Comparison of 2D and 3D PIC-DSMC Simulations of Pin-to-Plane Breakdown Through a Thin-Film Dielectric Coated Electrode

C.H. Moore(*)[1], A.K. Jindal[1], R. Martinez[1], A. Padgett[1]

[1] *Sandia National Laboratories, Albuquerque, NM 87185, USA*

(*) chmoore@sandia.gov

In devices where high voltages are present, thin (<1mm) dielectric coatings are often used to increase the standoff voltage in the presence of an air-filled gap (~mm–cm). When a device's surface is fully coated, breakdown can occur if an air-gap streamer produces fields inside the solid dielectric that exceed the dielectric's breakdown strength. If this happens, the resulting discharge is often catastrophic; damaging the device and/or preventing proper operation.

In prior work [1] we compared 2D electrostatic PIC-DSMC simulations using the Sandia code EMPIRE with experimentally measured breakdown voltages for a 1mm gap with various dielectric coating thicknesses, shown in Figure 1. Experimentally it was observed that the breakdown occurred through the dielectric for dielectric thicknesses less than ~100µm. However, based on the bulk dielectric holdoff strength EMPIRE simulations predict breakdown through the dielectric for much thicker dielectric films. Additionally, breakdown occurred at much lower voltages in the 2D EMPIRE simulations as compared to experiment.

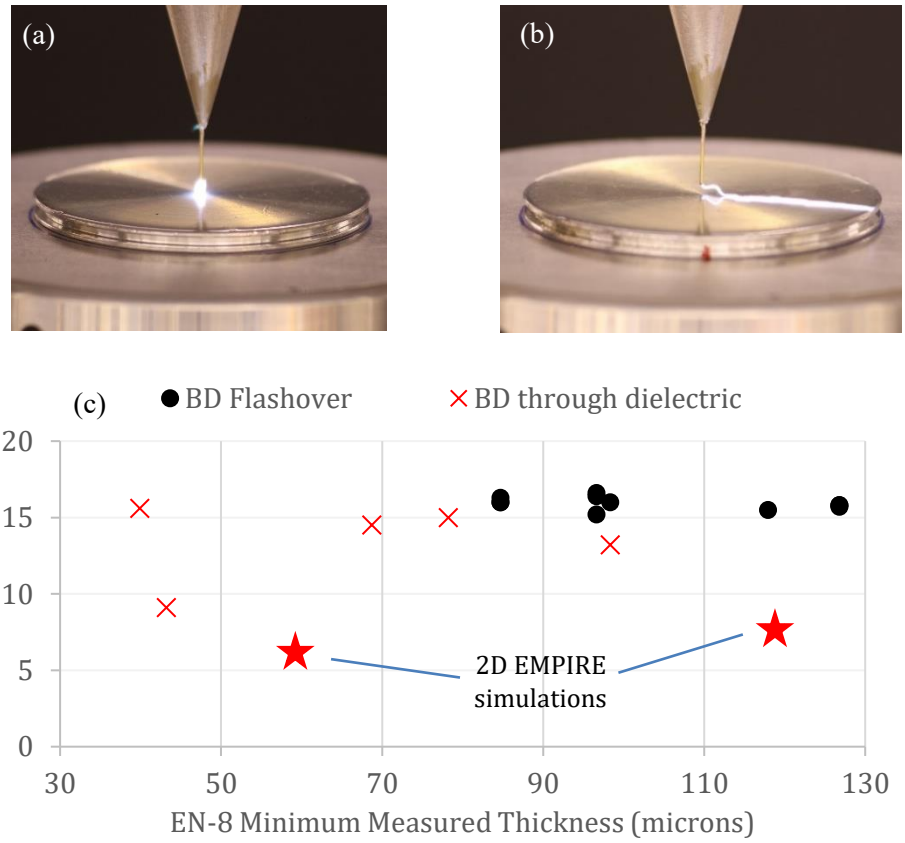

Fig. 1: (a) Breakdown through the EN-8 epoxy layer, (b) Surface flashover breakdown as the arc travel to the uncoated sample side, (c) Experimental breakdown voltage at various EN-8 thicknesses compared to simulated 2D EMPIRE breakdown voltage (through the dielectric film).

Figure 2 shows the electron density and E-field contours for a 2D EMPIRE simulation where the streamer, as it travels along the dielectric surface, results in an electric field inside the EN-8 dielectric that exceeds its bulk dielectric strength (~35MV/m). In order to predict surface flashover instead of breakdown through the dielectric, the EMPIRE simualtions needed significantly thicker dielectric coatings than experimentally observed. The present work will examine the effects of simulating the domain in a 3D wedge versus the prior 2D simulations and how much this changes the predicted breakdown votage and streamer dynamics.

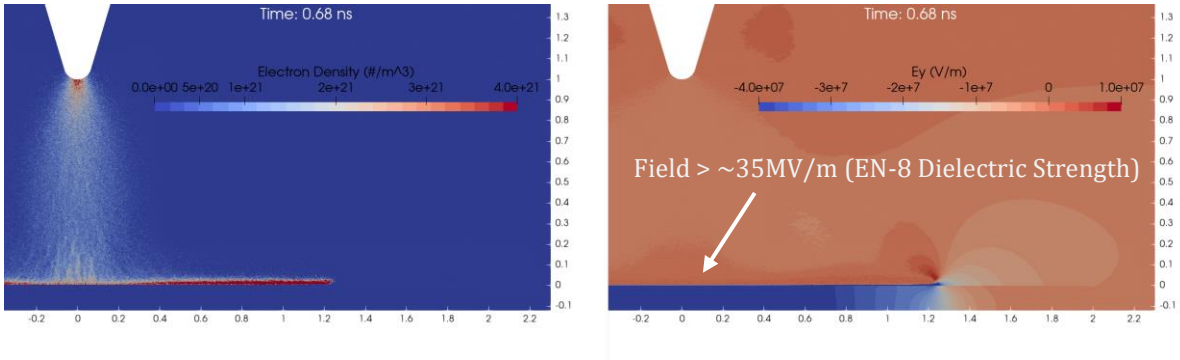

Fig. 2: 2D PIC-DSMC simulation of streamer formation from the pin to the dielectric covered planar electrode.

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[1] C.H. Moore, et. al., APS Gaseous Electronic Conference (2023)