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STRESS EVOLUTION IN NICOFECRMN AND NICOFECR HIGH ENTROPY ALLOYS IRRADIATED BY HELIUM AND KRYPTON IONS

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The operating environments envisaged for advanced nuclear reactors create significant challenges for structural materials due to a higher neutron flux, a more corrosive environment and higher operating temperatures [1]. It is therefore of interest to explore new alloy designs outside the paradigms of conventional steels, to meet these material requirements. High entropy alloys (HEAs) represent a new class of alloys that have the potential to replace conventional alloys in structural applications. Typically, they consist of four or five alloying elements in close to equiatomic concentrations. It is believed that maximizing the configuration entropy of HEAs promotes the formation of a single-phase disordered solid solution instead of the formation of complex intermetallic or second phases; as a result, the alloy has a simple microstructure with improved properties compared to traditional alloys. Numerous studies have shown that high-entropy alloys have a high elastic limit, wear, creep, and thermal and radiation resistance [2].

Multicomponent high entropy alloys NiCoFeCrMn and NiCoFeCr were synthesized using high-purity metals (>99.9%) by arc melting followed by homogenization. Then annealing was carried out for 24h and 72h at a temperature of 1150°C with cold rolling up to 85 % reduction in thickness.

Ion implantation of alloys was carried out on a DC-60 heavy ion accelerator (Nur-Sultan) separately with He (40 keV, 2×10^{17} cm^{-2}) and Kr (280 keV, 5×10^{15} cm^{-2}) ions.

The X-ray diffraction analysis showed that a single-phase solid solution with a FCC lattice is formed in all samples. The results of scanning electron microscopy and X-ray energy dispersive analysis confirm the formation of homogeneous equiatomic multicomponent solid solutions, the grain size in the NiCoFeCrMn and NiCoFeCr alloys was about 80-100 μm. It was revealed that internal stresses in the NiCoFeCrMn and NiCoFeCr alloys are tensile and are about 68 and 125 MPa, respectively.

It was found that irradiation with helium and krypton ions leads to the formation of compressive stresses. At the same time, the stress level in samples irradiated with helium (-288 and -192 MPa for NiCoFeCrMn and NiCoFeCr alloys, respectively) exceeds the values for samples irradiated with krypton ions (-17 and -6 MPa for NiCoFeCrMn and NiCoFeCr alloys, respectively).

X-ray studies of the distribution of internal stresses and dislocation density in the NiCoFeCr alloy irradiated with helium and krypton ions over depth were carried out. The studies were carried out in the geometry of a small angle of incidence of the X-ray beam using the $\sin^2\psi$ and Williamson-Hall methods. It was found that the distribution of macrostress values in the NiCoFeCr alloy has two maxima corresponding to -250 MPa at a depth of 100±25 nm and -530 MPa at a depth of 255±25 nm. The results obtained are consistent with the SRIM data. According to calculations, the maximum radiation damage (dpa) corresponds to a depth of 125 nm, and the maximum of the implanted helium peak corresponds to a depth of 164 nm. The discrepancy in depth for the second maximum is mainly due to the swelling of the alloy during helium implantation.

It was found that the increase in the dislocation density in the irradiated NiCoFeCr alloy compared to the non-irradiated alloy is 3.5×10^{12} cm^{-2} and remains constant in depth up to 150 nm, and then decreases in 3 times.

The paper discusses the mechanisms of radiation defect formation in high entropy alloys, the influence of the type of ions and radiation damage on the formation of radiation defects, and their influence on the level of internal stresses.

REFERENCES

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