

HIGH-TEMPERATURE OXIDATION OF CR/MO COATED ZR-1NB ALLOY*

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Currently, zirconium-based alloys are widely used in nuclear power industry for manufacturing fuel claddings and other structural elements of pressurized water reactor (PWR) due to their low thermal neutron capture cross-section, high corrosion and radiation resistance and acceptable mechanical properties [1–3]. Nevertheless, severe oxidation of zirconium alloys under possible high-temperature (HT) accidental conditions such as loss of coolant accident (LOCA) can cause a loss of claddings integrity and their destruction [4]. One of the possible method to protect zirconium alloy is coating deposition. Up to date, the most promising material considered as a protective coating for zirconium-based alloy claddings is chromium. However, Cr-Zr interdiffusion can occur at the coating/alloy interface at HT, that leads to the formation of Cr-Zr eutectic phase with a melting point of 1332 °C [5]. As a result of Cr-Zr interdiffusion, the Cr₂Zr intermetallic layer forms at the Cr-Zr interface, which lead to accelerated oxidation of the zirconium alloy. One way to solve this problem is to develop a new type of Cr-based protective coating with a barrier sublayer that can prevent Cr-Zr interdiffusion. In the present work Mo was deposited by magnetron sputtering as a diffusion barrier layer. The high-temperature oxidation and interdiffusion behavior of Cr coatings with a Mo sublayer were investigated in the paper.

Cr (8 μm)/Mo (3 μm)- and Cr (8 μm)-coated Zr-1Nb alloys were oxidized in air at 1100 °C during 15-60 min. According to SEM, XRD and optical microscopy it was established that a 3 μm-thick barrier Mo layer can limit Cr-Zr interdiffusion under high-temperature oxidation. The phase composition of the Cr/Mo-coated Zr alloy after oxidation consists of the Cr₂O₃, α-Cr and Cr₃Mo phases. In situ XRD under linear heating up to 1250 °C with a heating rate of 50 °C/min shows Mo₂Zr phase formation at the Mo/Zr interface. The thickness of residual Cr after 60 minutes of oxidation is greater in Cr/Mo-coated Zr alloy (~5 μm) compared to single-layer Cr-coated sample (~3.5 μm). The thickness of the Cr-Mo and Mo-Zr interdiffusion layers is equal to ~2 and 20 μm after 60 min HT oxidation, respectively. The thickness of outer oxide Cr₂O₃ layer after HT oxidation of Cr- and Cr/Mo-coated Zr alloy samples are similar indicating that the Mo sublayer has no significant effect on oxidation resistance of outer Cr layer. However, enhanced oxidation of the Mo-Zr layer can cause local oxidation of the coated Zr alloy samples when oxygen will penetrate up to Mo layer/Zr alloy interface. It was established that the weight gains depend on the coating type. The single-layer Cr coatings demonstrate better oxidation resistance that Cr/Mo. The weight gains reduces by ~3 times compared to Cr/Mo coating. This is due to the uncoated area oxidation of the samples. A thin layer of Mo and Cr remained beneath the oxidation zone of the Zr alloy since oxygen contacted with these regions. This can indicate on predominant oxidation of Mo-Zr layer compared with other systems.

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