Sandia National Laboratories

Surface Charge Effects on Secondary Electron Emission from Dielectrics

Zakari Eckert, Ron Goeke, & Matthew M. Hopkins

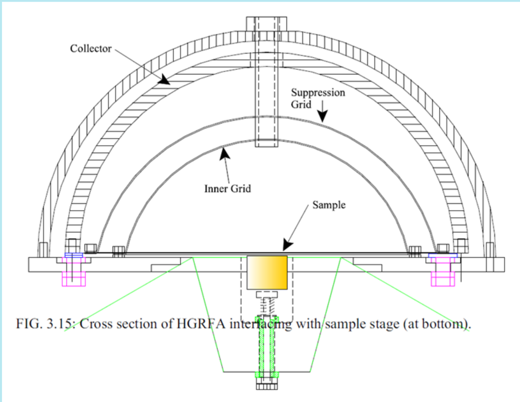
Conclusion: No evidence yet that dielectric surface charge affects secondary electron yield beyond secondary electron recapture

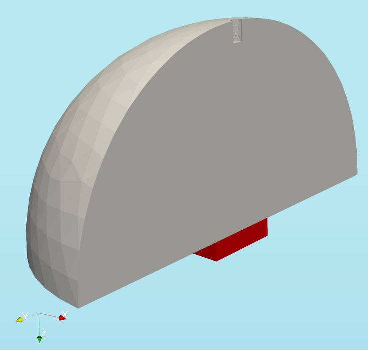
Motivation

Understanding and correctly modeling secondary electron emission yield is vital to predictive simulations of plasma surface interactions as well as bulk plasma phenomena. In the system of interest in this work, specifically vacuum surface flashover, secondary electron emission and electron-driven neutral desorption are the primary drivers of the flashover. The yield of secondary electrons is dependent upon the material, impinging particle characteristics, energy, and incident angle. In addition, for dielectric surfaces, the surface can charge and the local electric field can change the energy of the incident particle and the ability of the emitted secondaries to escape the potential well.
Our goal is to examine existing and new data of secondary electron emission on dielectrics versus deposited charge and attempt to predict the dependence. Any anomalies between the prediction and experimental data may hint at a dependence of the emission on surface charge beyond those phenomena mentioned previously, and, at minimum, will put an upper bound on the errors introduced by using existing models. This work presents such comparisons between experiments and kinetic simulations performed with Aleph, a particle-in-cell code.

Model Description

Aleph is a Particle-In-Cell with Direct Simulation Monte Carlo collisions (PIC-DSMC) model developed at Sandia National Laboratories [1].
The simulation domain captures the interior of the inner grid of a Hemispherical Grid Retarding Field Analyzer (HGRFA)





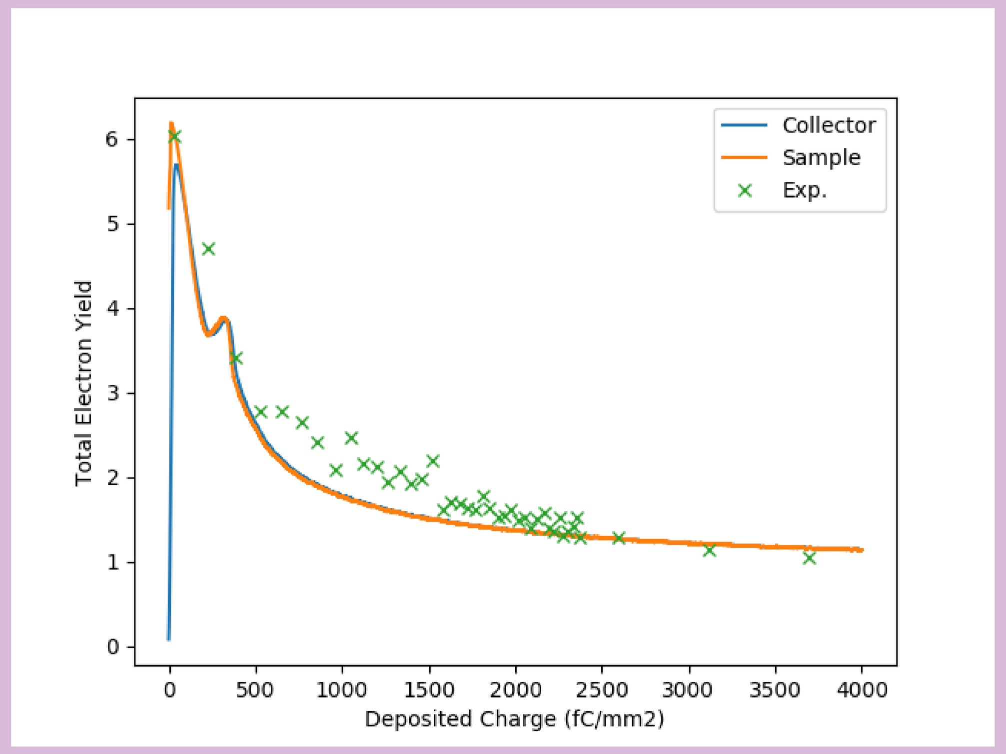
- Geometry
  - Inner grid radius: 31.5 mm
  - Sample size: 12 mm × 12 mm × 3 mm
- Electron beam
  - Diameter: 2 mm
  - Energy: 650 eV
  - Current flux: 1 fC/mm^2/ns
- Sapphire Sample
  - Relative Permittivity: 11.5
  - Max SEY: 6.4 at 650 eV
  - T_{SEE} = 10 eV for primaries, 2 eV for returned secondaries
  - No surface charge bleedoff/conduction

