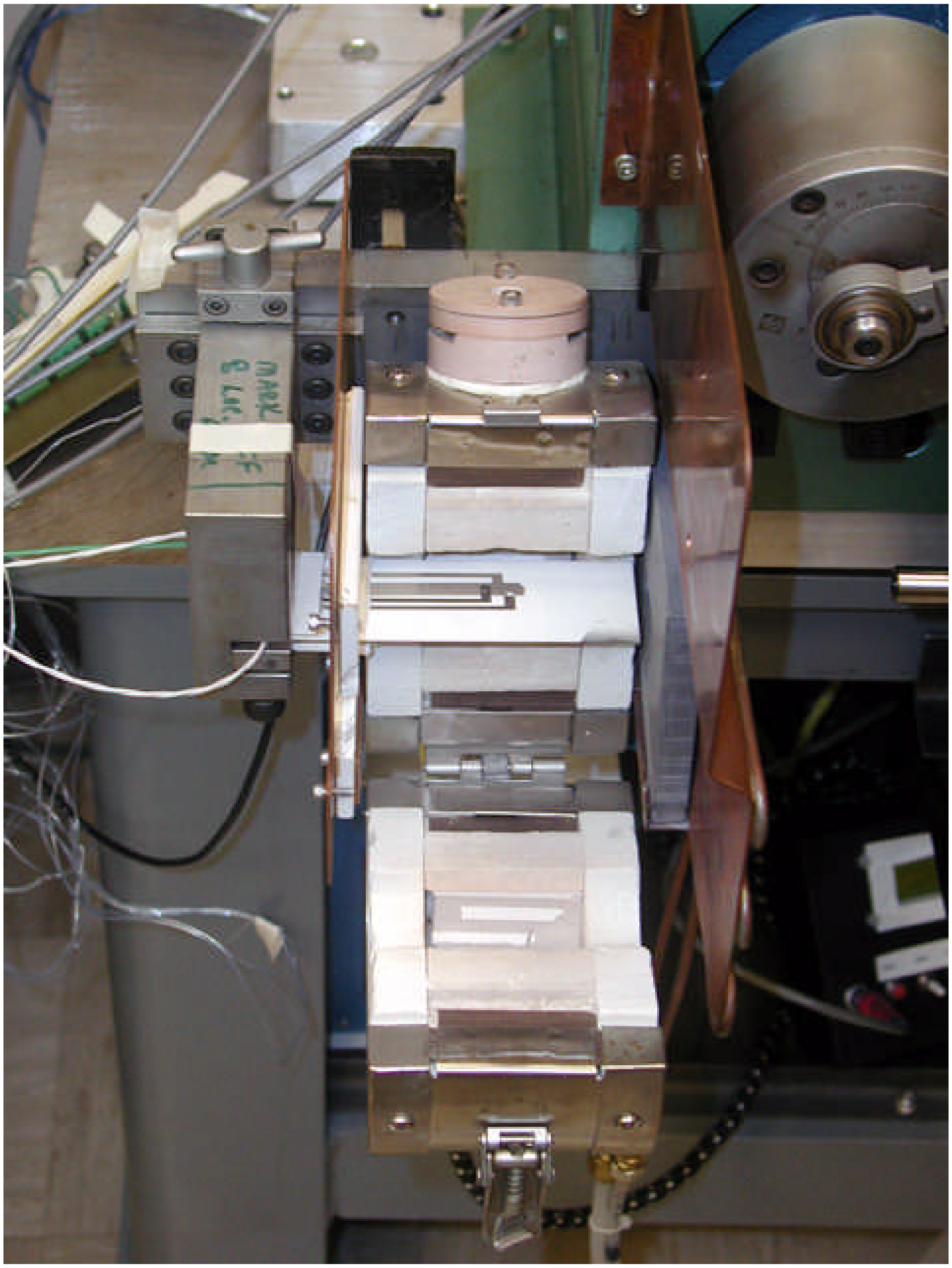
Thin-Film Ceramic Thermocouples Fabricated and Tested

