Contribution ID: **674** Type: **Poster**

Advances in Understanding of High-Z Material Erosion and Re-deposition in Low-Z Wall Environment in DIII-D

Friday, 21 October 2016 08:30 (4 hours)

Significant advances have recently been made in the understanding of erosion and re-deposition of high-Z plasma facing components in a mixed materials environment, encouraging prospects on control of high-Z material erosion for future reactors. Dedicated DIII-D experiments coupled with modeling reveal that the net erosion rate of high-Z materials is strongly affected by carbon concentration in the plasma and the magnetic pre-sheath, and can be actively controlled with electrical biasing, as well as by local gas puffing. Thin film tungsten (W) and molybdenum (Mo) samples of different diameters were exposed under well-diagnosed divertor plasma conditions in DIII-D using the divertor materials evaluation system (DiMES) to measure the gross and net erosion rates by ion beam analysis. The net erosion rate of high-Z materials is significantly reduced due to the high local re-deposition ratio, which is mainly controlled by the electric field and plasma density within the magnetic pre-sheath. The modeling indicates that decreasing the sheath potential can suppress the net erosion. New experiments have demonstrated the strong correlation of erosion with external biasing voltage. High carbon impurity concentration in the background plasma is also found to reduce the net erosion rate of high-Z materials. Both DIII-D experiments and modeling show that local 13CH4 injection can create a carbon coating on the metal surface. The 13C deposition provides quantitative information on radial transport due to ExB drift and the cross field diffusion. Additionally, new experiments show that local deuterium gas injection upstream of the W sample not only reduced W net erosion rate by a factor of 2 but also increased the W re-deposition ratio significantly, mainly due to local plasma cooling. High-resolution measurements of the W erosion rate during and between ELM events near the outer strike point (OSP) demonstrate that peak W erosion during ELMs is shifted away from the OSP radius, dramatically broadening the erosion profile at the divertor target. These new findings have significant implications for the understanding and active control of W divertor target operation in ITER with its low-Z beryllium first wall.
Work supported in part by the US DOE under DE-AC05-06OR23100, DE-FG02-07ER54917, DE-AC04-94AL85000, DE-AC05-00OR22725, DE-FC02-04ER54698, and DE-AC52007NA27344.

Paper Number

MPT/1-2Rb

Country or International Organization

USA

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Session Classification: Poster EX/9, EX/10, TH/7, TH/8, IFE/1, MPT/1, FNS/1

Track Classification: MPT - Materials Physics and Technology