Investigation On The Role Of Aperture Wall Thickness for The Generation Of Sheet Electron Beam Using COMSOL Multiphysics®

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INTRODUCTION:

- With increase of operational frequency of the microwave devices, the dimensions of the beam-wave interaction region gets reduced
- In THz frequencies, the dimensions are in sub millimeter ranges for which high current density electron beam is required
- For planner interaction structure, the sheet beam is required for the maximum beam-wave interaction
- Dimensions of hollow cathode aperture wall plays a major role in efficient sheet electron beam generation
- The role of the hollow cathode aperture wall thickness for high current density sheet electron beam has been reported

COMPUTATIONAL MODEL:

A 2D hollow cathode geometry have been modeled with different aperture wall thickness in COMSOL®.

UTILIZED MODULE :

The present work is carried out using the plasma module of COMSOL Multiphysics®. Argon is used as the inert gas in the model. The electronically excited states can be lumped into a single species, which results in a chemical mechanism consisting of only 3 species and 7 reactions.

Reaction	Formula	Type	Δε(eV)
1	e+Ar=>e+Ar	Elastic	0
2	e+Ar=>e+Ars	Excitation	11.5
3	e+Ars=>e+Ar	Super elastic	-11.5
4	e+Ar=>2e+Ar+	Ionization	15.8
5	e+Ars=>2e+Ar+	Ionization	4.24
6	Ars+Ars=>e+Ar+Ar+	Penning ionization	-----
7	Ars+Ar=>Ar+Ar	Metastable quenching	-----

Table 1. List of volumetric plasma chemical reactions considered

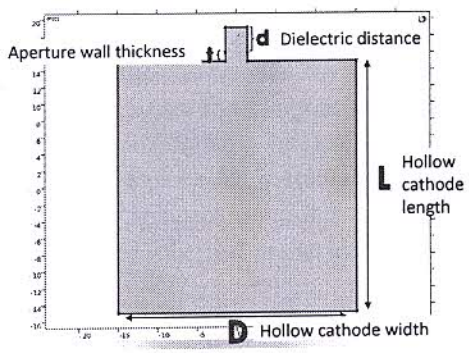

Figure 1. simulation model of hollow cathode in single gap Pseudospark configuration

RESULTS: It is observed that :

- With increase in wall thickness the field penetration inside the hollow cathode decreases

RESULTS:

- Decrease field penetration, cause the delay in the hollow cathode phase of the PS discharge.
- It has been analyzed that with increase in aperture wall thickness the duration of the hollow cathode phase increase.
- The beam current, due to electron beam, decreases with the increase in aperture wall thickness

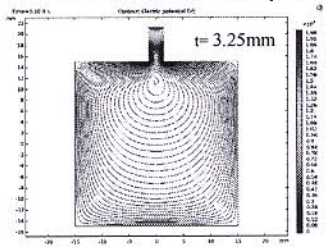

Figure 2. Electric field contour at 51ns for wall thickness of 3.25mm.

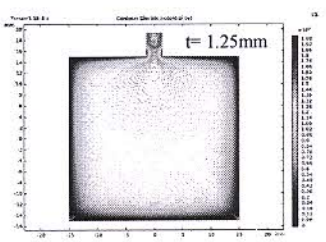

Figure 3. Electric field contour at 51ns for wall thickness of 1.25mm.

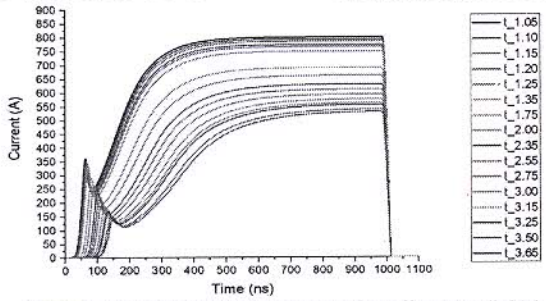

Figure 4. plot of beam current vs time for different wall thickness 't' that varies from 1.05mm to 3.65mm

DEVELOPMENT WORK: Based on the simulation results, hollow cathode have been fabricated with optimized aperture wall thickness and other geometrical parameters..

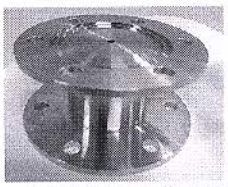

Figure 2. Fabricated hollow cathode isometric view

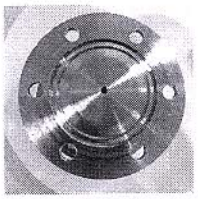

Figure 2. Fabricated hollow cathode top view

CONCLUSIONS:

- Effects of the aperture wall thickness have been reported.
- The cathode for the sheet electron beam source, capable of producing highest current density and suitable for sub-THz generation

REFERENCES:
1. N. Kumar, D. K. Pal, R. P. Lamba, U. N. Pal, and R. Prakash, "Analysis of geometrical design parameters for high-energy and high-current density pseudospark-sourced electron beam emission," IEEE Trans. Electron Devices, vol. 64, pp. 2688–2693, 2017.
2. N. Kumar, A. S. Jadon, P. Shukla, U. N. Pal, and R. Prakash, "Analysis of experimental results on pseudospark discharge-based electron beams with simulation model," IEEE Trans. Plasma Sci., vol. 45, pp. 405–411, 2017.
3. G. X. Shu, H. Yin, L. Zhang, J. P. Zhao, G. Liu, A. D. R. Phelps, A. W. Cross, and W. He, "Demonstration of a Planar W-band, kW-level Extended Interaction Oscillator Based on a Pseudospark-sourced Sheet Electron Beam," IEEE Electron Device Lett., vol. 39, pp. 432-435, 2018.

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