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Computational Modeling and Simulation of Micron-Scale Discharges and Their Interactions with High-Frequency Electromagnetic Waves

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In this work we discuss high-fidelity computational modeling of micron-scale discharges and their interactions with electromagnetic waves in the microwave regime. The study is motivated by applications in plasma metamaterials where large arrays of microdischarge structures are used to manipulate incident micro/terahertz waves. We use a combination of classical particle-in-cell (PIC) modeling and fluid modeling approaches to understand breakdown of individual microdischarge structures due to the electromagnetic wave excitation and the operation of stable microdischarges in the presence of these waves, respectively. The effect of length scale, frequency of excitation, surface electron emission physics on breakdown is addressed in detail with the PIC model. The fluid model represents both plasma physics and wave interaction effects. Self-consistent approach for modeling of plasma-wave interaction and the numerical implementation will be discussed in detail. The manipulation of incident electromagnetic waves as a function of individual microdischarge structure is reported. Also, we study non-linear interactions where sufficiently high-intensity electromagnetic waves modify the structure of the individual microdischarges leading.

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