Effect of the Chromium Content on the Mechanical Properties and Microstructural Evolution of Ion-Irradiated Fe-Cr Model Alloys

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Effect on the chromium content on the hardness changes and microstructural evolution in irradiated Fe-Cr model alloys (Fe-5, 9, 12 and 15wt%) before and after a post-irradiation heat treatment at 673K or 773K is investigated using a nano-indentor and transmission electron microscopy (TEM).

Ion-irradiation experiments (up to12dpa) were performed with 8Mev Fe$^+$ ions accelerated at room temperature. TRIM calculation and TEM observation indicated that the depth of maximum displacement damage layer of ion-irradiated regions was about 1.7µm. Nanoindentation with a continuous stiffness measurement (CSM) technique was used to measure a change of the relative hardness of thin ion-irradiated regions. Hardness measurement of the ion-irradiated Fe-Cr alloys before a post-irradiation heat treatment showed that an increase of the hardness by an ion irradiation rises linearly with the chromium content at a low dose level. However, Fe-9wt%Cr showed a reduced irradiation-induced the increase of hardness with the level of a dose. Fine ion-irradiation induced dislocation loops were observed by a weak beam dark field TEM imaging. These fine dislocation loops had Burgers vectors of $<001>$ and $1/2<111>$, which were distinguished with actual TEM images. TEM analysis showed that the size of the dislocation loops increased and the population of the dislocation loops with a Burgers vector of $<100>$ increased with the chromium additions. After a post-irradiation heat treatment, the hardness measurement of irradiated Fe-Cr alloys showed that the reduction of the hardness by a heat treatment decreased with the chromium additions. An interesting feature is that as the chromium content is lowered in Fe-Cr model alloys, the size of the ion-irradiation induced dislocation loops increases significantly after a post-irradiation heat treatment, whereas it decreases before a post-irradiation heat treatment.

Based on the present experimental results, we discuss in detail the correspondence between the irradiation-induced changes in the hardness and in the microstructure and the role of the chromium atom in Fe during an irradiated microstructural evolution.

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