Irradiation Behavior of Piezoelectric Materials for Nuclear Reactor Sensors

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Program: NSUF-1.1: Testing of Advanced Materials or Advanced Sensors for Nuclear Applications

ABSTRACT:

The objective of the proposed work is to investigate the impact of irradiation damage on the degradation of the dielectric and piezoelectric properties of aluminum nitride (AlN). AlN is a candidate material for use as an in-pile sensor in nuclear reactors. This material has attractive properties such as high melting temperature and chemical stability in extreme high temperature environments of various power applications. Prior irradiation studies focusing on nuclear applications have demonstrated its radiation hardness and the potential of this material as a piezoelectric element of an ultrasonic transducer. The focus of prior studies was device performance rather than particular physical properties of AlN. In this particular study, we are interested in understanding the evolution of its physical properties that enable its use as an ultrasonic sensor.

Ultrasonic testing is widely used as a nondestructive evaluation for characterization and diagnostics of structural components across a wide range of energy applications. The ultrasonic methods rely on the sensitivity of acoustic waves on their propagation environment where the speed depends on the material and its microstructure, in addition, small scale microstructural defects scatter acoustic waves and result in the amplitude attenuation of the waves. Defects with dimensions comparable to the wavelength of the acoustic wave, on the other hand, reflect the wave. The above physical processes constitute the basic principle of a broad range of ultrasonic methods. Application of these principles is of particular interest to *ultrasonic sensors* used in nuclear energy applications, especially for measurement of physical parameters such as temperature, strain, pressure, coolant flow and vibration. These sensors are already finding applications in harsh environments such as gas turbines, rotating machinery, high power electrical equipment, and nuclear research reactors.

The irradiation study will be conducted using a novel approach that measures a combination of piezoelectric, dielectric and elastic properties in-situ during irradiation. Experimental measurements will be achieved by a characterization of the surface acoustic wave (SAW) propagation generated and detected using an array of interdigitated transducers (IDT) on the surface of AlN specimen. The samples will be irradiated at nuclear reactor and ion beam accelerator facilities as instrumented-lead experiments, which will allow on-line measurements of its physical properties important for sensing applications. These online measurements will also act as a proof-of-principle experiments demonstrating the feasibility of SAW sensing technology for in-pile applications. Our experimental results will be analyzed utilizing well documented methods used to investigate the behavior of the SAW devices for radiofrequency applications. Degradation of the properties will be analyzed with the help of atomistic level computational studies and used to develop mechanistic understanding of this material's behavior in reactor applications.