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Characteristics of helium induced nano-structure on several refractory metals
種々の高融点金属におけるヘリウム誘起ナノ構造の形成

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Tungsten (W), Molybdenum (Mo) and Several refractory metals (Tantalum, Platinum) were exposed with low incident energy (100-250eV) and high irradiation flux (~10^{21} $m^{-2}s^{-1}$) and fluence (~$10^{25}m^{-2}$) of helium (He) ion bombardment at various specimen temperatures (300-700℃). He irradiations caused nano-scale morphology changes on the surface, e.g. Hebubble and nano-structures (fuzz) and its changes are influenced by the irradiation temperature. The Changes were observed by SEM and He trapping states were investigated by thermal desorption spectroscopy (TDS) compared with Surface Changes.

1. Introduction

Tungsten (W) is planned to be used in divertor region of fusion reactors because of its low sputtering yields and high melting point [1]. In recent research, W nano-structure (fuzz) was observed under long-time exposure of low-energy helium (He) ion bombardment. Since the structure is fragile and has low thermal conductivity. They are considered to be avoided under fusion divertor environments. In order to control the fuzz formation, it is necessary to understand the formation mechanism, however, which has not fully been understood yet.

To clarify the mechanism, relations between nano-scale surface changes and surrounding temperature have been investigated by controlling specimen temperature. In addition, to understand He roles on the fuzz stability, relations between characteristics of He thermal release and morphology changes of fuzzy surfaces have been investigated by using thermal desorption spectroscopy (TDS) and an electron microscope. In addition, we compare these results for different metals such as W, Mo and 6th group refractory metals.

2. Experiments

To make nano-scale morphology changes on each refractory metals, high density He plasmas are produced by electron cyclotron resonance (ECR) discharge by 2.45 GHz microwave. The specimens are exposed high He ion flux ~$10^{21}m^{-2}s^{-1}$ for 3-4 hours with the fluence of ~10^{25} m^{-2}. The specimen's holder is biased negatively to accelerate He ions to the energies of 100-250eV. The specimen's irradiation temperature is between about one fifth melting temperature (Tm) and about one third Tm in each metal. Following the observation about fuzz induced on the Surface, He desorption spectrum were obtained by TDS up to 1300 K with a temperature ramping rate of 0.1 K/s. Surface morphology changes of annealed specimens are also observed by SEM in comparison to the preceding specimen surfaces.

3. Results

As a result of the He irradiation, nano-scale morphology changes were occurred at elevated temperatures. Above one fourth of Tm, W, Mo and Platinum start to change its surface morphologies in a nano-scale range, many pinholes were observed on the surface. Fuzz was certainly observed above one third of Tm. However, in four metals (W, Mo, Tantalum and Platinum), Tantalum is the most difficult to form fuzz.

From desorption spectrums of both W and Mo with fuzzy surfaces, it was found that main peaks of He release appeared at the same temperature region (1050 K~1100 K), though the melting temperatures of Mo and W are different by about 20% (of the W melting temperature (3695 K)). Since the same He peaks were also observed for He irradiated specimens without the fuzz (He plasma irradiation at lower temperatures), He release characteristics are partly similar for the fuzz and the bulk (probably release from He bubbles).

W and Mo fuzz specimens heated to 950K (before the peak) did not show any changes in the fuzz. On the other hand, Mo fuzz completely disappeared by heating to 1300 K, while W fuzz still remained (but somewhat shrunk) at 1300 K. Therefore, He release around the peak of 1050 K~1100 K seems closely related to the stability of the fuzz especially for Mo. For W, probably more high temperature stages of He release could be present with regard to the stability of the fuzz.

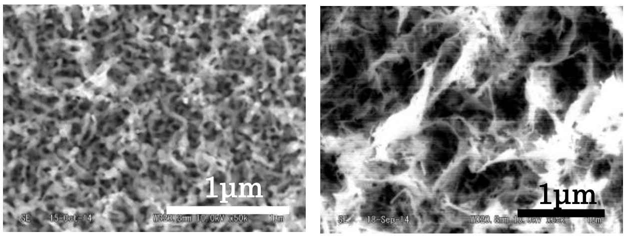

Fig.1. Nanostructures on a molybdenum surface (left) and a platinum surface (right)

References

[1] M.J. Baldwin, R.P. Doener: Journal of Nuclear Materials 404 (2010) 165–173.