Concave Cold Cathode Electron Gun Using Obstructed Discharge

Amir H. Sari[1,2], Mahmood Ghorannevis[1], Heinrich Hora[3,4], Frecrick Osman[2], Reynaldo Castillo[5], Mohammad R. Hantehzadeh[1], R.Höpfl[3]

[1] *Plasma Physics Research Center, Science & Research Campus Of I.Azad University, P.O.Box, 14665-678, Tehran, Iran*
[2] *School of Quant. Meth. & Mathemat. Sc., University of Western Sydney, Penrith South DC NSW 1797, Australia*
[3] *Dept. Theoretical Physics, University of New South Wales, Sydney 2052, Australia*
[4] *Faculty of Electr. Engineering, University of Applied Science, Deggendorf, Germany*
[5] *College of Science, Technology & Environment, University of Western Sydney, Penrith South DC NSW 1797, Australia*

Abstract:

Electrical gas discharge can produce a powerful electron beam which in this way where the traditionally used hot cathode electron source is not necessary. In this study a concave cold cathode electron gun with a simple configuration is described for the energy up to 30 keV. Helium in a low pressure is used as working gas. The discharge condition is called obstructed discharge. A negative DC high voltage is applied to a concave cathode up to -30 kV which determines electron energy. The dependence of gas pressure to the current at target plate for given voltages up to 30 kV and voltage-pressure characteristics at different beam currents were measured.

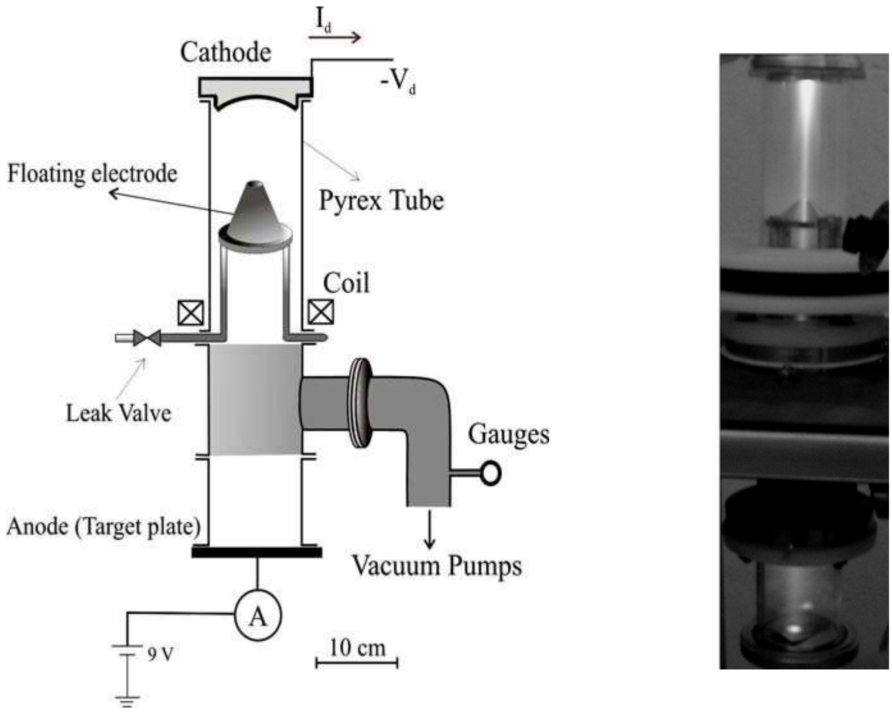
Keyword: Glow discharge electron gun; Obstructed discharge; Concave cold cathode; Fast neutrals; Charge exchange; Secondary electron emission

1. Introduction

In an electron gun, where the conventional thermoionic cathode is replaced by a cold, secondary electron emitting electrode, electron emission is stimulated by bombarding the cathode with high energy ions, fast neutrals and photons. The obstructed regime of glow discharge has been of interest for many years [1-6]. The usual definition of the obstructed discharge is given in term of reducing the electrode separation (or gas pressure) in a glow discharge [3, 4, 7]. When the separation is decreased to a value somewhat longer than the cathode dark space (CDS), the discharge voltage begins to rise. This effect is more pronounced if the cathode-anode separation is further decreased.

2. Experiments and results

Schematic configuration of the electron gun has been shown in figure 1. Both electrodes are in a Pyrex tube as vacuum chamber. The vacuum chamber is evacuated by a turbo molecular pump. All the vacuum seals are Viton O-rings. Pressure gauge is located at the top of the turbo molecular pump. The achievable end pressure is 5.7×10^{-4} Pa. The working gas is a high purity helium gas and is supplied through a needle valve into the chamber and system can operate in gas pressure from 1 to 10 Pa.



(a) (b)

Figure 1. (a) Schematic structure of the electron gun and (b) Constructed electron gun facility in an experiment.

