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Field Emission and its Effect on Microdischarge Formation

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The formation of plasmas and discharges at dimensions approaching 1 micrometer have held the plasma communitys interest for nearly two decades as the potential for massive arrays and high electron densities hold significant promise for a wide variety of applications. It is now apparent that at these extreme dimensions, field emission can occur, and as an additional electron source, significantly alter the discharge dynamics. Much of the attention has focused on how field emission can reduce the breakdown voltage for plasma initiation and modify Paschens curve [1], but less attention has focused on how it affects other plasma conditions. In recent work, we have sought to measure the canonical direct current (DC) current-voltage (i-V) curve from pre-breakdown conditions through breakdown and the onset of a glow discharge. Measurements with both different cathode materials and in different atmospheric-pressure environments reveal that when field emission is active, it can dramatically alter the i-V curve, showing very little voltage drop from breakdown to glow discharge conditions and a smooth transition through the partial glow regime [2]. Further, while it is typical for i-V curves to exhibit hysteresis, field emission appears to soften this effect and allow for both forward and backward ramping from pre-breakdown to glow and vice versa. This effect, which has also been observed under vacuum conditions, reflects the unique impact field emission has on plasma operation at the microscale, and opens the door for new and novel approaches to microdischarge devices.

[1] D. B. Go, A. Venkattraman, Microscale gas breakdown: ion-enhanced field emission and the modified Paschens curve, Journal of Physics D: Applied Physics, vol. 47, art. no 503001, 2014.

[2] M. A. Bilici, J. R. Haase, C. Boyle, D. B. Go, R. M. Sankaran, Experimental evidence for the transition from a field emission-driven Townsend discharge to a self-sustained microplasma, Journal of Applied Physics, vol. 119, art. no. 223301, 2016.