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Changes of fuzzy W surface structures due to pulsed plasma bombardment using a magnetized plasma gun device

磁化プラズマガンを用いたパルスプラズマ照射による ファジーW表面構造の変化

Ikko Sakuma[1], Kyohei Shoda[1], Daiki Iwamoto[1], Yusuke Kikuchi[1], Daisuke Nishijima[2], Russ Doerner[2], Naoyuki Fukumoto[1], Masayoshi Nagata[1] and Yoshio Ueda[3]

佐久間一行[1]，生田恭平[1]，岩本大希[1]，菊池祐介[1]，西島大輔[2]，Russ Doerner[2]，福本直之[1]，永田正義[1]，上田良夫[3]

[1]*Graduate School of Engineering, University of Hyogo*
2167 Shosha, Himeji, Hyogo 671-2280, Japan
[1]兵庫県立大学 工学研究科 〒671-2280 兵庫県姫路市書写2167
[2]*Center for Energy Research, University of California at San Diego,*
9500 Gilman Dr. La Jolla, CA 92093-0417, USA
[3]*Graduate School of Engineering, Osaka University*
2-1 Yamadaoka, Suita, Osaka 565-0871, Japan
[3]大阪大学 工学研究科 〒565-0871 大阪府吹田市山田丘2-1

Response of W surfaces with He-induced nanostructures 'fuzz' to ELM-like pulsed (~0.2 ms) D and He plasma loads at surface absorbed energy density Q ~ 0.3-1.1 MJ/m^2 was investigated in a plasma gun device. It was found from weight loss measurements that ~14% of fuzz was eroded with a single D plasma shot at Q ~ 1.1 MJ/m^2. Scanning electron microscopy observations revealed that each tendril of fuzz became larger with transients. This is consistent with an increase in the surface optical reflectivity measured with a He-Ne laser at 632.8 nm.

1. Introduction

In ITER, tungsten (W), which is one of the plasma-facing materials, will be subjected to both steady-state and transient plasma loads during edge localized modes (ELMs). Modifications of W surface morphology such as blisters [1] and helium-induced nanostructures [2] can occur during steady-state plasma exposure. Thus, transient plasma loads due to ELMs will interact with W surfaces with different surface properties. We have recently started sequential exposures of W to steady-state and pulsed plasmas by using the PISCES-A linear divertor simulator at UCSD [3] and a magnetized coaxial plasma gun at Univ. of Hyogo [4]. Effects of steady-state plasma exposure on W surface cracking due to pulsed plasma bombardment were investigated [5]. In this study, response of W surfaces with helium-induced nanostructures to pulsed plasmas was explored.

2. Experimental setup

W disk samples with a diameter of 25.4 mm and a thickness of 1.5 mm, commercially supplied from A.L.M.T. Corp., were used in this study. The W samples were annealed at 1173 K for 0.5 h to relieve internal stresses, and were polished to a mirror finish.

The W samples were first exposed to steady-state He plasma in PISCES-A at sample temperature of ~1223 K to make the surface fuzzy due to He-induced W nano-structures. The thickness of the fuzzy layer was measured with a scanning electron microscope (SEM) to be ~2 μm. The W samples, pre-exposed to steady-state plasma, were then bombarded by pulsed (~0.2 ms) D and He plasmas with surface absorbed energy density Q ~ 0.3, 0.7, and 1.1 MJ/m^2.

After pulsed plasma bombardment, W surfaces were observed with an SEM. Measurements of the optical relative reflectivity of W surfaces were performed to clarify/quantify surface morphology changes. The incident angle of light from a He-Ne laser at 632.8 nm to the surface is around 20 degrees, and the reflected light is detected with a photodetector.

3. Experimental results

Firstly, no weight loss of a mirror-polished W sample was observed with a single plasma pulse. On the other hand, weight losses of fuzzy W samples after single plasma pulse were confirmed, as shown in Fig. 1. With increasing Q, the weight loss increases up to ~80 μg. Since the total mass of the fuzz with ~2 μm thickness is around 580 μg [6], ~14% of the fuzz is lost with a single D

