Design and Development of Pseudospark based Hollow Cathode Plasma Electron Gun

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Abstract: *A single gap Pseudospark based hollow cathode plasma electron gun has been developed at CEERI. An experimental investigation for the above electron gun was conducted at different operating conditions in argon and hydrogen atmosphere. The electron beam (current ≥ 50 amps, density ≈ 700 Acm-^{2}) is travelling more than 200 mm in the drift region through gaseous environment without using guiding magnetic field. Theoretical studies for the initiation phase of Pseudospark discharges have also been carried out by two dimensional kinetic simulation code (OOPIC-Pro). The pre-breakdown and breakdown phases of a pseudospark discharge have been investigated. The spatial and temporal behavior of the electron density at the anode have been reported as a function of the hollow cathode dimension, gas types & their pressure and mean velocities of injected seed electrons at the cavity back wall.*

Keywords: Pseudospark discharge; hollow cathode; OOPIC-Pro; pre-breakdown phase.

Introduction

The high-power microwave devices filled with plasma have unique properties [1]. The problems caused by drifting of ions from the plasma toward the gun regions of the tube can be mitigated by replacing the material cathode with plasma cathode [2]. A pseudospark discharge is a viable possibility in this respect, due to the emitted linear beam's characteristic properties such as, high current density and high brightness as well as self-focusing during its propagation [3]. It is an axially symmetric, selfsustained, transient, low pressure (typically 50–500mTorr) gas discharge and takes place in special hollow-electrode geometry of a hollow cathode/planar anode configuration in various gases such as nitrogen, argon, hydrogen and xenon. It operates on the left-hand side (with respect to the minimum) of the hollow cathode analogy to the Paschen curve. During a pseudospark discharge, low temperature plasma is formed as a copious source of electrons and ions and can be regarded as a low work function surface that facilitates electron or ion extraction by applying voltages of different polarities.

A single gap Pseudospark based hollow cathode plasma electron gun has been developed in our group at CEERI. An experimental investigation for the above electron gun was conducted for the analysis of beam, discharge and collector currents, different operating conditions in argon and hydrogen atmosphere. The electron beam (current ≥ 50 amps, density ≈ 700 Acm^{-2}) is travelling more than 200 mm in the drift region through gaseous environment without using guiding magnetic field, which confirms that the beam transport of electron beam was based on the neutralization of the space charge of the electron beam due to ionization of the gas molecules by the beam itself. The simulations have been carried out for the analysis of different phases of Pseudospark discharges by two dimensional kinetic simulation code (OOPIC-Pro). The spatial and temporal behavior of the electron density at the anode have been reported as a function of the hollow cathode dimension, gas types & their pressure and mean velocities of injected seed electrons at the cavity back wall[4-5].

Simulation using OOPIC-Pro

The initiation phase of Pseudospark discharge is very important in the whole hollow cathode discharge procedure because it has direct influence to parameters of discharge current, stability, pulse width, amplitude, switching time and physical dimension of hollow cathode. The simulation studies of the initiation phase of Pseudospark discharges in argon atmosphere have been carried out by two dimensional kinetic simulation code (OOPIC-Pro) where the pre-breakdown and breakdown phases of a Pseudospark discharge have been investigated. The spatial and temporal behavior of the electron density at the anode has been presented as a function of the hollow cathode dimension, gas types & pressure and mean velocities of injected seed electrons at the cavity back wall (Fig. 1 and Fig. 2). The growth phenomena is dependent on the Townsend coefficient due to local space charge from initial ionization growth to onset of the hollow cathode effect, and then hollow cathode effect become leading factor.

Experimental work and Discussion

An experimental investigation for the above electron gun was conducted for the analysis of beam, discharge and collector currents, at different operating conditions in argon and hydrogen atmosphere (Fig. 3 and Fig. 4). The hollow cathode was kept at –ve high voltage, while the anode and collector was at ground potential. The electron beam (current ≥ 50 amps, density ≈ 700 Acm^{-}

[2]) is travelling more than 200 mm in the drift region through gaseous environment without using guiding magnetic field, which confirms that the beam transport of electron beam was based on the neutralization of the space charge of the electron beam due to ionization of the gas molecules by the beam itself.

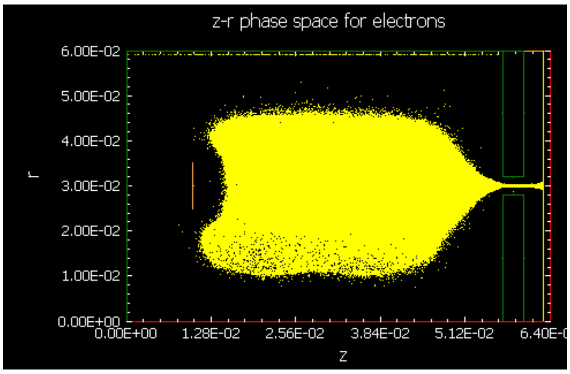

Figure1.Spatial distribution of electrons in the hollow cathode (Pressure: 30 Pa, V_a: 15 kV).

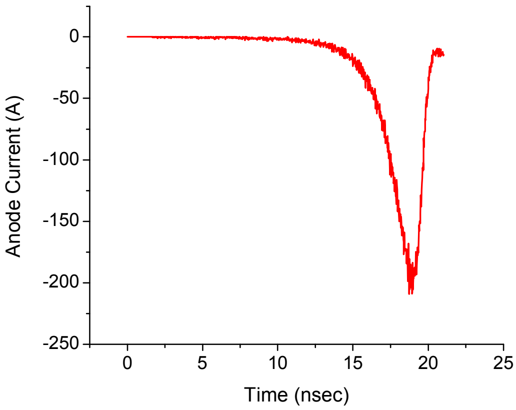

Figure 2. Profile of Anode current (Pressure: 30 Pa, V_a: 15 kV)

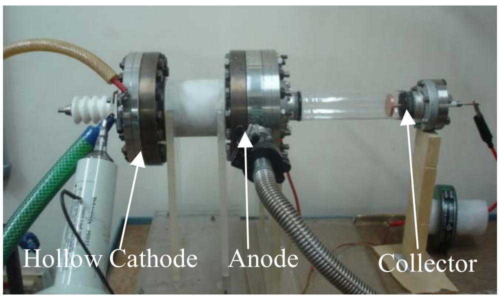

Figure 3. Photograph of the pseudospark plasma gun.

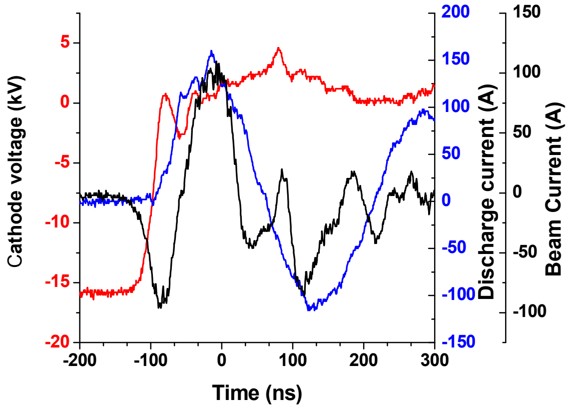

Figure4. Temporal evolution of beam produced from pseudospark chamber.

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