Design, Manufacturing Method and Testing of an 80 mm Diameter Prototype RF Ion Thruster

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The BURFIT-80 (Bogazici University Radio Frequency Ion Thruster) is an experimental laboratory ion thruster. It has a discharge chamber with an inner diameter of 80 mm with a length of 72 mm and is composed of alumina. It consists of a double grid system containing 91 apertures, where the grids are made from molybdenum. The apertures are formed through laser micromachining and spaced in a hexagonal pattern. An aluminum exoskeleton composed of a back plate, four cylindrical struts and the grid mounting platform provides the integrity of the thruster. Xenon is used as the propellant and is fed through a pipe connected to the flow regulator by a Swagelok joint. A 14 gauge copper wire is used to provide the 13.56 MHz rf coupling to the discharge chamber. The coil is wound 7 times over a total distance of 35 mm (pitch of 5 mm). Preliminary calculations suggest that the BURFIT-80 will generate a thrust in the range of 2-6 mN. The thrust will be estimated from calculations made on the ion beam current which is measured by a Faraday probe inside the 1.5 meter diameter and 2 meter long cylindrical vacuum chamber at Bogazici University. Figure 1 shows the prototype design of the BURFIT-80.

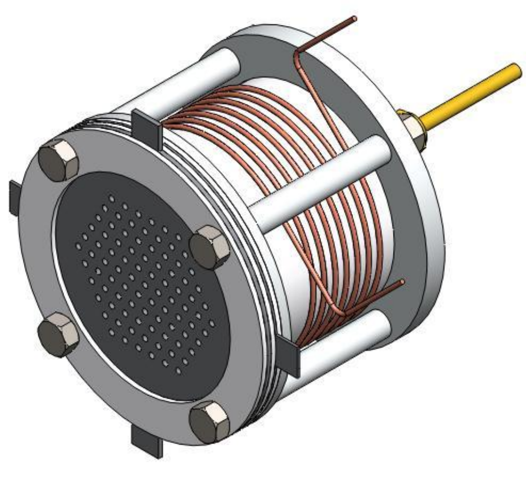

Figure 1. The BURFIT-80

The study of *ion optics* was not one of the objectives of this project. Therefore, previous work on the subject [1,2,3,4] influenced the design parameters of the grids of the BURFIT-80. The parameters used in the aforementioned previous work are summarized in Table 1.

Table 1. Grid Parameters of the RIT's

Ion Thruster	Screen Grid			Accel Grid			
	Thickness (mm)	*Hole Diameter (mm)*	*Spacing (mm)*	*Thickness (mm)*	*Hole Diameter (mm)*	*Chamber Diameter (cm)*	*Reference*
RIT-Artemis	2.00	4.0	0.8	2.0	2.4	10	[1]
RIT-Evo	0.30	1.9	0.7	1.0	1.2	10	[1]
RIT 15	2.00	4.0	1.0	2.0	2.0	15	[2]
RIT 15 LP	0.30	1.9	0.6	1.2	1.2	15	[2]
RIT 15S	0.35	2.2	0.9	1.2	1.4	15	[2]
RIT-XT	0.25	1.9	n/a	1.2	n/a	22	[1,3]
RIT-45	0.55	4.0	1.6	2.7	2.5	45	[4]

The grids are planar molybdenum sheet metal. They are not dished even though dishing is preferred in order to keep the apertures aligned after thermal expansion occurs in the grids and to preset the direction of possible buckling under thermal expansion [5]. The holes in the screen grid are 2.2 mm in diameter and the grid is 0.5 mm thick. The accel grid on the other hand is 1 mm thick, with apertures having a diameter of 1.3 mm. The grid spacing is 0.7 mm. From such a configuration, the resulting limiting ion beam current density is 30.65 mA/cm^2 from the Child–Langmuir equation [5], and this results in an ion beam current of 0.1 A for the thruster.

A 0D analytical model was generated to model the inductively coupled plasma inside the discharge chamber [6,7]. This model predicts the thruster performance by evaluating the design of the thruster according to the mean energy spent on the ionization of each neutral Xenon atom, which is called the discharge loss per ion. By supplying the model the geometry of the discharge chamber, preliminary results of the relation between the discharge losses versus the mass utilization efficiency were generated.

For the given parameters of 80 mm chamber diameter, 72 mm chamber length, 0.1 A beam current and a coil impedance of 50 Ω, the average discharge loss was calculated as 417 eV/ion. This high discharge loss per ion result is due to the fact that the shape of the discharge chamber was not optimized in order to decrease discharge loss, it was chosen as a cylindrical crucible for the easiness of manufacturing.

This paper will discuss the design, manufacturing and the testing processes of the BURFIT-80. The design will be thoroughly analyzed through comparison with existing rf ion thruster designs, where the material selection will also be discussed. The performance of the thruster, such as the specific impulse, thrust and ion beam current, as well as plume plasma parameters which will be measured using Langmuir and Faraday probes will be provided and the results of the tests will be compared with the results of the 0D model developed by Goebel [7] and implemented at Bogazici University by Turkoz [6].

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