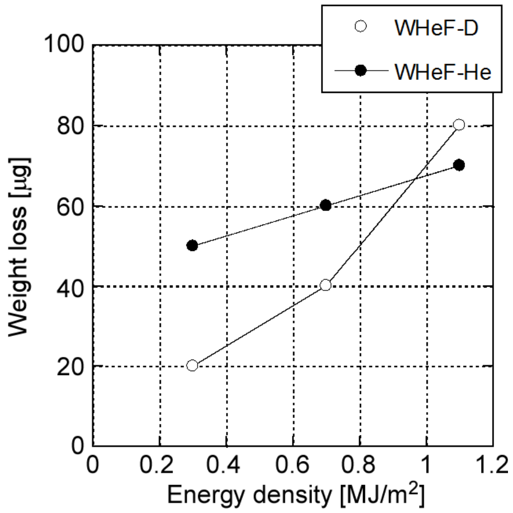

Fig. 1 Weight loss of fuzzy W samples exposed to D and He pulsed plasma loads.

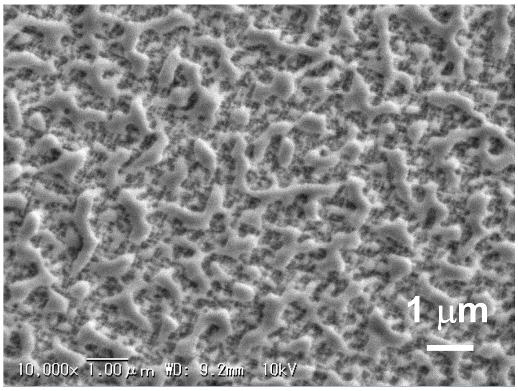

Fig. 2 SEM image of a W surface with 10 pulsed He plasma shots at Q~0.3 MJ/m^2.

plasma shot at Q ~ 1.1 MJ/m^2.

Figure 2 shows an SEM image of a fuzzy W sample exposed to 10 He plasma pulses of ~0.3 MJ/m^2. Melting of the tips of the fuzz is clearly seen. This modified structure leads to changes in optical properties of the W surface, as demonstrated in Fig. 3. The optical reflectivity of fuzzy W surfaces relative to that of a mirror-polished one is plotted against Q. The surface without pulsed plasma bombardment looks black. Accordingly, its relative reflectivity was measured to be zero within the accuracy of the measuring technique. With increasing Q, the relative reflectivity increased up to ~8%. Correspondingly, the surface looks more silver (see Fig. 4).

4. Summary

Modifications of fuzzy W surface structures

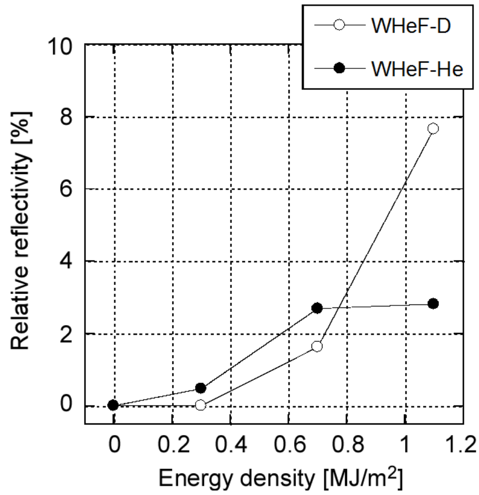

Fig. 3 Relative reflectivity of fuzzy W surfaces after pulsed plasma bombardment.

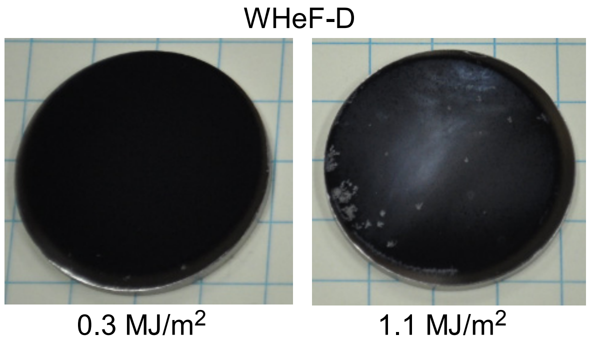

Fig. 4 Photographs of W samples with pulsed D plasma loads.

due to pulsed plasma bombardment were observed. With increasing Q, the fuzzy surface color changed from black to silver. Correspondingly, the relative optical reflectivity at 632.8 nm increased up to ~8%, and each tendril of fuzz was found from SEM observations to become larger. In addition, it was confirmed from weight loss measurements that ~14% of the fuzz was eroded with a single D plasma pulse at ~1.1 MJ/m^2.

Acknowledgments

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