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PROGRESS ON THIN-FILM SENSORS FOR SPACE PROPULSION TECHNOLOGY

Walter S. Kim
NASA Lewis Research Center
Cleveland, Ohio

The objective of this work is to develop thin-film thermocouples for SSME components. Thin-film thermocouples have been developed for aircraft gas turbine engines and are in use for temperature measurement on turbine blades to 1800 °F. The technology established for aircraft gas turbine engines will be adapted to the materials and environment encountered in the SSME. Specific goals are to expand the existing in-house thin-film sensor technology and to test the survivability and durability of thin-film sensors in the SSME environment.

STATUS OF WORK

An initial goal of thin-film sensor work was to augment the in-house capability in thin-film sensor technology. A thin-film sensor laboratory was established in a refurbished clean room which has been equipped with a new sputtering system for sputter deposition of both insulator and sensor films (fig. 1). Other equipment installed in the clean room includes a photolithography exposure system for masking sensor patterns, parallel gap welder, and ultrasonic wedge bonder for attaching leadwires to sputtered thin films. A scanning electron microscope was acquired for surface characterization of sputtered films and substrates. Also, a vacuum furnace was acquired to grow oxide coatings in controlled environments.

One major accomplishment was the fabrication and testing of a thin-film thermocouple on SSME HPFTP blade material. The thin-film thermocouple was fabricated on a sample of the HPFTP blade material (MAR M-246 + Hf) following the fabrication process used for aircraft engine turbine blade materials. The test specimen was coated with an MCrAlY anticorrosion coating and oxidized to grow an adherent, electrically insulating surface film of aluminum oxide. This film was augmented with additionally sputtered aluminum oxide upon which a type S thin-film thermocouple was sputter deposited (fig. 2). Junctions between the thin films and the leadwires were formed by parallel gap welding.

This thin-film thermocouple was tested for survivability in severe thermal shock conditions of 2000 °F and liquid nitrogen. This survivability test consisted of soaking the test piece at 2000 °F for 1 hour and then immediately immersing it in a pool of liquid nitrogen. The thin-film thermocouple survived five of these temperature excursions. After these immersion tests, the sensor output signals were recorded while thermal shock cycling the sensor between 2000 °F and liquid nitrogen (fig. 3). Sensor outputs were measured while consecutively soaking and immersing the sensor between those temperature extremes (fig. 4). The thin-film sensor has survived at least six of these thermal shock cycles.

Another major accomplishment was the fabrication of a thin-film thermocouple on a future candidate SSME material (fig. 5). The thin-film thermocouple was deposited on a flat specimen of a single-crystal nickel base superalloy such as PWA 1480. The preliminary tests indicated that this sensor is just as good as the sensor prepared on MAR M-26 (+Hf) specimen. Tests are underway to determine the survivability and durability of this sensor in the same thermal shock cycling conditions. However, the severity of the thermal shocks imposed on these sensors are not as severe as expected in SSME and thus the next step is to test these sensors in the SSME environment simulated in the Turbine Blade Tester at MSFC.

The original plan for testing thin-film sensors in an SSME environment has been modified. The plan to contract for test hardware to test aircraft engine thin-film thermocouples was changed so that in-house fabricated thermocouples on SSME blades will be tested. The current plan is to install thin-film thermocouples on flight-hardware blades and other blades made from candidate material such as single-crystal nickel-base superalloy. We obtained from MSFC a blade holder assembly that was previously used for a thermal barrier coating experiment. Thin-film sensors will be installed on this assembly and will be tested in the Turbine Blade Tester at MSFC.

SUMMARY

Significant progress was made in thin film sensor work by completing the establishment of a thin film sensor laboratory. One accomplishment was the development of a thin-film thermocouple on SSME HPFTP blade material. This sensor was thermal shock cycled for 12 cycles of consecutively soaking the test specimen between 2000 °F and liquid nitrogen. Another accomplishment was the development of a thin-film thermocouple on a candidate SSME material. This thin-film thermocouple has been deposited on single crystal material of nickel-base superalloy, and tests are underway to determine the survivability and durability under thermal shock cycle conditions. Lastly, the original plan to contract to test thin-film thermocouples on turbine blade material in an SSME environment has been changed. The current plan is to install thin-film thermocouples on flight-hardware blades and single-crystal blades mounted on the blade holder assembly obtained from MSFC for testing in their Turbine Blade Tester.

