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RADIATION-INDUCED PHASE INSTABILITY AND ITS ROLE IN THE FORMATION OF CORROSION RESISTANCE AND MECHANICAL PROPERTIES OF FERRITIC-MARTENSITIC STEELS

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High chromium ferritic-martensitic (F/M) steels are used as structural materials in sodium-cooled fast reactor (SFR) cores due to their excellent void swelling resistance. Their performance depends on the dual-phase structure of swelling-resistant, high-strength tempered martensite forming subgrains in a ductile, corrosion-resistant ferrite matrix. This paper investigates the radiation stability of the structure of EP-450 steel widely used in Russian SFRs, with implications for other F/M steels proposed for use in Gen IV nuclear reactors worldwide.
Specimens of EP-450 were irradiated to 50–53 dpa at 295–405℃ in the BN-350 SFR in Aktau, Kazakhstan, and also in the 6MWth WWR-K water-cooled research reactor at the Instiute of Nuclear Physics in Almaty, Kazakhstan to doses less than 0.1 dpa for a low-dose comparison. Microstructural changes were studied using a Toshiba TM4000plus SEM and JEOL JEM-2100 TEM equipped with EDS analysis. Corrosion behavior of BN-350 reactor specimens (high dose) was investigated directly using SEM, and specimens irradiated in the WWR-K reactor (low dose) were subject to standard-based testing for assessing pitting corrosion resistance.
Phase instability of EP-450 steel under high-dose irradiation was observed, with relaxation of martensite to ferrite as a key feature. The proportion of ferrite and martensite phases changed from 1:1.7 for unirradiated steel to up to 2.6:1 for steels irradiated to 53 dpa, depending on irradiation temperature. The main reason is the processes of recovery and recrystallization under irradiation, as indicated by structural changes in the residual martensitic phase: decrease in the density of sub-grain boundaries, simplified sub-grain structure, and a decrease in the density of dislocations. The role of this phase instability on corrosion resistance and mechanical properties of EP-450 was also studied, showing how martensite grains were preferentially corroded after exposure to spent fuel pool water (~20C) for 8 years. This work has significant implications for predicting corrosion and embrittlement performance for F/M steels after irradiation and in temporary storage in water.

Section

Energy and materials science (Section 2)

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