National Aeronautics and Space Administration

Technology Opportunity

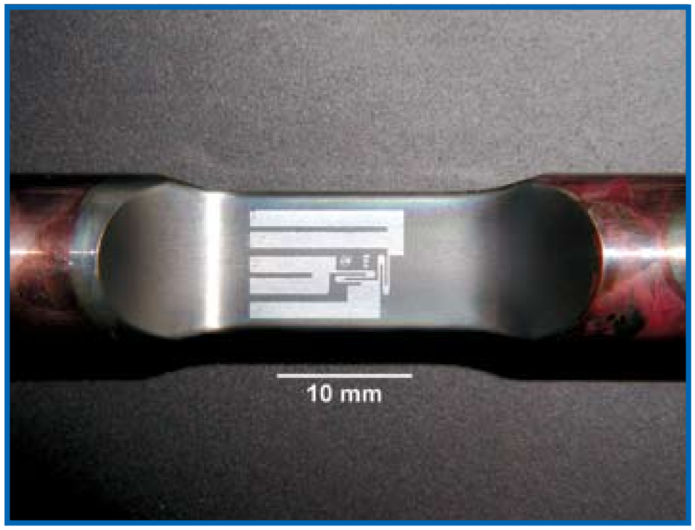
Technology Transfer & Partnership Office

TOP3–00059

High-Temperature Thin-Film Strain Gauges

Technology

The NASA Glenn Research Center has developed high-temperature thin-film strain gauges, which are miniature and deposited directly on the test articles. These sputter-deposited thin-film resistance strain gauges can provide minimally intrusive surface strain measurements in the temperature range from ambient up to 1100 °C.



PdCr thin-film strain gauge on a turbine engine alloy test specimen.

Benefits

- Minimally intrusive. A complete sensor unit is only 20 µm thick compared to 200 µm of the conventional foil or wire strain gauge system.
- Very high temperature operation. Sensors extend the maximum use temperature from the current capability of 600 °C up to 1100 °C.
- Sensors can be designed for either dynamic or static strain measurements, can have various patterns and gauge resistance, and can be fabricated directly on the test parts.
- Highly stable and repeatable. The repeatability (between thermal cycles) of the sensors is within 200 microstrain (µε) (25 to 1100 °C) compared to 1000 µε (25 to 600 °C) of the conventional gauges.
- Low cost. Sensors can be mass produced using microelectromechanical-systems- (MEMS)-based device fabrication technology.

Potential Applications

These sensors will be extremely useful in the design and development of high-speed civil transport vehicles and advanced gas turbine engines. They can be used for studying

- Crack development/propagation
- Residual stress, stress and strain distribution
- Thermal expansion coefficient of materials at very high temperatures

Any mechanical/structural design of new and advanced materials for applications in extremely high-temperature environments would benefit from the invention of these sensors.

Technology Description

An electrical resistance strain gauge is a strain-sensing element whose electrical resistance changes in response to an applied strain. Knowing the strain sensitivity of the gauge, one can determine the applied strain from the change in gauge resistance. This type of strain gauge (normally foil or wire gauge bonded onto the surface of a test article with glue, ceramic cement, or flame-sprayed ceramic) is widely used at low temperatures because of its simplicity, high sensitivity, reliability, and low cost.

As the operating temperature increases; however, the problems associated with this type of gauge also increase. At higher temperatures, the gauge materials currently in use experience either oxidation or structural changes. As a result, the characteristics of the gauge do not remain within acceptable limits over long periods of time, nor do they vary in a predictable manner. In addition, the bonding agents limit both the degree of strain transmitted from the test structure to the gauge and the maximum working temperature of the gauge. The bulky bonded gauge is also intrusive and thus disrupts the aerodynamic gas flow on the surface of the test structure.

In order to meet the urgent needs in aeronautic and aerospace research where stress and temperature gradients are high, aerodynamic effects need to be minimized, and higher operational temperatures are required, a thin-film strain gauge has been developed at the NASA Glenn Research Center. This gauge, a vacuum-deposited thin-film formed directly on the surface of a test structure, operates at much higher temperatures than do commercially available gauges.

The gauge uses an alloy, palladium 13 wt% chromium (hereafter, PdCr), which was developed by United Technologies Research Center under a NASA contract. This alloy is structurally stable and oxidation resistant up to 1100 °C; its temperature-induced resistance change is linear, repeatable, and not sensitive to the rates of heating and cooling. By developing gauge fabrication techniques utilizing sputter deposition, photolithography patterning, and chemical etching, we have made a PdCr thin-film strain gauge that can now measure dynamic and static strain to 1100 °C. For static strain measurements, a platinum element serves as a temperature compensator to further minimize the temperature effect of the gauge.

These thin-film gauges provide the advantage of minimally intrusive surface strain measurements and give highly repeatable readings with low drift at temperatures from ambient to 1100 °C. This is a 300 °C advance in operating temperature over the PdCr wire gauge and a 500 °C advance over the commercially available gauges made of other materials. This technology won an R&D 100 Award in 1995.

Options for Commercialization

NASA Glenn Research Center seeks partnership with industry for testing in aerospace and nonaerospace applications.

PdCr thin-film strain gauge on a ceramic turbine blade.

Contact

Technology Transfer & Partnership Office
NASA John H. Glenn Research Center at Lewis Field
Mail Stop 4–2
Cleveland, OH 44135
Phone: 216–433–3484
Fax: 216–433–5012
E-mail: ttp@grc.nasa.gov
http://technology.grc.nasa.gov

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LEW–15079–1, LEW–15518–1, LEW–15379–1, LEW–15197–1, IC–030–1, C–95–2799

Key Words

Thin-film technology
Strain gauges
High-temperature operation
Palladium-chromium alloy

M–1625–9
Dec 07