Fiber Optic Microsensors for Automotive Power Electronics

Transportation

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ENERGY EFFICIENCY AND RENEWABLE ENERGY

OFFICE OF FREEDOMCAR AND VEHICLE TECHNOLOGIES

Background

Automobile technology is evolving toward hybrid- and fully-electric propulsion that relies on advanced batteries to store and generate electricity. These batteries will power state-of-the-art motors through an interface of advanced power electronic control devices which help to shape the supplied voltages to match driving conditions. Power electronics will also be necessary to achieve integration of powertrain and chassis system controls, as well as for navigational and communication systems.

Researchers at Oak Ridge National Laboratory (ORNL) have combined fiber optics with the latest in micro-electromechanical machines (MEMS) technology to develop an effective means of measuring current and voltages in the power electronics inverter drive package. Such sensors must be accurate and able to function in the rugged environment that characterizes today's automobile, and they must be inexpensive to manufacture. However, present sensor technology uses significant drive current, takes up space, and is both heavy and too expensive for inclusion in consumer drive packages.

The Technology

For current measurement, microcantilevers which have been micro-machined from silicon are coated with a magnetic material. When placed close to a current source, the cantilever flexes in proportion to the induced magnetic field that accompanies the current. The degree of flexing can be sensed by a single optical fiber and the resulting signal used to control a power electronic inverter in a hybrid vehicle. The target range for current sensing is 1 to 600 amps. The work at ORNL has focused on lowering the cost of such advanced sensors, and researchers there have recently demonstrated that an optical reader head from a consumer compact disc player can be used to detect minute displacements in the microcantilever. The optical package inside the commonly available CD player houses a fairly sophisticated system, including an onboard laser light source, detector, and associated electronic circuitry. Manufacturers of these optical devices have already achieved economies of scale with a unit costing only about $1 to make and occupying approximately 10 cm^3. The ORNL research shows that, using such an optical system, the position of the microcantilever surface can be measured with a resolution of 14 nanometers (nm), or 14 millionths of a millimeter. This extreme sensitivity is sufficient for determining the motion of a cantilever caused by a current-induced magnetic field. When combined with the small, lightweight, and rugged nature of optical fibers, as well as their high-temperature operational capabilities, it will soon be possible to make measurements in locations not currently accessible to conventional electronic sensors.

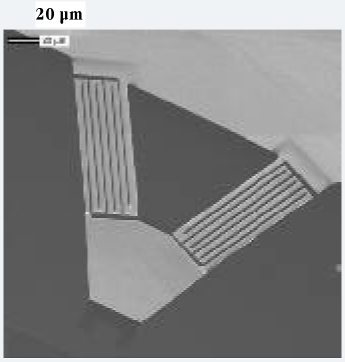
In a dual fiber system, light is sent through a delivery fiber and reflected off of the micro-cantilever. The reflected light is then transferred by a collection fiber to a photon detector. Researchers at ORNL have demonstrated the capability of measuring currents down to 0.1 amps using a cobalt-coated microcantilever and simple dual optical fiber for determining cantilever flexure. The new, fiber-optic based sensors will be energy efficient, inexpensive, accurate, and immune to electromagnetic interference — qualities that will ultimately improve the performance and efficiency of power electronic inverters by enabling very precise switching.

Commercialization

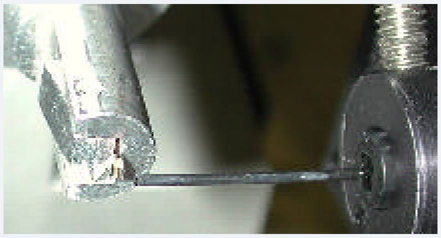
Oak Ridge is teaming with Luna Innovations of Blacksburg, Virginia to commercialize this technology. Luna Innovations is known for its ability to design turnkey solutions to specific measurement applications, including integrating fiber optic sensing instrumentation with existing measurement and control equipment. Luna Innovation's sister company, Luna Technologies, manufactures optical test instruments incorporating new and revolutionary photonics technology based on research done at NASA.

Benefits

- Reduced weight and volume
- Fast, accurate measurements
- Cheaper to manufacture and lower life-cycle costs through better long-term operation
- Functions in the harsh environment of an automobile; high temperature operational capabilities
- Not affected by electromagnetic or radio frequency interference



A typical microcantilever (above). Microcantilever and a 1-mm diameter optical fiber in test apparatus (below).



Contacts:

Stephen Allison
Oak Ridge National Laboratory
(865) 946-1287
allisonsw@ornl.gov

Luna Innovations
(540) 552-5128
solutions@lunainnovations.com

Success Story

March 2003