Ferromagnetic Enhanced Inductively Coupled Plasma Cathode for Thruster Ion Neutralization

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INTRODUCTION

Plasma cathodes can be used as electron sources in electric propulsion applications. Unlike hollow cathodes where a low work function insert material that needs to be heated to elevated temperatures is utilized for the electron emission, plasma cathodes do not need to be preheated, and could be switched on instantaneously. Recently, at Bogazici University Space Technologies Laboratory (BUSTLab), radio frequency (RF) plasma cathode devices for use as electron sources of plasma thrusters have been studied, manufactured and successfully tested. Introduction of a ferromagnetic core enhances the power transfer efficiency of the inductively coupled plasma (ICP). In this paper, we present the design, manufacture and tests of two prototype radio-frequency cathodes, one with a standard coil antenna and the other with Mn-Zn ferrite core, for use in space propulsion applications as an electron source. The extracted electron current, electron extraction cost and the gas utilization factor for the developed plasma cathodes have been studied.

EXPERIMENTAL SETUP

Diameter: 1.5 m

Length: 2.7 m

Background pressure: 2×10^{-5} Torr at 5 sccm argon flow rate

FIGURE 1. BUSTLab Vacuum Chamber

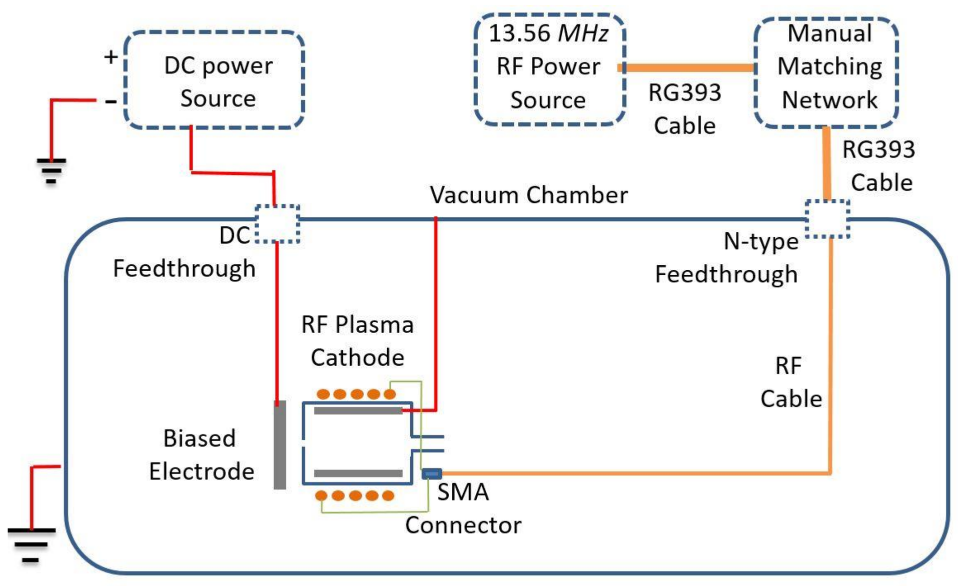


FIGURE 2. Experimental Setup for the RF cathode tests

DESIGN OF THE RF PLASMA CATHODES

Drawings of the built RF plasma cathode devices are shown in Figure 4. Figure 4a shows the cathode with a coil antenna, whereas in Figure 4b, the cathode with an antenna where a novel design of ferrite materials in desired orientations (as shown in Figure 5) is shown.

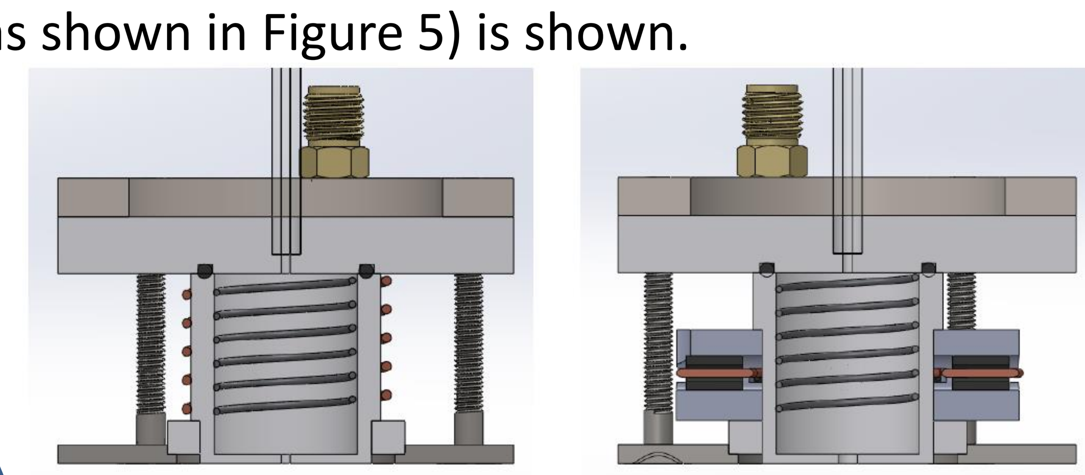


FIGURE 4. Cross-sectional drawing of the a) RF plasma cathode with a standard coil antenna b) RF plasma cathode with a ferrite core antenna

