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Evaluation of irradiation-induced point defects migration during neutron irradiation in modified 316 stainless steel

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For the development of nuclear core materials, especially fuel cladding tube, in sodium-cooling type fast breeder reactor, void swelling suppression is one of the most important issues to keep the dimensional stability in reactor. A large number of theoretical and experimental investigations on void swelling behavior have been carried out, and void swelling directly depends on the diffusion of point defects induced by neutron irradiation as well as the strength of point defect sinks such as dislocations and precipitates. Evaluations of the point defects diffusion in metal during neutron irradiation have been qualitatively done through various researches, however the quantitative estimation is hardly performed due to the difficulty of in-situ experiments during neutron irradiation. Instead of that, the indirect estimations from the temperature dependence measurements of dislocation loop densities and growth rates using electron in-situ observation are often carried out, but the irradiation correlation between electron and neutron irradiations, such as the differences of irradiation dose rate and damage morphology, should be discussed with accuracy.

Therefore, the evaluation of point defects diffusion, especially vacancy migration, during neutron irradiation by the other method was tried in this study. In detail, from already neutron-irradiated microstructures, vacancy migration energy was estimated using the knowledge that void denuded zone (VDZ) widths formed near random grain boundaries depend on temperatures. The test material was PNC316 steel, which is the modified 316 stainless steel with cold-working and additives to improve the void swelling resistance. The fuels assemblies composed of PNC316 steel were irradiated in the experimental fast reactor JOYO. For the PNC316 specimens cut from these assemblies, which were irradiated at temperatures from 722 K to 821 K and doses of 74.5–87.5 dpa, VDZ widths were analyzed from the transmission electron microscope observations and the temperature dependence was investigated.

As the result, VDZ widths increased with increasing temperature. From the Arrhenius plots of VDZ widths and the reciprocal temperatures, the vacancy migration energy during neutron irradiation in PNC316 steel was quantitatively estimated to be about 1.4-1.5 eV. As vacancy migration energy in Fe-Cr-Ni model alloy is about 1.05 eV, the value of PNC316 steel implies that the vacancy mobility is low as a result of interaction of vacancies with minor alloying elements.

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