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ヘリウム照射によるタングステン表面構造変化の照射量依存性

Simulation Study on Time Evolution of Tungsten Surface under Helium ion Irradiation

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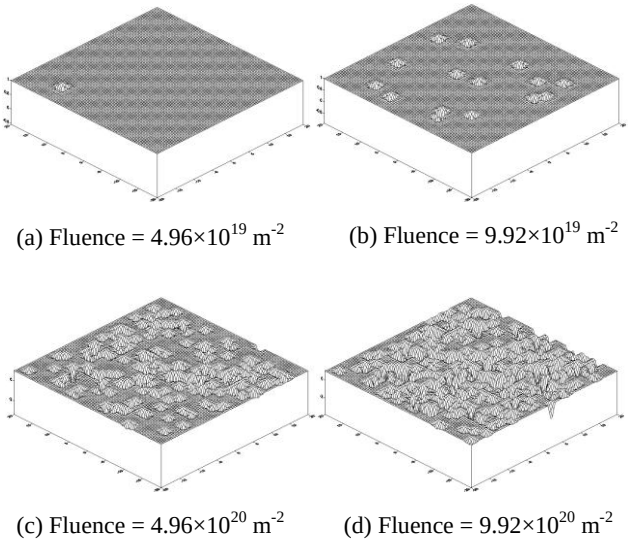
Tungsten has been selected as a candidate material of the ITER divertor plates because of its high melting temperature, good thermal conductivity and highly resistive nature against erosion due to high threshold energy for sputtering. Divertor plates in a fusion device are exposed to high intensity heat fluxes of energetic particles.

The formation of nanostructure “fuzz” at tungsten surface due to helium plasma irradiation has been observed in recent experiments [1,2]. The formation of the fuzz at tungsten surface leads to the change in effective thermal conductivity and effective particle/energy reflection coefficients of tungsten. These properties relevant to hydrogen isotope retention on tungsten are also expected to change by the fuzzy nanostructure formation. The fundamental processes of the fuzzy nanostructure formation, however, have not been clarified yet.

A Monte Carlo simulation code, ACAT [3] (Atomic Collision in Amorphous Target), have been used to calculate the modification of surface structure of a target material. So far, the ACAT code has treated that the surface of the target material forms a completely flat boundary, and the modification of the material proceeds homogeneously. As the surface of a plasma facing material should be modified due to energetic particle bombardments, the ACAT code has been being revised so as to calculate the inhomogeneous development of the modification of the surface structure due to energetic ion bombardment. The target material is divided into unit cells for calculation of collision cascades, and the positions of the vacant cells formed by ejection process are integrated to calculate the surface geometrical structure. The modifications of the surface structure of tungsten have been calculated with the revised ACAT code.

Figures 1 (a), (b), (c), (d) show the change in surface structure of a tungsten material depending upon fluences of 100 eV helium ion bombardments at normal incidence. The results indicate inhomogeneous development of pits forming a pattern on the surface at around 4.96×10^{20} m^{-2}.



(a) Fluence = 4.96×10^{19} m^{-2} (b) Fluence = 9.92×10^{19} m^{-2}

(c) Fluence = 4.96×10^{20} m^{-2} (d) Fluence = 9.92×10^{20} m^{-2}

Figure 1. Developments of the modification of tungsten surface structure due to 100 eV helium ion bombardments at normal incidence. Heilum ion fluence of (a); 4.96×1019 m^{-2}, (b); 9.92×10^{19} m^{-2}, (c); 4.96×10^{20} m^{-2}, and (d); 9.92×10^{20} m^{-2}.

We have also performed the case where the initial positions of target atoms in unit cells are changed for the above mentioned calculations by using the different set of random numbers in the ACAT calculations. Even though the distributions of target atoms are different, the surface structures have shown similar patterns. The results have indicated that the change of the surface structure does not depend strongly upon the initial condition of a target material. However, the erosion pattern may become sensitive to the initial conditions if one assumes a large difference like the non-uniform distribution of defects initially present in the target material.

References

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