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Comparison of Tungsten Fuzz Growth in Alcator C-Mod and Linear Plasma Devices[1]

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The growth of tungsten (W) nano-tendrils or "fuzz" is a well-known process in linear plasma devices (LPD) requiring a clean tungsten surface, elevated surface temperatures (T_{surf} = 900-2000 K), and a flux of low-energy helium ($E_{He} > 20$ eV). In a dedicated experiment on Alcator C-Mod, W fuzz was grown, for the first time, in a tokamak environment. The W fuzz was grown on a Langmuir probe in the lower divertor. During L-mode helium plasma discharges this W Langmuir probe received $q_{surf} \sim 30$ MW/m^2 and its surface temperature increased from 400 K to 2300 K. Over 14 sequential discharges, the W probe had an integrated exposure time of ∼15 s at temperatures between 900-2300 K. Focused ion beam cross-sectioning showed a 600 ± 150 nm thick tungsten fuzz layer was grown on the probe surface. The W fuzz showed no signs of uni-polar arcing and there was no nano-tendril melting or damage despite the high surface heat fluxes. Three full current (900 kA) unmitigated mid-plane plasma disruptions occurred during the discharge sequence including one on the final discharge of the experiment, but the W fuzz was undamaged. The W probe fuzz layer thickness is, within uncertainties, in agreement with an empirical fuzz growth rate formula from the PISCES LPD. However the validity of the PISCES formula in the high temperature regime experienced by the W Langmuir probe is uncertain. For a more relavent comparison, an experiment on the Pilot-PSI high-power LPD has exposed a tungsten target to surface temperatures, He flux densities, and exposure times similar to what was experienced by the W Langmuir probe in Alcator C-Mod. The W target in Pilot-PSI grew W fuzz with a morphology and layer thickness nearly identical to the Alcator C-Mod W fuzz demonstrating the growth process and mechanism is nearly identical in tokamaks and LPD. This helps validate LPD research on W fuzz for predictions or calculations of growth in tokamaks.

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