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The Impact of Electrode Surface Roughness on Field Emission Driven Breakdown for Microscale Gaps

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While gas breakdown is generally driven by Townsend avalanche, field emission dominates for microscale gaps [1]. Recently derived closed form solutions unify these mechanisms with good agreement to experiment while analytically demonstrating the transition between them [2]. One weakness of these approaches is that they fit the field enhancement factor empirically, preventing a priori predictions of field emission driven microscale breakdown. This becomes particularly critical since the field enhancement factor may vary between samples due to variations in surface roughness.
Previous experiments measured the breakdown voltage of a flat plate electrode and a sharp-tipped electrode for microscale gaps at atmospheric pressure [3]. We extend this study by modifying the surface roughness of the flat electrode and measuring the breakdown voltage and current as a function of gap distance and time. Preliminary results suggest that differences in surface roughness may lead to 50% changes in breakdown voltage for 5 um gaps. Furthermore, we will present a new geometry to assess the impact of tip aspect ratio, gap distance, gas, and pressure will permit a full parametric study to benchmark to theory. Implications on gas breakdown for microscale and smaller gaps and the conceptual understanding of breakdown regimes will be discussed.
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[2] A. M. Loveless and A. L. Garner, "A universal theory for gas breakdown from microscale to the classical Paschen law,"Phys. Plasmas, vol. 24, art. no. 113522, 2017.
[3] M. A. Bilici, J. R. Haase, C. R. Boyle, D. B. Go, and R. M. Sankaran, "The smooth transition from field emission to a self-sustained plasma in microscale electrode gaps at atmospheric pressure,"J. Appl. Phys. vol. 119, art. no. 223301, 2016.

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