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The Orientation Dependence of Surface Damage in He Ion Irradiated Mirror Materials

ヘリウムイオン照射したミラー材料における表面損傷の結晶方位依存性

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The crystal orientation dependence on a surface damage in molybdenum mirror is investigated under the irradiation with 3 keV helium ions to a fluence of 10^{21} ions/m^2. A strong correlation between the surface roughening and the grain orientation was confirmed from SEM-EBSD analysis. It was found that significant surface roughening including crater-like depressions is formed on grains with the direction close to <001>, while relatively smooth surface remains on grains with the other directions. The grains which stay smooth surface under the irradiation show rather large erosion than the strongly roughened grains.

1. Introduction

In an optical diagnostics system using first mirrors, the degradation of reflectivity due to interactions between plasmas and mirror surfaces are becoming a problem regarding reliability and long term usefulness of the system [1,2]. Therefore the reflectivity behaviors for some mirror materials have been extensively investigated using ion beams [3,4], fast neutrons [5] and plasma confinement devices [6,7].

In our recent study, we reported that the level of degradation of the optical properties of a single crystal molybdenum (Mo) mirror with a certain orientation irradiated with low energy helium ions is considerably lower than that of polycrystalline Mo mirrors [8]. This indicates that the crystal orientation of the mirror should significantly affect the optical reflectivity. In this study, the orientation dependence of a surface damage in helium ion irradiated Mo mirror is investigated.

2. Experimental

The specimens used in the present study were 99.95% nominal purity polycrystalline Mo supplied by Nilaco Corp. After the vacuum annealing at ~1900K for 10 min. to facilitate recrystallization, the samples were cut into sheets of a size of 10×10×1.0 mm^3 and then mechanically mirror-polished with alumina powder.

Before the irradiation, the crystal orientation on the sample surface was analyzed using SEM-EBSD (HITACHI S-3100H) to avoid uncertainty in the orientation analysis of radiation damaged samples. The subsequent irradiation was carried out with 3 keV-He^+ ions to a fluence of 1×10^{22} He/m^2. After the irradiation, surface morphology was examined considering its crystal orientation.

3. Results and discussion

Figure 1 shows a low magnification SEM image of Mo irradiated with 3 keV-He^+ to a fluence of 1×10^{22} He/m^2. Some grains still have smooth surfaces, while other surfaces are strongly roughened by the irradiation. The clear dependence of the surface roughening on the grain orientation was confirmed from EBSD analysis. Figure 2 shows typical morphologies observed in each grain with a specific crystal orientation in the irradiated Mo, and the corresponding stereographic triangle. Here, the orientations are exhibited along the normal direction to the sample surface in the triangle. It is evident from this figure that significant surface roughening including crater-like

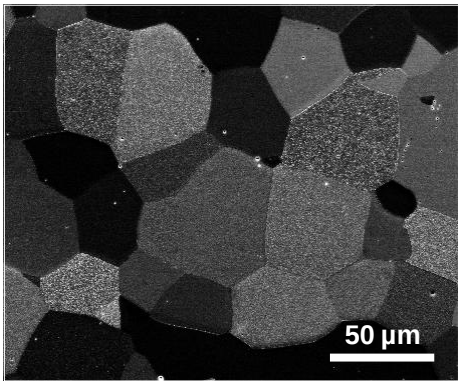

Fig. 1. Low magnification SEM image of re-crystallized Mo irradiated with 3 keV-He^+ ions to a fluence of 1×10^{22} He/m^2.

depressions is formed on grains with the direction close to <001>, while relatively smooth surface remains on grains with the other directions. Figure 3 shows high magnification SEM images of the surface on the grains with the direction close to (a) <001> and (b) <011> in the irradiated Mo. Complex surface textures shown in Fig. 3 (a) seem to be caused due to localized flaking and nonuniform erosion. On the other hand, very fine asperous surface with tiny holes which should be traces of helium bubbles is uniformly observed in Fig. 3 (b). From the surveillance of scratches which was created during the sample polishing procedure (not shown in the figures), it is confirmed that the grains remaining in smooth surface under the irradiation show rather large erosion depth than the strongly roughened grains. This means that the grain of the orientation with a high sputtering yield shows the high smooth surface under the irradiation. The several possible mechanisms of the dependence of the crystal orientation on the surface roughness will be discussed in the poster.

