DEVELOPMENT OF AN RF DRIVEN PLASMA CATHODE FOR ION SOURCES*

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Abstract

Conventional tungsten cathode driven plasma sources are limited in the ability to provide large discharge currents and high discharge voltages for CW discharge plasmas. An RF driven plasma cathode based on the multicusp ion source technology has been developed at LBNL. It is shown that large electron currents at high discharge voltage can be achieved for CW discharge operation while maintaining very long cathode lifetime.

1 INTRODUCTION

Multiple-charge-state ions are of current interest for several applications, such as MeV ion implantation, nuclear physics experiments, and radioactive beam accelerators.[1] Many of these applications require DC or 100 % duty factor operation. Production of multiple charge state ions requires high energy primary electrons. It has been demonstrated that modest charge state ions can be produced in a conventional tungsten filament driven multicusp ion source, however, cathode lifetime is limited.[2] As the discharge voltage is increased, the plasma density increases causing increased ion bombardment of the filament. At some point the ion bombardment dominates the heating of the filament and temperature runaway will occur. This can result in either exceeding the current limit of the discharge power supply causing the discharge voltage to drop or the filament to burn out. Results have been reported for a programmed filament ion source which produced a high voltage pseudo-CW discharge with good percentages of multiply-charged ions while improving cathode lifetime.[3] The ion source presented here is based on RF driven multicusp ion source technology.

2 EXPERIMENTAL SETUP

An RF driven multicusp plasma cathode was utilized for these tests. It was coupled to a multicusp plasma chamber by a two grid extraction system.

A schematic representation of the ion source configuration is shown in Figure 1. The cathode chamber is 10 cm diameter by 13 cm long. Plasma confinement in the cathode chamber is maintained by 20 line cusp magnets on the side cylindrical wall and 4 line cusps placed on parallel chords on the back flange. The front wall contains the plasma electrode which is a molybdenum disk with two hundred 2 mm diameter holes. They are arranged to provide 50 % transparency over an area approximately 4 cm in diameter. The electron extraction electrode has a similar pattern and is spaced 2 mm from the plasma electrode. The source chamber is 20 cm in diameter, 15 cm long. Magnetic cusp confinement is present on the side and front walls. The cylindrical wall has ten columns of samarium-cobalt magnets installed longitudinally on the external surface. The front wall, the extraction end, has ten magnets placed radially with an iron ring located at the hub to close the magnetic field lines at the center. This arrangement provides a 3 cm diameter field free region around the 2 millimeter diameter extraction aperture. Access ports are provided between the side wall magnets for viewing windows, gas feeds or diagnostics. A simple two-electrode system was used to extract ions from the source chamber.

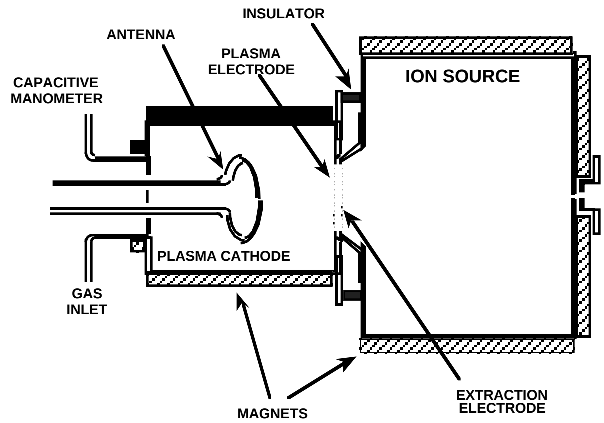

Figure 1: Schematic of the plasma cathode/ion source arrangement.

Figure 2 shows a schematic of the experimental set-up. The plasma cathode was driven by a 13.56 MHz RF generator. The generator was coupled through a matching network to a single loop antenna mounted within the cathode. The network includes an adjustable turn-ratio transformer to match the 50 Ω output impedance of the RF generator to the single loop antenna. It also provides high voltage isolation between the generator and the ion source.

Cathode and source chamber pressures were measured with capacitive manometers. The operating gases were

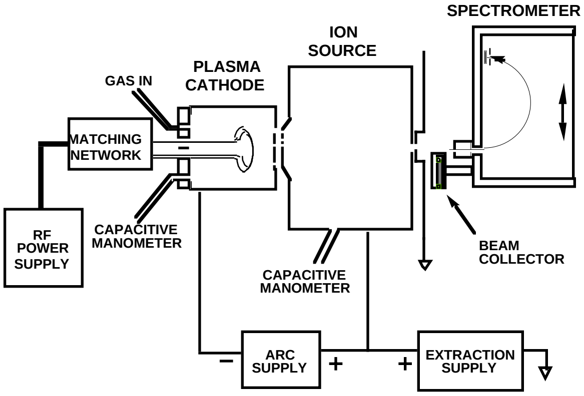

Figure 2: Experimental setup.

introduced into the plasma cathode chamber. Analysis of the extracted beam was performed with a 180° mass analyzer. The analyzer magnet was energized by a programmable power supply. The magnet current and Faraday cup signals were used to drive the input channels of an X-Y recorder. Total extracted current could be measured with a separate Faraday cup mounted on the front of the spectrometer. In this arrangement one could either measure the ion species distribution or the total beam current.

