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Depth-resolved deuterium retention profiles in displacement-damaged tungsten measured via laser-induced ablation quadrupole mass spectrometry

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Tungsten (W) is the front-runner candidate for use as plasma-facing material in future deuterium-tritium (D-T) fusion reactors due to its favorable properties, such as low sputtering yield, low chemical reactivity, high melting point, and low intrinsic fuel retention. However, the highly energetic neutrons from DT fusion reactions cause displacement-damage in the W lattice, enhancing fuel atom retention. This has an impact on the tritium cycle requirements and safety. Therefore, diagnostics are required to quantify the D and T content in the plasma-facing and structural materials. Laser-induced ablation quadrupole mass spectrometry (LIA-QMS) is a promising method for quantifying fuel content with good depth resolution. LIA-QMS can be simultaneously applied with laser-induced breakdown spectroscopy (LIBS). Combining both techniques could provide the high depth resolution of LIBS with the calibration capabilities of LIA-QMS. This study compares pico-second LIA-QMS D profiles with LIBS as well as nuclear reaction analysis (NRA) with 3He on displacement-damaged W samples which act as a proxy for fusion neutron damage. A set of similarly 10.8 MeV W3+ irradiated ITER-grade W samples from PLANSEE was gently loaded with D from a low-temperature plasma at 370 K without further damage. The D concentration was varied by vacuum annealing of the samples at different temperatures after the D loading. Recording HD and D2 with a 10:1 ratio for the total amount of D release, LIA-QMS shows a higher sensitivity ($<$ 0.1 atu nm average ablation rate (AAR)) than LIBS. While LIBS provides a depth profile with 15 nm AAR, LIA-QMS requires a signal generated by using ˜ 45 nm AAR, which is achieved by integrating over three laser shots of 15 nm AAR each. Qualitatively, LIA-QMS can reproduce the NRA depth profiles with the lowest AAR of 45 nm. Quantitatively, the D content differs by a factor of ˜ 3 in the current setup. The laser-induced crater surface stays relatively flat for up to 4 μm until the roughness exceeds 30% of the crater depth.