Transport and Deposition of ^{13}C From Methane Injection into L- and H-Mode Plasmas in DIII-D*

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The study of impurity transport on DIII-D is primarily focused on carbon as nearly all of the plasma facing surfaces are graphite. In particular, we are interested in the flows of carbon, and plasma in the scrape-off layer (SOL) and divertor, and how these are influenced by various drifts, including $E \times B$ and $B \times \nabla B$ drifts. UEDGE fluid modeling continues to indicate that these drifts are critical for the understanding of particle transport in DIII-D divertor discharges. In turn, deposition regions of carbon may be particularly important for THE International Thermonuclear Experimental Reactor (ITER), as tritium can be co-deposited with the carbon layers, resulting in a large in-vessel inventory. We have examined carbon transport in both L- and H-mode plasmas in DIII-D by injecting $^{13}CH_4$ from a toroidally symmetric source into the top of lower single-null plasmas, at a flux that was carefully adjusted so as to not significantly perturb the core or divertor plasmas(~4.5 Tl s^{-1} for ~3 s or 1.0×10^{22} atoms for L-mode and (~19 Tl s^{-1} for ~2 s or 2.2×10^{22} atoms for H-mode). This injection geometry simulates methane entering the scrape-off-layer at the top edge of the main chamber walls. The deposition patterns for ^{13}C in the lower divertor are compared in Fig. 1.

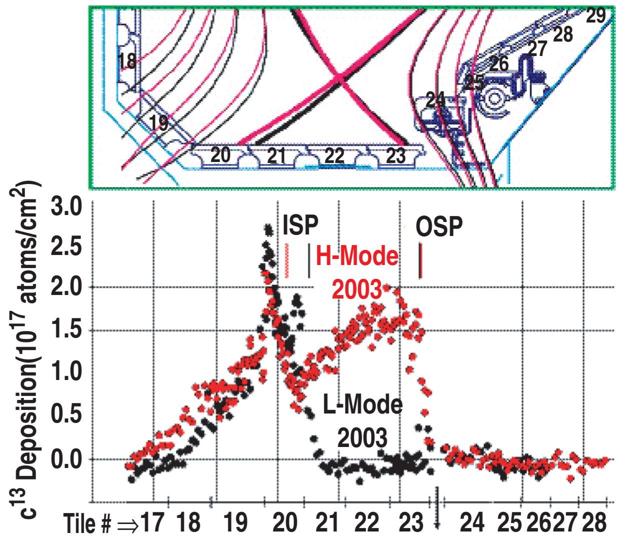

Fig. 1. ^{13}C deposition in the DIII-D divertor region as measured by NRA analysis for both L- and H-mode discharges. Note the additional deposition in the private-flux p zone between the divertor strikepoints for the H-mode case.

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In the 2004 L-mode experiment, 22 identical plasmas with $^{13}CH_4$ injection were obtained just before the machine vent. In the 2005 H-mode experiment, 17 identical 5 s partially-detached-divertor ELMy H-mode plasmas were used. During plasma operation in both cases, the divertor plasma was well characterized by divertor diagnostics, including a 2-D tangential view of the upper half of the plasma. At the conclusion of the each run campaign, carbon tiles were removed (29 for L-mode in 2004 and 64 for H-mode in 2004) and analyzed by two different Nuclear Reaction Analysis (NRA) surface techniques at Sandia Labs and the University of Wisconsin.

In both H- and L-mode plasmas, high ^{13}C coverage (~$2.2x10^{17}$ atoms cm^{-2}) was found just inboard of the inner divertor for both L-mode and H-mode plasmas (Fig. 1). However, in the private flux zone between the two divertor strike points, the carbon deposition was very different for the two cases. In L-mode plasmas, there was no deposition in this region, but in the partially-detached H-mode plasmas, there was substantial deposition out to a region near the outer divertor strike point. Tiles were removed at two toroidal locations, and the deposition data was very similar, verifying the toroidally-symmetric deposition.

A toroidal integral of these profiles in the divertor accounts for about one-third of the injected ^{13}C. The second, more sensitive resonant NRA technique shows a low value of ^{13}C on selected tiles in the upper divertor and centerpost. If this concentration is distributed uniformly over this large area, it accounts for roughly another one-third of the injected ^{13}C. The asymmetry between deposition at inner and outer divertors, and images of singly and doubly ionized carbon near the region of injection, suggest that much of the carbon is swept towards the inner divertor by a deuterium flow in the main scrape-off layer. Spectroscopy in the divertor region showed that in both experiments the inner divertor plasma was significantly colder than the outer divertor plasma, which may also affect carbon deposition.

These experimental results are being compared with UEDGE, DIVIMP, and OEDGE models. So far, UEDGE modeling with drifts has not agreed well with the overall deposition patterns, and further work is in progress. OEDGE modeling of methane break-up, carbon transport in the scrape-off layer, and deposition from the divertor plasma is consistent with a M~0.5 flow in the SOL. Data from other methane breakup experiments, notably a "porous plug" divertor injector on DIII-D is being used to benchmark these codes.

Thermal oxidation studies of the DIII-D tiles used in the ^{13}C experiments are in progress at the University of Toronto surface analysis facility as part of the development of a tritium removal method for ITER. These results, along with data from other experiments are being used to develop an experimental plan for possible future deuterium (as proxy for tritium) removal experiments on DIII-D. These data, along with the modeling results, will contribute to the database required for estimating the ITER tritium inventory.