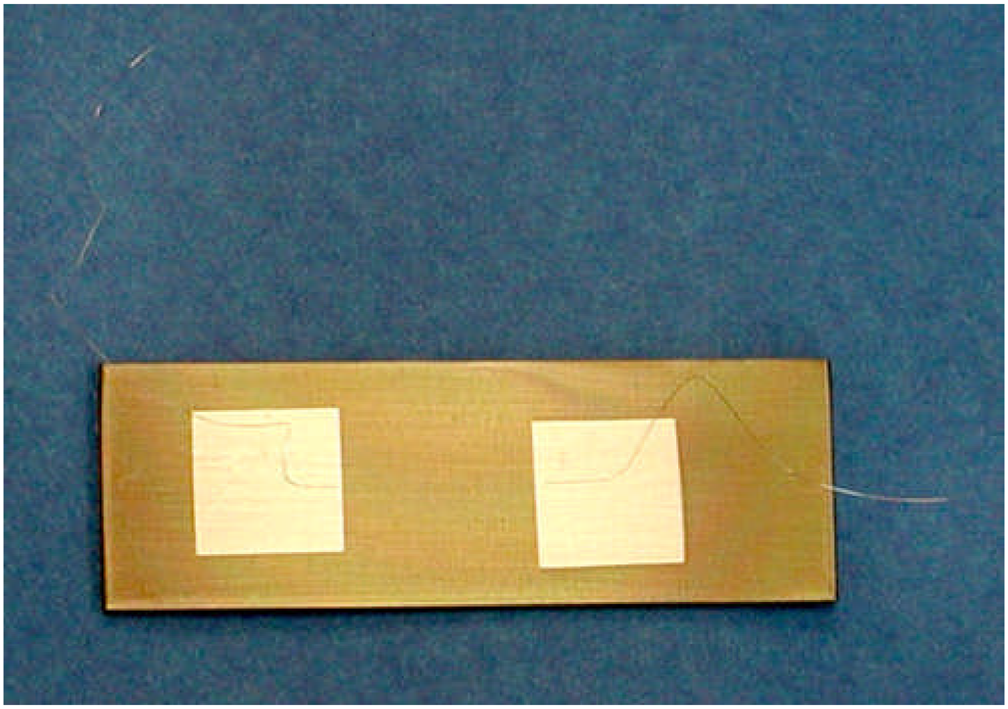
Collaboration of the NASA Glenn Research Center and Rolls-Royce Developed Thin Film Multilayered Dielectrics for Harsh Environments

The use of thin films to electrically insulate thin film sensors on engine components minimizes the intrusiveness of the sensors and allows a more accurate measurement of the environment. A variety of insulating films were investigated for preventing electrical shorting caused by insulator failure between the sensor and the component. By alternating layers of sputtered high-temperature ceramics, a sequence of insulating layers was devised that (1) prevents pinholes from forming completely through the insulator and (2) maintains high electrical resistivity at high temperatures. The total thickness is only a fraction of that needed for conventional insulating techniques.

The Sensors and Electronics Technology Branch of the NASA Glenn Research Center has an in-house effort to develop thin film 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 (less than 10 μm thick) than wire or foil sensors. The thin film sensors are thus much less disturbing to the operating environment and have a minimal impact on the physical characteristics of the supporting component.

To further this research, NASA Glenn and Rolls-Royce (Derby, UK), with assistance from the Ohio Aerospace Institute (OAI) and the Akima Corporation, pursued a joint investigation using multilayered thin film dielectrics as a reliable insulator in harsh environments. The use of a multilayered scheme is thought to be promising for the fabrication of electrically insulating thin films. A major cause of conduction in thin film dielectrics is the presence of defects, such as pinholes, that propagate through the film to the underlying substrate surface. By alternating the insulating material, each new growth pattern would deviate from the previous one, eliminating direct pathways for conduction to the substrate.

The film depositions and testing were conducted in the Instrument Research Laboratory at Glenn. The multilayered insulator test samples were made from alumina and stainless steel shims that were first covered with a sputtered underlayer of either yttria-stabilized zirconia or chromium carbide, and then overcoated with a sputtered top layer of alumina. An example of a test sample is shown in the following photograph. Each multilayered insulator sample was 5 μm thick, at least an order of magnitude thinner than conventional insulators. The insulating properties of the samples were tested in a high-temperature air oven to determine their suitability.


Zirconia-alumina multilayer on a metal substrate.

The multilayer insulators tested showed a stabilized film at temperatures in excess of 800 °C (1472 °F). The underlying materials in these multilayers allow thermal expansion stresses produced during the heating to be graded. The chromium carbide-alumina multilayer had the best adhesion at high temperatures, presumably from the induced chemical bonding between the substrate and the chromium carbide underlayer. However, the zirconia-alumina multilayer proved to have slightly better insulating properties when adhering.

The application of the zirconia-alumina insulator has been demonstrated on a nickel-alloy fan blade, as shown in the next photograph. The insulators using thin film sensors still need to be tested in a relevant high-temperature combustion environment.

Zirconia-alumina multilayer insulating a resistance temperature detector on a nickel-alloy fan blade.

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