§27. Bubble Formation in Tungsten Material under Helium Plasma Irradiation by Binarycollision-approximation-based Simulation

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Tungsten material is planning to employ for divertor plates in ITER (International Thermonuclear Experimental Reactor). Because the divertor plates directly contacts with energetic plasmas, the erosion of the surface of the divertor plates is inevitable. Some changes of the characteristics as plasma facing material are caused by the erosion. Therefore, it is necessary to reveal the change of the characteristics to design the divertor system. Many experimental studies reported bubble formation on the surface of tungsten materials under helium plasma irradiation in wide range of incident energy[1-4]. Helium ash is generated when nuclear fusion between deuterium and tritium is caused. Therefore, the bubble formation might be observed on the divertor plates in ITER. In this study, therefore, binary-collision-approximation-based (BCA) simulation is performed for the investigation of effect of bubble growth in the tungsten material under helium plasma irradiation.

Tungsten atoms are initially arranged as perfect bcc crystalline structure. The lattice constant is set to 3.2046 Å. The size of target material is set to 80.11 Å × 6.41 Å × 8011.5 Å. The *z*-axis of the simulation box is set parallel to the edge of the target material whose length is 8011.5 Å. Periodic boundary conditions are used in *x*- and *y*-directions. The temperature of the target material is set to 0 K. The threshold of displacement energy of tungsten atom is set to 38 eV. The incident energy is set to 1000 eV. A total of 10,000 helium atoms are injected one by one into the target material. The incident angle is set to parallel to *z*-axis, i.e., perpendicular to (100) surface of bcc crystal. The *x*- and *y*-coordinates of the starting position of the helium atom are set randomly. The *z*-coordinate of the starting position is set 100 Å above the surface of the target material. "Cumulative simulation" is employed to take into account the structural changes of the target material and accumulation of helium atoms by injection. The calculation of structural relaxation of the target material is performed every 1000 injections. For the calculation of the relaxation, a tungsten-helium potential[5] is employed.

Figure 1 shows the time evolution of the target material. Red and black dots show the positions of tungsten and helium atoms, respectively. The bubble formation is observed. The bubbles are spread over a wider range in the target material. First, the target material expands and its surface moves in the +*z*-direction as the bubble grows until the surface exfoliates. Figure 2 shows the time evolution of the sputtering yield of tungsten atoms. From the virgin (perfect bcc crystal) value, sputtering yield increases as fluence increases because the crystalline structure is destroyed. The sputtering yield for the tungsten material of amorphous structure that does not contain helium atoms is 0.0058. The sputtering yield of bubble formed tungsten is approximately 20% less than that of the amorphous case because of the existence of helium bubbles.

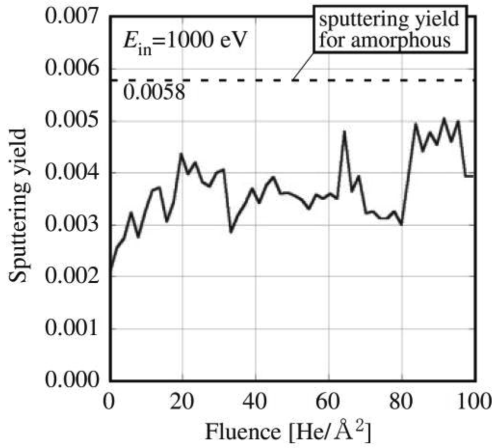

Fig. 2 Time evolution of sputtering yield. [6]

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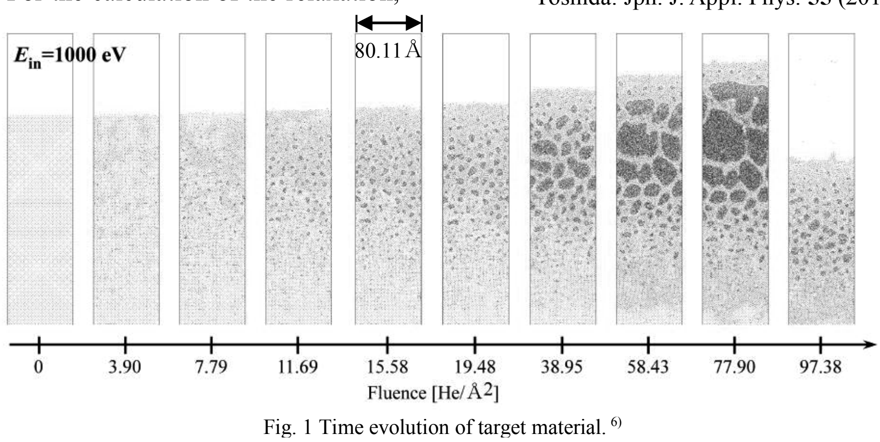

Fig. 1 Time evolution of target material. [6]