Study of irradiation induced defects and phase instability in β phase of Zr Excel alloy with in-situ heavy ion irradiation

Hongbing Yu

Department of Mechanical and Materials Engineering, Queen’s University

Synopsis

Zr Excel alloy (Zr-3.5Sn-0.8Nb-0.8Mo, wt.%) which has been proposed as candidate material of pressure tubes for CANDU-SCWR is a dual-phase alloy containing primary hcp α-Zr and metastable bcc β-Zr. Hexagonal ω-Zr phase could form in β-Zr as a result of aging during the processing of the tube. Extensive research work has been done on the counterpart of Zr Excel alloy, Zr-2.5Nb, showing that the metastable β-Zr (Zr-20 wt. %Nb) experiences decomposition and elemental redistribution under irradiation [1-5]. However, little research has been done for the irradiation properties of the metastable β phase in Zr-Excel so far, thus leaving several problems unaddressed. 1) The stability of the minor phases in Zr-Excel alloy under irradiation; 2) the elemental redistribution induced by irradiation in the β-Zr and ω-Zr phases; 3) irradiation induced defects in bcc β-Zr phase. In this study, in-situ heavy ion irradiation with 1 MeV Kr²⁺ at two different temperatures was carried out to investigate the stability of β-Zr and ω-Zr phases under irradiation. Qualitative Chemi-STEM EDS mapping was used to characterize distribution of alloying element before and after irradiation. Due to the presence of ω particles which cause difficulties in characterizing small defects induced by irradiation, single phase bcc Zr-20Nb, which has a similar lattice parameter with the β-Zr in Zr Excel, was used as a model alloy to study the accumulation behavior of irradiation induced dislocation loops in β phase of Zr Excel alloy.

Experiment results

1) Stability of ω particles depends on irradiation temperature. The ω-Zr particles experienced shape changes and eventual dissolution from outer layer to core associated with enrichment of Fe in at the β/ω interface at 200 °C irradiation but not at 450 °C.

2) No decomposition of β-Zr phase was observed under irradiation at either 200 °C or 450 °C.

3) There is an increase in the level of Fe in α matrix after irradiation at both 200°C and 450 °C. The concentrations of Nb, Mo and Fe are increased in ω phase but decreased in β phase at 200°C.

4) Dislocation loops with Burgers vector ½<111> and <001> were both present in β-Zr after irradiation at room temperature. The mean size of the defects is bout 5-6 nm, and the threshold dose for visible defects is much higher than for its hcp counterpart.

Reference