References

[1] Matthew T Bettencourt, Jeremiah J Boerner, Paul S Crozier, Andrew S Fierro, Anne M Grillet, russell W Hooper, Matthew M Hopkins, thomas P Hughes, Harold E Meyer, Christopher H Moore, Stan G Moore, Lawrence C Musson, and Jose L Pacheco. Aleph manual. Technical Report SAND2017-10343, Sandia National Laboratories, Albuquerque, New Mexico 87185 and Livermore, California 94550, 2017.

[2] J. J. Scholtz, D. Dijkkamp, and R. W. A. Schmitz. Secondary electron emission properties. *Philips J. Res.*, 50:375–389, 1996.

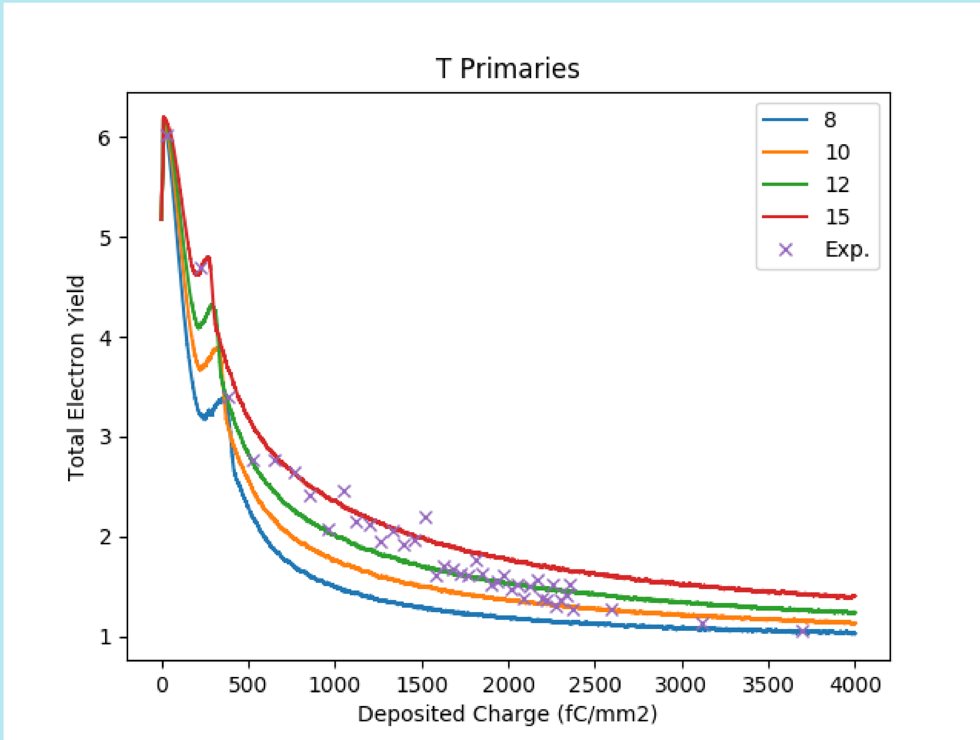
Nominal



- Collector: Current on all non-sample surfaces
- Sample: net current at sample surface
- Transient rise due to finite time for electron beam to cross the domain
- "Bump" at 500 fC/mm^2 due to numerical instability from running the simulation at stability limits (refinement resolves it)
- Reasonable agreement shown between experiment and simulation

To discover if surface charge has a non-neglible effect on secondary electron yield, we need to understand the sensitivity of the predictions to model form errors and experimental uncertainty.