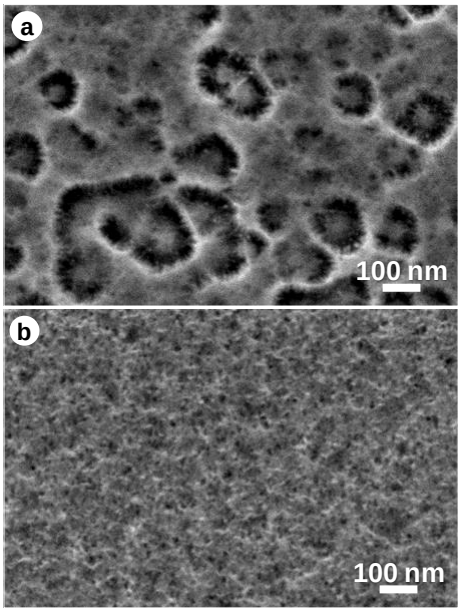

Fig. 3. High magnification SEM images of the surface on the grains with the direction close to (a) <001> and (b) <110> in Mo irradiated with 3 keV-He^+ ions to a fluence of 1×10^{22} He/m^2.

4. Summary

The dependence of the orientation on the surface damage in Mo mirror is investigated under the 3 keV-He^+ irradiation. As results of SEM-EBSD analysis, it was found that significant surface roughening including crater-like depressions is formed on grains with the direction close to <001>, while relatively smooth surface remains on grains with the other directions. The grain of the orientation with a high sputtering yield shows the high smooth surface under the irradiation.

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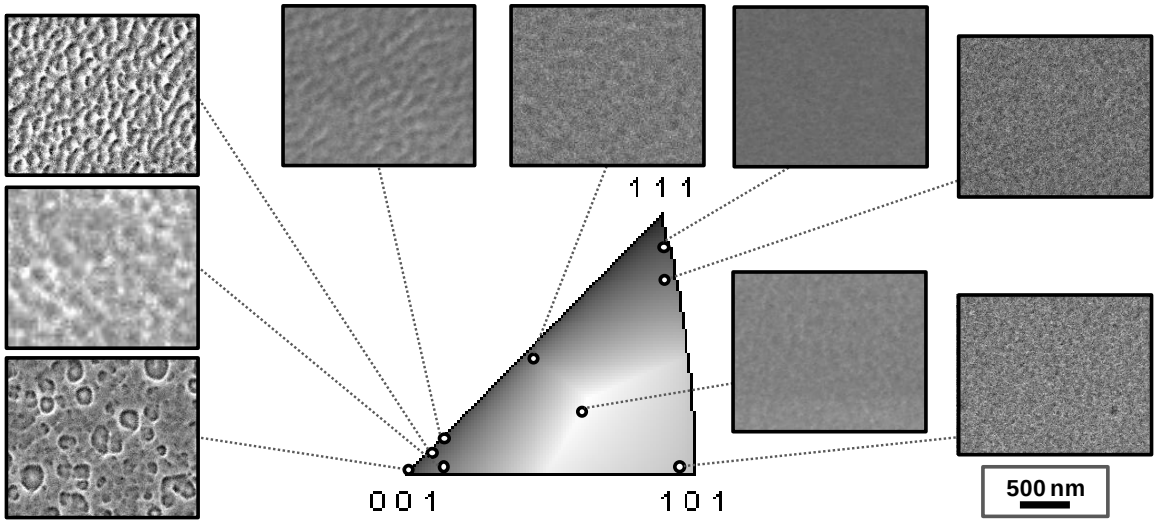

Fig. 2. Typical morphologies observed in each grain with a specific crystal orientation in Mo irradiated with 3 keV-He^+ ions to a fluence of 1×10^{22} He/m^2. The orientations are exhibited along the normal direction to the sample surface in the stereographic triangle.