Plasma Chamber Erosion in a CW H^- Ion Source Powered by a Planar External RF Antenna

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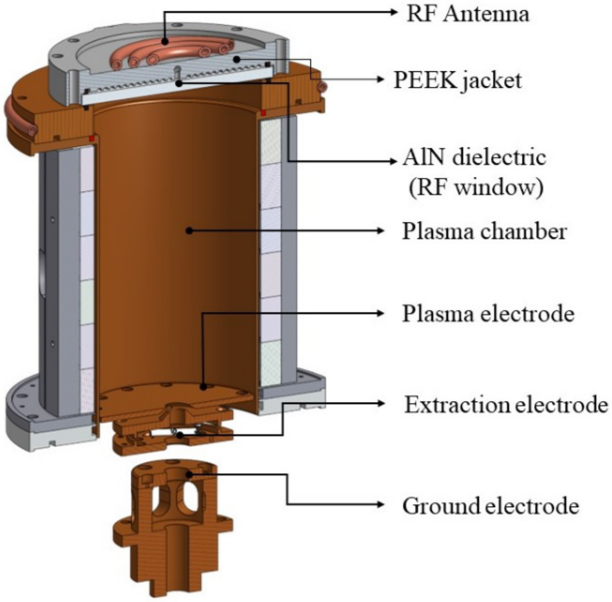
Abstract. One of the challenges in D-Pace's 13.56 MHz external planar RF antenna-powered H^- ion source is the erosion of the copper plasma chamber and subsequent deposition of copper on the RF window. The deposition reduces the power coupling between the RF antenna and the plasma, and leads to unstable beam currents from the ion source. Some factors like the gas pressure in the plasma chamber, the plasma chamber material and the inductance of the RF antenna, can affect the extent of the copper erosion. These factors are examined in this study and the corresponding H^- beam current behaviour is reported.

1. **Introduction.** External Radio-Frequency (RF) antenna-powered ion sources should offer maintenance-free operation due to the absence of filaments which erode in the plasma. D-Pace is developing a 13.56 MHz external planar RF antenna-powered ion source capable of producing negative ions. This is a hybrid design between TRIUMF-licensed filament ion source [1] and RADIS ion source licensed from the University of Jyvaskyl¨a¨ [2]. The section view of the RF ion source is shown in Fig. 1(A). The ion source can produce about 11.8 mA of H^- beam current at 30 keV beam energy, at about 5 kW of RF power applied to the external RF antenna [3]. The corresponding tunes are shown in Fig. 1(B). Unfortunately, our goal of maintenance free operation of the RF ion source is challenged by the erosion of the copper plasma chamber and subsequent deposition of copper on the AlN (Aluminum Nitride) dielectric disc that forms the window between the antenna and the plasma. A typical picture of the deposition is shown in Fig. 2. The current study deals with the details of the erosion and the various experimental attempts performed to overcome the challenge.

2. **Methods and experiments.** The copper erosion from the plasma chamber could be due to the capacitive coupling effects from the RF antenna. A high voltage on the RF antenna leads to a high voltage in the RF sheath [5]. This can further lead to ion acceleration to the grounded plasma chamber walls and subsequent chamber erosion. Experiments were conducted to determine the influence of different parameters on the copper erosion. Factors like the operating pressure in the plasma chamber (10 sccm, 15 sccm, 20 sccm H_2 gas flow rates), inductance of the external RF antenna (1.1 μH, 0.8 μH) and the plasma chamber material (copper plasma chamber and molybdenum lined plasma chamber) were considered in the experiments. Beam currents and tunes were recorded for all the experiments and the AlN window was checked visually after the experiments for the metal deposition.

3. **Results and discussions.** Experiments suggest that the gas pressure inside the plasma chamber can significantly affect the copper erosion rate. High pressure operation (20 sccm gas flow) achieved about 11.8 mA H^- beam current whereas the low pressure operation (10 sccm gas flow) could achieve only about 2 mA of H^- beam current. The reduction in the optimum plasma



Parameter	Value (H^-)
Total beam current (mA)	11.8
Forward RF power (W)	4800
Reflected RF power (W)	40
Bias power supply(mA, kV(beam energy))	20.1 , 30.0
Extraction electrode (mA, kV)	93.4 , 3.4
Plasma electrode (A, V)	12.0 , 34.6
Gas flow (sccm)	20
4 RMS Normalized emittance (mm.mrad)	0.68

(B)

(A)

Figure 1. (A) Section view of the RF ion source. AlN window is cooled by water flowing between the window and PEEK jacket [4]. (B) Tune data for 11.8 mA H^- beam current from the ion source.

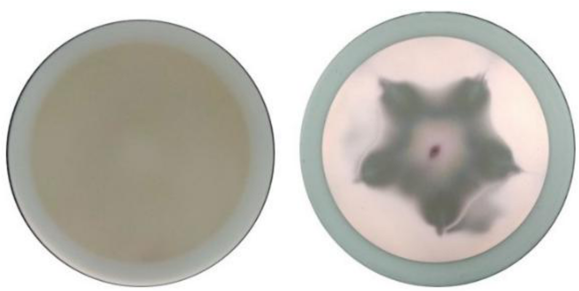


Figure 2. A typical picture of the AlN dielectric window (RF window), before (left) and after (right) the experiments. The copper eroded from the chamber gets plated on the window during the experiments, leading to decrease in power coupling from the RF antenna to the plasma. The experiments were performed at 30 keV beam energy.

electrode voltage (~ 55 V for 10 sccm and ~ 30 V for 20 sccm) for higher gas flow indicates a reduction in the RF sheath voltage. This effect can be explained by the capacitive coupling model [5], where it can be seen that the RF sheath voltage decreases as the plasma density increases. Reduction in antenna inductance from 1.1 μH to 0.8 μH resulted in poor coupling between the antenna and the plasma. This is due to the reduction in mutual inductance between the antenna and the plasma [6]. The experiments with Mo liners on the copper chamber indicate a lower erosion rate. But, it can be seen that the Mo liners also eroded and got deposited on the RF window.

4. Conclusions. Experiments suggest that the RF sheath voltage is directly influenced by the operating pressure in the plasma chamber. The RF sheath voltage further depends on the voltage on the external antenna. A reduction in the inductance value of the antenna leads to poor power coupling and hence is not useful in reducing the erosion. Other methods (Fara-day shield, capacitive termination of antenna circuit, additional dielectric shielding, low sputtering plasma chamber material etc.) need to be pursued for reducing the capacitive coupling effectively.

5. References.

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