

High-Temperature Oxidation Behavior of Cr/CrN Multilayer Coatings on Zr–Nb Alloy for Accident Tolerant Fuels

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After Fukushima Daiichi nuclear accident, ATFs (Accident Tolerant Fuels) are being developed to prevent severe accident or to delay the progression of accidents in nuclear power plants. Some of the new designs are focused on conventional Zr cladding coated with materials that improve cladding behaviour in high-temperature environments. This paper presents high-temperature experiments carried out in the temperature ranges of 900–1200 °C and different times in both steam and air environments on the Cr/CrN multilayer coated samples. The coatings with the average thickness of about 7 µm and the individual layer of about 20 nm have been deposited on the Zr-1%Nb cladding by cathodic Arc-PVD technique. The phase structure and morphology of the coated and uncoated samples have been evaluated via grazing incident angle X-ray diffraction (GI-XRD), optical microscopy (OM) and scanning electron microscopy (SEM) equipped with energy dispersive spectroscopy (EDS). The XRD analysis results reveal the presence of three phases: Cr, CrN, and Cr₂N in multilayer coated sample. The results show that the thickness of the oxide layer was increased with the increase in oxidation time. In the case of oxidized uncoated samples, holes and micro-cracks were observed in the oxide layer, which can be caused by the increasing stresses due to the growth of the oxide layer. The cross sectional SEM morphologies and EDS results of the oxidized (Cr/CrN) multilayer coated samples indicated that the thickness of remained Cr interlayer of the oxidized sample in steam was more than the oxidized sample in air. Besides, with the increase in the oxidation temperature, the thickness of the oxide layer and the oxygen-rich layer beneath the oxide layer were increased. Finally, the findings demonstrate that the use of alternating Cr/CrN multilayer can be controlled the oxidation rate of the Zr-Nb alloy at high temperatures, results in the improved performance of the cladding tube in the in-reactor accident conditions.

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