Unraveling the Atomic-Scale Dynamics of Dust-Wall Interactions in Tokamaks

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Dust particles impacting the plasma-facing material in tokamaks pose significant challenges to device performance and longevity [1-2]. Understanding the intricacies of these interactions is crucial for mitigating damage and improving operational efficiency. In this study, we present an atomistic investigation of dust-wall interactions, comprehensively exploring a wide range of dust velocities observed in experiments. Through extensive molecular dynamics simulations involving approximately 100 million and more atoms, we shed light on the pivotal roles of impact velocity and wall material properties in shaping dust-wall interactions. Notable variations in the influence of dust on the wall are observed, contingent upon these factors. To facilitate a comprehensive understanding, we categorize dust-wall interactions into four distinct levels based on the degree of impact and resulting damage. Our analytical model, developed to unravel the underlying mechanisms governing these interactions, provides valuable insights into the dynamics and predictive capabilities of dust-wall interactions. This study's findings have significant practical implications, as they enable effective prediction and assessment of potential damage resulting from high-velocity dust impacts on plasma-facing components (PFCs). The developed analytical model serves as a valuable tool for practical applications, offering insights into the complex dynamics of dust-wall interactions and facilitating the optimization of PFC designs to withstand high-velocity dust impacts.

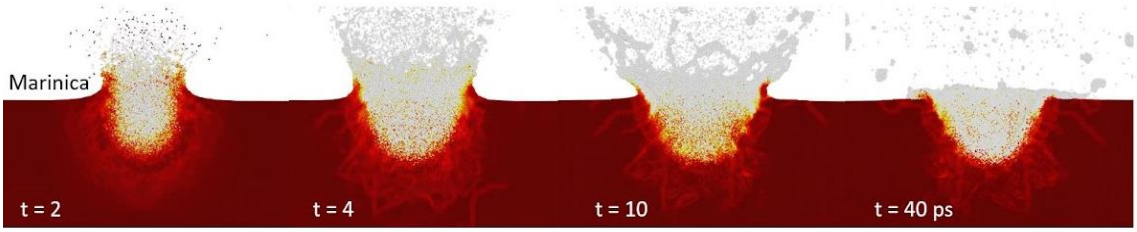

Figure 1: MD Simulation of 8 nm W spherical dust Impacting on W Single-Crystal Target at 3 km/s: Time Evolution at 2, 4, 10 and 100 ps.

References

[1] S. Ratynskaia, C. Castaldo, K. Rypdal, et al., Nucl. Fusion 48(1), 015006 (2008).

[2] S. Ratynskaia, A. Bortolon, and S. I. Krasheninnikov, Rev. Mod. Plasma Phys. 6(1) (2022).