Investigation of High Density and High Energetic e-Beam Generation and Propagation from Triggered Pseudospark Discharge Based Plasma Cathode Electron Source

Varun [#*1], Gulab Singh[#2], Mahesh Kumar[#3], Niraj Kumar[#*4], U. N. Pal[#*5]
[#] *Microwave Devices Area, CSIR- Central Electronics Engineering Research Institute, Pilani, Rajasthan-333031, India*
[*] *Academy of Scientific and Innovative Research (AcSIR), CSIR-CEERI, Campus, Pilani, India*
[1]varundixit1992@gmail.com
[5]udit@ceeri.res.in

***Abstract*- An analysis has been carried out for the generation of high density and energetic electron beam in the pseudospark discharge based plasma cathode electron (PD-PCE) source. The study of e-beam generation and propagation has been performed for single as well as multi-gap arrangement of PD-PCE source using 2-D PIC simulation code, and also experimentally at different operating and geometrical parameters. The investigations clearly show that the cathode aperture, gas pressure and seed electron energy are some of the important parameters strongly affecting the generation of pseudospark discharge based high density and energetic electron beam generation. The PIC simulation and experimental investigation of different configuration of PD-PCE source would be utilized for the generation of efficient plasma generation inside the hollow cathode cavity and hence electron beam for different geometrical sizes and operating parameters**

I. INTRODUCTION

Pseudospark (PS) discharge is a cold cathode, self-sustained, transient and low pressure gas discharge [1]. Since, the discovery of the PS discharge, it has been used for various applications, such as, high power plasma switches, high density electron beam generation, EUV/X-ray radiation production, microwave and THz radiation sources [1-4]. It has been proven that PS discharge can produce electron beams with a high combined current density and brightness with a fast current rise which can be used for the above mentioned applications. PS discharge comprise of a hollow cathode and planner and/or hollow anode. It has been classified in two different configurations namely single-gap and multi-gap PS discharge devices [1, 2]. The multi-gap arrangement of PS discharge is used to improve the performance of electron beam. In fact, electron beam generation in the PS discharge is influenced by various complex discharge processes which depend on the geometric configuration as well as operating parameters [5-8].

An investigation has been carried out using 2-D PIC simulation code OOPIC PRO™ to analysis geometrical and operating parameter for plasma formation inside the hollow cathode (HC) and generation of e-beam. This analysis has been carried out for both single gap and multi-gap arrangement of PD-PCE source as shown in figure 1.

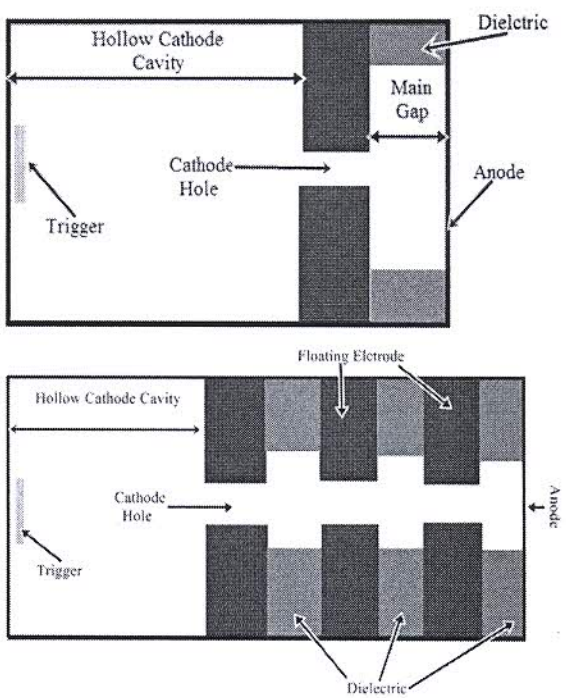

Fig. 1: Schematic of (a) single-gap, (b) multi-gap configurations of PD-PCE Source

It has been observed that the cathode aperture, gas pressure and seed electron energy strongly influences the plasma formation process inside the HC and electron beam generation. On increasing the gas pressure, an electron beam of higher current is generated and time for electron beam generation reduces. However, on increasing cathode aperture, electron beam of lower current is generated and also time of e-beam generation reduced. On increasing gas pressure and number of gaps the seed electron energy plays significant role for the

generation of electron beam. After certain higher gas pressure, there is requirement to increase the seed electron energy which has reflected for the higher value of peak electron beam current generation. Apart from geometrical and operating parameter, it has been observed that the equipotential distribution lines in the PS discharge based plasma cathode electron (PD-PCE) source controls confinement of plasma and also responsible for the generation of different sizes of e-beams as shown in figure 2.

