Recovery of Tungsten Surface with Fiber-Form Nanostructure by the Argon Plasma Irradiation at a High Surface Temperature

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One of the serious concerns for tungsten materials in fusion devices is the radiation defects caused by helium plasma irradiation, while the helium is one of fusion products. Fiber-formed nanostructure is worried to have a possible weakness against the plasma heat flux and may destroy the reflectivity as an optical mirror. In this communication an interesting method for a recovery of such a tungsten surface is shown.

Keywords: plasma-facing material, tungsten surface, nanostructure, recovery of surface flatness, helium defect, argon plasma

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Tungsten material is very important in terms of plasma-facing component in fusion devices. Helium defects are the strong concerns when employing the tungsten for the divertor target and/or the first wall, and also optical mirrors set inside the vacuum chamber since the helium is the fusion product. Recently the nano fiber-form structure has been identified on a variety of tungsten surface irradiated by helium or helium/deuterium mixture plasmas [1,2].

The surface characteristics of thus formed tungsten plate would change compared with the flat non-damaged surface, especially the heat conduction [3]. The damaged surface could be thought to have a weakness against the plasma heat flux. Therefore, a diminution of many nanofibers would be very favorable for protecting the tungsten surface from a possible melting. Figure 1 shows top-views of typical damaged tungsten surface images obtained with FE-SEM, fiber-form nanostructured tungsten surface due to helium plasma irradiation with the ion energy of 53 eV, its fluence of 7×10^{25} m^{-2} and the starting surface temperature of 1420 K. The tungsten is made with cold-worked powder metallurgy. The helium plasma condition in AIT-PID (Aichi Institute of Technology - Plasma Irradiation Device) is similar to that in the previous report [4].

The experiment of temperature excursion in helium plasma [5] has shown a shortening and a fattening of originally long and thin nano fibers when the surface temperature increases up to 1600 K for a few minutes. However, the holes and bubbles [6, 7] are newly created or survived so that a surface roughness may not be removed when the incident helium ion energy is larger than 6 eV.

After almost two hours irradiation of helium plasma in AIT-PID, the target with a complete black in color was immersed in a high heat flux argon plasma with the plasma density of 2.4×10^{18} m^{-3}, the electron temperature of 5 eV and the ion fluence of 6×10^{24} m^{-2} in the same AIT-PID. The damage from argon ions on the tungsten surface would be small since any apparent morphological change has not

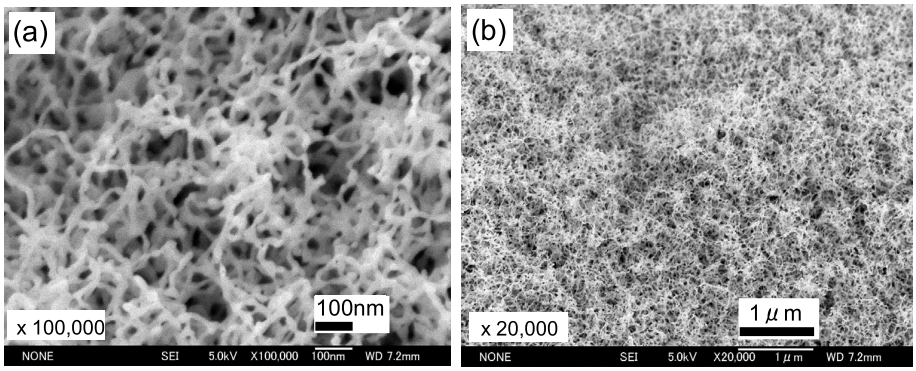

Fig. 1 Fiber-form nanostructured tungsten surface due to helium plasma bombardment with the ion energy of 53 eV and the starting surface temperature of 1420 K.

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been detected on the surface in pure argon plasma irradiation. The history of apparent surface temperature is shown in Fig. 2 where the sheath voltage is adjusted 7 V corresponding to the incident ion energy of singly ionized argon ions. A spontaneous temperature increase may come from a reduction of radiation emissivity. In the course of measurement it is fixed at $\varepsilon = 0.43$ for the infra-red emission of 0.9 μm. The slow temperature increase means a gradual recovery of original tungsten surface.

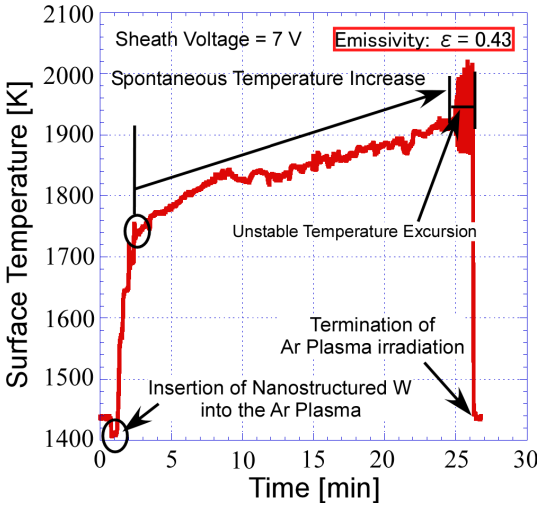

Fig. 2 Time history of apparent tungsten surface temperature on the way to recovery of surface flatness with the argon plasma irradiation. The emissivity for radiation thermometer is fixed at $\varepsilon = 0.43$.

Figure 3 shows some typical FE-SEM images after 25 minutes irradiation of argon plasma. The apparent surface has a silver like metallic white color. A substantial diminution of nano-fiber forest was obtained with some short remains of fiber roots, although we do not know any possible damages inside. On the way of recovery any serious tungsten contamination was not detected. The above procedure would be one of healing technique for tungsten surface with helium defects.

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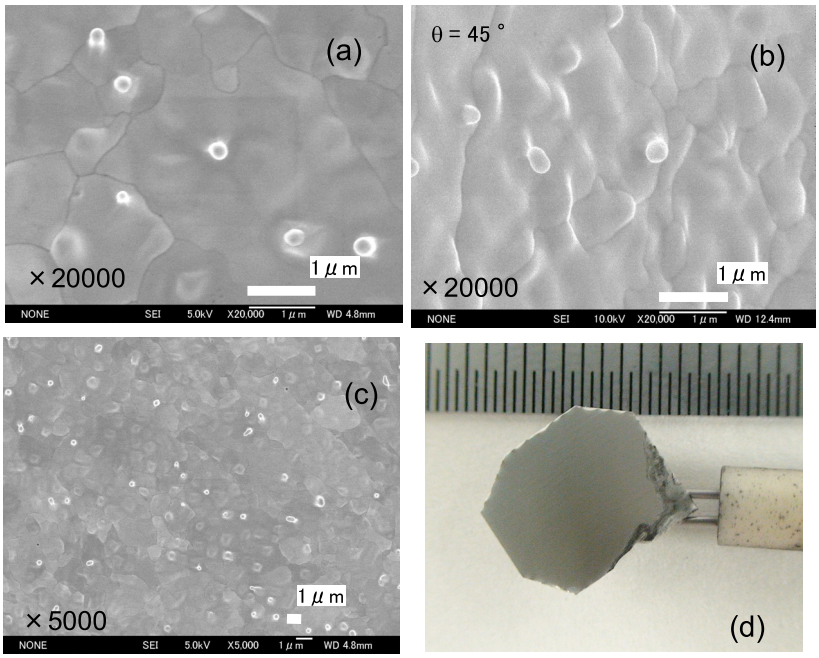

Fig. 3 Surface morphology and photo for recovered tungsten surface. (a)~(c) are obtained with FE-SEM while (b) shows a grazing view, and (d) is a photo of tungsten target with a support.