Low-Z Impurity Transport in DIII–D — Observations and Implications*

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The degree to which plasma surface interactions play a critical role in the attainable plasma performance of a reactor-grade fusion plasma is inherently linked to plasma transport of the particles created by such interactions. In particular, the relatively long mean free path of low Z impurities typically result in ionization sources well away from their generation point at the plasma-surface interface. The transport of these impurities in the edge and core plasma then determines the overall contamination of the core plasma due to these sputtered particles. Therefore, it is crucial to develop an understanding of impurity transport in the edge and core plasmas to quantify the maximum level of sputtering yield that is allowed before plasma performance will be adversely affected. In both the SOL and core plasmas, analysis of DIII–D experimental data suggests that impurity transport results from a balance between collisional and turbulence-driven transport. For example, modeling of carbon transport in the SOL and divertor in DIII–D presented at this conference [West et al.] suggests that the transport of carbon in the SOL is governed by a balance between cross-field transport and classical parallel transport, the latter dominated by collisional processes such as frictional drag and ion temperature gradient forces).

In the core plasma, a theoretical description of impurity transport in tokamak plasmas is beginning to emerge. This description is based on the premise that the total impurity transport rate is simply a linear combination of collisional (i.e., neoclassical) transport and turbulence-driven transport. This "theory" describes many observations in DIII-D and other tokamaks including: 1) the robust similarity between helium and electron density profiles in all confinement regimes; 2) similarity between low-Z impurity and energy transport rates in turbulence-dominated plasmas; 3) moderately hollow carbon density profiles in H–mode plasmas even when measured diffusivity is much larger than neoclassical predictions; 4) strongly hollow moderate-Z density profiles in VH–mode plasmas; and 5) strong accumulation of moderate Z impurities in NCS plasmas with an internal transport barrier. Details of the experimental data and the theoretical comparison to this data will be presented.

The ramifications of this theoretical description are far reaching in terms of reactor design and, in some cases, place strict restrictions on the impurity source emanating from the edge plasma. To study this more thoroughly, ignition calculations similar to those carried out by Reiter et al· [1] except with profile effects included have been carried out to assess the impact on obtaining ignition in certain confinement regimes. In plasmas with internal transport barriers, the strong central accumulation of low-Z impurities predicted by neoclassical theory (and measured experimentally in DIII–D) restrict the volume-averaged carbon (neon) concentration to less than 1% (0.1 %) — far more restrictive than envisioned in any reactor design to date. On the other hand, the hallow impurity density profiles in VH–mode plasmas allow a volume-averaged carbon (neon) concentration up to 4% (1%). Details of these calculations as well as similar ones for ITER will be presented.

[1] D. Reiter et al., Nucl. Fusion **30**, 2141 (1990).

*Work supported by the U.S. Department of Energy under Contract Nos. DE-AC03-99ER54463 and DE-AC05-96OR22464.