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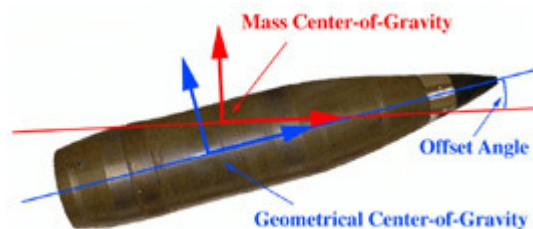
RESEARCHERS TRY TO TOUGHEN UP TINY MACHINES SO THEY CAN TAKE THE HEAT, STAND TEST OF TIME

By Rosemary Clandos
Small Times West Coast Correspondent

To find out just how reliable MEMS devices are, researchers will try just about anything to test the strengths and weaknesses of micromachines.

At the Aberdeen Proving Grounds in 1998, for example, the U.S. Army took a commercial MEMS product sold by Analog Devices Inc.

and attached it to a 155 mm projectile. Then they shot it out of a cannon.



MEMS devices were attached to artillery shells to determine if the devices would survive firing and transmit data during flight. Courtesy U.S. Army.

The device survived the launch, and as it raced toward the target it sent back information about acceleration and other data. Although the device was not expected to survive impact with the target, it did tolerate a force of 80,000 G's.

Highly capable of withstanding shock and fracture, MEMS devices have some outstanding qualities that make them a perfect fit for some jobs. But for other applications, the technology still needs a lot of work.

"On the issue of fracture, (MEMS) are amazingly robust," said William M. Miller, principal member of the technical staff at Sandia National Laboratories in New Mexico, where a three-year study was done on the reliability of MEMS.

At Sandia, a polysilicon device tolerated an intense shock when it was placed on a Hopkinson bar. A 3-inch diameter by 8-inch long pellet was fired from an air gun and hit the bar. The shock traveled down the bar and hit the device at 40,000 G's.

It's a simple law of physics that keeps microdevices ticking after intense shocks: When mass is very small and the acceleration or shock is very large, the force will be relatively modest.

But to make MEMS reliable, they also need to be able to live long lives. One example is in optical fiber communications.

"People in this industry are accustomed to 99.999 percent reliability," said Denny Miu, president and chief executive of Integrated Micromachines Inc. in Monrovia, Calif. "If something fails more than five minutes a year, it's too much." Miu said that about \$26,667 worth of revenue runs through telephone company switches each second when they run at full capacity. So they must be reliable.

"Our products can do one billion cycles -- that's 32.5 years if you switch it once every second," Miu said. "We avoided reliability issues that come with moving parts; we made something that has no friction."

For accelerometers and other sensors, reliability problems are expected to be minimal because there is no movement or contact with the rest of the MEMS device. But friction and potential wear become an issue when parts move, flex and rub.

Texas Instruments is one company that mastered the problem. It developed a digital micromirror device that has millions of vibrating mirrors deflecting beams of light and is used in tabletop video projectors, digital cinema projectors, high-definition televisions and large-venue projectors.

After initial wearing problems, the product now is capable of sustaining billions of cycles of back-and-forth movement.

"The reliability is nothing short of phenomenal on these things," Miller said. "It's a case where reliability has been very important and dealt with successfully."

At Sandia, the reliability study gave researchers a few surprises that didn't make them happy. One was the effect of humidity.

Humidity is an issue in the defense industry, where MEMS may be used in underground arsenals or on conventional weapons on aircraft, submarines or out in the desert.

"It's going to see extremes in temperatures, salt water and corrosive effects," said Danelle Tanner, who is also a principal member of Sandia's technical staff.

Scientists found that at high humidity, the moving parts on MEMS devices had a tendency to stick together. Minuscule droplets of moisture lock gears in place.

"That issue can be taken care of by drying the surfaces," Miller said.

But too dry can be troublesome, too.

To solve the high humidity problem, MEMS devices were put in vacuum packaging -- without air, and without friction from air. However, in the low humidity environment, the lack of moisture caused excess wear.

"So you have two competing effects," Miller said.

In moderate humidity, which might be ideal, individual water molecules act as a lubricant on the surfaces that are rubbing against each other. "There may be some issues with wear and moving parts and packaging in a moderate humidity. We have yet to deal with this," Miller said.

In the meantime, researchers have developed a special process that involves applying a tungsten coating on structures, reducing wear and friction.

Another wear problem involved electrostatic discharge -- the type of shock you experience in the winter when you walk on carpeting and then touch a metal doorknob -- creating a small arc that welded two pieces of a MEMS device together.

"We weren't happy when we saw that either," Miller said. Attempts to negate the effects of electrostatic discharge are being addressed through packaging.

"The real concern about reliability of MEMS in the weapons systems is dormancy," said Tanner. "Will it sit for five years and work when it needs to work? And we can't let it sit for 30 years and find out it doesn't work. We try to find ways to accelerate failures due to dormancy -- you can heat things up or drive them at a higher voltage. We are struggling with it."

Tests of MEMS devices show that they can withstand temperatures from -40 degrees Celsius (which equals -40 Fahrenheit) to 150 degrees Celsius (or 302 degrees Fahrenheit).

From the thermal expansion point of view, small objects can tolerate greater temperature extremes, Miller said. "With MEMS, because they are small, even a large change in temperature may not cause a large change in the size."

One of the areas in which packaging has presented the greatest problem is in the biomedical field, where caustic biofluids like blood, urine and interstitial fluid in the organs and tissues can cause the devices to deteriorate.

Biomedical business manager Elizabeth Montgomery at Standard MEMS Inc., which designs and manufactures MEMS in Hauppauge, N.Y., said that advances are being made so that devices can withstand the onslaught of challenges in the human body.

"There is a menu of surface treatments that are currently being utilized," Montgomery said. Silicon rubber has been used in the medical community for years, and titanium is well tolerated by the human body and has been used in pacemakers. Gold and titanium are used in sputtering technology, which lays down thin films over the devices. Iridium is also tolerated by the human body, but it is extremely rare and expensive.

The choice of materials used in packaging depends on "how you coat the MEMS devices and how long they will be exposed to the biofluids," Montgomery said.

COVER PHOTO: A shock test machine used to test MEMS at the Army Research Laboratory, Aberdeen Proving Ground, Md. *Courtesy U.S. Army.*

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