The use of microchannels as an electron source for the Polywell

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1. Abstract

A new and simple type of electron gun is presented. Unlike conventional electron guns, which require a heated filament or a discharge, extractor, accelerator and focusing electrodes[1-4], this gun uses the collimated electron microchannels of an IEC discharge to achieve the same outcome. A cylindrical cathode is placed coaxially within a cylindrical anode to create the discharge that produces collimated beams of electrons that emerge along the axis. This geometry essentially isolates one of the microchannels that emerge in a negatively biased IEC grid [7-9]. The internal operating pressure range of the gun is 50 - 400 mTorr. As a result, a small aperture separates the gun from the main vacuum chamber in order to achieve a pressure differential, which enables the Polywell that is located within the chamber to operate in the units of mTorr pressure range. The collimated electron beam emerges from the aperture into the vacuum chamber and can be injected into the Polywell. The performance of the gun is unaffected by the pressure differential between the vacuum chamber and the gun.

2. Electron Gun Design

This plasma electron gun is of considerably simpler design then most plasma electron guns. The cathode used in this gun is a open ended cylinder, which is different from most hollow cathode guns in which the body of the gun forms the well known cup shaped hollow cathode. The cylindrical cathode in this gun is encased within a closed cylindrical anode, with the only opening being the aperture. This setup requires no extraction, acceleration or focusing electrodes to create the electron beam. Because of this there is no requirement for a pressure differential between the discharge and beam target areas. However a pressure differential can easily be created by simply adding the required gas through the gun, and letting it diffuse into the target region via an aperture.

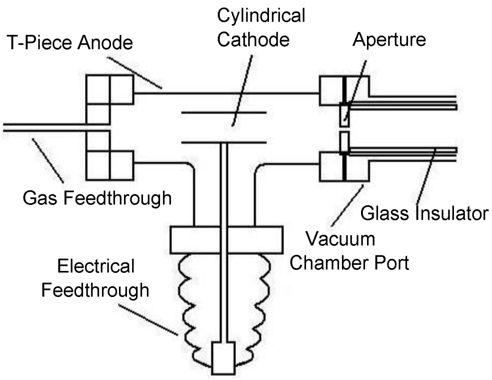
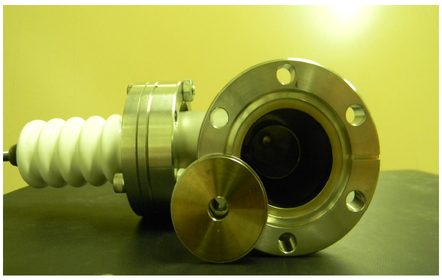


Fig 1: *(LEFT)* The electrode configuration of the gun is a CF tee-piece with a length of 125mm and a 35mm inner diameter. One end of the tee is the gas feed through, the side of the tee is a 35kV electrical feed through. The other end of the tee has a metal plate with a central aperture and is placed in the lip of the tee and then bolted onto the chamber. Three sizes of aperture were used 5mm, 7.5mm and 10mm. The electrical feed through is attached to a cylindrical cathode 37mm long and inner diameter or 27mm. All of the metal pieces used in the gun are stainless steel.

__Fig 2:__ (Right) Photograph of the plasma cathode electron gun. The cylindrical cathode can be seen inside.



3. Experimental Setup

The electrode configuration of the gun is a CF T-piece with a length of125mm and a 35mm inner diameter. One end of the Tee is the gas feed through, the side of the Tee is a 35kV electrical feed through. The other end of the Tee has a metal plate with a central aperture and is placed in the lip of the Tee and then bolted onto the chamber. Three sizes of aperture were used 5mm, 7.5mm and 10mm. The electrical feed through is attached to a cylindrical cathode 37mm long and inner diameter or 27mm. All of the metal pieces used in the gun are stainless steel.

