Helium Plasma Implanted Metallic Nanostructures : growth process, fractality, and its applications

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Tungsten (W) will be used for plasma facing components in future fusion devices including ITER. It has been revealed that helium (He) plasma irradiation to W leads to the formation of fiberform nanostructures on the surface when certain conditions are satisfied [1,2]. The width of fiber is approximately 10-30 nm, and the layer thickness increases in proportional to the square root of He fluence. In addition to W, the nanostructurization was identified on various metals such as molybdenum, titanium, iron, and nickel [3]. The nanostructures change various physical and optical properties: the thermal conductivity decreases, the sputtering yield decreases, the particle reflection coefficient increases, and the optical reflectance significantly decreases. Although the changes in the physical property may provide concerns for divertor material in fusion devices [4], they can have a potential to be used for application materials.

In this paper, the growth process and fractal features are discussed based on the detailed surface analysis, and the potential for the application is shown mainly as a visible light response photocatalysis. The fractal property of the nanostructures was investigated from the scanning electron microscope (SEM) micrographs, gas adsorption isotherms, and transmission electron microscope (TEM) micrographs. From the cross sectional SEM micrographs, the fractal dimension was deduced and compared with the one obtained from the adsorption; they were consistent with each other. Fractal features are identified on various aspects. Pinholes are observed on the surface when the He fluence was lower than 10^{25} m^{-2}. The numbers and the area of the pinholes on the surface have a fractal relation, similar as the craters on the moon.

Photocatalytic experiments were conducted using the nanostructured W to decolorize methylene blue. Significant decolorization occurred on the nanostructure W for visible light. The decolorization proceeded even for the light of which the wavelength was >700 nm. Although the mechanism of the process is yet to be fully understood, it is a surprising fact that the photon energy was significantly lower than the normal WO_3 band gap energy of 2.5 eV. From the experiments using various degree of oxidization from 20-100%, it was shown that the sample with 60% of the oxidization degree had the most significant photocatalytic activity. It was suggested that the boundary of W(0)-WO_3 is the active site, which is more active compared to WO_3[5].

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