Cratering of Tungsten Walls Under High-Velocity Dust Impacts: Effects of Angle and Temperature

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In fusion reactors, the integrity of plasma-facing components (PFCs) is critically challenged by high-velocity tungsten (W) dust impacts, particularly during events like runaway electron terminations [1]. These incidents can propel dust particles at velocities potentially exceeding several km/s, leading to severe material erosion and damage [2]. Current models predominantly address only low-velocity impacts, revealing a significant gap in our understanding necessary for reactors such as ITER and DEMO [3]. To address this, our study employs large-scale molecular dynamics simulations to investigate the effects of high-velocity W dust on W walls under extreme operational conditions. We analyze a broad range of impact velocities (2.5 to 4.5 km/s), angles (0° to 75°), and temperatures (300 to 3000 K). Our simulations, incorporating up to 300 million atoms, highlight how the impact angle and temperature predominantly dictate the morphology of impact craters and the distribution of ejecta. The detailed examination of sputtering, degradation, and deformation mechanisms provides crucial insights into the atomic-level dynamics of dust-wall interactions. This research significantly advances our understanding and capability to design more resilient and efficient materials for future fusion energy systems, enhancing the durability and operational efficacy of PFCs.

References

[1] Angeli, M. De, *et al.* Nuclear Fusion, vol. 63, no. 1, 2022, p. 014001.

[2] Krasheninnikov, S. I., *et al.* Plasma Physics and Controlled Fusion, vol. 53, no. 8, 2011, p. 083001.

[3] Ratynskaia, S., *et al.* Reviews of Modern Plasma Physics, vol. 6, no. 1, 2022.