Effect of Ar^+ irradiation on the microstructure and corrosion resistance of Zircaloy-4

Jintao Xi, Meiyi Yao*, Zhiyuan Gu, Shitong Xu, Lijuan Hu, Yaoping Xie, Bangxin Zhou

Institute of materials, Shanghai University, Shanghai 200072, China

Presenter's e-mail address: xijintao0402@163.com

yaomeiyi@shu.edu.cn

Abstract Zirconium alloys used as nuclear fuel cladding materials will be irradiated by neutrons during in-pile service, which will affect their corrosion resistance. Ion irradiation can be used to simulate neutron irradiation to study the irradiation effect. In this study, Zircaloy-4 plate was irradiated by Ar^+ irradiation with electrostatic accelerator. The unirradiated and 5 dpa irradiated samples were corroded in 360 ℃ /18.6 MPa/3.5 ppm Li+1000 ppm B aqueous solution and 400 ℃ /10.3 MPa superheated steam for 300 days using autoclave tests. Scanning electron microscopy and transmission electron microscopy were used to characterize the microstructure of the samples. It was found that in the unirradiated sample, $Zr(Fe, Cr)_2$ second phase particles (SPPs) were closely packed hexagonal structure, and the Fe/Cr atomic ratio was in the range of 1.8 ~ 2.0. After irradiation, SPPs occurred to amorphization. The thickness of oxide film of irradiated sample is smaller than that of unirradiated sample at the initial stage of corrosion after 70-day exposure under the two corrosion conditions, which indicates that Ar^+ irradiation can enhance the corrosion resistance of Zircaloy-4 to some extent. The small thickness of the initial oxide film and the presence of irradiated damaged matrix hinder the growth of the oxide film. Additionally, defects introduced by irradiation reduce stress accumulation in the oxide film, delaying pore and crack formation to reduce O^{2-} diffusion rate. The weight gain curves showed 1 to 2 corrosion transitions for Zircaloy-4 samples before and after irradiation over a 300-day period, following cubic rule before transition and parabolic or straight line rule after transition. In all, under the two corrosion conditions, irradiation can enhance the corrosion resistance of Zircaloy-4， which is different from the results of neutron irradiation.

Keywords irradiation; corrosion; Zircaloy-4; second phase; oxide film；Microstructure