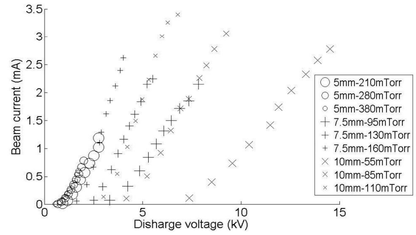
The discharge of the gun was powered with a 25kV 45mA regulated power supply. The vacuum chamber is cylindrical, roughly 2m tall with a 0.4m diameter and a dome shaped top. This is being pumped by a Pfeiffer Balzer type TPH-510 turbopump with a rotary backing pump this achieves a background pressure of 0.2mtorr. The internal pressure of the gun was varied from 35-190mtorr of hydrogen for target pressures of 4-12mtorr.

The Electron beam current was measured by a grounded copper plate 100mm away from the the end of the insulating glass. A total diatance of 160mm away from the aperture of the gun.

4. Results and Discussion

This gun is able to operate at discharge and target pressures as high as 190mtorr as there is no longer any possibility of the extraction and focusing electrodes breaking down. This problem is usual the basis for the upper limit of pressures for plasma cathode electron guns, however lower target pressures are also required for some applications. A pressure differential was easily created by feeding the gas through the gun, and letting the gas diffuse into the chamber. The internal pressure of the gun was varied from 35-190mtorr for target pressures of 4-12mtorr, however it is not necessary to have the target at a lower pressure. The current produced is between 0.07-3mA for discharge currents of 1-45mA and breakdown voltages of 0.5-12kV.

__Fig3:__ (Right) The electron beam current as a function of the discharge voltage. The legend shows aperture size and gas pressure. A larger beam current is observed for increasing aperture size and increasing pressure. Except for the 5mm aperture which shown the opposite relationship to pressure.



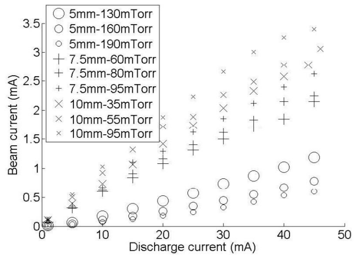
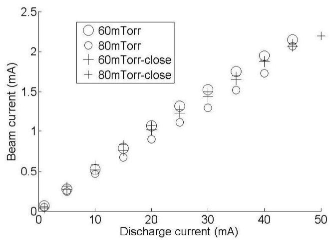


__Fig4:__ (Left)The electron beam current is again shown here but instead as a function of the discharge current. The same relationship that was observed in Fig3: is seen again. It is important to note that the current measured is an underestimate of the beam current. This is due to the ejection of electrons from the plate by fast neutral hydrogen molebules and the energetic beam electrons themselves. It is estimated that this disprecpancy is a factor of 2-4 depending on the beam energy

__Fig5:__ (Right) A copper plate was 10mm away from the gun aperture. This is compared to the current collected at 160mm. There is no appreciable beam loss ove this distance.



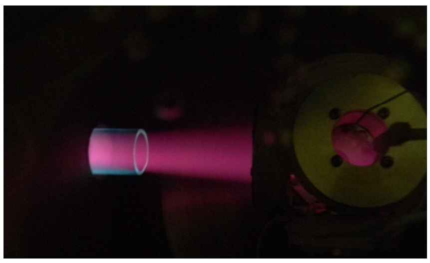


__Fig6:__ (Left) Here the chamber pressure was increased to 25mTorr. The electron beam can now be seen by the excitation of the backgroud gas.

5. Conclusions

This style of electron gun is simpler than conventional plasma cathode electron guns. It does not require an additional extraction electrode, focusing electrode or magnetic field for the discharge or beam focusing. The current produced by conventional guns can achieve 30-100% the total discharge current [4,5,6]. While this gun will only produce ~5% of the discharge current for the smallest aperture to ~30% for the largest aperture. With a maximum expected percentage of ~40% due the discharge characteristics of the open ended cylindrical cathode. Due to the lack of external electrodes the target pressure can be as high as 190mTorr, or as low as 4mTorr when he gas is fed through the gun.

6. References

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