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Quantification of runaway electron impact in the lower divertor of DIII-D tokamak using an instrumented sacrificial probe

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Studies of post-disruption runaway electrons (RE) impact on plasma-facing surfaces were performed in the DIII-D tokamak using the Divertor Material Evaluation System (DiMES) with instrumented sacrificial probes allowing unique measurements of the RE energy and pitch angles [1, 2]. Understanding the impact of REs on the first wall is critical for ITER and fusion pilot plants (FPPs), as it is needed for prediction of the effectiveness of disruption mitigation systems, determining safe performance limits, and for evaluations of machine safety. Quantifying RE-induced wall damage is extremely challenging, and previous work has dominantly relied on post-mortem inspection of the campaign-integrated PFC damage caused by REs. Our experiments with controlled RE impact on sacrificial probes were first of the kind and allowed quantification of the RE wall impact at an unprecedented level by using built-in thermo-luminescent dosimeters (TLDs). Experimental observations are backed up by the novel multi-code workflow modeling [2].

Graphite DiMES probes 5 cm in diameter were inserted into the lower divertor of DIII-D under well-diagnosed plasma conditions and struck with high current (600 kA) RE beams. The initial experiment [1] featured a plain graphite sample with a semi-spherical dome of 3.3 cm radius protruding over the divertor tile surface by 1 cm. Upon the RE beam impact, the top of the dome suffered an explosive destruction to a depth of ~1 mm with an estimated volume loss of ~150 mm^3, and dust ejection was observed by the cameras. Modelling of the brittle failure of graphite using a novel workflow with KORC, Geant4 and COMSOL codes was able to reproduce the volume loss and estimate the RE energy and pitch angle by varying the input to the codes [2]. The following experiments used domed and flat samples instrumented with thermocouples and TLDs. RE energies of 2-4 MeV and pitch angles of $\theta \sim 0.4$ (~25°) were estimated from the TLD readings, consistent with the modeling results of the initial experiment. Penetration depth of REs into the sample is found to be ~1-2 mm, as expected for the measured energies. Shot-to-shot variation in RE energy deposited into the samples is ranging between 1-10 kJ, indicating that the toroidal phase of the final loss instability is not locked, but highly variable. Further analysis of the latest experiments is underway, including MARS-F modeling of the RE beam MHD and new KORC and Geant4 modeling.

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References

[1] E.M Hollmann *et al.*, Plasma Phys. Control. Fusion **67** 035020 (2025)
[2] S. Ratynskaia, *et al.*, Nucl. Fusion **65** 024002 (2025)

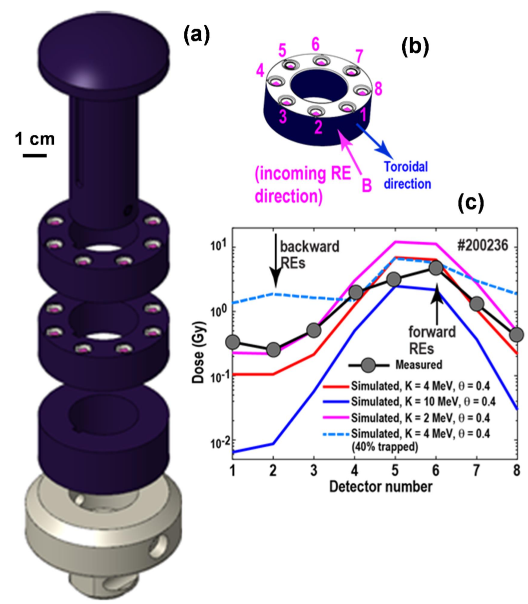

Figure 1: (a) Exploded view of domed graphite DiMES probe holding 16 TLD chips in two trays; (b) TLD numbering and orientation in a tray; (c) TLD doses, measured (dots) and simulated for different RE energies and impact angles