Characterization of A Neutron-Irradiated Zr-Nb-O Alloy Using Analytical Scanning Transmission Electron Microscopy

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Modern zirconium alloys for commercial nuclear power plants, such as zirconium-niobium-oxygen (Zr-Nb-O), are developed to minimize the water-side corrosion reactions and hydrogen ingress during operation. This is mainly achieved by niobium (Nb) addition where it forms β-Nb precipitates in the α-zirconium (α-Zr) matrix. Microstructural characterization of these alloys is essential to understand the effect of Nb on the performance of nuclear fuel cladding. In this study, we characterized a neutron-irradiated Zr-Nb-O alloy using scanning transmission electron microscopy with energy dispersive X-ray spectroscopy (STEM-EDS). The distribution of niobium in the zirconium matrix and at an oxide layer on the fuel side was examined. The nano-grained oxide layer was identified as tetragonal ZrO_2, based on spot diffraction pattern from one grain and ring pattern from multiple grains. While globular β-Nb precipitates were still found in the irradiated sample, apparent segregation of Nb to the <c> loops were observed. Tiny Nb-rich acicular ("needle-like") precipitates less than 10 nm in length were aligned approximately along the (0002) plane were found. No specific microstructural features, like hydrides or hydride rim, was determined at the metal oxide interface region.