Seminar

Institute for Plasma Research

Title : Design and Development Studies of Pseudospark Discharge based Plasma Cathode Electron Source for High Density and Energetic Electron Beam Generation for Pulsed Power Applications

Speaker: Dr. Varun Dixit
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Date : 22nd July 2022 (Friday)

Time : 03.30 PM

Venue : Online - Join the talk:
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Abstract:

In the recent past, pseudospark discharge based devices have gained much attention in various growing applications in the field of high-power plasma switches, electron-beam lithography, plasma processing, extreme ultraviolet sources, intense X-ray source, and microwave radiation source [1]-[3]. Recently, the research and development of the pseudospark discharge based plasma cathode electron (PD-PCE) source is more focus toward the generation of high density and energetic electron beam for the application of the surface modification and EUV/Soft X-ray radiation emissions [4]-[5]. In fact, PS discharge based devices have the capabilities for the generation of high current density ($\geq 10^4$A/cm^2), high power density (~10^9 W/cm^2) and high brightness (~10^{12} A/m^2 rad^2) with low emittance (~15mm mrad) electron beams [1]-[2].

In the research work, simulation and experimental investigations have been carried to generate high density and energetic electron beam from the developed 4-gap pseudospark discharge-based plasma cathode electron (PD-PCE) source suitable for EUV/soft x-ray radiations and microwave generations. Investigations have been carried out for the generation of electron beam from different configurations (single gap and multi-gap) of PD-PCE source for a wide range of geometrical and operating parameters, such as cathode aperture, gas pressure, and seed electron energy, using 2-D kinetic plasma simulation code. In fact, electron beam generation and propagation is a complex discharge process which is influenced by geometrical and operating parameters [6]-[9]. It has been observed that improper sequence of electrode aperture diameter can create the problem of quenching in the rise of electron beam current. The quenching phenomenon can be further avoided by the optimization of gas pressure and geometrical parameters [10].

Further, combined analysis of a single gap to multi-gap PD-PCE source with the operating argon gas pressures, applied voltages 20– 35 kV, and electrode aperture sizes 2–4 mm for the generation of pulsed

electron beams suitable for potential and growing applications in extreme ultraviolet (EUV)/Soft X-ray, microwave, and surface modification has been presented. The simulation analysis has helped in the design and development of multi-gap (4-gap) PD-PCE sources having uniform sequence of electrode aperture diameters (2 - 4 mm) for the generation of high-density and energetic electron beams suitable for EUV/soft X-ray radiations. The generated high density ($\sim 2.8 \times 10^5$ A/cm^2) and up to 32 kV electron beams are governed by the penetrated dynamic equipotential lines in the 4-gap PD-PCE source having uniform electrodes aperture diameter of 2 mm.

The characterization of multi-gap (4-gap) PD-PCE source for the generation of high current and energetic electron beams along with its propagation in the drift region has been performed by both experimental and plasma simulation analysis [11]. A high current of 0.5 kA (conductive phase) and up to 19.6 kV electron beam (HC phase) have been generated by the optimization of gas pressure, applied voltage, and external storage circuit parameter in the 4-gap PD-PCE source. The capacitance of the external storage capacitor has regulated the HC phase for the generation of energetic electron beam and conductive phase for the high current generation. The pulse width of the electron beam is controlled by the charging capacitors. The distribution of potential profile has shown the significant parameter for the propagation (upto 60 mm) and focusing of electron beam without use of any external magnetic field.

The developed PD-PCE source has shown the capability to generate repeatedly the high pulsed electron beam current of ~1.4 kA with current density of $\sim 1.1 \mathrm{x} 10^4$ A/cm^2 at 35 kV applied voltage with 4 mm electrode aperture. In addition, energetic pulsed electron beam of 32.5 keV is successfully generated and propagated to 60 mm distance without using any external guiding magnetic field from the developed 4-gap PD-PCE source having uniform sequence of electrode aperture diameter of 2 mm. The investigations and findings in the Ph.D. research work would certainly help for the optimization of suitable design and development of multi-gap PD-PCE source for the generation of high density and energetic electron beams required for the potential and growing applications in EUV and soft X-ray radiations, surface modifications, microwave and THz sources, etc.

References:

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