TEM STUDY OF Y-Ti-O AND Y-Al-O IN ODS ALLOYS IRRADIATED WITH SWIFT HEAVY IONS

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In recent years, nuclear industry development must be response to new requirements of safety, sustainability and effectiveness. The operating conditions of nuclear reactors of new design would tend to more damage operation mode, in particular, high temperature and high dozes. Oxide dispersion strengthened (ODS) alloys now have been widely investigated as perspective constructive materials for fuel claddings in Generation IV nuclear reactors due to their high values of high temperature creep resistance and resistance to irradiation swelling [1-3]. High operation properties of ODS alloys are due to nanosized dielectric particles based mainly on yttrium oxides embedded in the metallic matrix. These thermostable nanosized particles are responsible for resistance to dislocation motion that regulate high-temperature creep resistance and tensile properties at high temperatures as well as provide swelling resistance while acting as sinks for radiation defects. Nowadays most literature data are devoted to study structure stability of ODS alloys under neutron and low-energy ion irradiation that didn't show any significant effect on the ODS structure [4,5]. At the same time apart from neutron irradiation cladding materials in reactor core will contact with fission fragments (FF) that can dramatically affect the structure of dielectric materials even down to complete amorphization due to high levels of electronic excitation [6]. Therefore, studying the structure behavior of oxide nanoparticles in metallic matrix under FF impact can broaden the idea of operational limits and conditions of ODS steels for new reactors. The aim of present study is the complex investigation of radiation stability of nanostructured Y-Ti-O and Y-Al-O compounds embedded in metallic matrix and as separate oxides at a broad range of electronic stopping power and ion fluences.

In present work different yttrium oxides composition that can be presented in ODS steels were studied. Swift heavy ion irradiation (167 MeV Xe, 107 MeV Kr and 710 MeV Bi ions) simulating FF impact as well as 46 MeV Ar ion irradiation were performed at the IC-

100 and U-400 cyclotrons (FLNR, JINR, Dubna). Additional irradiation experiments with 220 MeV Xe ions were performed at the DC-60 cyclotron (INP, Nur-Sultan, Kazakhstan). In order to vary electronic energy loss levels aluminum degraders of different thickness were used during irradiation. Irradiation experiments were made using conventional ODS steel specimens, Y-Al-O powder deposited on TEM grids and pressed Y-Al-O powder as well.

After 107 MeV Kr and 167 MeV Xe ions irradiation individual latent tracks were registered in Y2Ti2O7 particles embedded in ODS steels without reference to the steel type. The latent tracks parameters were found and latent track diameter dependency on electronic stopping power was obtained according to TEM observations (Fig.1). The threshold electronic energy loss for latent track formation in Y2Ti2O7 was found at the range of 7,4-9,7 keV/nm.

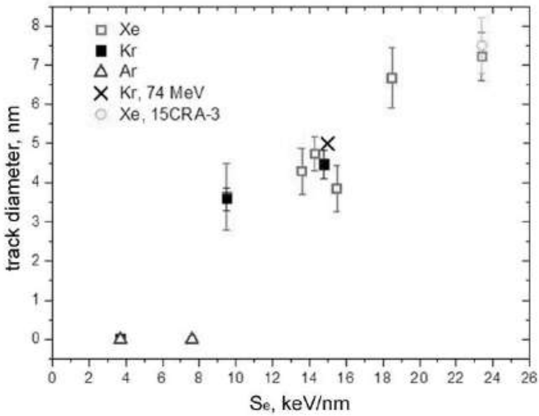

Fig.1 Latent track diameter dependency on electronic energy loss in Y2Ti2O7: squares and triangles are the results obtained on EP450 ODS steel, green circle – 15CRA-3 ODS steel and × - is the result from [7].

Obtained experimentally latent track parameters in Y2Ti2O7 by TEM are in good agreement with results of thermal spike model. With increasing fluence to 2×10^{12} cm^{-2} latent tracks in Y2Ti2O7 began overlapping and oxide particles become amorphous. Post-irradiation annealing of irradiated ODS steels has no effect on amorphous structure of Y2Ti2O7 particles.

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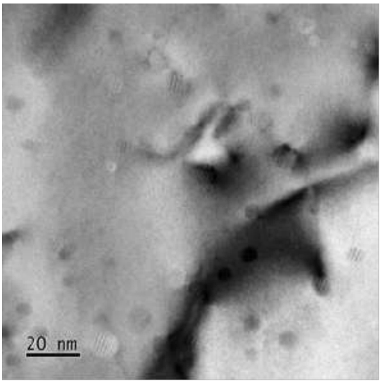
Previous results [8] show that YAM particles are more stable than Y2Ti2O7 oxides under SHI irradiation: no latent tracks can be observed in the oxides and the structure remains crystalline that is confirmed by the presence of moire contrast at HRTEM image (Fig. 2, left). With increasing fluence to 10^{14} cm^{-2} YAM particles in ODS steel become amorphous. At the same time TEM observations of separated SHI-irradiated YAM particles show the presence of amorphous latent tracks in the structure (Fig 2, right). It should be noted that according to XRD analysis of the pressed YAM powder the proportion of amorphous phase is increasing with ion fluence and starting with 10^{13} cm^{-2} YAM structure is completely amorphous. Difference in obtained results may be due to the more effective heat transfer in case of ODS steel in comparison with individual oxide particles.



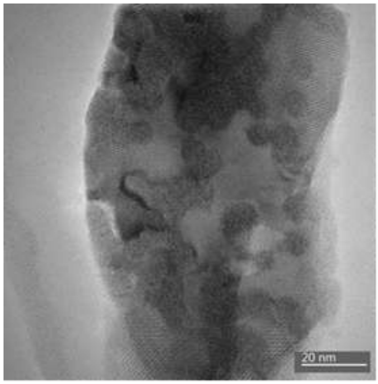


Fig.2 HRTEM image of KP4 ODS steel irradiated with 1×10^{12} cm^{-2} of 167 MeV Xe ions (left) and HRTEM image of separated YAM particle irradiated with 1×10^{12} cm^{-2} of 220 MeV Xe ions (right).

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