Custom Microinstrumentation for Sensing Systems

Various technology programs at LLNL demand new sensors that measure physical phenomena like contact stress, force, displacement, strain, acceleration and temperature. LLNL engineers provide custom instruments that are required to meet a myriad of constraints. This effort builds capabilities and tools that may find use in a variety of applications, including stockpile diagnostics and surveillance.

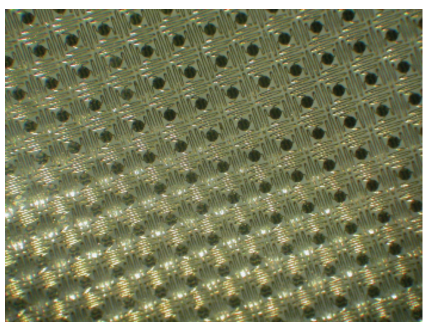

Figure 1. Contact-Stress Sensing Array with 900 independent silicon sensor islands on flexible and extensible interconnects.

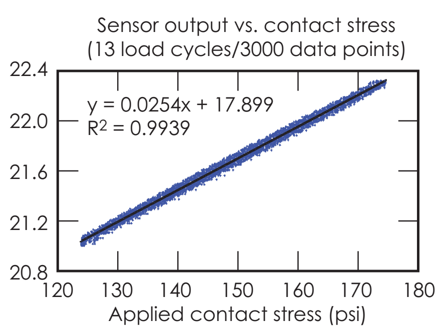

Figure 2. Contact-stress sensor data.

Project Goals

This project consists of three major parts. The first goal was to prove, integrate, and test all the components necessary to form a contact-stress-sensing array (CSSA) and to test the completed system. The second was to produce and implement all components of an Optical Force Probe (OFP) to be used for measurements with an optical readout system. The third was to characterize and implement a Modular Optical Assembly (MOA) to be used in the OFP and other optical instruments. The MOA addresses alignment and protection of the sensitive optical chamber necessary for the optical instruments' functions.

Relevance to LLNL Mission

Custom microinstrumentation for stockpile stewardship and other LLNL applications is in great demand. LLNL's Microsensors Program leverages capabilities in meso-, micro-, and nanotechnology to field microscale sensors for high-fidelity

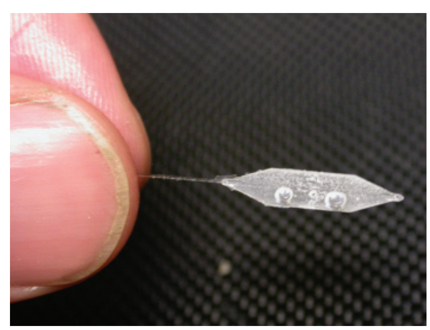

Figure 3. Photograph of Optical Force Probe.

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measurements. These instruments provide new diagnostic capabilities to measure the state of health of complex systems.

FY2005 Accomplishments and Results

The components of the CSSA system have been built and tested and are currently being integrated (Figs. 1 and 2). MEMS process refinement has been completed and will now facilitate the production of large, 2-D arrays of contact-stress sensors interconnected by flexible and extensible wiring that can conform to surfaces of complex curvature. These arrays readily conform to complex curvatures of less than 12 mm radius.

New individual sensing mechanisms offer contact-stress sensing with an accuracy of +/- 6% with a 50-μm-thick silicon device. These devices show a hysteresis of less than 2% of full scale, 0.03 mV/V/psi sensitivity and +/- 0.46%/ºC thermal dependence, with a load range of 0 to 3.5 MPa. Alternate load ranges can be accommodated with silicon geometry scaling.

Modeling shows the multiplexed control and readout system offers array communication with a minimal wire set and less than 1% error. The minimal wire set facilitates array fabrication, performance, and system integration. Based on the models, the electronics and acquisition software have been completed. They have been characterized and proven with a mock array and have been connected to a 64-sensor MEMS array to show full-system integration. New capabilities have been established to package, load-test, and thermally characterize the devices.

For the OFP (Fig. 3), new plasma- and wet-etching processes have been defined to form high-performance silicon devices. These processes provide superior mechanical deformation through surface polishing, allowing the devices to far exceed expectations and criteria. A packaging methodology has been defined and executed that permits fielding of the completed system in a variety of systems. The package protects delicate features of the device and can be tuned to adapt the sensor to a variety of load ranges and system geometries.

The MOA has been characterized with commercial and LLNL-built components. This system has been successfully deployed as part of the OFP. Additionally, the system has been demonstrated in a custom Optical Gap Gauge (Figs. 4 and 5) with programmatic applications. A typical device shows 0.23 μm/mm displacement-measurement sensitivity for a system capable of resolving 0.001 μm to 20 μm range. This device can measure displacements of several millimeters and can be readily scaled to accommodate other displacement ranges.

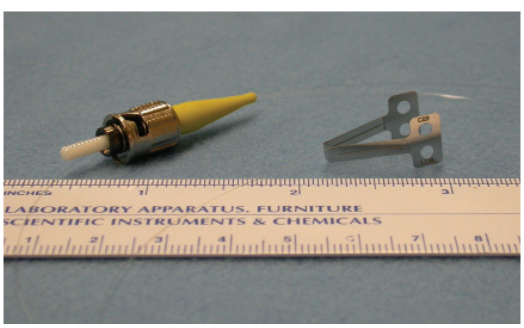

Figure 4. Optical Gap Gauge.

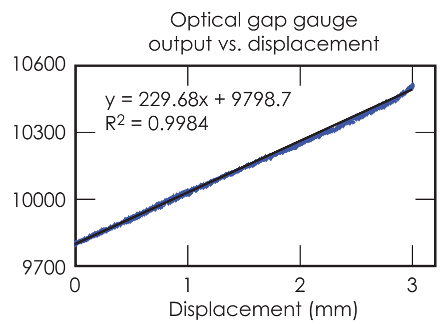

Figure 5. Optical Gap Gauge data.