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Enhancement of helium exhaust by resonant magnetic perturbation fields

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Exhaust of helium as a fusion born plasma impurity is a critical requirement for future burning plasmas. We demonstrate in this paper that resonant magnetic perturbation (RMP) fields can be used to actively improve helium exhaust features. We present results from the TEXTOR tokamak with a pumped limiter and from the LHD heliotron with the closed helical divertor. The results show an important additional functionality of the ITER RMP ELM control coils and dedicated experiments on present day devices like DIII-D, EAST or KSTAR which obtained full ELM suppression by RMP field application are motivated. In both devices RMP fields are applied to generate a magnetic island located in the very plasma edge and this magnetic island has a noticeable impact on the helium exhaust. At the TEXTOR tokamak, the effective helium confinement time $\tau_{p,He}$*is reduced by up to 43% and the actual reduction depends on the coupling of the magnetic island to the pump device. The LHD heliotron device, in contrast, features intrinsically a 3-D boundary and the closed helical divertor was designed for optimal pumping in this geometry. Without RMP field applied,* $\tau_{p,He}$ is a factor of ˜4 higher for LHD compared to TEXTOR discharges in a comparable plasma density range. Ion root transport - one out of several different impurity transport regimes at LHD - is the most likely inward transport driver causing the high $\tau_{p,He}$. *When a magnetic island is seeded into the intrinsic edge stochastic layer, a decrease of* $\tau_{p,He}$ by up to 30% and hence values closer to the tokamak situation are established. This shows that RMP fields are a fine-tuning actuator for the exhaust of helium, which is an attractive additional functionality for the ITER ELM control coils. 3-D fluid plasma edge transport and kinetic neutral gas modeling with the EMC3-EIRENE code shows for LHD that the actual helium concentration in the plasma core is dominated by wall recycling of helium. This points out that the back-fueling of the plasma by helium emitted from the plasma and recycled at the wall elements needs to be controlled. The edge magnetic island induced is shown to be an effective actuator to retain the recycled helium in the plasma periphery where it can be pumped away.

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