Reduction of Temperature Threshold for W Fuzz Growth by surface pre-treatment

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In future tokamak reactors, tungsten (W) is expected to serve as the main plasma-facing material. When subjected to helium (He) plasma—a byproduct of fusion reactions—and heated above 900 K, W surfaces can develop nanofiber-like structures known as "fuzz," which significantly degrade thermal conductivity [1]. This phenomenon has been linked to the dynamics of helium bubble formation and rupture, but the detailed mechanisms, particularly those governing growth from tens of nanometers to micrometers, are still under active study. Notably, previous research indicates a relatively stable temperature threshold for fuzz initiation [2].
Interestingly, our W thin film experiments revealed that an initially roughened surface can lower the fuzz formation temperature by about 100 K [3]. To examine the influence of surface topology, we designed a two-step process: W samples were first exposed to He plasma at temperatures exceeding 900 K to induce a rough, fuzz-like surface morphology, as shown in Fig. 1(a). Plasma irradiation then continued while the temperature was decreased to 730 K. Remarkably, as shown in Fig. 2(b), fuzz growth persisted even under the reduced thermal conditions.
Thermal desorption spectroscopy (TDS) confirmed that He ion implantation during the initial high-temperature step plays a vital role in promoting continued fuzz development at lower temperatures. To further explore this surface effect, we employed femtosecond laser treatment to selectively roughen specific regions of W, generating well-known Laser Induced Periodic Surface Structures (LIPSS), as illustrated in Fig. 1(c). Subsequent He plasma exposure was used to compare the fuzz evolution in laser-patterned versus untreated areas.

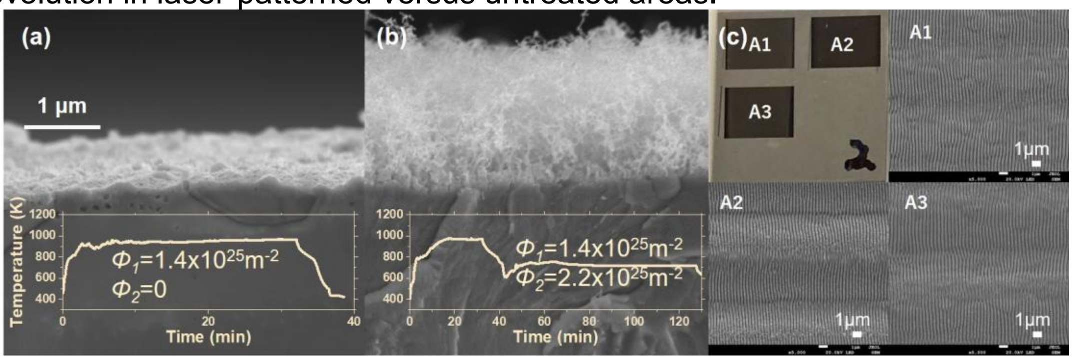

Fig. 1 SEM images of the cross-section view of W sample with the same irradiation fluences of $\Phi_1 = 1.4.\times10^{25}m^{-2}$ (a, b), and different $\Phi_2 = 0$ (a), $2.2\times10^{25}m^{-2}$. (c) Three area (A1, A2, and A3) of laser treated sample and the SEM images corresponding to different area.

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[2] G. De Temmerman et al., Plasma Phys. Control. Fusion 60 (2018) 044018.
[3] Q. Shi et al., Nucl. Mate. Energy 39 (2024) 101668.
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