Impact of divertor target material on recycling and discharge fueling during the full ELM cycle


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Simultaneous ELM-resolved measurements of Balmer-α and Fulcher-band radiation from both D atoms and D₂ molecules, respectively, recycling at the outer strike point (OSP) were conducted in DIII-D during Metal Rings Campaign (MRC). The MRC involved operation with two toroidally continuous rings of W-covered TZM (Mo alloy with 0.5% titanium and 0.08% zirconium) inserts in the lower divertor. It was found that the relative fraction $F$ of D atoms originating from D₂ molecules in the total recycling D flux changes during ELMs. Between ELMs, $F$ on carbon and on tungsten is $F_C \sim 60\%$ and $F_W \sim 85\%$, respectively, consistent with expectations if all atomic recycling is due to reflections. During ELMs, $F$ dropped to $F_C \sim 40\%$ and $F_W \sim 60\%$.

This effect has been studied with a variety of samples (C, Mo, uncoated and W-coated TZM, W, W fuzz, and Ti) exposed using Divertor Material Evaluation System (DiMES) manipulator in the lower divertor near an attached outer strike point in L-mode discharges. External voltage bias of square waveform between $+10$ V and $-150$ V with frequency 10 Hz was applied to the sample to investigate the dependence of atomic and molecular recycling on the D⁺ ion impact energy ($E_i$). It was found that an increase of $E_i$ by $\sim 160$ eV due to the bias leads to a transient increase of the recycling fraction above unity, similar to [1]. The flux of D₂ in contrast to D only showed a transient increase on C where ion induced D₂ desorption is an important channel of D₂ re emission [2]. Thus, the surface material and the ion impact energy as well as the surface temperature [3] are important factors in controlling the fraction of recycling molecules. This result has implications for both divertor detachment and pedestal fueling, as reflecting D atoms have longer ionization length and contribute to density pedestal recovery after an ELM. D₂ molecules, on the other hand, aid detachment and produce cold Frank-Condon atoms upon dissociation. During the MRC, with the total fraction of the W-covered area on each metal ring $\sim 0.6\%$ of the total wall area, the effect of W in the divertor could be seen in a $\sim 10\%$ increase of the line averaged density when OSP was placed on the W ring. This is qualitatively similar to what was seen on ASDEX upon a complete change from C to W PFCs [4]. We also present results of EDGE2D-EIRENE simulation assessing the effect of adding W in the divertor on divertor fueling and modification of the temperature and density profiles.


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