ICFRM2007/495
An Experimental and Modeling Study of Helium in Irradiated BCC Iron

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Ferritic and ferritic-martensitic steels are being considered as structural materials for fusion and advanced nuclear reactors. These steels have been selected since they exhibit resistance to void swelling, irradiation creep, and helium (He) and hydrogen (H) embrittlement at higher temperatures. During the operation of the reactors these materials will be subjected to both irradiation displacement damage, as well as the generation of H and He through \((n,p)\) and \((n,\alpha)\) transmutation reactions, respectively. The transmutation gases and irradiation damage have a significant impact on the resultant microstructure and material properties. The current work is aimed at quantifying these effects in ways that were not possible in earlier studies. This is accomplished through a systematic and coordinated group of experiments and computational modeling. The experimental studies utilized ion implantation to simulate the radiation damage processes over a range of He/dpa values, dose levels, and temperatures. The resulting microstructures are characterized using slow-beam positron annihilation spectroscopy and transmission electron microscopy. The experimental results are compared to calculations resulting from molecular dynamics and kinetic Monte Carlo simulations.

Number of words in abstract: 173
Keywords:
Technical area: 23. Radiation effects He and H effects
Special session: Not specified
Presentation: No preference
Special equipement: No special equipment