Microsensors without microfabrication

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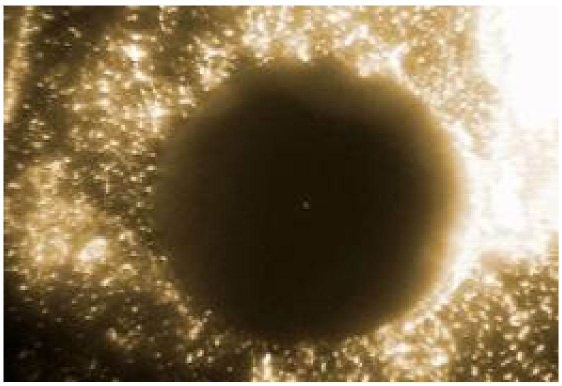

A tiny metal bead suspended in an electric field is just visible in the middle of a hole drilled through a circuit board. The hole itself is only the diameter of the wires used to connect circuit elements on the circuit board. Image: Rehmi Post/Center for Bits and Atoms

(PhysOrg.com) -- Miniature motion sensors are everywhere these days, detecting the orientation of cell phones, deploying air bags in cars and measuring stresses in buildings and mechanical systems. But manufacturing the sensors' tiny moving parts requires the same high-tech, billion-dollar facilities that churn out computer chips.

Researchers at MIT’s Center for Bits and Atoms (CBA) have now built a motion sensor that consists of a tiny metal bead suspended in what the center’s director, Neil Gershenfeld, describes as “a hole drilled in a circuit board.” A fluctuating electric field holds the bead aloft, in a tight orbit, and disturbances of the orbit indicate the sensor’s direction of motion. Gershenfeld believes that the sensor opens the door to a new class of miniaturized devices that exploit the dynamics of simple physical systems instead of the mechanical interactions of precisely micromachined parts. Such "microdynamical" devices, Gershenfeld says, could enable cheaper, simpler, more responsive sensors for a range of applications, including the measurement of sound, pressure, fluid-flow and magnetic fields.

The CBA researchers' device can do the work of at least six different micromechanical sensors. It can measure linear motion in three dimensions, which would ordinarily require three accelerometers. But it can also gauge its orientation — whether it's tipped sideways or forward, or it's been rotated — which would usually require an additional three gyroscopes.

A six-dimensional sensor would make the motion detection of handheld devices much more precise. The Wii game controller, for instance, wouldn't need an infrared emitter mounted to the television, and the Apple iPhone would change its screen orientation more reliably. Rehmi Post, a visiting scientist at CBA who initiated the sensor project as a PhD student at MIT, points out that the three-axis accelerometer is the most expensive component of the Wii remote. He believes that ultimately, a six-dimensional microdynamical sensor could be manufactured for about a tenth as much.

"If they can get all six degrees out of it, it would be huge," says Michael Judy, a researcher at Analog Devices, the company that built the Wii's accelerometers. "That's the holy grail right now in the human interface to electronics." Judy says that the application of motion sensing that has sparked the most interest is navigation in environments where GPS information is either unreliable or too imprecise. For instance, local spatial tracking would let hospital workers immediately determine each other's locations, even on different floors of a large building.

Gershenfeld suggests some other applications, too: scrolling through web pages, or viewing a 3-D virtual object from different angles, simply by moving a cell phone in space; or pens that can digitally record whatever's written with them.

Back in the saddle

In the most recent issue of the journal *Applied Physics Letters*, Gershenfeld, Post and George Popescu, who worked on the project as a graduate student, describe how they built their microdynamical sensor. At its heart is a particle trap, a device commonly used in experimental physics. Physically, the trap is very simple: two metal plates on either side of a circuit board, with a hole about the diameter of an electrical wire drilled through them. But a computer circuit hooked up to the plates exerts precise control over the electric field they produce.

The electric field, Gershenfeld explains, can be thought of as saddle-shaped: front to back, it curves upward at the ends, but side to side, it curves downward. The field fluctuates as if it were rotating, and a particle at its center is like a marble on a warped turntable. The marble starts to roll down one of the downward slopes, but the turntable revolves, and the marble finds itself rolling up an uphill slope instead. When it falls back down the slope, it repeats the whole process on the opposite side of the turntable, and so on.

A particle in the trap is thus not perfectly still but rapidly oscillating as, in effect, it rolls back and forth between upward slopes. Each of the six types of motion detected by a complete set of accelerometers and gyros disturbs the particle in a distinctive way.

"It's great research," says Judy. "It has a lot of possibilities. But it needs a lot of work." He points out, for instance, that generating the electric field in the prototype sensor required voltages in the vicinity of 1,000 volts.

Building up that kind of voltage in a handheld device isn't impossible, but it can introduce power inefficiencies: "The higher the voltage, the more power you burn to get it," Judy says. Post, however, observes that the lenses in cell phone cameras typically require about 100 volts and that existing technology can generate that type of voltage efficiently. And a commercial version of the sensor would probably use a smaller particle trap, he says: "The necessary voltage decreases as the diameter of the trap decreases."

Another unresolved question, however, is how to measure the particle's oscillation. In their prototype, the CBA researchers used a miniature camera, and Gershenfeld says that incorporating an optical sensor into a practical, mass-producible device is an engineering challenge "on the order of the optics of a CD player." In the meantime, however, the researchers are working on a version of the device in which the metal bead is mounted on a wire that can directly relay electrical information about its oscillation. The wire would restrict the particle's motion in one dimension, but the sensor would be easier to manufacture, and it would still be useful in cars or other vehicles that tend not to suddenly launch into the air.

Provided by Massachusetts Institute of Technology

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