STRUCTURAL-PHASE STATE OF ACCIDENT-TOLERANT Cr/Mo-COATED Zr–1Nb ZIRCONIUM ALLOY UNDER HIGH-TEMPERATURE OXIDATION

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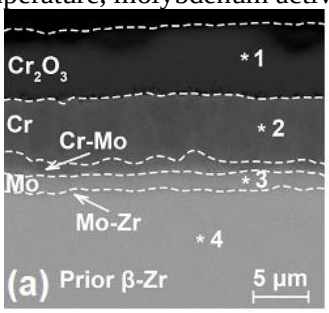
Introduction. Currently, chromium is a promising material for the protection of the zirconium cladding of fuel elements during a loss of coolant accident [1]. The main advantage of choosing this coating is that it forms a protective Cr_2O_3 oxide layer on the surface of the zirconium alloy during high-temperature oxidation. Nevertheless, the interdiffusion of Cr and Zr increases at high temperatures with subsequent eutectic formation (1332 °C) [2]. The solution to this problem may be the deposition of a barrier sublayer between Cr and Zr. Molybdenum is considered as a material that can effectively limit the formation of the Cr-Zr interdiffusion layer for a long time [3]. Therefore, the aim of this work is to establish the regularities of interdiffusion and high-temperature oxidation of Cr/Mo-coated Zr–1Nb zirconium alloy.

Materials and methods. A bilayer Cr(8 μm)/Mo(3 μm) coating was deposited on the zirconium alloy by magnetron sputtering. High-temperature tests were carried out in steam at 1200, 1330 and 1400 °C for 1000–2000, 120–720 and 120 s, respectively. The weight gain of the samples was measured on a CP 124S analytical balance. The microstructure and elemental composition of the samples after oxidation were analyzed by TESCAN MIRA3 scanning electron microscopy (SEM) with Ultim Max 40 energy dispersive spectroscopy (EDS) attachment.

Results. The Cr/Mo-coated samples remained in a protective state throughout the oxidation time at 1200 and 1330 °C in steam, as the weight gain was one order of magnitude lower compared to the uncoated sample. Increasing the oxidation temperature to 1400 °C did not significantly affect the difference in weight gain between coated and uncoated samples (10–12 mg/cm^2). This indicates a weak protective effect of the coating at this temperature.

SEM results showed no formation of a Cr-Zr interdiffusion layer at 1200 and 1330 °C throughout the oxidation time (Fig. 1). Thus, a molybdenum barrier sublayer suppresses interdiffusion of chromium and zirconium at 1200 and 1330 °C for at least 2000 s and 720 s, respectively. At 1400 °C for 120 s oxidation, zirconium oxides and interdiffusion layers with the presence of Cr, Mo and Zr are formed under a thin Cr_2O_3 oxide layer. In addition, cavities were formed at the ZrO_2/α-Zr(O) interface. Consequently, at 1400 °C the use of a molybdenum sublayer does not effectively suppress the interdiffusion of Cr and Zr for 120 s. At this temperature, molybdenum actively diffuses deep into the zirconium alloy and loses its barrier properties.



Point	Cr	O	Zr	Mo
1	40	60	-	-
2	87	12	-	1
3	37	-	31	32
4	3	-	90	7

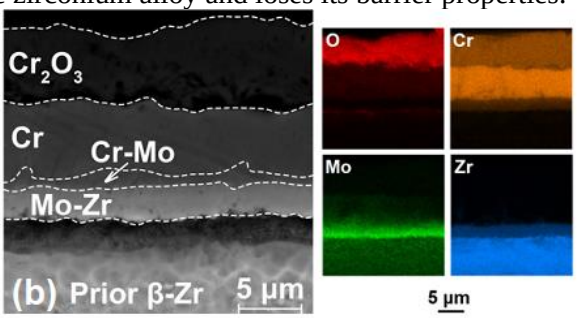


Fig.1. Cross-section SEM images and EDS data of the Cr/Mo-coated Zr alloy samples after steam oxidation at (a) 1200 °C for 2000 s and 1330 °C for 720 s.

Conclusion. The molybdenum barrier layer limits the interdiffusion of Cr and Zr during high-temperature oxidation at 1200 °C for 2000 s, as well as at 1330 °C for 720 s. After oxidation at 1400 °C for 120 s, the Cr/Mo-coated sample showed a weight gain comparable to the single-layer Cr coating. Significant diffusion of molybdenum into the zirconium alloy indicates a loss of barrier properties of the deposited sublayer.

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