The anode, conic intermediate electrode (floating electrode) and the pumping duct are grounded and a negative DC voltage from -1 to -30 kV can be applied to the cathode, which determines the electron beam energy. The cathode and target plate were made of aluminium and floating electrode by stainless steel. The cathode surface seems very essential for secondary electron emission. The cathode face was made concave to focus the electron beam electrostatically. The curvature of the concave cathode decides the beam focus. We produced different curvature radii 60, 80 and 100 mm for concave cathode. The floating electrode works as a barrier for differential pumping by introducing the gas into cathode region. In the experiments we made a connection between the floating electrode and ground to avoid accumulation of minus charge on the floating electrode. A pancake coil with current density of 4.2 A/mm^2 is used as a focus magnetic lens to adjust the beam position on the target plate (see Fig.1-b). Because of smaller cross section of scattering and ionization for electron in helium atoms than other kind of gases like argon we used helium as operating gas. The measured electron beam current at target plate was in the range between 1-12 mA.

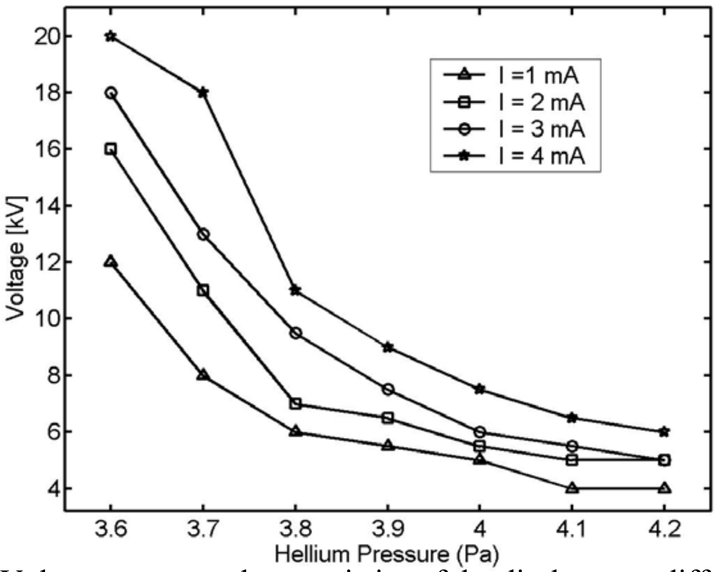


Figure 2. Voltage-pressure characteristics of the discharge at different currents.

The obstructed discharge in low operating gas pressure produces a monochromatic beam owing to little interactions of electrons with neutrals [8]. The model of electron producing has numerically and experimentally disscussed by M.Fukao et.al (ref. 8). Figure 1 (b), shows the constructed electron gun in a typical experiment. A thin metal sheet was used at target plate in order to determine the electron beam spot size which was about 1 cm.

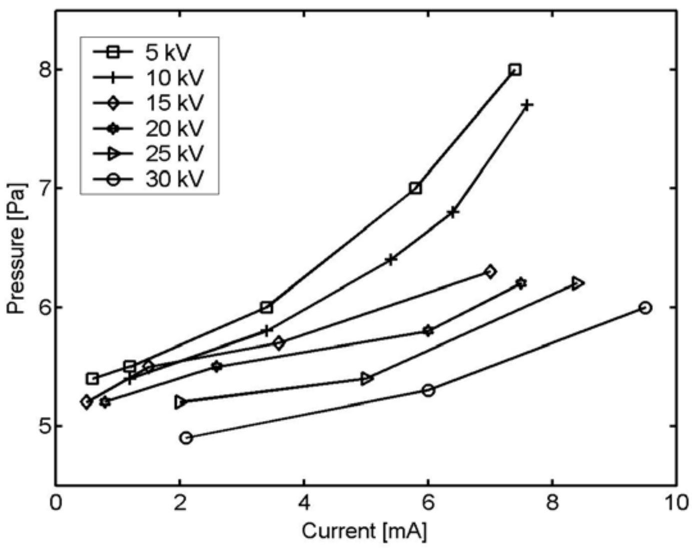


Figure 3 Pressure vs. current measured at target plate for given voltages

The result show that the increase of cathode curvature radius leads to decrease of electron beam spot size. Figure 2 shows the measured voltage-pressure characteristics of discharge at different discharge current. The sharp rise of discharge voltage (characterizing the obstructed regime) around p=3.6 Pa pressure can be clearly observed. The results confirm that the breakdown voltage follows the curve of Pachen's law in which the breakdown voltage is given as a function of pd where p and d are gas pressure and anode-cathode distance, respectively. The dependence of helium gas pressure and current measured at target plate for different discharge voltages carried out. Figure 3 shows these characteristics for voltages between 5 to 30 kV.

3. Conclusion

In this paper we described construction of a concave cold cathode electron gun using helium obstructed discharge. The pressure-current characteristics of the discharge at target plate for given voltages up to 30 kV and, voltage-pressure characteristics of discharge at different discharge current have been measured. The electron beam spot size dependence to cathode curvature radii was determined. Main mechanism of electron supply is the charge exchange of an ion and neutral bombardment of cathode. The advantage of this method is that a monochromatic electron beam could be produced which dose not need any extra focusing tools with a very simple structure.

Acknowledgments

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