High Fluence Irradiation Testing of Fiber Optic Material Transmission

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This work leveraged a recently completed irradiation of capsules assembled and inserted into the High Flux Isotope Reactor (HFIR) in FY 2017. NSUF funding allowed for post-irradiation measurements by Dr. Petrie of the contents of the rabbit capsules. Each capsule contained 12 fiber-optic-material slab specimens, split equally between: 1) low-OH fused silica, 2) high-OH fused silica, and 3) single crystal-sapphire materials. The nominal sample dimensions were 16 mm long × 5 mm wide × 0.85 mm thick. The rabbit capsules were irradiated for approximately one 24 day HFIR cycle. Each capsule was designed to achieve a unique temperature that is typical of light-water reactors or some high-temperature advanced reactors.

The pre- and post-irradiation transmission and density measurements were made at Oak Ridge National Laboratory (ORNL) at the Low Activation Materials Development and Analysis (LAMDA) Facility. Optical transmission was measured through the sample thickness, using a broadband optical-transmission system, which allowed for the measurement of radiation-induced attenuation (RIA) in the specimens over a wavelength range from approximately 200–1700 nm.

Results

Measurements of RIA and radiation-induced dimensional changes were made in a-SiO_2 samples that were subjected to high-dose neutron irradiation at temperatures of 95, 298, and 688°C (based on dilatometry, using passive SiC temperature monitors) (Figure 1). These temperatures are higher than those of previous work. Results show that RIA may be approaching saturation for the range of photon energies that were tested and that the hydroxyl content has a significant impact on RIA when the irradiation temperature is increased to 688°C. For 1550 nm operation, however, the observed increase in RIA does not preclude interference-based measurements of fiber temperature. A model was developed for predicting radiation-induced compaction, and the resulting impact on signal drift and RIA for Bragg grating sensors as a function of neutron fluence and temperature. The data were well fit by a simple model. The sapphire samples showed significant RIA that increased with increasing temperature. However, the samples may have suffered from diffusion of impurities from the surrounding capsule materials at high temperatures. Additional characterization is being planned to confirm whether impurities were introduced.

Conclusion

The primary concern for implementing a-SiO_2 fiber-optic sensors in a nuclear environment is the RIA of the light signal due to the formation of radiation-induced color centers. In addition, Bragg-grating sensors drift under irradiation due to radiation-induced compaction of the a-SiO_2 structure. Our work provides new data regarding RIA and radiation-induced compaction of a-SiO_2 samples irradi-

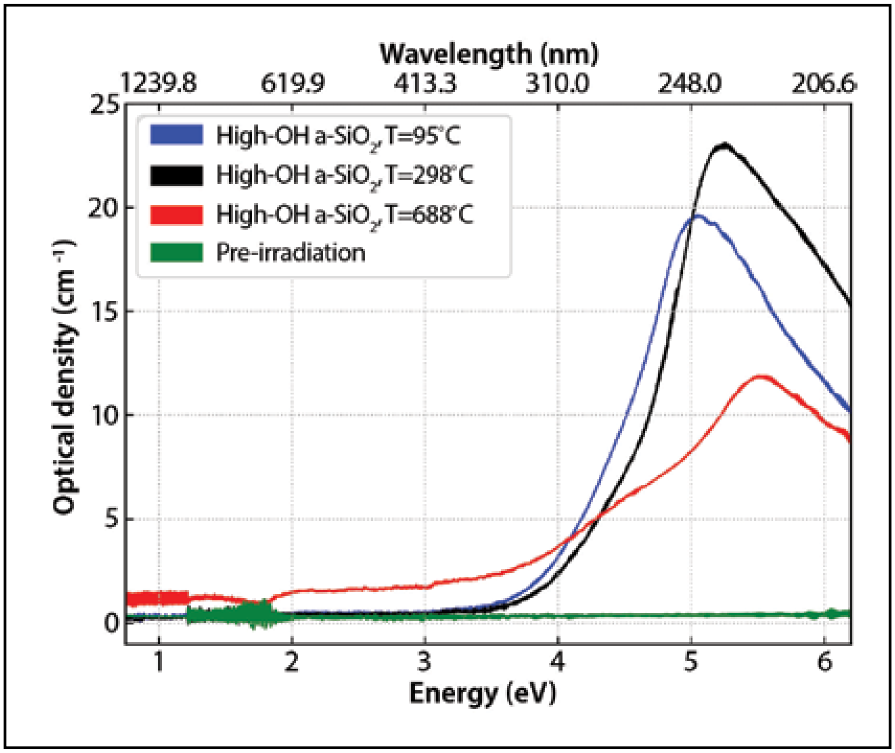

Figure 1. Optical density vs. photon energy and wavelength with irradiation temperature (T) as a parameter for the high-OH a-SiO$_2$ samples.

ated to a fast neutron fluence of 2.4 × 10^{21} n/cm^2 at temperatures of 95, 298, and 688°C. The observed increase in RIA does not preclude interference-based measurements of fiber temperature. However, the effects of drift can be significant and may require compensation.

Publications

[1.] Christian M. Petrie, Anthony Birri, Thomas E. Blue , High-Dose Temperature-Dependent Neutron Irradiation Effects on the Optical Transmission and Dimensional Stability of Amorphous Fused Silica, *Journal of Non-Crystalline Solids* 525 (2019) 119668

Distributed Partnership at a Glance

NSUF and Partners	Facilities and Capabilities
Oak Ridge National Laboratory	Low Activation Materials Design and Analysis Laboratory
Collaborators	
Oak Ridge National Laboratory	Christian M. Petrie (co-principal investigator)
Ohio State University	Dr. Thomas E. Blue (principal investigator)