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Influence of crystal orientation on damages of tungsten exposed to helium plasma
ヘリウムプラズマ照射によるタングステンの損傷に結晶方位の与える影響

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To figure out the mechanism of the morphology change of tungsten (W), which is the candidate material for divertor in ITER, we investigated the influence of crystal orientation on damages of tungsten exposed to helium plasma. ITER grade W was used for the specimens. The specimens were polished to mirror finish and heated by electron for crystal growth. After helium plasma exposure, the surface of specimens was analyzed by scanning electron microscope and orientation imaging microscopy. The difference in the surface morphology was observed on different crystal grains. The regular wavy structure and helium bubbles were observed on grains of {001}, {101}, {111} surface, but there is little change and helium bubbles on the grain of {102} surface. It is thought that the area density of grains is important to the surface morphology change of tungsten.

1. Introduction

Because divertor in ITER is exposed to high heat and particle load, material for divertor needs to have high thermal property and low sputtering yield. From those point of view, tungsten is regarded on one of the candidate material for divertor in ITER [1,2].

However, by helium plasma irradiation, it has been observed that helium bubbles, holes and fiberform nanostructure are formed on the tungsten surface even when the incident ion energy was less than the threshold energy of sputtering [3,4]. It is likely that these surface morphologies lead to the reduction of the durability to particle and heat load [5,6].

Recently, the difference in surface morphology change was observed on different crystal grains [7]. It is speculated that the difference in the helium induced structure can be attributed to the difference in the orientation of crystal structure.

In this study, we will report that influence of crystal orientation on damages of tungsten exposed to helium plasma, which including bubbles, holes, and fiberform nanostructure.

2. Experiment

ITER grade W was used for the specimens. The specimens were polished to mirror finish and heated by electron bombardment in plasma for crystal growth so that crystal grains grew about 100μm. Helium plasma irradiation to the specimens was conducted in the linear divertor plasma simulator NAGDIS-II [8]. The surface temperature of the specimens was measured with a radiation pyrometer. After helium plasma irradiation, the surface of specimens was analyzed by scanning electron microscopy (SEM), and crystal orientation was analyzed by orientation imaging microscopy

(OIM).

3. Results and discussion

Figure 1 shows the ITER grade W exposed to helium plasma at the surface temperature of 1700 K, and the incident ion energy and fluence were 25 eV and 5.3×10^{26} m^{-2} respectively. Figure 2 is expanded images of Fig. 1. We analyzed crystal grains of which the crystal orientations were {001}, {101}, {102}, and {111} surfaces of bcc crystal structure. The {101} face is the highest area density surface in bcc crystal structure.

As shown in Fig. 2, the difference in the surface morphology was observed on different crystal grains. The regular wavy structure and helium bubbles were observed on crystal grains of {001}, {101}, and {111} surface, and the size of wavy structures were different at different crystal orientations. However, there are little change and few helium bubbles on the {102} surface.

These differences show that crystal orientation has an effect on helium bubbles and the density of crystal face may be important because the formation of helium bubbles is originated with the interaction between the thermal vacancies and helium atoms. Moreover, the results indicate that it is more difficult to form the helium bubbles when the density of crystal face is lower. The area density of {102} face is lower than the other, it may be harder for defects to be migrated. Therefore less helium bubbles were observed on {102} surface than the other surfaces. On the other hand, since {001}, {101}, and {111} surfaces have higher area density of crystal face, the defects could be easily migrated, and, consequently, more helium bubbles were formed compared with {102} surface.

{101} face is slip face which has the highest area density face in bcc crystal structure, and binding energy of tungsten atoms in this face is stronger than that of the other faces. Taking account of this, the pressure from helium bubbles in specimen increases. Consequently, {101} face may be moved in the slip direction and the wavy structure is formed. Thus, it is speculated that this regularity of the wavy structure is associated with the angle between {101} face and surface of crystal grain.

4. Conclusions

The difference in the tungsten surface morphology was observed on different crystal grains exposed to helium plasma. Concerning the relationship between helium bubbles and crystal orientation, the density of crystal face seems to be important. The surface morphology change is likely to relate to formation process of fiberform nanostructure. So we will research the relationship between regularity of direction on wavy structure and crystal orientation.

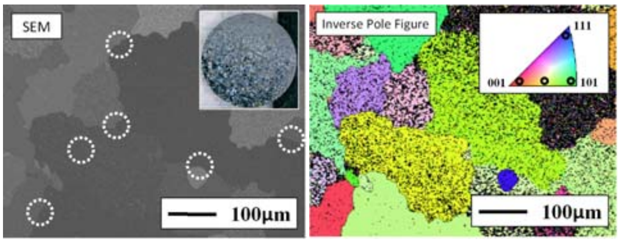

Fig.1. SEM and OIM images of helium irradiated ITER grade W

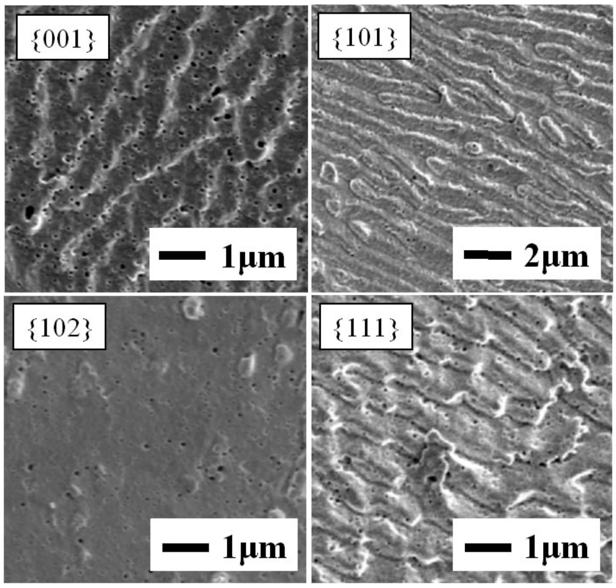

Fig.2. SEM images of grains in helium irradiated ITER grade W

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