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Breakdown Modes in Capacitively Coupled Plasmas: A Numerical Study

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This study investigates the breakdown modes of capacitively coupled plasmas (CCPs) across varying pressures using an implicit particle-in-cell/Monte Carlo collision (PIC/MCC) model. The research reveals both self-sustained and non-self-sustained discharge modes, contributing to a comprehensive understanding of gas discharge phenomena.

In the realm of self-sustained discharges, several modes are identified, including glow discharge, normal multipactor, and abnormal multipactor discharges. The transition from glow discharge to abnormal multipactor occurs below 2 mTorr, followed by the evolution into normal multipactor within a narrow voltage range. These self-sustained modes are maintained by higher electron emission rates and high-frequency RF power, with the emergence of multipactor discharges in the 60 MHz range potentially expanding the theoretical framework of gas discharge.

The study also examines non-self-sustained discharges, specifically normal failure discharge, bias failure discharge, and runaway failure discharge. Normal failure discharge is characterized by a failed electron avalanche, while bias failure results from the charging effect of the blocking capacitor. Runaway failure discharge arises from a decrease in electron emission rate during sheath formation. Analyzing the effects of background pressure and voltage on these failure discharges enhances our understanding of discharge failures in low-pressure environments.

Overall, this work aims to identify the limits of self-sustained discharges and prevent plasma instabilities, ultimately improving equipment safety, enhancing product yield, and mitigating industrial losses and optimizing plasma-based industrial applications..

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