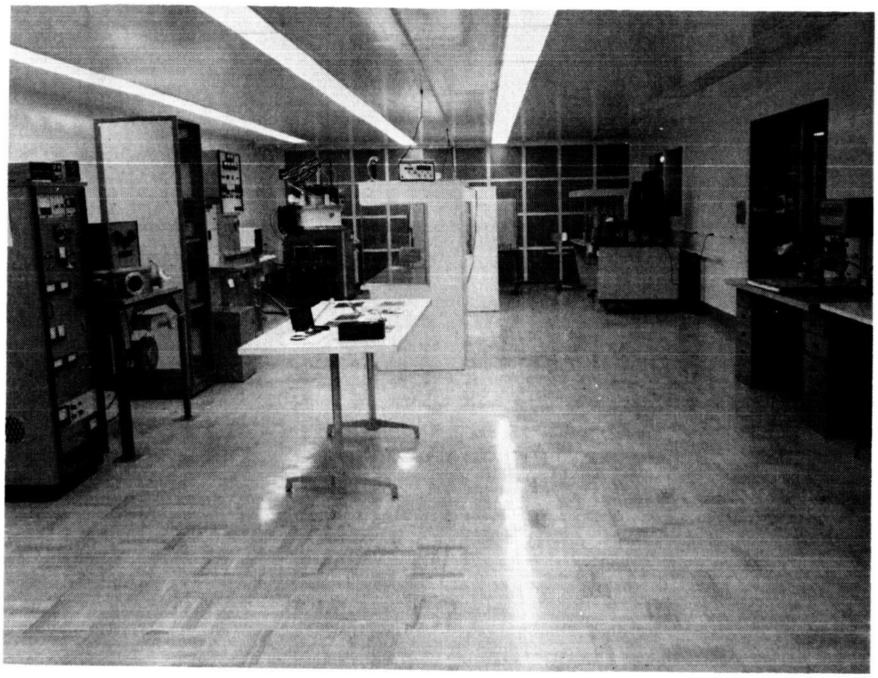

Figure 1. - Thin-film sensor laboratory.

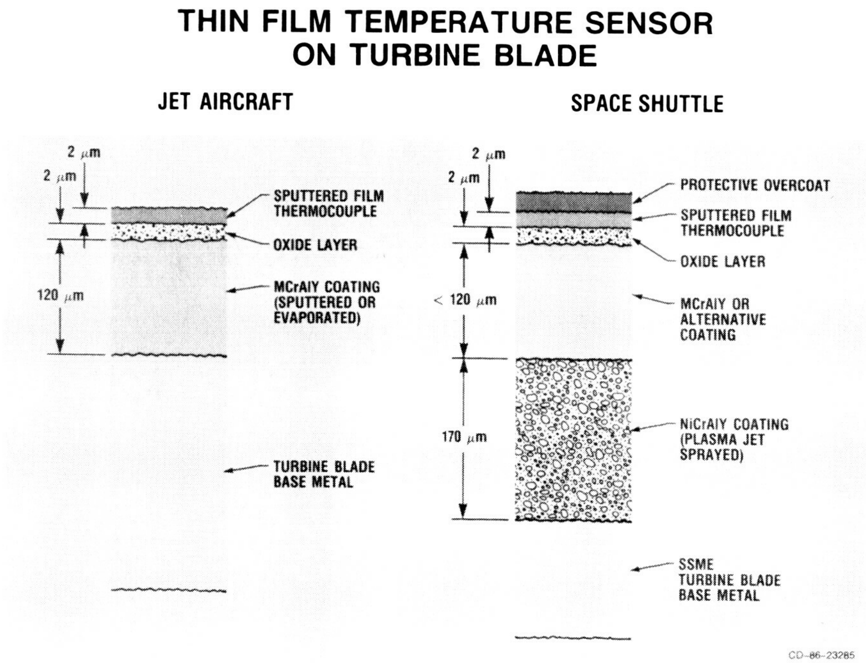

Figure 2. - Basic thin-film thermocouple technology.

