TITLE: **Elevated Temperature Sensors for On-Line Critical Equipment Health Monitoring**

AUTHOR: James R. Sebastian

STUDENTS: Michael Frede, Matt Pacyna

INSTITUTION: University of Dayton
300 College Park
Dayton, OH 45469-0120

PHONE: 937-229-4647

FAX: 937-229-3712

EMAIL: sebastian@udri.udayton.edu

GRANT NO.: DE-FG26-02NT41534

PERIOD OF PERFORMANCE: 9/30/2002 to 9/29/2005

DATE: March, 2003

Project Objective:

The objective of the proposed research program is to improve high temperature piezoelectric aluminum nitride (AlN) sensor technology to make it useful for instrumentation and health monitoring of current and future electrical power generation equipment. The sensor's temperature range will be extended from approximately 700°C to above 1000°C. Ultrasonic coupling to objects at very high temperatures will be investigated and tailored for use with the sensor. The sensor will be demonstrated in a laboratory simulation of an application of health monitoring for power generation equipment.

Two implementations of the AlN sensor are possible. As an ultrasonic transducer, the sensor could be used to measure the thickness of a material or to look for the formation of cracks or voids in a material. Performed on-line at high temperature, a thickness measurement could be used to monitor the extent of corrosion damage in metallic or ceramic components. Ultrasonic waves may additionally be used to monitor bonds, such as that between a metal and a ceramic, as found in thermal and environmental barrier coatings commonly found in power generation equipment. The AlN sensor could also form the basis of an accelerometer which could be used to monitor a change in the vibration modes of a component or system as degradation occurs.

Accomplishments to Date:

Initial work on the program focused on AlN 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, with films failing upon reheating. Deposition on silicon carbide is proceeding well, with a highly conductive grade of silicon carbide required for practical use. Additional substrate materials, including refractory metals and conductive ceramics, have been considered but are generally not promising in light of the experience with titanium. Titanium silicon carbide, a relatively new material, may prove feasible as a machinable substrate.

Alternate means of creating the piezoelectric material were also investigated. A preliminary effort to use pulsed laser deposition has created AlN films on silicon carbide and may provide a means for deposition on large structures or to repair defects in CVD films. In addition, a source for single crystal AlN has been located. A sample of this material with the proper orientation has recently become available and was procured for comparison purposes. The single crystal material has advantages for lower frequency ultrasonic operation, and possibly for sensor fabrication; its cost is expected to decrease with time as improved production methods are developed.

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. An additional task directed toward eventual application of the sensor has been to design an AlN-based accelerometer expected to operate in the required temperature range.

Future Work:

Future work for the remainder of the contract will be focused in three primary areas. The first will be to complete the maturation of the AlN film deposition process on SiC and possibly Ti_3SiC_2, including testing of the sensitivity and oxidation of the deposited films to above 1000C. The second focus will be to construct AlN-based sensors capable of operation at these temperatures. Problems to be overcome in this area include the aforementioned ultrasonic coupling, as well as the necessary electrical leadwires and insulation. Finally, the third focus will be to identify a target health monitoring application where one or more sensors can be demonstrated in a simulated service application and environment.

Papers Published, Patents, Conference Presentations:

No papers, patents, or conference presentations have resulted from this grant to date.

Students Supported:

1. Matthew Pacyna, undergraduate student in the department of Electrical Engineering, University of Dayton.
2. Michael Frede, undergraduate student in the department of Mechanical Engineering, University of Dayton.

Michael is researching high temperature ultrasonic coupling in support of the program in fulfillment of the requirements for his senior Honors Thesis.