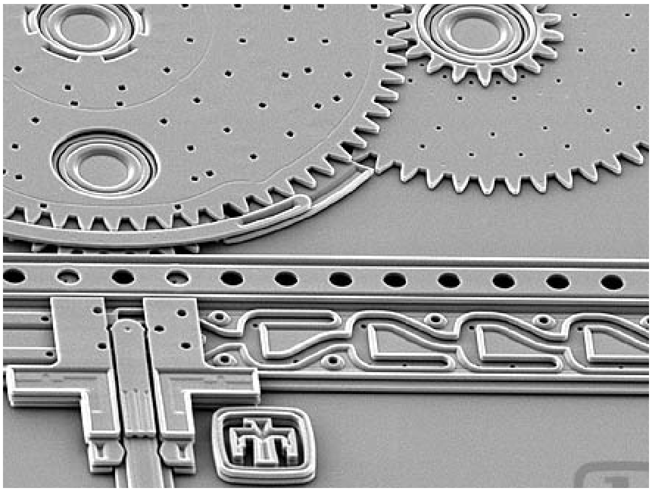
Nano nukes for micromachines?



SANDIA NATIONAL LABORATORY

Sandia's micromechanical (MEM) locking device fits on the head of a pin but can still prevent unauthorized access to a computer. Shown here is a 24-bit "maze," which can only be traversed forward. Unauthorized users cannot go back if they make a mistake. (www.mdl.sandia.gov/micromachine)

Computers grow smaller each year. Portions of food at fine restaurants likewise. Even the U.S. deficit is shrinking. So why not that die-hard of the industrial age, the machine?

We're not talking a little smaller, or even a lot smaller. As reported in the January/February *Bulletin*, researchers at Sandia National Laboratories have created tiny microelectromechanical systems, or MEMs, smaller than a grain of sand and capable of performing a variety of tasks. Some can spin wheels as small as .3 millimeters at 350,000 revolutions per minute. Others are equipped with mirrors or motors on the same scale.

One problem yet to be solved, however, is scaling down a suitable power supply. So far, no effective solution exists.

Not all MEM technology—also known as nanotechnology or micromechanics—needs power. The sensing devices used in automotive airbags, for example, just hang around waiting for something to happen *mechanically*. Other devices, however, require a jolt of power, and since even a hearing aid battery might be thousands of times larger than the machine itself, finding suitable power sources has turned into one of the biggest challenges faced by MEM designers.

Researchers at the University of Wisconsin believe the answer lies in nuclear-powered batteries so small they could be lined up on a human hair. The Energy Department seems to agree, and in July it awarded the university a $450,000 grant to study the technology.

Although researchers elsewhere are looking into using fossil fuel or fuel cell technology to solve the MEM power issue, James Blanchard, an associate professor of nuclear engineering, believes the power density and longevity of radioactive materials—although he preferred not to mention which ones they plan to study—gives them an advantage over other potential sources.

The Wisconsin study will investigate ways of turning the natural decay of radioactive materials—either by directly harnessing the particles emitted from a radioactive source, or by using the heat they produce—into electric current. In theory, the batteries could be similar to the fist-sized nuclear batteries used on some space missions. Blanchard's department plans to have prototypes sometime next year.

"If you have a device like a grain of sand, you obviously want a power source that gives you the most power output for the size of fuel. For that, you cannot get better than nuclear power. It has the best power density available," Blanchard told The *London Times*.

But could the battery for a future surgical device or automobile monitoring system be a mini-Chernobyl waiting to happen?

Not a chance, Blanchard told the *Bulletin*. "We've been comparing the radiation level to that emitted by a smoke detector." And since the batteries would not rely on nuclear fusion or fission, only decay, there's no chance of an explosion.

Once developed, the batteries still won't have enough juice to power even a small consumer device. The power output, Blanchard continued, "will be quite small—from microwatts to milliwatts, somewhere in that range—but we're turning small little gears so we don't need much power."

There's a real need for these batteries, according to Paul McWhorter, deputy director for microsystems at Sandia National Laboratories. "One of the biggest challenges with these micromachines is building autonomous systems that are self-contained.

"Today, even if you have everything small, you still have two leads coming off for the power. The challenge is how to shrink the power source to a usable size," he said.

But power sources don't scale down well since their output is primarily a function of volume. Nuclear materials, on the other hand, have the high energy density needed at small sizes, although McWhorter wondered if the public is ready to have small bits of radioactive materials spread throughout their microsystems. Even though the amount is minuscule, it would still take "lots of education before the public is ready for nuclear batteries," he said.

The benefits could be enormous. "The real power is that we can make very complex systems at a very low cost," he said. For example, a micromechanical system that costs tens of thousands of dollars to manufacture conventionally might only cost a dollar or two when manufactured as a MEM, which is created much the same way as a microchip. However, instead of forming the silicon into millions of transistors, as you would with a computer microchip, MEM technology allows you to create gears, motors, mirrors, and other parts that can move.

Developing a practical power supply for all these MEMs "is a really interesting and relevant area of research," McWhorter concluded. "You're going against some very fundamental scaling laws. It's like running a truck with a rubber band, so this research is a real need for a very tough

"I was a 24-hour virus, but thanks to antibiotics, I'm now a 48-hour virus."

problem."

But the lack of micro-sized power sources hasn't stopped the spread of MEM technology. According to McWhorter, current MEM devices are found most often in inertial measurement chips that measure motion and position.

"In effect it is a chip that knows where it is," he said, and you'll find them in automotive airbags and sensors as well as computer input devices, especially gaming controllers.

Many high-end video projection systems also have a MEMs chip at their heart, such as the one made by Texas Instruments that sports a million fluctuating mirrors to project an image on a screen. Even the little device in an inkjet printer that spits ink onto a page is a micromachined device, McWhorter noted, "so most people already own micromachines and don't know it."

In the same way that the integrated circuit industry has replaced costly printed circuit boards with inexpensive microchips, McWhorter believes that MEM technology is the next step in the silicon revolution, one that will not only allow chips to "think," but also to "sense, act, and communicate." Recent studies by Systems Planning Corporation, according to information provided on Sandia's web site, estimates the market for intelligent micromachine-based systems to be around $100 billion a year.

Another advantage of MEMs is that at the micro level a different set of physics applies to moving objects, said Bill Trimmer, president of Belle Mead Research. Although surface forces such as friction and electrostatics loom large—and are a main obstacle faced by researchers—gravity and inertia are no longer significant. Consider how an ant can carry several times its own weight, or how a water bug can walk on water, and the physics of the micro world begin to come into focus.

"As things become smaller their mass decreases dramatically," he said, "so small things tend to be very robust."

"The applications are really exploding," he said. "Many are still being worked on, but soon we'll be seeing them everywhere.

"Take endoscopic and laparoscopic surgery," he noted, describing a MEM system that could be inserted into a patient through a biopsy needle or tiny incision and that would allow a surgeon to get tactile feedback from inside the patient's body.

"And just imagine the applications for information-gathering," he said. "You would be able to have bugs smaller than a bug."

—Bret Lortie