Technology Focus: Sensors

Amperometric Solid Electrolyte Oxygen Microsensors With Easy Batch Fabrication

These microsensors are applicable to fire detection, environmental monitoring, fuel leak detection, and engine emission monitoring.

John H. Glenn Research Center, Cleveland, Ohio

There is a great need for oxygen microsensors for aerospace and commercial applications. Current bulk or thick-film solid electrolyte oxygen sensors have the disadvantages of being large in size, high in power consumption, difficult to batch-fabricate, and high in cost.

An amperometric solid electrolyte oxygen (O_2) microsensor using a novel and robust structure has been developed with a detection range of 0.025 to 21 percent of O_2 concentration. The microsensor has a simple structure with a sensing area of 1.10×0.99 mm^2, and is operated by applying voltage across the electrodes and measuring the resulting current flow at a temperature of 600 °C.

Semiconductor microfabrication techniques are used in the sensor fabrication. The fabrication of oxygen microsensors includes two steps: deposition of platinum interdigitated finger electrodes, and deposition of yttria stabilized zirconia (YSZ) on the finger electrodes. The platinum interdigitated finger electrodes were deposited as follows: Alumina substrates (250 µm in thickness) were patterned with photoresist and an interdigitated finger electrode photomask. A layer of 50 Å of titanium and a layer of 2,500 Å of platinum were deposited on the substrate by sputter deposition. After photoresist liftoff, the solid electrolyte YSZ was deposited on top of the electrode area by sputtering using a shadow mask. The sensor testing is conducted by applying a voltage to the electrodes and measuring the resulting current.

The novel and important aspect of the development is that, instead of applying an extra structure on top of the sensor surface, which involves very complicated fabrication processes, the YSZ itself is used as both a diffusion barrier and sensing layer. Therefore, a thicker YSZ layer than that used in other structures is deposited. The extra YSZ thickness prevents the sensor from being saturated by high concentrations of oxygen gases. This novel approach enabled a simpler sensor structure, easier batch fabrication process, higher sensor yield, and lower cost.

Another important aspect is that while the extra thickness of the YSZ is meant to be a diffusion barrier, it also contributes to the current output of the sensor. By adjusting the YSZ thickness, different detection ranges can be achieved. At 7,500 Å, the sensor has a viable detection range of 0.025 to 16 percent, with a linear response to the logarithm of oxygen concentrations. By increasing the thickness of solid electrolyte YSZ to 2.6 µm, the O_2 detection range has been expanded to higher concentrations; an overall range of 0.025 to 21 percent is achieved.

The microsensor has a wide detection range and high current output considering its size. It can be integrated into a sensor array with other sensors and electronics, power, and telemetry on a postage-stamp-sized package as part of a smart sensor system.

This work was done by Gary W. Hunter and Jennifer C. Xu of Glenn Research Center and Chung-Chiun Liu of Case Western Reserve University. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18592-1.

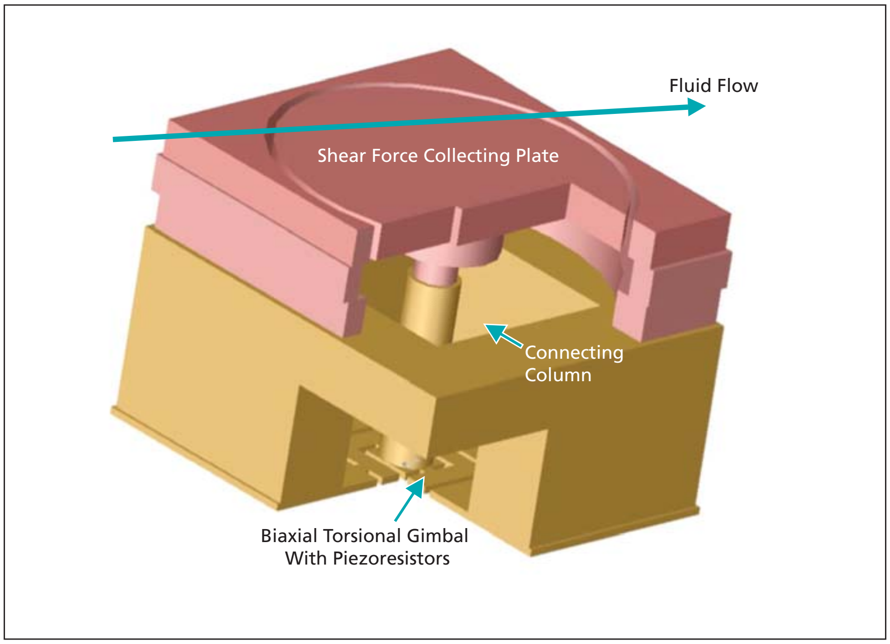
Two-Axis Direct Fluid Shear Stress Sensor for Aerodynamic Applications

This microsensor, fabricated using MEMS technology to enable low-cost production, makes truly nonintrusive biaxial shear stress measurements.

