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Microstructure evolution of recrystallized Zircaloy-4 under charged particles irradiation

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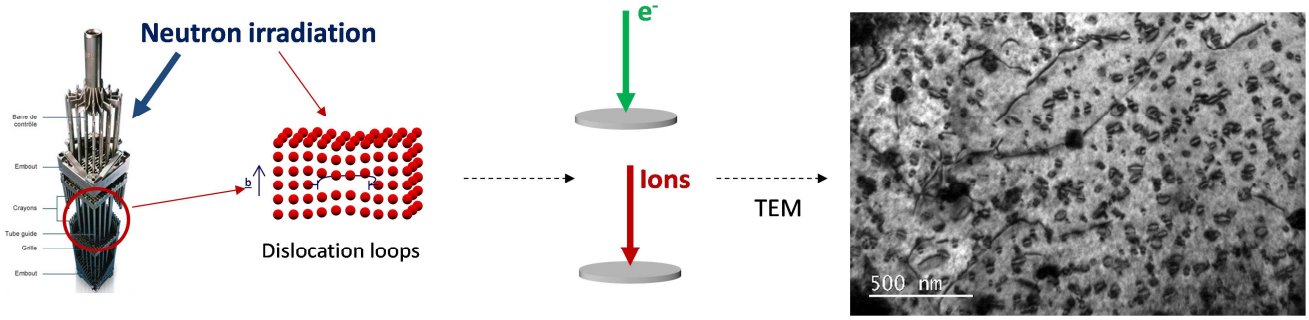
Abstract

Recrystallized zirconium alloys are used as nuclear fuel cladding tubes of Pressurized Water Reactors. During operation, these alloys are submitted to fast neutron irradiation which leads to their in-reactor deformation and to a change of their mechanical properties. These phenomena are directly related to the microstructure evolution under irradiation and especially to the formation of <a>-type dislocation loops. In the present work, the radiation damage evolution in recrystallized Zircaloy-4 has been studied using charged particles irradiation. The <a> loop nucleation and growth kinetics, and also the helical climb of <a> linear dislocations, were observed *in-situ* using a High Voltage Electron Microscope (HVEM) under 1 MeV electron irradiation at 673 and 723 K. In addition, 600 keV Zr^+ ion irradiations were conducted at the same temperature. Transmission Electron Microscopy (TEM) characterizations have been performed after both types of irradiations, and show dislocation loops with a <a> Burgers vector belonging to planes close to $\{10\bar{1}0\}$ first order prismatic planes. The nature of the loops has been characterized. Only interstitial <a> dislocation loops have been observed after ion irradiation at 723 K. However, after electron irradiation conducted at 673 and 723 K both interstitial and vacancy loops were observed, the proportion of interstitial loops increasing as the temperature is increased. The loop growth kinetics analysis shows that as the temperature increases, the loop number density decreases and the loop growth rate tends to increase. An increase of the flux leads to an increase of the loop number density and a decrease of the loop growth rate. The results are compared to previous works and discussed in the light of point defects diffusion.

Graphical Abstract



Keywords

Recrystallized Zircaloy-4 ; electron irradiation ; ion irradiation ; <a> loops ; High Voltage Electron Microscope; Transmission Electron Microscopy