation process by enabling the switching station to simply bounce the light signals to their new network pathway.

With companies talking about the need to keep up with Internet traffic -- WorldCom says it must add the equivalent of its entire 1998 network

every month by next year -- MEMS switches could become a billion-dollar market by 2003, according to industry analysts.

Communications companies say MEMS switches are attractive not just for their reduced power demands and compact size but for "scalability." Currently, when a fiber optic cable carrying dozens of different wavelengths of light reaches an electronic switch, each wavelength must take a different path through the switch. As optical cables evolve to handle more and more wavelengths, which is crucial in expanding capacity, electronic switches must be reconfigured or replaced. But the newest MEMS switches, once installed, can redirect 10 wavelengths or hundreds without needing to be changed or expanded.

"The Holy Grail has been to put something in the network that has a long life span," said Jack Wimmer, vice president for network technology and planning at WorldCom, adding that MEMS devices could be widely deployed next year if they prove to be reliable in testing this year.

The simplest MEMS switches are like gates. When the mirror is in its open position, the signal passes through uninterrupted; when it pivots or is pushed into the signal path, the signal is deflected.

The limitation in such designs is that each mirror in the array pivots on a single axis. That means everything must be switched to destinations in a single plane. Picture a flat city grid with every avenue having a pop-up barrier at each intersection, capable of diverting traffic down any side streets. The traffic can be rerouted, but only on the plane of the city's streets.

A newer, somewhat more expensive design uses arrays of pinhead-size mirrors that can pivot on two axes simultaneously. The forward-backward tilt can be controlled separately from the left-right tilt. The tilting is controlled by electrical charges, but the principle is the same as in the children's game in which one tries to roll a ball past holes and through a maze by using two knobs to control the pitch of the playing surface. Instead of a mirror at every intersection, each avenue now has a single mirror that can direct traffic to multiple destinations in more than one plane.

In principle, such switches could be easily scaled up to direct thousands of incoming signals to thousands of destinations. In practice, since many signals at different wavelengths are traveling simultaneously down each fiber, the MEMS package requires a device that separates the arriving wavelengths and directs each to a different mirror so that it can be switched to its specific destination. The system also requires a similar device to intercept and rebundle the switched signals so that each outgoing fiber also carries as many different wavelengths as possible.

The development challenges and the absence, so far, of a successful track record mean that MEMS could once again fail to live up to expectations. And the makers of MEMS optical switches risk confusing customers with their competing designs.

"Two or three will emerge as the industry standard in time, but I expect seven or eight to be out there next year," said Kathleen C. Szelag, vice president for marketing for Lucent's Optical Networking Group.

In addition, electronic processors continue to plummet in price and increase in speed, which means that the electronic switching technology that MEMS designers hope to supplant is far from obsolete.

MEMS will also have to compete with other optical technologies. Agilent Technologies, a subsidiary of Hewlett-Packard, surprised a major optical products trade show in Baltimore in March with a new system capable of switching wavelengths of light from one fiber to another by bouncing them off bubbles in a grid of liquid. Tiny changes in heat cause the bubbles to form or disappear in 5 milliseconds. The grid can handle 512 wavelengths simultaneously.

MEMS advocates say the bubble technology has several drawbacks, including a need for much more power. But investors apparently listened to the company's case that similar technology had proved to be reliable for years in Hewlett-Packard's bubble-jet printers and could be easily manufactured. Agilent's stock soared 47 percent the day after the announcement. Alcatel of France, Europe's second-largest telecommunications equipment company, has signed an agreement to work on developing the bubble technology.

"We are very interested in MEMS, but we are also talking with vendors of about half a dozen other optical switching technologies," said Wimmer of WorldCom.

If MEMS switches take over the market the next few years, it may be just in time for their creators to start worrying about yet another competitor for their flexible mirrors and other chip-based machines. In the field of nanotechnology, researchers have already begun exploring the theoretical advantages of far smaller devices built from handfuls of atoms and molecules. If their work pans out, the next step could be switches and other machines invisible to the naked eye.

Related Sites

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- Tutorial information about MEMS, from the MEMS Clearinghouse