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Fabrication of a 50 keV Cold Cathode Electron Gun

SARI Amir H., GHORANNEVISS Mahmood, HORA Henrich[1,2], OSMAN Frederic[3], HÖPFL Reinhard[1], HANTEHZADEH Mohammad R. and BOLOUKI Nima

Plasma Physics Research Center, Science & Research Campus of Islamic Azad University, Tehran, Iran
[1]Faculty of Electr. Engineering, University of Applied Science, Deggendorf, Germany
[2]Dept. Theoretical Physics, University of New South Wales, Sydney 2052, Australia
[3]School of Quant. Meth. & Mathemat. Sc., Univ. Western Sydney, Penrith, NSW, Australia

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Abstract

In this study the structure and schematic configuration of a concave cold cathode electron gun has been shown, which use obstructed discharge for electron producing. The concave cathode works well to coverage the electron beam and reduce particle loss to the chamber wall. The discharge current is adjusted by gas pressure, which after helium introducing is 4.5–8 Pa. A negative DC high voltage is applied to a concave cathode up to –50 kV which determines electron energy. The gas pressure dependence to current for given voltages up to 30 kV and breakdown voltage characteristics have been investigated.

Keywords:

electron gun, obstructed discharge, concave cold cathode

1. Introduction

The cathode fall in potential is necessary in order to maintain a cold cathode glow discharge and occurs over a distance, the cathode dark space (CDS), which is determined by the gas pressure, the current density, the cathode material and the gas species. If the electrode separation is reduced so that the anode enters the normal CDS, then the sustaining voltage of the discharge increases such that the current is maintained. This operation regime is known as an "obstructed glow discharge" [1,2]. An obstructed discharge may also be produced if the electrode separation is maintained constant and the pressure is decreased. Helium, in particular has anomalously large increase in sustaining voltage as the electrode separation is decreased [3-7].

2. Experiments

Figure 1 shows a schematic structure of the constructed electron gun. Both electrodes are in a Pyrex tube as vacuum chamber. 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. A turbo-molecular pump is used to evacuate the chamber. The achievable end pressure is 1.4×10^{-3} Pa. All the vacuum seals are Viton O-rings. The working gas is a high purity helium gas and is supplied through a leak valve into the chamber and vacuum reaches to 4.5–8 Pa.

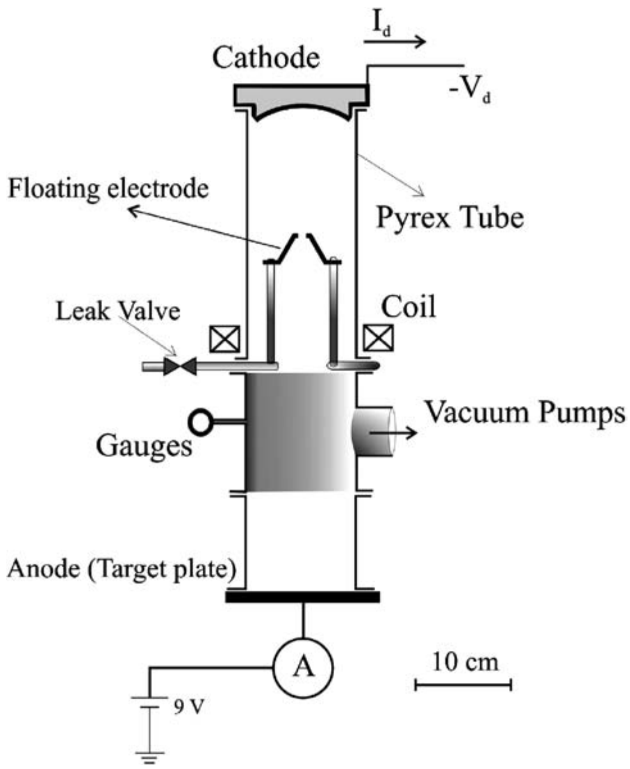

Fig. 1 Schematic structure of the electron gun with a concave cathode.

Corresponding author's e-mail: amirsari@hotmail.com (Amir H. Sari)

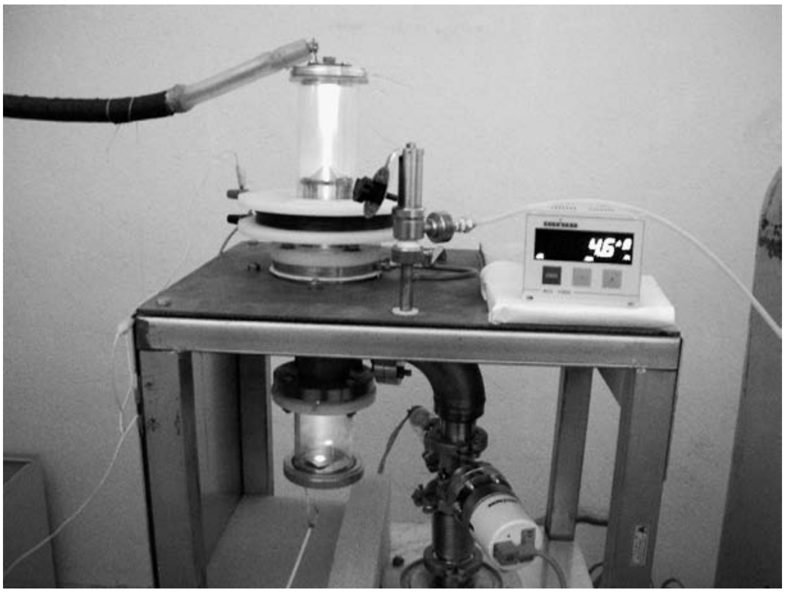

Fig. 2 Constructed electron gun facility in an experiment.

