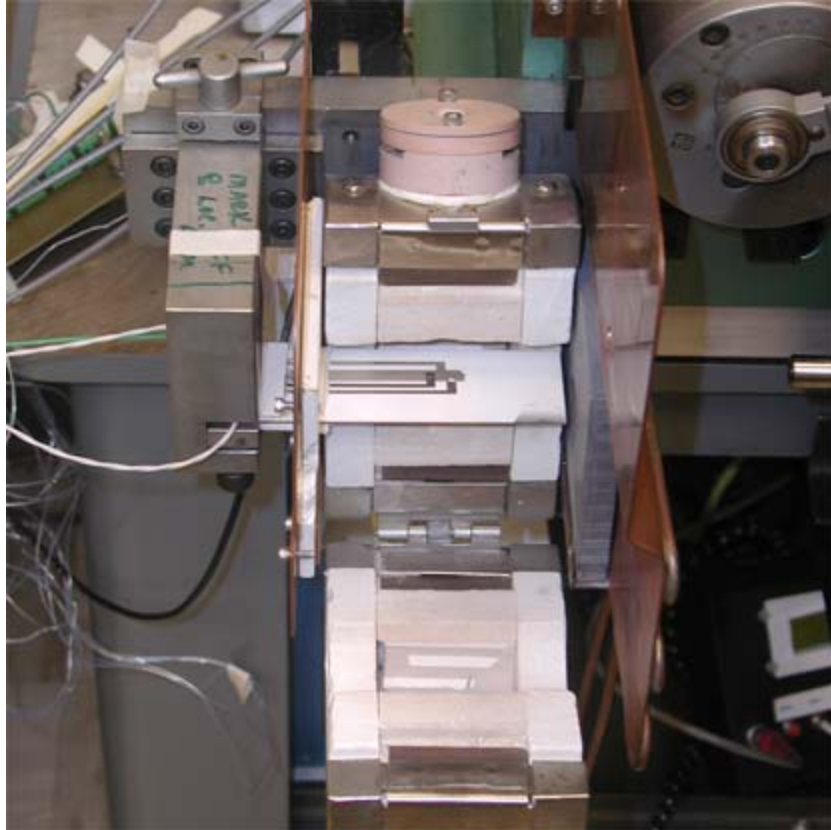


High-Temperature, Thin-Film Ceramic Thermocouples Developed

To enable long-duration, more distant human and robotic missions for the Vision for Space Exploration, as well as safer, lighter, quieter, and more fuel efficient vehicles for aeronautics and space transportation, NASA is developing instrumentation and material technologies. The high-temperature capabilities of thin-film ceramic thermocouples are being explored at the NASA Glenn Research Center by the Sensors and Electronics Branch and the Ceramics Branch in partnership with Case Western Reserve University (CWRU). Glenn's Sensors and Electronics Branch is developing thin-film sensors for surface measurement of strain, temperature, heat flux, and surface flow in propulsion system research. Glenn's Ceramics Branch, in conjunction with CWRU, is developing structural and functional ceramic technology for aeropropulsion and space propulsion.

Ceramic-based thermocouples are known for their high stability and robustness at high temperatures in environments where metals could not survive, but typically, they are found in the form of rods or probes. Ceramics also have a substantial cost advantage. At present, sensors intended for use at high temperatures are made of platinum and other noble metals. The current price of platinum exceeds \$900 per troy ounce, more than 50,000 times the cost of the basic material cost of ceramics.

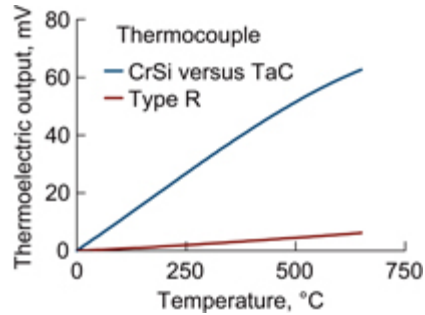
Glenn and CWRU have joined forces to investigate the feasibility of using ceramics as thin-film thermocouples for extremely high temperature applications, thus taking advantage of both the stability and robustness of ceramics and the nonintrusiveness of thin films.



Test fixture in Glenn's Thin Film Sensors Laboratory with the CrSi-TaC test sample in place.

Long description of figure 1. The fixture is a clam-shell furnace that is open to reveal the test sample in place. The test sample is a strip of alumina with the thin films placed along side each other on the top, meeting in the center of the furnace.

Thermocouple samples for testing are fabricated from high-purity sputtering targets in Glenn's Microsystems Fabrication Laboratory. Thermoelectric data on thin-film chromium silicide (CrSi) and tantalum carbide (TaC) were measured for temperatures up to 650 °C for CrSi and to 450 °C for TaC. The thermoelectric voltage output of a thin-film CrSi versus TaC thermocouple was found to be at least 10 times that of the standard type R (platinum-rhodium vs. platinum) thermocouple, producing 59 mV with a 600 °C temperature gradient. The preceding photograph shows the CrSi-TaC thermocouple in a test fixture at Glenn, and the resulting output signal is compared with a type R thermocouple output in the following graph. The temperature differential across the sample, from the center of the sample inside the oven to the sample mount outside the oven, is measured using a type R thermocouple on the sample.



Relative thermoelectric voltage output of the CrSi-TaC thermocouple compared with the standard type R thermocouple on the test sample.

Long description of figure 2. This graph of thermoelectric output in millivolts versus temperature in degrees centigrade shows a nearly linear ceramic thermocouple output reaching 63 millivolts over 650 °C. Type R output on the same graph outputs only 6.2 millivolts over the same range.

Because of the low oxidation temperatures of these thin-film thermocouple elements, additional research needs to be conducted into protective overcoats for the films if they are to be practical in oxidizing environments. Also, thin-film ceramic thermocouples must be tested in an inert atmosphere or vacuum to gain an understanding of their performance and applicability in space-relevant environments.

This merging of the high-temperature capabilities of ceramics with the nonintrusiveness of thin films is ongoing. It appears that a new class of ceramic thin films can be used as high-temperature thermocouples, and this technology is believed to have applications as resistive temperature and strain sensors as well. This research advances the effort to develop a complete sensor package using ceramics as thin-film sensors in environments where standard metal sensors would not survive.

Bibliography

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Find out more about this research at <http://www.grc.nasa.gov/WWW/sensors/>

Glenn contacts: John D. Wrbanek, 216-433-2077, John.D.Wrbanek@nasa.gov; Gus C. Fralick, 216-433-3645, Gustave.C.Fralick@nasa.gov; and Dr. Serene C. Farmer, 216-433-3289, Serene.C.Farmer@nasa.gov

Case Western Reserve University contact: Dr. Ali Sayir, 216-433-6254, Ali.Sayir@grc.nasa.gov

Authors: John D. Wrbanek, Gustave C. Fralick, Dr. Serene C. Farmer, Dr. Ali Sayir, Charles A. Blaha, and José M. Gonzalez

Headquarters program office: Aeronautics Research

Programs/Projects: PR&T

