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Utilization of isotopically enriched tungsten tracer particles and outer-midplane collector probes for impurity transport studies in the far scrape-off layer of DIII-D*,

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First-of-its-kind experiments using isotopically-enriched, W-coated divertor tiles coupled with midplane collector probes (CPs) have been performed on DIII-D to understand divertor impurity production and transport. Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) results are presented characterizing the isotopic ratios of deposited W on the mid-plane CPs and give quantitative information on the transport of W from specific poloidal locations within the lower outer divertor region. The setup includes two toroidal tile arrays (5 cm wide) of W-coated, TZM inserts in the lower outer divertor with the remaining plasma facing materials (PFMs) being carbon tiles. The inner ring was coated in natural-W (with 26.5% W-182) and the outer ring was coated with 93% isotopically enriched W-182. The unique "isotopic fingerprints"for the W impurities released from each coating in a dominant C PFM environment enables their use as tracer particles to be collected and distinguished at other locations. A triplet set of replaceable graphite CPs each with collection regions on opposing faces oriented normal to the magnetic field and distinct parallel connection lengths were mounted at the outboard mid-plane and inserted at the distance of R-R_{sep} <˜ 6-8cm. Initial motivation for the CP is similar to that of W ring experiments on ASDEX Upgrade [1] and determination of the probe sampling (parallel connection) length was understood in the context of previous theory development of large probes in scrape-off layers (SOL) [2].
Rutherford Backscatter (RBS) analysis of these CPs has provided areal densities of elemental W content along the length of each CP face at 5 mm increments and found peak deposited densities on the order of 5x10¹⁴ W atoms/cm² and all CPs collected above the minimum RBS resolving threshold of 10¹² W atoms/cm². These resultant W deposition profiles were compared with DIVIMP modelling of the far-SOL to better understand impurity transport in the edge plasma. ICP-MS analysis of the CPs performed at 5 mm increments along the probe length has successfully identified the presence of the enriched W isotopes and yielded isotopic ratios of the deposited W. By using a two-source Stable Isotope Mixing Model (SIMM) [3], the amount of W from each of the divertor rings that contributed to the total W deposition on the CP has been determined and shown to vary with the given plasma conditions, particularly ELM amplitude as examined through divertor spectroscopy and CP deposition profiles. An extensive comparison of deposited W profiles with strike point positioning, H-mode/L-mode, ELM frequency, and forward/reverse B_t is reviewed.
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[2] P.C. Stangeby, J. Phys. D: Appl. Phys. 18, 1547-1559 (1985)
[3] J.G. Wiederhold, Environ. Sci. Technol. 49, 2606 (2015)
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