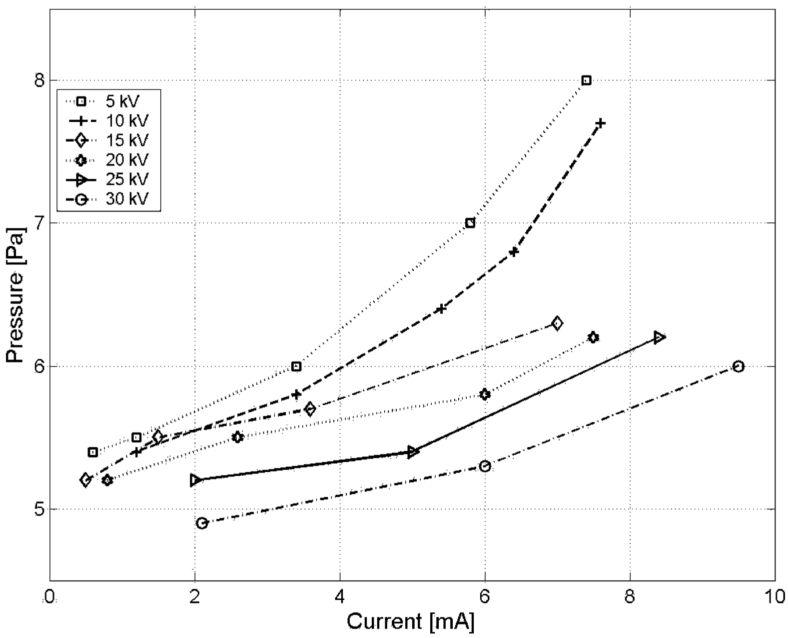

Fig. 3 Pressure vs. current measured at target plate for given voltages.

The anode and the pumping duct are grounded and a negative DC voltage from –1 to –50 kV is applied to the cathode, which determines the electron beam energy. 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 magnetic field with current density of 4.2 A/mm^2 is used to adjust the beam position on the sample as shown in Fig.1. Figure 2 shows the constructed electron gun facility in Plasma Physics Research Center. We produced different curvature radii 60, 80, 100 mm for concave cathode. The cathode surface seems very essential for secondary electron emission.

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.

Measurements of dc-breakdown voltage for the vacuum chamber were made over the helium gas from 5.3 to 7.9 Pa. The breakdown voltages as a function of helium pressure (p) are shown in Fig 4. The results show that the breakdown

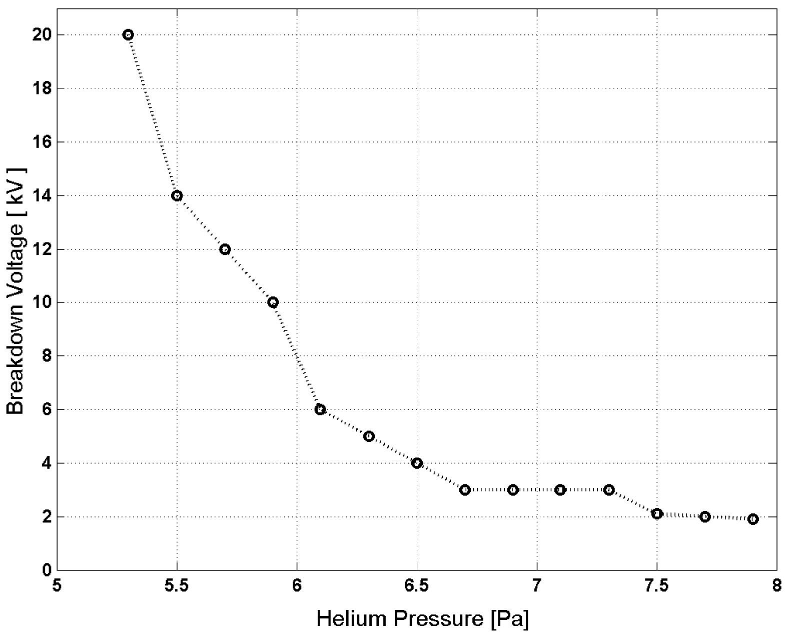

Fig. 4 Experimental breakdown curve.

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.

Spot size dependence to cathode curvature was measured by using a thin metal plate. The results of this measurement have listed in Table 1.

The obstructed discharge in low operating gas pressure produces a monochromatic beam owing to little interactions of electrons with neutrals [7]. Under the discharge condition in this mode, the potential exists over the whole Anode-Cathode space. Therefore, an ion produced by electron-bombardment ionization is always accelerated toward the cathode by the potential gradient. On its way the ion suffers charge exchange with neutrals and then is converted into a neutral with the same energy as the ion possessed before and at the same time a cold ion remains. The cold ion is accelerated again and produces another energetic neutral repeatedly. As a result, an ion can make many fast neutrals before the charge arrives at the cathode. The fast neutrals collided with the cathode ballistically, are producing enough secondary electrons on the cathode to sustain the discharge [7].

3. Conclusion

Electrical gas discharge can produce a powerful electron beam which in this way where the traditionally used hot cathode electron source is not necessary. The structure and schematic configuration of the concave cold cathode electron gun with obstructed discharge mechanism was described. The gas pressure dependence to current at target plate for given voltages up to 30 kV, breakdown voltage profile and spot size dependence to cathode curvature radii were measured. 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 simple structure.

Table 1 Spot size measurement or different concave cathode curvature radii.

Curvature radii (mm)	Spot Size (mm)
100	5.5
80	8.75
60	11

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