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Multi-scale multi-physics simulations of vacuum breakdown phenomena

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Although vacuum arcs have been studied intensively for more than a century, the physical mechanisms involved in their ignition have not been fully understood yet. This is mainly due to the extreme nature and high complexity of the physical processes involved. Extreme phase changes occur in a sub-nanosecond timespan, involving various physical processes that occur at an atomic level and scale up to macroscopic sizes. In order to investigate such complex phenomena, multi-scale and multi-physics simulations that concurrently capture the various processes are necessary.

In this talk, an overview of recent advancements in multi-scale multi-physics simulations of vacuum breakdown phenomena shall be presented. Such simulations include molecular dynamics to model the movement of atoms under heating and electromagnetic field stress, concurrently coupled with particle in cell plasma simulations and finite element analysis for electrostatics, electron emission and heat transfer. These simulations capture the processes that occur when a nanoscopic field emitting metal protrusions enter thermal runaway, evaporate and ignite vacuum arc plasma, with the purpose of understanding the plasma ignition mechanisms, along with their limitations that can be exploited to minimize breakdown occurrence. Finally, a short overview of recent advancements of density functional theory calculations and kinetic Monte Carlo simulations for metal surface diffusion shall be given, showing that surface diffusion is a strong candidate mechanism for explaining protrusion growth on metal surfaces exposed to high electric field.

Summary

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