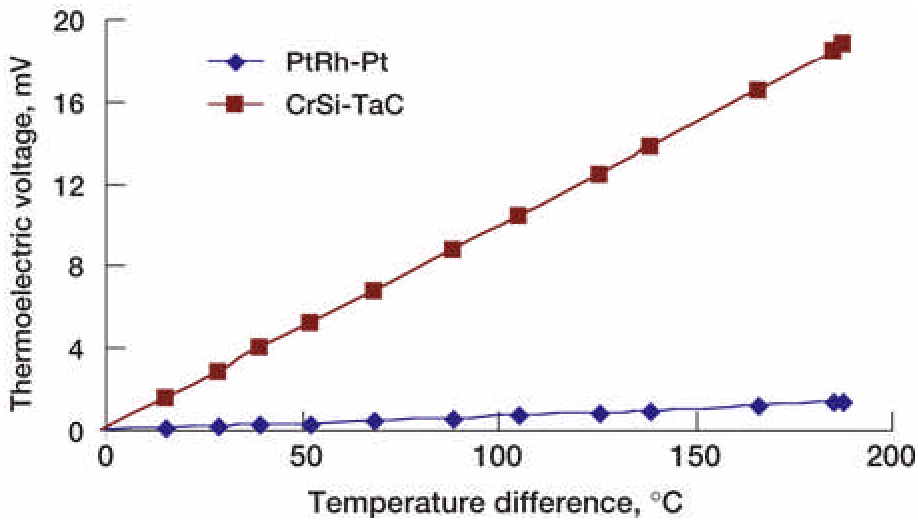
The Sensors and Electronics Technology Branch of the NASA Glenn Research Center is developing thin-film-based sensors for surface measurement in propulsion system research. Thin-film sensors do not require special machining of the components on which they are mounted, and they are considerably thinner than wire- or foil-based sensors. One type of sensor being advanced is the thin-film thermocouple, specifically for applications in high-temperature combustion environments. Ceramics are being demonstrated as having the potential to meet the demands of thin-film thermocouples in advanced aerospace environments.

The maximum-use temperature of noble metal thin-film thermocouples, 1500 °C (2700 °F), may not be adequate for components used in the increasingly harsh conditions of advanced aircraft and next-generation launch vehicles. Ceramic-based thermocouples are known for their high stability and robustness at temperatures exceeding 1500 °C, but are typically in the form of bulky rods or probes. As part of ASTP, Glenn's Sensors and Electronics Technology Branch is leading an in-house effort to apply ceramics as thin-film thermocouples for extremely high-temperature applications as part of ASTP.

Since the purity of the ceramics is crucial for the stability of the thermocouples, Glenn's Ceramics Branch and Case Western Reserve University are developing high-purity ceramic sputtering targets for fabricating high-temperature sensors. Glenn's Microsystems Fabrication Laboratory, supported by the Akima Corporation, is using these targets to fabricate thermocouple samples for testing. The first of the materials used were chromium silicide (CrSi) and tantalum carbide (TaC). These refractory materials are expected to survive temperatures in excess of 1500 °C. Preliminary results indicate that the thermoelectric voltage output of a thin-film CrSi versus TaC thermocouple is 15 times that of the standard type R (platinum-rhodium versus platinum) thermocouple, producing 20 mV with a 200 °C temperature gradient. The photograph on the left shows the CrSi-TaC thermocouple in a test fixture at Glenn, and the resulting output signal is shown on the right. 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.