3. EXPERIMENTAL RESULTS

The primary goal of these tests was to demonstrate that the RF driven multicusp plasma cathode could provide large currents of primary electrons at various energies. All reported data was obtained with argon as the operating gas. The gas was introduced to the plasma cathode and allowed to flow through the electron extraction electrodes to the ion source chamber. Measurements showed that the plasma cathode pressure was less than 5 % higher than the ion source chamber. Quoted pressures are for the plasma cathode chamber.

The plasma cathode was driven by a 13.56 MHz RF generator capable of delivering 2500 watts. The electron extraction power supply could supply 16 amps up to 600 volts. It was found that the extraction power supply current limit was typically attained at an RF power less than 1600 watts. Figure 3 is a plot of extracted electron current as a function of RF power at several plasma cathode pressures. The extraction voltage was 100 volts. It can be seen that the extracted electron current is a strong function of RF power. The dependence of extracted electron current on pressure is modest. It was difficult to maintain a cathode discharge below 400 watts of RF power.

Figure 4 shows the relationship between extraction voltage and extracted current at a fixed plasma cathode power for two cathode pressures. The cathode RF power was 1000 watts. It can be seen that at the lower voltages the extracted current is a weak function of extraction

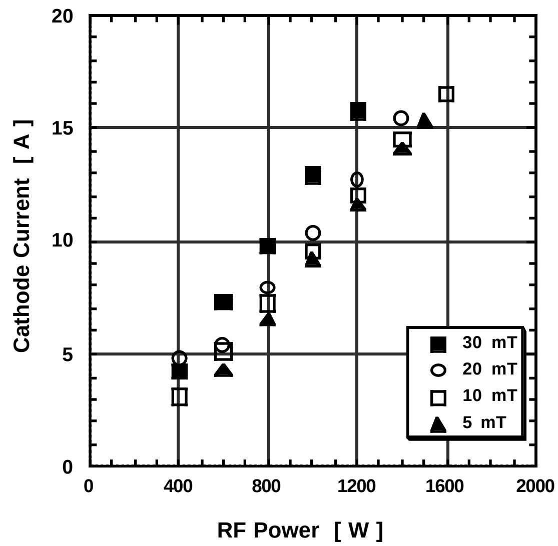

Figure 3: Extracted electron current as a function of plasma cathode pressure.

voltage. There were some problems with breakdown at the higher voltages and the data may be effected by the breakdowns.

The principal purpose for these tests was to enhance the production of multiply-charged ions. It can be seen in Figure 5 that the production of doubly charged argon was enhanced as the discharge voltage was increased. Discharge current was held constant at 6 amps and the cathode pressure at 30 mT. CW discharge operation was maintained for several hours. There were voltage breakdowns in the extraction electrodes for discharge voltages above 200 volts.

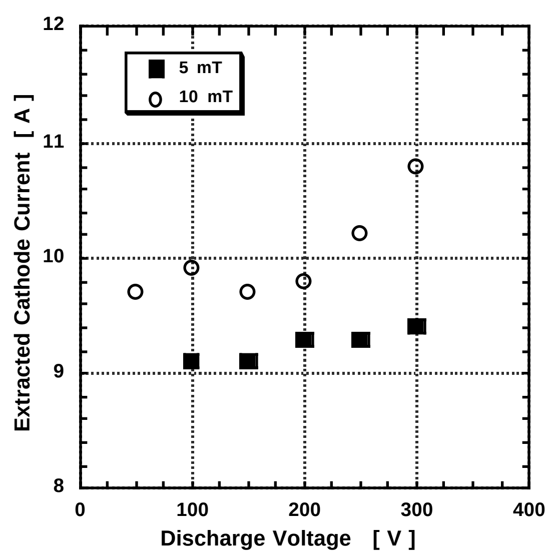

Figure 4: Extracted cathode current as a function of extraction voltage.

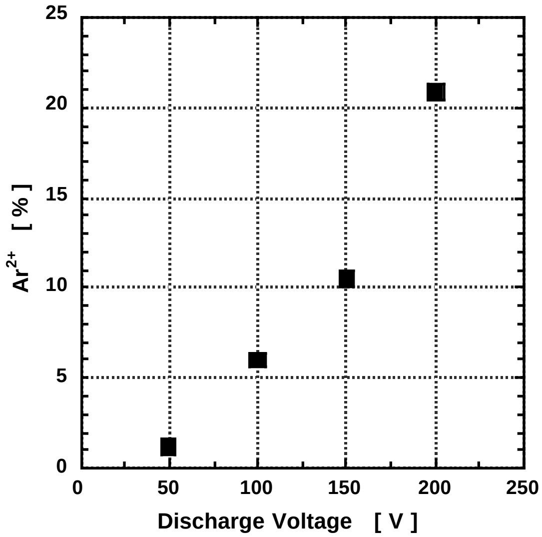

Figure 5: Ar^{2+} as a function of discharge voltage.

4 CONCLUSIONS

These preliminary studies have indicated that a plasma cathode based on RF driven multicusp technology can supply significant DC electron currents at high voltages. It is shown that production of multiply-charged ions can be enhanced with the higher discharge voltages and currents while maintaining cathode lifetime. The primary problem encountered was deformation of extraction electrodes due to heating from the plasma and intercepted extracted electrons. This contributed to breakdown problems at higher extraction voltages. New extraction electrodes have been fabricated and the cathode is being modified. The new electrode design will allow for free expansion of the grid structure which should eliminate grid deformation. This should allow for more stable operation with less breakdowns. Tests will continue with the goal of expanding this technology to more applications.

5 ACKNOWLEDGMENTS

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