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Operating principles of microplasmas assisted by field emitting cathodes

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Microplasmas have contributed to an exciting new direction in low-temperature plasma science and engineering with various applications including electronics, nanomaterial synthesis, and lighting to name a few. The rapid miniaturization of microplasma devices has provided the opportunity to exploit physical mechanisms that are considered unimportant in traditional macroscale plasmas. Specifically, the intense electric fields encountered in microplasma devices lead to an auxiliary source of electrons via field-induced electron emission from the electrodes. Also, recent advances in nano/microfabrication have resulted in the engineering of thin film materials (such as ultrananocrystalline diamond) with field emission threshold electric fields as low as 1 $V/\mu m$ thereby allowing us to exploit them in microplasmas with dimensions ~ 100 μm. In this regard, this talk deals with the principles that govern the operation of microplasma devices assisted by field emitting cathodes. Specifically, the talk will focus on the interesting interplay between field emission and the corresponding microplasma properties with surface-normal electric field serving as the link. Results are presented for the operating modes of field emission assisted microplasmas in the direct current and radio frequency/microwave regimes. The one-dimensional analyses include a combination of simplified global/spatial sheath models, fluid simulations as well as kinetic simulations using the particle-in-cell with Monte Carlo collisions (PIC-MCC) method. Two-dimensional fluid simulations are also presented for microcavity plasmas augmented by field emitting cathodes. The simulations are validated with experimental data whenever possible and a need for additional suitable experimental datasets is highlighted.