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Experimental pathways to understand and avoid high-Z impurity contamination from ICRF heating in tokamaks[1]

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Recent results from Alcator C-Mod and JET demonstrate progress in understanding and mitigating core high-Z impurity contamination linked to ICRF heating in tokamaks with high-Z PFCs. Theory has identified two likely mechanisms: impurity sources due to sputtering enhanced by RF-rectified sheaths and greater cross-field SOL transport due to ExB convective cells. New experiments on Alcator C-Mod and JET demonstrate convective cell transport is likely a sub-dominant effect, despite directly observing ExB flows from rectified RF fields on C-Mod. Trace N_2 introduced in the far SOL on field lines connected to and well away from an active ICRF antenna result in similar levels of core nitrogen, indicating local RF-driven transport is weak. This suggests the core high-Z density, $n_{Z,core}$, is determined by sheath-induced sputtering and RF-independent SOL transport, allowing further reductions through antenna design. ICRF heating on C-Mod uses a unique, field aligned (FAA) and a pair of conventional, toroidally aligned (TAA) antennas. The FAA is designed to reduce rectified voltages relative to the TAA, and the impact of sheath-induced sputtering is explored by observing $n_{Z,core}$ while varying the TAA/FAA heating mix. A reduction of approximately 50% in core high-Z content is seen in L-modes when using the FAA and high-Z sources at the antenna limiter are effectively eliminated, indicating the remaining RF-driven source is away from the limiter. A drop in $n_{Z,core}$ may also be realized by locating the RF antenna on the inboard side where SOL transport aids impurity screening. New C-Mod experiments demonstrate up to a factor of 5 reduction in core nitrogen when N_2 is injected on the high-field side as compared to low-field side impurity fueling. Varying the magnetic topology helps to elucidate the SOL transport physics responsible, laying a physics basis for inboard RF antenna placement.

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