Damage structure development in electron / helium ion dual irradiated austenitic steels

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The structural materials of fusion reactors are exposed to long-term high flux irradiation of 14MeV neutrons and helium atoms will be produced in the matrix by transmutation reaction. Void swelling and grain boundary brittleness are strongly influenced by helium atoms. The effects of helium on damage structure development such as phase stability, void swelling, precipitate formation and so on are not clarified in Fe-Cr based austenitic alloys. Therefore, it is important for fusion reactor materials to investigate the irradiation behavior under helium existence conditions.

In this study, SUS304 (Fe-18Cr-8Ni) and 83N(Fe-13Cr-16.5Mn-1Ni-0.26C-0.12N) specimens were investigated to clarify the effect of helium on electron irradiation damage structure using by a High Voltage Electron Microscope (JEM-ARM1300) and 300keV ion accelerator to implant helium atoms. The TEM discs with 3mm diameter were prepared and solid solution treated at 1323K for thirty minutes. Then, they were electrochemically polished to thin foil for Transmission Electron Microscope (TEM) observation.

Electron irradiations and in-situ observations were performed at 673K to dose of 5 and 10 dpa with 1250keV acceleration voltage in three different conditions such as electron single irradiation, electron and helium dual irradiation and electron irradiation after helium implantation. Electron irradiation rate was 1x10-3 dpa / sec and helium ion implantation and electron irradiation rate was 70 atppm He / dpa. In the case of electron irradiation after helium injection, 350 atppm He atoms were pre-implanted

into matrix. After irradiation, damage structures of the specimens were examined using by JEM-2000FX TEM. Energy Dispersive Spectroscopy (EDS) analysis was employed to identify the grain boundary segregation.

After irradiations, cavities were formed in all specimens. The void number density was very high in He pre-injected and He / electron dual irradiated specimens compared to electron single irradiation. From these results, He atoms enhanced cavity nucleation. Very small cavities, ranging in 1-3 nm, were recognized in 83N (Fe-Cr-Mn) alloys. The damage structure developments in SUS304 (Fe-Cr-Ni) was different from those in 83N (Fe-Cr-Mn) specimens under He atom existence. Grain boundary segregation such as Ni enrichment and Cr depletion was recognized in all specimens. The amount of segregation in He injected specimens were lower than those in electron single irradiated specimens.