§18. In-situ Observation of the Formation Behavior of the Fuzz Structure on Tungsten

Miyamoto, M., Iijima, N., Nagashima, H. (Shimane Univ.), Tokitani, M.

Tungsten (W) nano-structures, so called fuzz, induced by He plasma exposure, have been observed in linear plasma devices [1-2] and in a tokamak environment of Alcator C-Mod [3]. Recently, its formation and growth conditions have been identified, and both positive and negative aspects of fuzz as a plasma-facing surface have been revealed. In our previous work, in-situ TEM observations during He^+ ion irradiation and annealing were conducted using with pre-thinned W samples to investigate the formation process [4]. It was revealed that fuzzy structures can be formed at a very thin part even without helium bubbles, if the sample temperature is high enough. In this study, the formation processes in several metals such as Mo, Ti and Al are compared to examine the formation mechanisms of fuzz in more detail.

The samples used in this study were 99.95 % nominal purity W, Mo, Ti and Al supplied by Nilaco Corp. After the vacuum annealing, thinned samples were prepared by electrochemical polishing for TEM observations. In-situ observations were carried out with JEOL-JEM2010 equipped with a low energy ion gun. For sample annealing in the TEM, a furnace type sample holder with a temperature control function, Gatan-model 628, was used. The microstructural evolution during the annealing and/or the irradiation was recorded continuously with a video recording system. The samples were irradiated with 3 keV He^+ ions of the flux of the order of 10^{17} He^+ $m^{-2}s^{-1}$ at R.T., and then annealed to ~1473 K.

Fig. 1 shows the microstructural evolution of each samples after the 3 keV-He^+ irradiation at room temperature and annealing to the prescribed temperature shown in the figure. For every irradiated samples, fine and high density helium bubbles were observed. Due to the post-annealing, fuzzy structures appeared in Mo and Ti as well as in W [4]. For these samples, it was revealed that fuzzy structures form at around the recrystallization temperature of each metals as shown in Fig. 2. Especially for Ti, the shrinking of the fuzzy structure and the recovery were also observed during the annealing at higher temperature. If the enough high temperature could be obtained, the recovery seems to occur even in Mo and W. On the other hand, the fuzzy structure was not observed in Au. The thinned part of the sample edge showed only retreat with keeping the smooth shape.

These findings demonstrate that fuzzy structures can be formed in not only W but also other metals, if the sample temperature is high enough. These structural changes are probably dominated by surface diffusion driven by surface tension, and an adequate viscosity is required. Future further work using with various materials seems to provide the correlation between the fuzzy structure forming condition and the physical property value of materials. Since the samples used in this study are limited to the thinned foils due to the experimental method, one also should pay careful attention to the difference in phenomena observed in bulk materials.

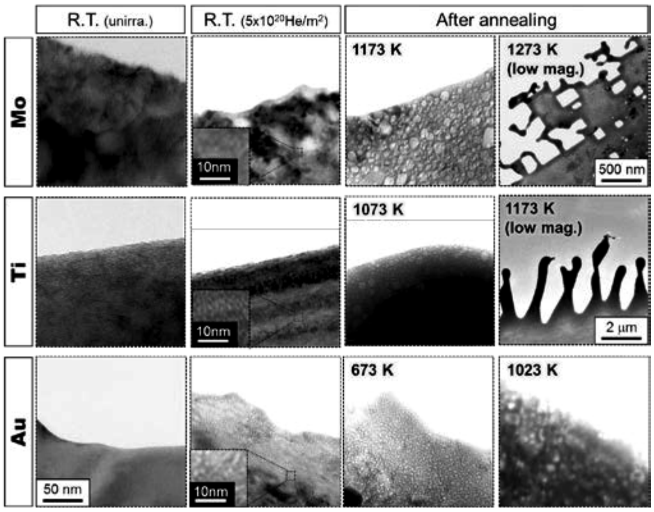

Fig. 1. The microstructural evolution in Mo, Ti and Au under the 3 keV-He^+ irradiation at room temperature and annealing to the prescribed temperature shown in the figure.

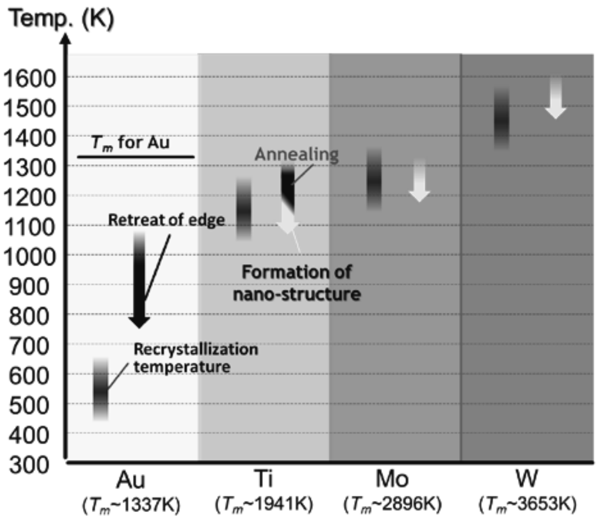

Fig. 2. The temperature regions producing the microstructural evolution of the edge parts in Au, Ti, Mo and W.

1) Takamura, S. et al., Plasma Fusion Res. **1** (2006) 051.
2) Baldwin, M.J. et al., Nucl. Fusion **48** (2008) 035001.
3) Wright, G.M. et al., Nucl. Fusion **52** (2012) 042003.
4) Miyamoto, M. et al., Phys. Scr., T **159** (2014) 014028.