Goddard Space Flight Center, Greenbelt, Maryland

This miniature or micro-sized semiconductor sensor design provides direct, nonintrusive measurement of skin friction or wall shear stress in fluid flow situations in a two-axis configuration. The sensor is fabricated by microelectromechanical system (MEMS) technology, enabling small size and multiple, low-cost reproductions. The sensors may be fabricated by bonding a sensing element wafer to a fluid-coupling element wafer. Using this layered machine structure provides a truly three-dimensional device.

The sensor design (see figure) includes a shear-force collecting plate (fluid-coupling element) with dimensions tailored to application-determined resolutions (spatial, temporal, and force). The plate is located coplanar to both the sensor body and flow boundary. This plate is coupled to a biaxial gimbal structure provided with piezoresistors on its torsional hinges, and, located parallel to but some distance from the force collection plate, with a connecting column. This design thus allows a nonintrusive method to



This **Sensor** is designed for nonintrusive measurement of the shear force on aerodynamic bodies.

qualitatively measure the shear force vector on aerodynamic bodies.

The sensors themselves are typically made in single crystal silicon with the piezoresistor elements formed by doping the silicon (by ion implantation or other means) to a suitable type and level of conductivity that provides the desired sensitivity depending on the crystal orientation. Metallic electrical leads on the back face of the device are provided to route excitation currents and output signal voltages from these sensors to the external world.

Subjecting the plate of the device to a shear force, by mounting it on an aerodynamic surface exposed to flow, will result in a moment acting on the hinges of the biaxial gimbal structure that is proportional to the shear stress on the plate, the arm, and torsional hinge dimensions. This moment creates a mechanical torsional shear stress within the hinges and, thereby, an output signal proportional to the shear stress on the plate from the piezoresistive sensor. The shear stress at the fluid-sensor interfaces is thus initially converted to a mechanical shear stress in the hinge that is sensed with a piezoresistive sensor. The two orthogonally located hinges and sensors enable measuring the shear stress existing on the plate in both directions. This configuration of the sensor device enables a large moment and stress level to be generated at the hinge from relatively small shear stress acting on a small plate, thereby enabling high spatial and stress resolution capability.

This work was done by Sateesh S. Bajikar of Goddard Space Flight Center and Michael A. Scott and Edward E. Adcock of Langley Research Center. Further information is contained in a TSP (see page 1).
GSC-15431-1

Target Assembly to Check Boresight Alignment of Active Sensors

This assembly can simultaneously measure the co-boresite alignment of multiple transmitter laser beams and receiver channels.

Goddard Space Flight Center, Greenbelt, Maryland

A compact and portable target assembly (Fig. 1) has been developed to measure the boresite alignment of LRO's Lunar Orbiter Laser Altimeter (LOLA) instrument at the spacecraft level. The concept for this target assembly has evolved over many years with earlier versions used to test the Mars Observer Laser Altimeter (MOLA), the Geoscience Laser Altimeter System (GLAS), and the Mercury Laser Altimeter (MLA) space-based instruments. These earlier laser altimeters were single ranging channel instruments, but as demonstrated with the five-channel LOLA instrument, the target assembly can simultaneously measure the co-boresite alignment of multiple transmitter laser beams and receiver channels (Fig. 2).

The target assembly flips the transmitter laser beam into the optical receiver aperture and measures their co-alignment error by scanning the laser far-field image across the receiver field-of-view (FOV) in two orthogonal axes. Plotting the receiver response as a function of the transmitter beam deviation angle yields the effective laser altimeter transceiver alignment. The target assembly components include a Laser Beam Dump (LBD) to attenuate the input laser energy by an order of magnitude, a lateral transfer retro-re-

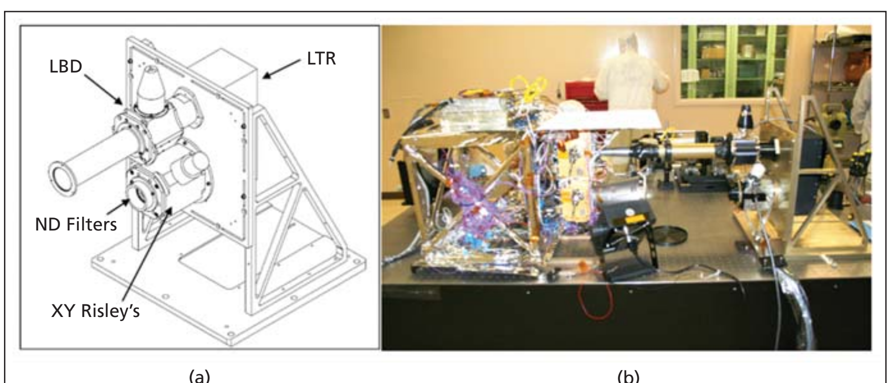


Fig. 1. **Target Assembly**: (a) LOLA target assembly components, (b) LOLA instrument test with target assembly.