Calculating Field Enhancement Factor Using the Boundary Element Method

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Abstract— **The requirement for stronger electric fields for multiple applications, including telecommunications, directed energy, and vacuum micro- and nanoelectronics, has necessitated efficient, accurate characterization of field emitter effects. The field emitter aspect ratio, field emitter cone angle, distance between emitter tip and anode, and distance between multiple emitters in an array impact the field enhancement factor, which is the ratio between the peak and the applied macroscopic electric fields. In this study, we benchmark the results from the new software Charge [http://fieldscale.com/Charge], a boundary element solver for electrostatics problems, to published computational results from finite element solvers (such as COMSOL Multiphysics and ANSYS Maxwell) and semi-empirical models. Novel geometries and arrays of field emitters will also be explored.**

I. INTRODUCTION

The field enhancement factor, β, introduced by surface roughness, microstructure, and geometry of electrodes can influence breakdown within electronic devices [1-4]. Efforts have been made to derive equations for β, but are semi-empirical and often require some level of fitting to experimental data [2-4].

II. METHODS AND RESULTS

In this work, we calculate β using the new software Charge [5], an electrostatic boundary element software package, to benchmark it to published results [6]. Previous studies have simulated field enhancement by using a hemisphere-on-post geometry [6], as depicted by Figure 1.

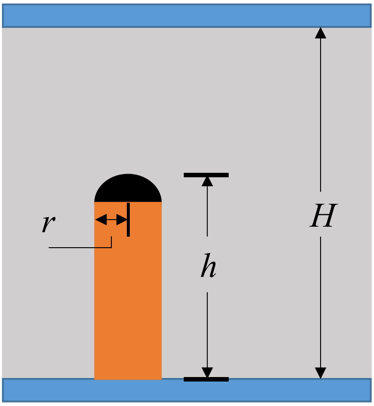

Fig. 1. Schematic of a field emitter geometry using a hemisphere-on-post geometry, where *r* is the tip radius, *h* is the emitter height, and *H* is the distance between the electrodes.

Figure 2 shows the comparison of the simulation results from Charge to those from [6] with an average agreement of 11% across the full range of aspect ratios studied and a 7.5% difference for aspect ratios between 10 and 1000.

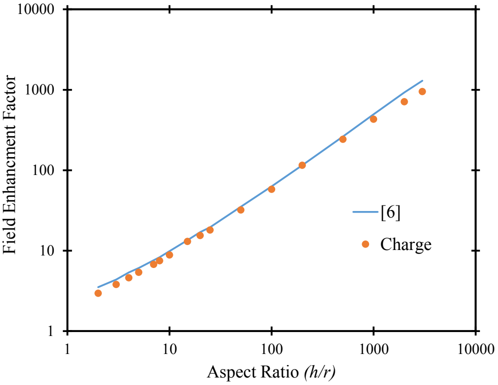

Fig. 2. Comparison of field enhancement factors from Charge and [6] for a hemisphere-on-post geometry. There is an average percent difference of 11% between results from Charge and [6] over the full range and a percent difference of 7.5% between aspect ratios of 10 and 1000.

After successfully benchmarking Charge to [6], we assessed the impact of field emitter tip geometry on field enhancement by using the exact same hemisphere-on-post geometry with a flat tip. Figure 3 showed the field enhancement factor calculated using Charge for the hemisphere-on-post geometry and purely cylindrical geometry. The difference is less pronounced at larger tip radii, suggesting that the tip may begin to appear relatively flat.

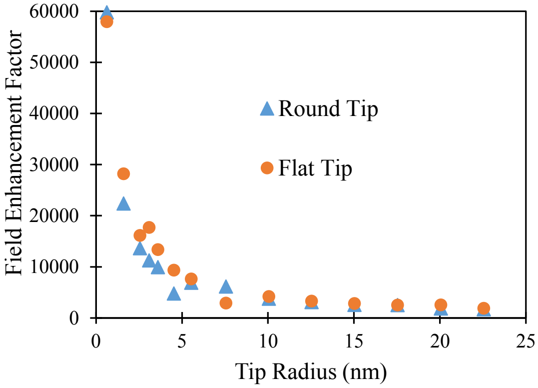

Fig. 3. Field enhancement factor as a function of tip radius for a round tip and a flat tip.

This study demonstrates the feasibility of using Charge to assess field enhancement. Future work will explore different emitter tip shapes (such as using different tip angles) and various alignments of multiple emitters (such as linear, triangular, and rectangular arrangements).

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