Microstructure Characterization of Proton Irradiated Zircaloy-4

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Irradiation can affect the base Zr metal, the oxide layer and the environment, which may result in accelerated corrosion of Zr alloys in the light water reactor environment. Because corrosion under neutron irradiation is difficult to perform, ion irradiation has been adapted in recent years to emulate neutron damage effects with the advantages of lower residual radioactivity, faster turnaround and greater cost efficiency, as well as more precise control of individual variables. The focus of this study is to understand the temperature and damage rate required for proton-irradiated microstructures to reproduce key microstructure features observed in high fluence neutron irradiated Zircaloy-4. Samples of Zircaloy-4 were irradiated with 2 MeV protons to damage levels up to 5 dpa at the Michigan Ion Beam Laboratory at temperatures ranging from 280-350˚C. Detailed dislocation analysis was carried out using bright-field scanning transmission electron microscopy (TEM) and the microchemical evolution of the second phase particles (SPP) was analyzed with energy dispersive x-ray spectroscopy (EDS). The analysis revealed an increase of <a> and <c>-dislocation loop sizes with increased irradiation temperature and irradiation dose. The transformation from crystalline to amorphous of $Zr(Fe,Cr)_2$ precipitates under proton irradiation has been observed, the transformation is accompanied by Fe depletion in the amorphous regions and is strongly dependent on the irradiation temperature.