§18. Experimental Study of Atomistic Process of Evaporation and Re-accumulation of Diverter and First Wall of Fusion Reactor

Shimomura, Y., Mukouda I., Sugio, K. (Faculty of Engineering, Hiroshima University)

On an environment of fusion reactor operation a diverter suffer intense gas ion irradiation such as helium and hydrogen and also 14MeV DT-neutron irradiation. In the present work, we examined experimentally damage evolution under simultaneous irradiation of self-metal ion and gas atom ion (Hydrogen and helium atom). During the formation of defects metal atoms which constitutes of diverter surface evaporate by sputtering an atom or direct removable of nano-partcles. These processes are very sensitive on a damage structure near surface of diverter. In the present work, experiments were carried out to study the evolution of damage structure at diverter surface of copper and nickel, which were annealed at high temperature before an irradiation.

Multi-ion irradiation was carried out by 5MeV metal ions, 500 keV H^+ and 600 keV He^+ ions. Specimen temperature was kept constant, which ranges from 300°C to 600°C during an irradiation. Damages form in a limited region near specimen surface. The depth of damage region is within a few microns from surface. We developed the method of specimen preparation with focused ion beam device (FIB) [1] to observe the depth dependence of defect structure by electron microscopy. At first a copper film was electro-plated on ion-entrance surface of irradiated specimens and then specimen was cut with FIB as shown in Fig. 1 by 30 keV Ga ion illumination. During a FIB thinning a Frenkel defect of interstitial-vacancy pair form near surface. Interstitial atoms aggregate to form their clusters which are visible by TEM observation. To eliminate damage formation due to 30 keV Ga^+ glancing illumination along surface, specimens were cooled down to 130 K during FIB thinning. At low temperature the formation of interstitial cluster occurs only within several hundreds nm thickness from surface. After a preparation of specimen, FIB damaged region was removed by electro-polishing. We could observe successively defects which were formed by multi-ion irradiation. Fig. 2 shows an example of defects by TEM observation of multi-ion irradiated copper. Specimens were irradiated to 50 dpa and 300 appm/dpa of helium and hydrogen contents. It can be summarized the present results as follows [2]:

(1) In single metal-ion irradiated Cu, voids formed above 500°C while they form in neutron-irradiated copper above 180°C. Difference of void formation in copper between neutron-irradiation and ion-irradiation was explained due to the different damage formation rate [3].
(2) A large number of voids was observed in dual-ion beam irradiated copper of self metal-ion and helium atom. Helium atoms are very effective on nucleation of voids in copper.
(3) Any void was not observed in dual-ion irradiated copper of metal-ion and hydrogen below the temperature of 500°C. Many voids were observed in dual beam irradiated copper at 600°C, while the number density of void in single metal-ion irradiated copper was very small. This means that hydrogen can nucleate heterogeneously voids in copper at 600°C.
(4) Simultaneous triple ion beam irradiation of self metal-ion, hydrogen and helium was carried out. The number density of voids increased than that of dual-beam irradiation.
(5) Computer simulation of molecular dynamics shows that helium atoms form their clusters in vacancy cluster in Cu while hydrogen stay in vacancy cluster as isolated dispersed state.

Reference

[1] I. Mukouda, Y. Shimomura, T. Iiyama Y. Katano, D. Yamaki, T. Nakazawa and K. Noda, Mat. Res. Soc. Symp. Proc. Vol. 540 (1999) 549-554.
[2] I. Mukouda and Y. Shimomura. J. Nucl. Maret. (2000) in press.
[3] Y. Shimomura and I. Mukouda, Mat. Res. Soc. Symp. Proc. Vol. 540 (1999) 527-532.