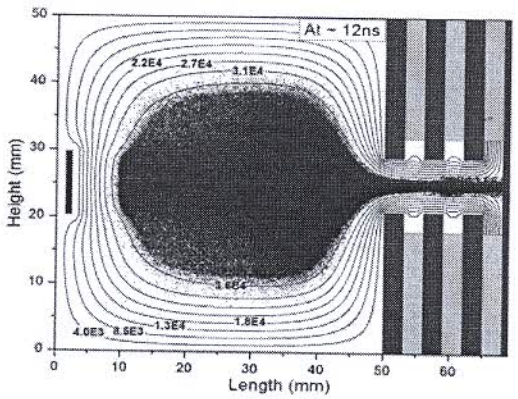

Fig. 2: Potential distribution in the multi-gap (three gap) PD-PCE source at 60 Pa, with 8mm cathode aperture at 40kV anode potential

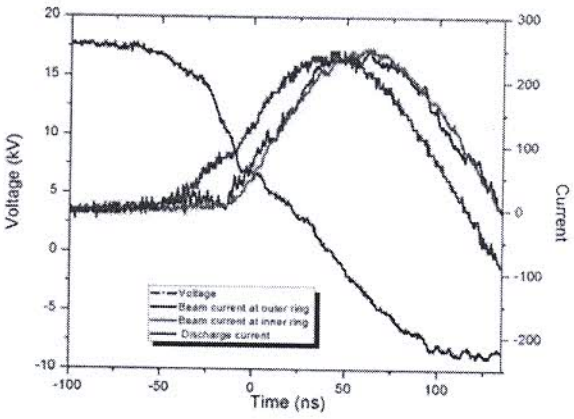

Fig. 3: Experiment result of three gap PD-PCE source at 6 Pa gas pressure at 20 kV operating voltage

The investigation has also been performed experimentally for the generation and propagation of high density and energetic electron beam at different geometrical and operating conditions in triggered PD-PCE source as shown in figure 3. It has been observed that the electron beam of high density ($\geqslant$ 100 Acm^{-2}) propagated greater than 100 mm without using any external magnetic field.

In fact, plasma formation inside the HC cavity and generation of the electron beam have clearly shown the dependency on the HC aperture size, gas pressure, and seed electron in the simulation model. These simulation analysis and also experimental investigations are very much useful for the optimization and enhance the quality of PS discharge based electron beam for the various applications.

ACKNOWLEDGMENT

The authors wish to acknowledge Director, CSIR-CEERI for valuable support. The work has been supported under CSIR YSA project scheme.

REFERENCES

[1] J. Christiansen and C. Schultheiss, "Production of high current particle beams by low pressure spark discharges," *Zeitschrift. Phys. A, Atoms Nucl.*, vol. 290, no. 1, pp. 35–41, Mar. 1979.

[2] A. W. Cross, H. Yin, W. He, K. Ronald, A. D. R. Phelps, and L. C. Pitchford, "Generation and application of pseudospark-sourced electron beams," *J. Phys. D, Appl. Phys*, vol. 40, no. 7, pp. 1953–1956,Jul. 2007.

[3] R. P. Lamba, U. N. Pal, B. L. Meena and R. Prakash, "A sealed-off double-gap pseudospark switch and its performance analysis" *Plasma Sources Sci. Tech.*" vol. 27, no. 3, p. 035003, Feb. 2018.

[4] J. Vieker and K. Bergmann, "Influence of the electrode wear on the EUV generation of a discharge based extreme ultraviolet light source," *J. Phys. D. Appl. Phys.*, vol. 50, no. 34, p. 345601, Aug. 2017.

[5] Varun and U. N. pal, "PIC simulation to analyze peak electron current generation in a triggered pseudospark discharge based plasma cathode electron source", *IEEE Trans. Electron Devices*, vol. 65, no. 4, pp. 1542-1549 Apr. 2018.

[6] Varun and U. N. pal, "Investigation of Electron Beam Generation in Pseudospark Discharge-Based Plasma Cathode Electron Source", *IEEE Trans. on Plasma Science*, vol. 46, no. 6, pp. 2003-2008, Jun. 2018.

[7] Varun, H. K. Dwivedi and U. N. pal, "Breakdown Characteristics of Triggered Pseudospark Discharge-Based Multigap Plasma Cathode Electron Source", *IEEE Trans. Electron Devices*, vol. 65, no. 10, pp. 4607-4613, Aug. 2018.