PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Advanced Research

09/2004

Elevated Temperature Sensors for On-line Critical Equipment Health Monitoring

Description

New sensors capable of operating at elevated temperatures in harsh environments are required for more efficient operation of current and future power-generation equipment; monitoring of critical components of this equipment will be required to reduce maintenance and inspection time. Examples include monitoring the thickness of gasifier refractory materials and metal water-walls, and detecting loss of adhesion of thermal barrier coatings in turbines. Future extensions of such sensors might include on-line crack detection in critical components, measurement of slag thickness in gasifiers and combustion chambers, and sensing of dynamic pressure events in equipment. The University of Dayton is developing an ultrasonic transducer which will be useful for such applications at temperatures exceeding 1000 °C with little or no cooling required.

The core of such sensors is aluminum nitride (AlN) ceramic, a naturally piezoelectric material which maintains its piezoelectric properties at very high temperatures. The AlN is grown as an oriented polycrystalline film by a chemical vapor deposition process. Thinner films produce higher frequency ultrasonic energy due to their higher resonant frequencies. Films produced to date have been in the 10 MHz to 100 MHz range, with emphasis on the lower frequencies. The goals of this project include improving the process used to create of AlN films for sensors, demonstrating film survival and functionality above 1000 °C, determining a reliable method of ultrasonically coupling the sensors to test objects at very high temperatures, and performing a capstone test which will simulate an industrial application for the sensors.

Overall photo of AlN film (full coverage) on tungsten carbide, produced by chemical vapor deposition.

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$199,929

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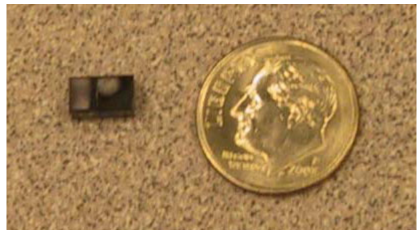
WEBSITES

www.netl.doe.gov/coal

Accomplishments

The initial work on the program has focused on film deposition. The AlN deposition process was successfully transferred from film production on tungsten carbide substrates to titanium alloy and silicon carbide substrates. Further evaluation of films on titanium caused it to be discarded as a candidate material due to an excessive thermal expansion coefficient mismatch, causing film failure as samples were reheated. Adhesion on silicon carbide looks promising, but a more electrically conductive grade of silicon carbide will be required for practical use. Additional substrate materials, including refractory metals and conductive ceramics, have been considered but are not promising in light of the experience with titanium.

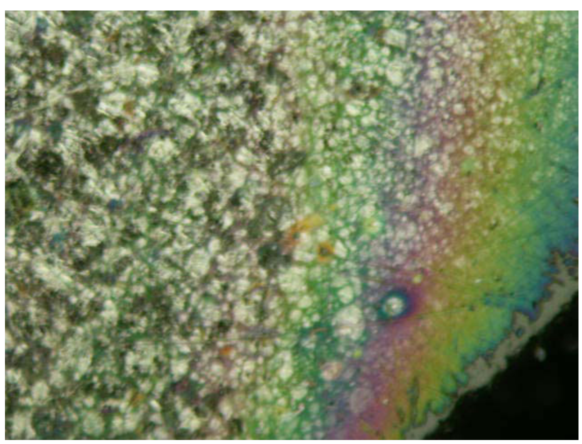
Overall photo of AlN film (full coverage) on SiC, produced by chemical vapor deposition.



Overall photo of AlN film (rounded light colored area) on SiC produced by pulsed laser deposition.

Alternate means of creating the piezoelectric material are also being considered. A preliminary effort to use pulsed laser deposition has created AlN films on silicon carbide. While the piezoelectric strength of these films has not yet been confirmed, this method might be better suited for deposition on large structures or for creating small areas of AlN film. In addition, a source for single crystal AlN has been located. Samples of this material with the proper orientation have recently become available and will be procured and tested. The single crystal material has advantages for lower frequency operation, and possibly for sensor fabrication.

A concurrent effort has focused on investigation of means of coupling ultrasound from the sensor into the test object at high temperature. A literature search combined with preliminary experimentation has resulted in the selection of two methods for coupling: low melting point glasses and metal foil- pressure couplant. A test apparatus for these methods is being designed and constructed.



The edge of an AlN film produced by pulsed laser deposition showing thinning.