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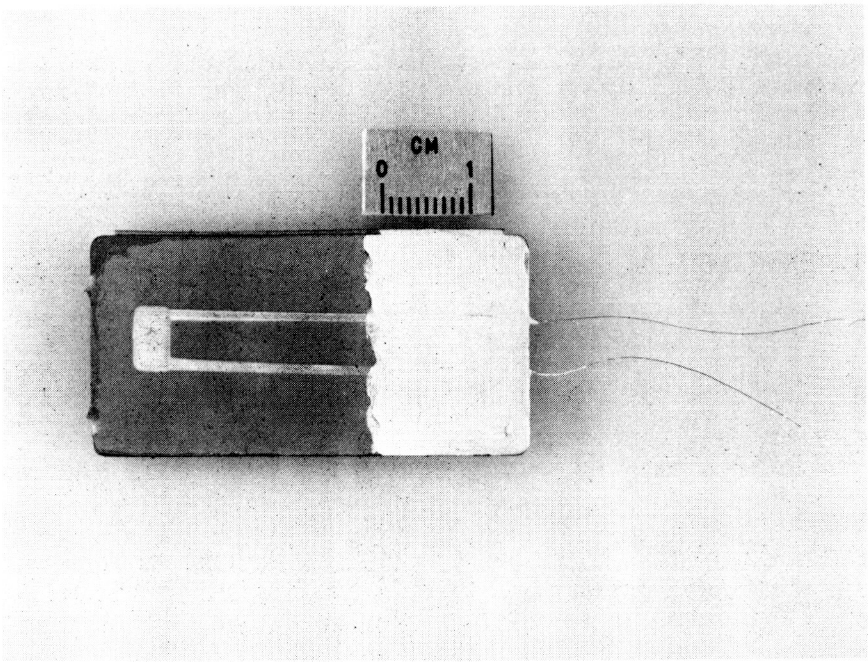

Figure 3. - Thermal-shock-cycled thin-film thermo-couple deposited on flat plate of MAR M-246 + Hf.

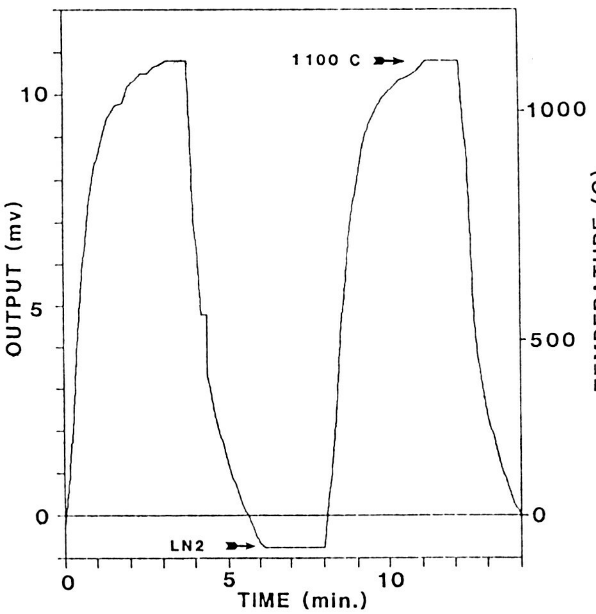

Figure 4. - Signal output of thin-film thermocouple during thermal shock cycling between 2000 °F and liquid nitrogen.

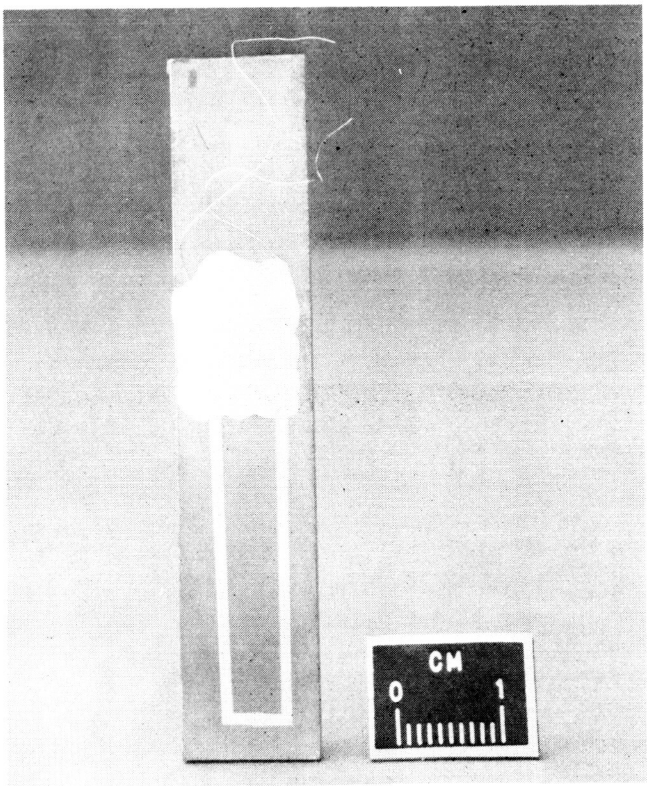

Figure 5. - Thin-film thermocouple on flat bar of single-crystal nickel-base superalloy.