The effects of thermal history on the He plasma-material interactions of tungsten and tungsten-based refractory alloys

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The differences in He bubble formation mechanisms at 573 K (LT) and 1050 K (HT) of bulk W exposed in the Magnetised Plasma Interaction Experiment device were investigated. In-situ TEM annealing showed that visible bubbles formed at LT were stable up to annealing temperatures of 1000 K, while the bubbles formed at 1050 K were more mobile and prone to desorption[1]. Grazing-incidence small-angle X-ray scattering (GISAXS) of these samples ex-situ annealed to different temperature steps up to 998 K corroborated this finding[2]. Thermal Desorption Spectroscopy up to 1673 K suggests that desorption from the LT sample stems from leftover He interstitials, while that of the HT sample originates from larger bubbles formed. An Ostwald-ripening-like behaviour is suggested to be the root cause for the difference in post-plasma He thermodynamics. These results contribute to the fundamental knowledge of the He-plasma material interactions (PMI) with W. Hopefully, it may help improve predictions of the PMI of the components in ITER and beyond.

The experiments were repeated on magnetron sputtered W, W-5%(wt)Tantalum (Ta), W-3%(wt)Chromium (Cr) and W-5%(wt)Ta-3%(wt)Cr. Ta was selected as an alloying element due to its capability of suppressing He bubble formation, and Cr was selected for it's potential to form a self-passivating layer. SEM results show that the addition of Ta to either W or WCr suppresses the rate of grain growth due to annealing. TDS yielded similar He desorption interpretations, with the HT alloys showing more complex desorption spectra. Elastic Recoil Detection Analysis on bulk W and these sputtered samples is currently ongoing to compare the total He retained in the materials. In-situ TEM annealing and GISAXS analysis are also in progress to better understand the He bubble dynamics within the material. Finally, a Van der Pauw method has been conducted to examine the impacts of He on the resistivity of these materials as a surrogate for thermal conductivity. Characterising the PMI of these alloys helps in the search for a suitable replacement of pure W as a plasma-facing material. In addition to that, these elements are typically used in high-entropy alloy studies. The stepwise analysis of the changes in PMI from the binary alloys to the ternary alloy may help develop a better understanding of more complex alloying behaviour that may eventually lead to high-entropy effects.

1. Teo, S.H.B., et al., *Investigating the temperature dependence of helium bubble dynamics in plasma exposed tungsten via in-situ TEM annealing.* Materialia, 2024. **35**: p. 102110.
2. Teo, S.H.B., et al., *Thermal evolution of helium bubbles in tungsten by GISAXS and TDS.* Journal of Nuclear Materials, 2025. **604**: p. 155524.

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