Effects of Pre-Plasma Exposure on Tungsten Surface Cracking Due to ELM-like Pulsed Plasma Bombardment

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Tungsten (W), a divertor armor material in ITER, will be subjected to both steady-state and transient plasma loads. It is therefore expected that surface morphology changes and hydrogen isotope and helium retention due to steady-state plasma exposure can affect response of W to transient loads, and vice versa.

To address this issue, it is planned, under the US-Japan Joint Project TITAN, to attach a magnetized coaxial plasma gun (MCPG) [1], to mimic transient plasma loads expected for type I edge localized modes (ELMs) in ITER, to the linear divertor plasma simulator PISCES [2], which can produce a high-flux steady-state plasma. In advance of the construction, the following "off-line" experiments have been conducted. Stress-relieved, pure W samples were first exposed to deuterium (ion fluence Φ ~5x10^{25} m^{-2} at sample temperature T_s ~573 K) or helium (Φ ~5x10^{25} m^{-2} at T_s ~573 K or ~1100 K) plasma in PISCES-A. Blisters were formed on the surface of D-plasma exposed samples, while He-plasma exposed samples at ~573 K contained nano-sized He bubbles in the sub-surface region. The surface of He-plasma exposed samples at ~1100 K becomes fuzzy due to He-induced W nano-structures. The samples were then bombarded by ELM-like pulsed deuterium plasmas (~0.5 or 0.7 MJ/m^2 at ~0.5 ms) in a MCPG. Surface cracks appeared on the sample containing nano-sized He bubbles following 10 shots at ~0.5 MJ/m^2, while other samples including a sample with no pre-plasma exposure did not exhibit cracks after similar transient exposures. This implies that the energy density threshold for surface cracking is lowered by the existence of He bubbles. At a higher energy density of ~0.7 MJ/m^2, all samples except a fuzzy one exhibited surface cracking following 10 transient exposures. This discrepancy may be due to the fact that most of the incoming heat was dissipated within the fuzzy layer with a worse thermal diffusivity. As a consequence, a large thermal stress was not induced in the bulk. Effects of ELM-like pulsed plasma exposures on deuterium retention in W will be also presented.

[1] Y. Kikuchi et al., IEEE Trans. Plasma Sci. in press (2010).
[2] R.P. Doerner et al., Phys. Scr. **T111**, 75 (2004).