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In-situ Observation of Irradiation Induced Defects in Fe and Fe-Cr Alloys

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The selection of structure materials is a key issue for achieving the success of future fusion and advanced fission reactors. Candidate materials for these applications include reduced-activation ferritic-martensitic (RAFM) steels with Cr contents ranging between 9-12%. These steels have better thermal properties and higher swelling resistance than austenitic steels, but may become embrittled under irradiation at temperatures less than about 400ºC [1-3]. It is important to develop a detailed mechanistic understanding of the development of radiation damage in ferritic alloys, which is lacking at present. The work reported here is part of this endeavor. The experiments of heavy-ion irradiation in iron was performed by using Argonne IVEM-Tandem Facility, which comprises an electron microscope linked to a heavy-ion accelerator. Thin foils of pure Fe were irradiated with 150 keV Fe+ ions at temperatures 30-500^{o}C. Dynamic observations under weak-beam diffraction conditions followed the evolution of damage over doses 0-10 dpa. At low doses, ≤ 1 dpa, damage took the form of small, isolated dislocation loops with Burgers vectors b = < 100 > and ½< 111 >. Loops with b = ½< 111 > were highly mobile, moving by discrete hops from one position to another, both during and after ion irradiation. At temperatures ≤300^{o}C and doses ≥1 dpa, complex microstructures developed in thicker regions of the foils. First strings of several loops, all with the same ½< 111 > Burgers vector formed, involving elastic interactions and cooperative movement of individual loops. Then larger loops were produced by the coalescence of loops in a string. In high-purity Fe irradiated at 300^{o}C, further coalescence and complex glide and climb processes led to the formation of large (several μm) finger-shaped loops with b = ½< 111 > and large shear components. By this stage the loop nature could be shown to be interstitial. At temperatures higher than 300^{o}C, square-shaped sessile edge interstitial loops with b = < 100 > nucleated and grew to large sizes. At temperatures ≤ 450^{o}C, these < 100 > loops co-existed with ½< 111 > loops, but at 500^{o}C only < 100 > loops formed. Small voids were found at 300^{o}C. In this contribution these dynamical processes will be shown in the form of videos.

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