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Assimilation of deuterium into relativistic runaway electron beams and the implications for benign terminations in present devices, ITER, and future devices

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Localized wall damage from post-disruption runaway electron (RE) wall impact is a significant concern for future large tokamaks. One possible method for reducing this wall damage in the event of an unavoidable RE-wall impact is massive injection of low-Z (H2 or D2) gas. This injection can have the effect of partially recombining the cold thermal background plasma, resulting in a greatly increased RE final loss instability MHD amplitude, larger RE wetted area, and reduced local RE heat flux and damage. Experimental trends in thermal plasma partial recombination resulting from massive D_2 injection into high-Z (Ar) containing runaway electron (RE) plateaus in DIII-D and JET were studied with the goal of understanding the parameters needed to achieve sufficiently low electron density (n_e≈10ˆ18/mˆ3) to increase the RE final loss MHD levels. In both DIII-D and JET, thermal electron density n_e is found to drop by ˜ 100× when the thermal plasma partially recombines, with a minimum at a vacuum vessel-averaged D_2 density in the range 10ˆ20-10ˆ21/mˆ3. RE effective resistivity also drops after partial recombination, indicating expulsion of the Ar content. Achieving partial recombination is found to become more difficult as RE current is increased. The amount of initial Ar in the RE plateau is not observed to have a strong effect on partial recombination. Partial recombination timescales of order 5 ms in DIII-D and 15 ms in JET are observed. These basic trends and timescales are matched with a 1D diffusion model, which is then used to extrapolate to ITER and SPARC tokamaks. It is predicted that ITER will be able to achieve sufficiently low n_e values on time scales faster than expected RE plateau vertical drift timescales (of order 100 ms), provided sufficient D_2 or H_2 is injected. In SPARC, it is predicted that achieving significant n_e recombination will be challenging, due to the very high RE current density. In both ITER and SPARC, it is predicted that achieving low n_e will be easier with Ar as a background impurity (rather than Ne).

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