

Effects of Bi on microstructure and corrosion behavior of Zr-1Nb alloy in 500 °C/10.3 MPa superheated steam

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Abstract In water-cooled power nuclear reactors, zirconium alloys as fuel cladding are important structural materials. Many factors will lead to the failure of the zirconium alloy cladding, and the corrosion resistance is the most important factor that affects the service life of the fuel element. To further enhance fuel burnup and reduce the cost of nuclear power, it is necessary to develop advanced zirconium alloys with superior corrosion resistance. We investigated the corrosion resistance of Zr-1Nb alloy with the addition of Bi in superheated steam at 500 °C/10.3 MPa. And combining experimental characterization and density functional theory calculation, a mechanism of Bi improving corrosion resistance was proposed. Results revealed that addition of trace amount of Bi improved the corrosion resistance of Zr-1Nb alloy. Based on the experimental and DFT calculation results, we propose that the reduction of micro-pores and micro-cracks in the oxide film is mainly attributed to Bi³⁺ stabilizing the tetragonal phase and reducing the volume expansion of the tetragonal→monoclinic phase transition. Meanwhile, Bi can improve the proportion of columnar grains by delaying the microstructural evolution from columnar grains to equiaxed grains.

Keywords zirconium alloy; Bi; Corrosion; oxide film; DFT