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Helium plasma induced fuzzy metal: growth mechanism and its application

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Interaction between helium (He) plasma and metals lead to unique morphology change on the metal surfaces. Especially, when a certain set of conditions is satisfied, fiberform nanostructures, which is known as fuzz, is grown [1]. The width of the nanostructure is several dozen nm thick and contains many He bubbles inside. The formation of fuzz changes various physical properties such as porosity, sputtering rate, optical reflectance, thermal conductivity, and field electron emission properties. These material property changes raise concerns for the material life time in nuclear fusion reactor, because the fuzz could increase the erosion of materials. For example, in response to pulsed heat load, unipolar arcing can be triggered and release a lot of impurity as forms of atoms, ions, droplets, and dusts. On the other hand, increase in the surface area and optical absorptivity can be used for functional materials such as gas sensor and photocatalysts.

Figure 1 shows a scanning electron microscope (SEM) micrograph of nano-tendril bundles formed in a He plasma with a small amount of neon gas [2]. In pure He plasmas, fuzzy layer is less than 10 µm even if the He fluence is significantly high. However, the height of the structures identified in Fig. 1 is greater than 50 µm, suggesting that the growth process is different from that of conventional fuzz. Furthermore, with auxiliary metal deposition experiments, where fuzz growth rate increased on the orders of magnitude, and mm-thick large-scale fiberform structure (LFN) is grown on the surface. An enhance deposition by the formation of electric field around nanofibers, surface diffusion of deposition atoms, and epitaxial growth on the tip of the fibers are thought to be involved in the growth process[3]. In fusion reactor, there is a concern that prompt deposition will lead to the formation of NTB/LFNs, resulting in the enhancement of arcing and erosion rate.

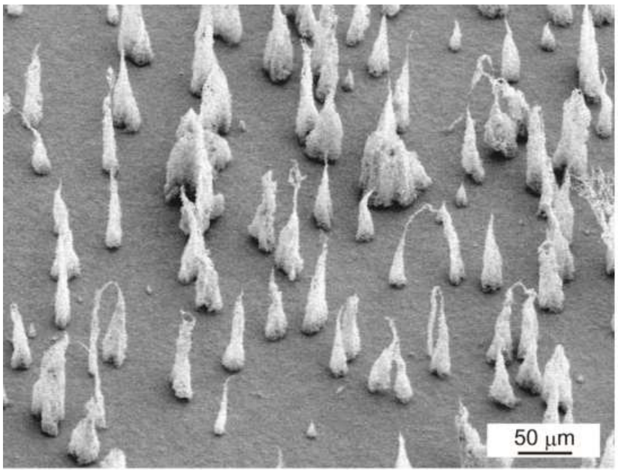

Figure 1: An SEM micrograph of nano-tendril bundles [2].

Increase in the surface area and optical absorptance/absorbance by the formation of nanostructures on the surface is beneficial for photocatalysts. Metals themselves cannot be photocatalysts; oxides of various metals such as vanadium, titanium, chromium, zin, tin, tungsten, cerium are prosperous semiconductor photocatalysts. After fuzz was identified on W, two photocatalytic reactions have been tested after oxidization: methylene blue decolorization reaction and photoelectrochemical characterization (photocurrent measurements).

Figure 2 shows linear sweep voltammetry curves under chopper incident light for different WO_3 samples. It is found that WO_3 sample from a thin fuzz layer (15 min irradiation) has higher performance than the one from thicker fuzz layer (30 min irradiation). This was because recombination occurs before the produced electrons reach the conduction layer when the thickness is too much. In addition to the increase in the surface area, the He plasma irradiation has advantages in terms of the formation of oxygen vacancy and formation of stable anatase on TiO_2.

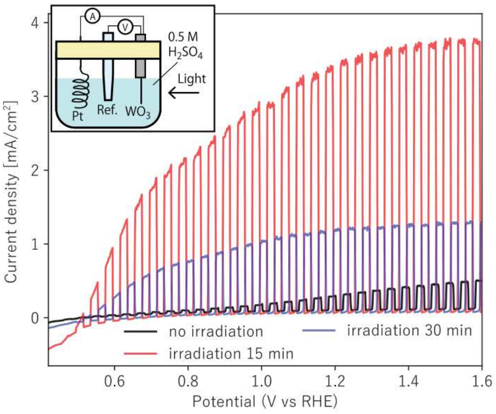

Figure 2: Linear sweep voltammetry curves under chopper incident light for different WO_3 samples [4].

References
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