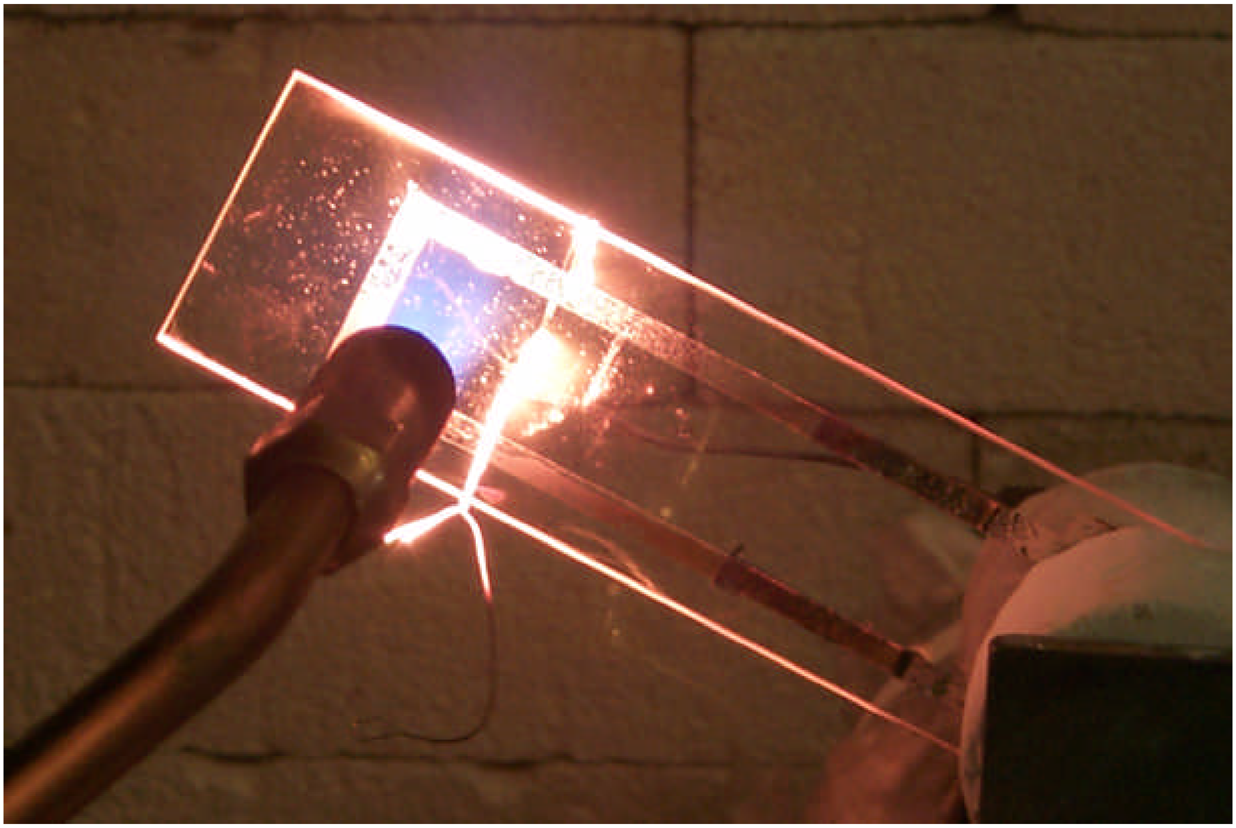


Test fixture in Glenn's Thin Film Sensors Laboratory with the CrSi-TaC test sample in place.



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

Glenn's Sensors and Electronics Technology Branch has enlisted the Thin Films and Interfacial Research Center of the University of Rhode Island in ceramic-based thermocouple research. The initial results of their thermocouple research have been promising. At the University of Rhode Island, two thin-film indium-tin-oxide- (ITO-) based thermocouples have been fabricated and tested to 1500 °C, and the thermoelectric voltage outputs are consistently similar to that of type R thermocouples. The following photograph shows the ITO thermocouple being tested.



ITO ceramic thermocouple deposited onto a quartz substrate and tested in an open flame at the University of Rhode Island.

This merging of the high-temperature capabilities of ceramics with the non-intrusiveness of thin films is ongoing. NASA has shown that a new class of ceramic thin films can be used as high-temperature thermocouples and intends to apply this technology to strain gauges as well. This research advances the effort that Glenn is leading to develop a complete sensor package to enable the use of ceramics as thin-film sensors in environments where standard metal sensors would not survive.

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