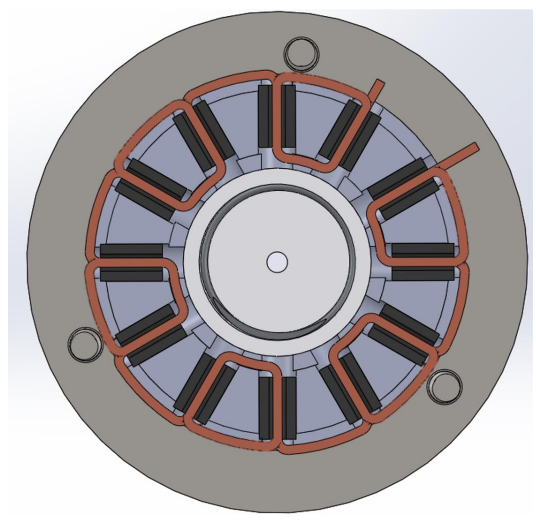


FIGURE 5. Structure of the ferrite core antenna

RF PLASMA CATHODES

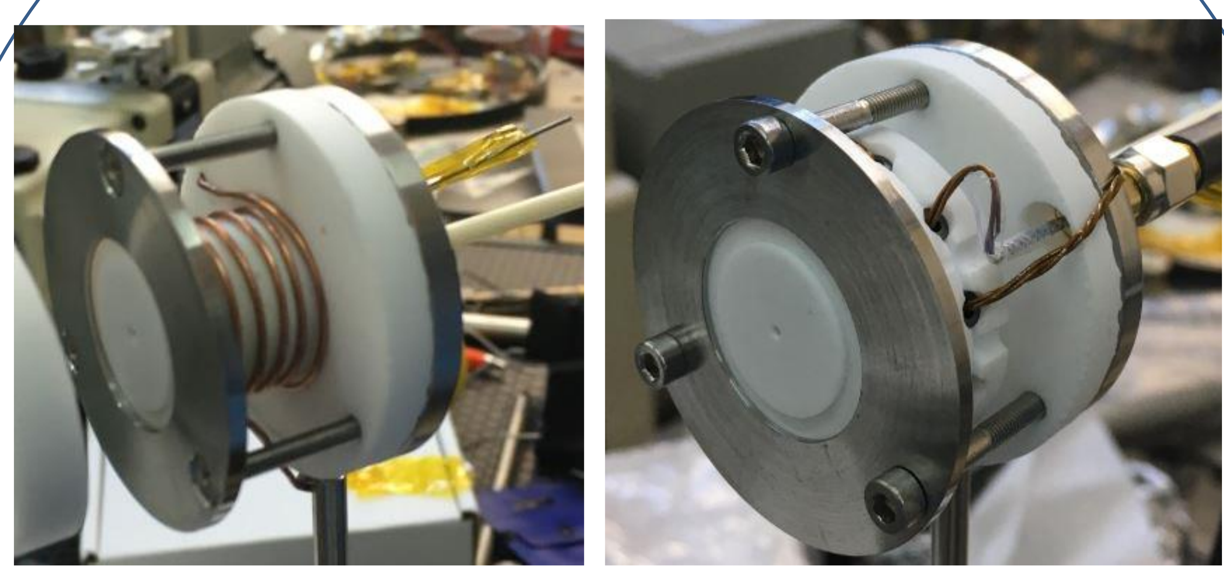
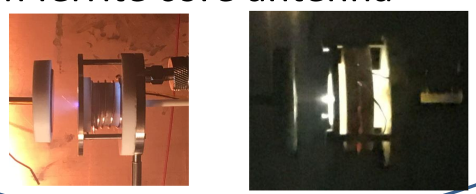


FIGURE 3. a) Picture of the ICP plasma cathode with 5 turn coil antenna, b) Picture of the plasma cathode with single turn ferrite core antenna



EXPERIMENTAL MEASUREMENTS

FIGURE 6. A biased electrode is placed 12mm in front of the cathode orifice for electron extraction

ELECTRON EXTRACTION

The measured values are compared with similar studies from the literature as presented in Table 1. The electron extraction cost is defined as the power required for the plasma production and the extraction of 1 A of electron current. The gas utilization factor indicates the average number of times that an atom repeats ionization/recombination while it stays inside the discharge chamber.

TABLE 1. Comparison of the performance parameters for the plasma cathodes with and without ferrite core

Device	Propellant	Volume Flow Rate [sccm]	Extracted Current [mA]	Electron Extraction Cost [W/A]	Gas Utilization Factor
RF cathode with single turn ferrite core antenna	Argon	9	1420	216	2.21
RF cathode with five turn coil antenna	Argon	4	780	182	2.73
RF cathode by Hatekeyama[6]	Xenon	2.0	1500	93	10.6
RF cathode by Longmier[10]	Argon	15	3500	186	3.8
RF cathode by Weis[5]	Xenon	1.5	100	510	0.37

5] IEPC-2005-086.
6] IEPC-2007-226.
10] AIAA-2005-3856.

CONCLUSIONS

Two different RF plasma cathodes are manufactured, and tests were conducted to investigate the effect of a ferrite core antenna on the performance of these RF plasma cathode devices. The RF plasma cathodes are operated at 13.56 MHz frequency. For the presented tests, Argon is used as the propellant gas. It is observed that the presented novel design increases the power coupling to the plasma, thus reducing the electron extraction cost.

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