Quantifying the effect of helium nano-bubble formation on tungsten recrystallization kinetics

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Recrystallization has been identified as a critical issue for the ITER divertor but currently the synergistic effects of heat and particle bombardment on tungsten recrystallization are still unclear. Certain events, such as slow transients during divertor reattachment could lead to a significant increase in the heat flux to the tungsten plasma facing armour over a time scale of seconds, thereby increasing the material surface beyond the recrystallization temperature. The process is complicated by the presence of helium ion bombardment which is known to drive bubble formation beneath the tungsten surface [1]. This is known to have a retarding effect on recrystallization which may be beneficial for ITER’s divertor operation [2]. The strength of this effect, its temperature dependence, and the impact it has on the mechanical properties of tungsten are important outstanding questions.

Here, we present a recent comprehensive study to quantify the impact helium bubble formation has on recrystallization in tungsten. Tungsten samples were exposed to helium plasma under different operating temperatures in the MAGPIE linear plasma device in order to induce helium bubble formation with different size distributions. Samples were then annealed at temperatures from 1373 K to 1673 K for 1 hour. The recovery phase of recrystallization, which precedes the nucleation of new grains, was measured by measuring microstrain broadening of X-ray Diffraction peaks, showing near-complete microstrain recovery by 1473 K independent of helium exposure conditions. More advanced stages of recrystallization were measured by quantifying grain growth of surface crystals using Electron Backscatter Detection (EBSD). Helium bubble sizes were measured directly via Grazing Incidence Small Angle X-ray Scattering, revealing a reduction in the extent of recrystallization grain growth that was greater in the presence of smaller helium bubbles. Cross-sectional EBSD analysis suggests this effect extends much deeper than the region where nano-bubbles form, indicating recrystallization may nucleate primarily near the surface and extend downward over time.