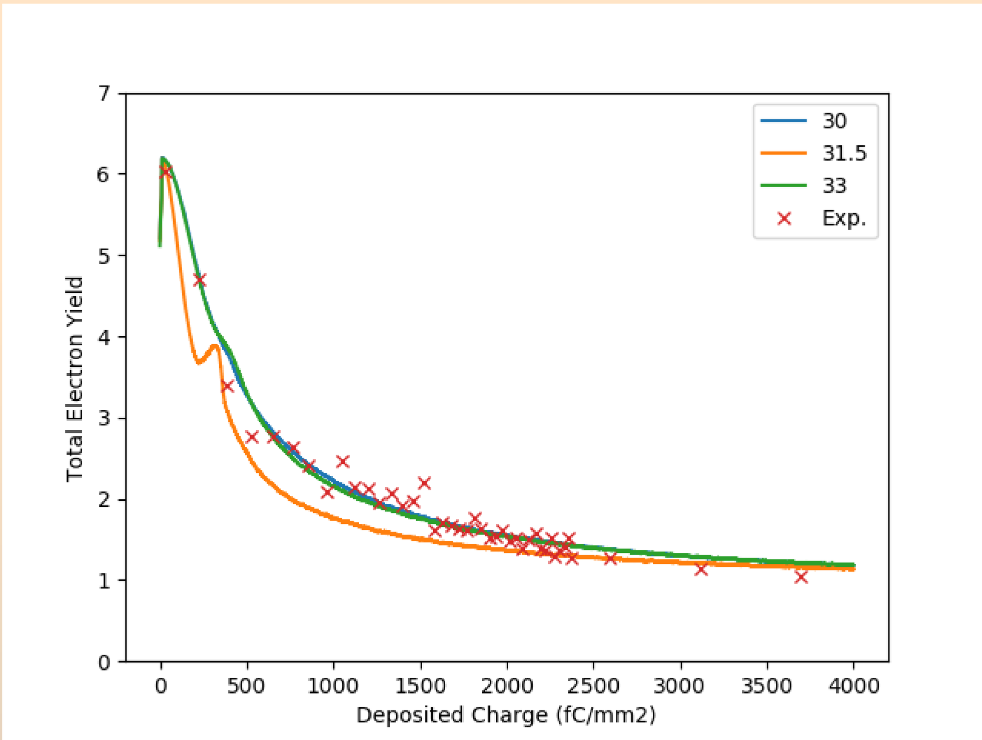
T_{SEE} of electrons emitted by primary impacts



Varied the temperature of the electrons produced by primary electrons from the original electron beam

- Nominal: 10 eV
- Assumed a Maxwellian distribution, although that is not physically correct
- Moderate sensitivity in decay of SEY
- Decay of SEY tends to be predicted as too low

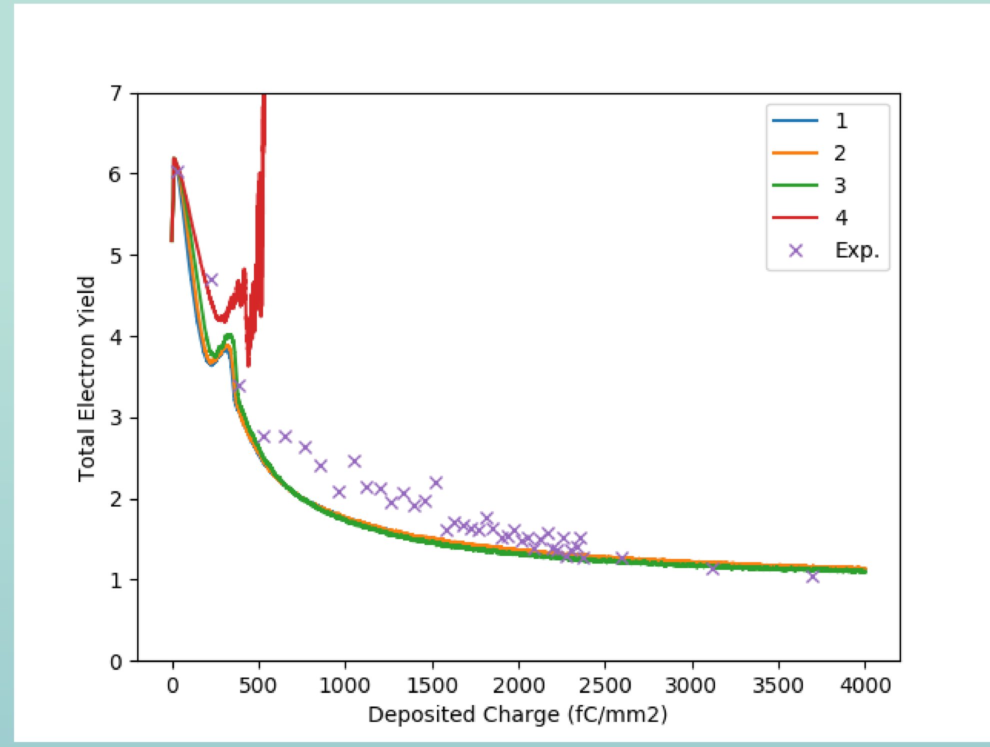
System Capacitance



The measurement of SEY versus deposited charge is similar to measuring the voltage on a capacitor. Here we varied the radius of the inner shell to change the capacitance and charging characteristics.

- Modest changes in decay, including improvement at higher deposited charge values
- Still need to measure sensitivity to test sample size/thickness
- Lack of "bump" in other cases means we need to revisit results with finer resolution to guarentee that the numerical instability isn't affecting the result

T_{SEE} of electrons emitted by returned secondaries



The energy of produced secondaries both affects what fraction can escape the charged surface and whether they produce their own secondaries upon being returned to the surface

- Value has little effect on results
- Between 3 and 4 eV, returning secondaries pass a threshold where the average SEY passes one, leading to electron avalanche
- This is non-physical, but results from our assumption of a Maxwellian energy distribution
- Current work to implement Scholtz backscatter probability into Aleph will resolve this problem [2]

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