Achievement of Runaway Electron Energy Dissipation by High-Z Gas Injection in DIII-D*

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Disruption runaway electron (RE) formation followed by RE beam-wall strikes is a concern for future tokamaks, motivating the study of mitigation techniques to reduce the RE beam energy in a controlled manner. A promising approach for doing this is the injection of high-Z gas into the RE beam. Massive (100 torr-l) injection of high-Z gas into RE beams in DIII-D is shown to significantly dissipate both RE magnetic and kinetic energy. For example, injection of argon into a typical 300 kA current RE beam is observed to cause a drop in kinetic energy from 50 kJ to 10 kJ in 10 ms, thus rapidly reducing the damage-causing capability of the RE beam. Both the RE kinetic energy and pitch angle are important for determining the resulting wall damage, with high energy, high pitch angle electrons typically considered most dangerous. The RE energy distribution is found to be more skewed toward low energies than predicted by avalanche theory. The pitch angle is not found to be constant, as is frequently assumed, but is shown to drop from $\sin(\theta)$ ~1 for energies less than 1 MeV to $\sin(\theta)$ ~0.2 for energies greater than 10 MeV. Injection of high-Z impurities does not appear to change the overall shape of the energy or pitch angle distributions dramatically. The enhanced RE energy dissipation appears to be caused primarily via collisions with the cold plasma leading to line radiation. Synchrotron power loss only becomes significant in the absence of high-Z impurities, while radial transport loss of REs is seen to become dominant if the RE beam moves sufficiently close to the vessel walls. The experiments demonstrate that avalanche theory somewhat underestimates collisional dissipation of REs in the presence of high-Z atoms, even in the absence of radial transport losses, meaning that reducing RE wall damage in large tokamaks should be easier than previously expected.

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