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NANOSTRUCTURE OF OXIDE DISPERSION-STRENGTHENED STEELS AND ITS REARRANGEMENT UNDER ION IRRADIATION

KLAUZ A.V.[1,2], KHOMICH A.A.[1,2], BOGACHEV A.A.[1,2], NIKITIN A.A.[1,2], ZALUZHNYI A.G.[1,2], ROGOZHKIN S.V.[1,2]

[1] *National Research Center "Kurchatov Institute", Moscow, Russian Federation*
[2] *National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Moscow, Russian Federation*

Dispersion-strengthened oxide steels are prominent potential core materials for the next generation of fast-neutron reactors as well as perspective thermonuclear reactors. These steels are expected to withstand radiation loads up to damaging doses of around 200 dpa at irradiation temperatures of 400-700°C. Such loads can be withstood by materials due to being reinforced by small oxide particles which create barriers for dislocation movement as well as pining grain boundaries.

Production method of powder metallurgy allows for size and composition optimization of small inclusions, which leads to an increase of mechanical properties and radiation stability of affected steels. Mechanical properties of ODS steels significantly depend on characteristics of the nanostructure: the size and spatial distribution of dispersed inclusions and nanoscale clusters. These particles provide a significant increase in the creep strength, being effective barriers for dislocation motion.

The aim of this work was to study the initial state of the ODS steel samples with different alloying systems as well as conducting studies for irradiated samples to observe stability of inclusions and of the entire microstructure. Irradiated samples were obtained through ion beam irradiation, since it is considered that these types of defects (as well as their size and number density) caused by neutron bombardment from the nuclear reaction to be closely reproduced with the ion beam experiments.

To analyze the evolution of oxide inclusion and cluster distribution in the material during irradiation, simulation experiments were carried using Fe^{2+} ion irradiation at 5.6 MeV using samples of multiple ODS steels: KAERI 10Cr ODS, KP-3 ODS and Eurofer ODS.

Irradiation with doses of 3, 6 and 30 dpa at 350 °C was used to analyze low-temperature radiation embrittlement and its effects on material nanostructure. Additionally, studied steels were irradiated up to 100 dpa at 500 °C in order to analyze the oxide inclusion stability at enhanced temperatures of high dose irradiation.

The study of initial and irradiated materials was carried out using modern ultramicroscopy methods: transmission electron microscopy (TEM) and atom probe tomography (APT). This combination of techniques allowed for study of both small and large inclusions (oxide particles and clusters) as well as the analysis of their chemical composition.

The local nanochemical APT analysis showed the presence of high density of clusters with sizes of 2–5 nm. In all the steels studied, the clusters were enriched in Cr, Y, and O atoms. In Eurofer ODS steel, clusters also contained V atoms; there were Ti atoms in clusters in 10Cr ODS and KP-3 ODS steels, while clusters in KP-3 ODS steel also contained Al atoms.

The analysis after irradiation showed dissolution of both larger oxides and clusters. At 350 °C this effect was most prominent for ODS KP-3 with clusters that were no longer detectable at 30 dpa. As for Eurofer ODS, it had the most stable clusters and oxide particles when irradiated to 30 dpa.

The dissolution effect was even more prominent at 100 dpa and 500 °C. Which allowed us to determine which steels are more appropriate for nuclear core applications since oxide particles play a key role in radiation stability under operational conditions.