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Autosensing for Autos

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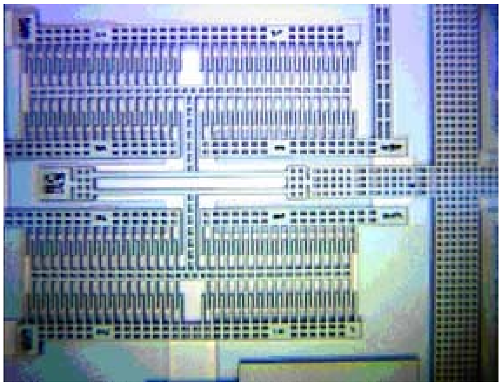
Automobile rollovers often occur when a car's wheels lose traction, the vehicle slides sideways, and the lateral force causes the car to flip. Of course, the tires "know" they're skidding long before the driver can react by turning the wheel. But what if the wheels were smart enough to alert the vehicle's control and stability systems to compensate for the loss of traction with an appropriate power boost? That's just one future application of the tiny, wireless strain sensors that UC Berkeley engineers are developing in the Microfabrication Laboratory. Someday, the sensors could be bonded to most any steel structure -- from an automobile suspension to a critical girder in a building -- to keep a constant vigil on the forces that affect a structure's performance.

The MEMS strain gauge team: (L-R) Prof. Liwei Lin, Ken Wojciechowski, Professor Oliver O'Reilly, Brian Sosnowchik, Babak Jamshidi, Robert Azevedo, and Professor Albert Pisano. Not pictured, professor Bernhard Boser, Dr. Anand Jog, Wayne Huang and I-yang Chen.

"Binding a tiny strain gauge to steel enables you to monitor the behavior and state of a solid in real time," says graduate student Babak Jamshidi.



A microscopic photo of the Double-Ended Tuning Fork (DETF) resonant strain gauge. At the right is a strain simulator that enables the researchers to test the device. (courtesy the researchers)

Jamshidi is collaborating on the project with students Robert Azevedo, Wayne Huang, Brian Sosnowchik, Ken Wojciechowski, and I-Yang Chen, and research specialist Anand Jog. The principal investigators on the project are mechanical engineering professors Oliver O'Reilly, Albert Pisano, and Liwei Lin, and professor Bernhard Boser of the Department of Electrical Engineering and Computer Sciences. All of the researchers are affiliated with the Berkeley Sensor & Actuator Center (BSAC), home to the new Micro and Nano Technologies for Automotive Research (MINATAUR) project.

BSAC has a long track record pioneering the development of micro-electromechanical systems (MEMS), tiny machines no bigger than the period at the end of this sentence that are now found in everything from automobile airbags to the wireless networks of Smart Dust sensors making headlines. Because MEMS are fabricated from silicon with processes similar to those used in integrated circuit manufacturing, the strain gauges will be cheap and small enough to be installed in many environments.

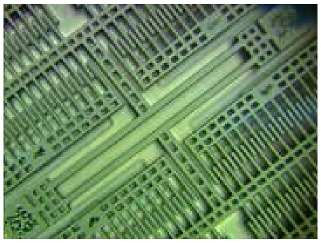
"One near-term application is to add them to a car's suspension so they could continuously measure the vehicle's alignment as you drive," O'Reilly says.

A self-monitoring suspension, he explains, would inform the driver when it's time to bring the car in for realignment, before the tires prematurely wear out or other costly repairs become necessary. The concept is not unlike having a ride-along mechanic that diagnoses problems before the symptoms emerge.

The researchers are currently working on two designs for the strain gauge. The resonant strain gauge is based on tuning fork-like tines not much longer than a human hair is thick. The tines are mechanically vibrated and the frequency of that vibration is detected by onboard electronics. As force is applied to the steel that it's mounted on, the device stretches and the frequency changes.

"It's like a musician strumming a guitar string and then pinching the string against the neck of the instrument," Azevedo says. "Altering the length of the string affects the frequency of the note. Our strain gauge detects the equivalent of that change."

The prototype MEMS resonant strain gauge is 100 times more sensitive than today's "industry standard" strain gauges. Its ability to take measurements 10,000 times each second makes it ideal for automotive applications where critical changes in strain can occur in the blink of an eye.



A microscopic photo of the vibrating tines in the resonant strain gauge. (courtesy the researchers)

Meanwhile, Jamshidi is exploring a different design for the sensor. The capacitive strain gauge contains two tiny electrode plates with miniscule space between them. Strain causes the plates to shift slightly closer together or further apart, affecting the measurable electric field between them.

One tough challenge with both designs is packaging the gauge so that it's protected from the environment, but not contained so much that the sensor's ability to measure the external forces is blocked. Meanwhile, Lin and his students are testing processes to bond the silicon microsensors to steel substrates. The intense heat of welding would damage the sensor and glues aren't expected to hold up over the long haul. So far, a specialized solder process has shown the most promise.

The researchers predict that it will take some time to perfect the sensor and the bonding technique. Only then will the new MEMS strain gauge be ready for a test drive for automobile applications. What else lies on the road ahead?

"We're also looking at other potential applications," O'Reilly says. "You could install the sensors on bridges, underground pipes, or maybe even the wings of airplanes to monitor the behavior of those structures."

Your Turn

Do you have a comment or question regarding this research?

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Oliver M. O'Reilly's home page

Albert P. Pisano's home page

Bernhard Boser's home page

Liewei Lin's home page

Berkeley Sensor and Actuator Center

UC Berkeley Microfabrication Laboratory

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