

abrasive scratch tests, it was found that the ASTM International Standard G 171 specified a generic metric based only on visually determined scratch width as a way to compare abraded materials. A limitation to this method was identified in that the scratch width is based on optical surface measurements, manually defined by approximating the boundaries, but does not consider the three-dimensional volume of material that was displaced. With large, potentially irregular deformations occurring on softer materials, it becomes unclear where to systematically determine the scratch width. Specifically, surface scratches on different samples may look the same from a top view, resulting in an identical scratch width measurement, but may vary in actual penetration depth and/or plowing deformation. Therefore, two different scratch profiles would be

measured as having identical abrasion properties, although they differ significantly.

With these refined measurements, a wider variety of testing needs can be addressed with greater resolution while using the most appropriate abrasive tip and test material combination for the intended application. The core of this innovation in two-body abrasion research involved scratch testing with ASTM G 171 used as a guideline for determining the number of tests to be conducted. The resultant profiles of each scratch were digitized using an optical interferometer and accompanying software. To accomplish this objective, software code was developed to produce a suite of metrics based on a zero line (ZL) through the scratch, which allowed quantitative definition of the scratch and associated wear metrics.

The computer code determines a ZL through individual cross-sections, then produces the following metrics: Negative Volume Displaced, Positive Volume Displaced, Net Volume Displaced, and Absolute Volume Displaced, along with a secondary set of metrics composed of six roughness parameters that allow definition of the ZL. From these metrics, a Zone of Interaction (ZOI) can be established.

This work was done by K. W. Street, Jr. of Glenn Research Center and R. L. Kobrick and D. M. Klaus of the University of Colorado – Boulder. 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-18675-1.

Detection of Carbon Monoxide Using Polymer-Carbon Composite Films

NASA's Jet Propulsion Laboratory, Pasadena, California

A carbon monoxide (CO) sensor was developed that can be incorporated into an existing sensing array architecture. The CO sensor is a low-power chemiresistor that operates at room temperature, and the sensor fabrication techniques are compatible with ceramic substrates.

Sensors made from four different polymers were tested: poly (4-vinylpyri-

dine), ethylene-propylene-diene-terpolymer, polyepichlorohydrin, and polyethylene oxide (PEO). The carbon black used for the composite films was Black Pearls 2000, a furnace black made by the Cabot Corporation. Polymers and carbon black were used as received. In fact, only two of these sensors showed a good response to CO. The poly (4-vinylpyridine) sensor is noisy, but it

does respond to the CO above 200 ppm. The polyepichlorohydrin sensor is less noisy and shows good response down to 100 ppm.

This work was done by Margie L. Homer, Margaret A. Ryan, and Liana M. Lara of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47612

Substituted Quaternary Ammonium Salts Improve Low-Temperature Performance of Double-Layer Capacitors

Low cell resistances are observed when used with modified acetonitrile electrolyte blends.

NASA's Jet Propulsion Laboratory, Pasadena, California

Double-layer capacitors are unique energy storage devices, capable of supporting large current pulses as well as a very high number of charging and discharging cycles. The performance of double-layer capacitors is highly dependent on the nature of the electrolyte system used. Many applications, including for electric and fuel cell vehicles, back-up diesel generators, wind generator pitch control back-up power systems, environmental and structural distributed sensors, and

spacecraft avionics, can potentially benefit from the use of double-layer capacitors with lower equivalent series resistances (ESRs) over wider temperature limits. Higher ESRs result in decreased power output, which is a particular problem at lower temperatures. Commercially available cells are typically rated for operation down to only -40°C .

Previous briefs [for example, "Low Temperature Supercapacitors" (NPO-44386), *NASA Tech Briefs*, Vol. 32, No. 7

(July 2008), p. 32, and "Supercapacitor Electrolyte Solvents With Liquid Range Below -80°C " (NPO-44855), *NASA Tech Briefs*, Vol. 34, No. 1 (January 2010), p. 44] discussed the use of electrolytes that employed low-melting-point co-solvents to depress the freezing point of traditional acetonitrile-based electrolytes. Using these modified electrolyte formulations can extend the low-temperature operational limit of double-layer capacitors beyond that of commercially avail-