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Hollow Cathode Neutralizer for Micro Electric Propulsion

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Cathode neutralizers are an integral part of many electric thrusters such as Hall thrusters and ion engines. The main role of cathode neutralizers is to start the thruster's plasma discharge, serve as the negative terminal of the thruster's electric circuit and supply electrons to neutralize the ion beam coming out of the thruster [1]. Cathode neutralizers operate by using a low work function material, usually referred to as the electron emitter that is sustained at high temperatures so to emit the required electrons. As such, cathode neutralizers incorporate a meticulous thermal design, especially for micro-propulsion applications where the main discharge is low.

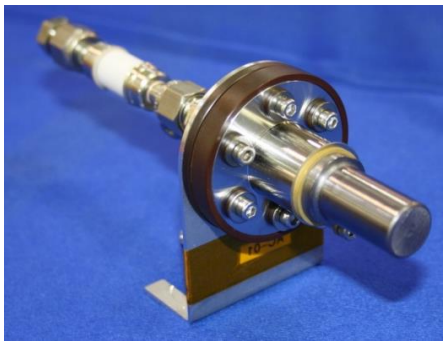

Figure 1. Picture of the Rafael Heaterless Hollow Cathode (RHHC).

Heaterless Hollow Cathodes (HHC) are a subclass of hollow cathodes that do not require a heater for cathode ignition [2]. In this type of cathodes the heating process is by plasma discharge generation in the emitter-keeper gap. Consequently, HHCs use a unique ignition technique. Firstly, high voltage pulse is applied between the emitter and keeper so to electrically breakdown the injected gas. Immediately after initial discharge creation a separate power supply controls the emitter-keeper current, a process during which the emitter is heated. The heating process lasts until the emitter reaches its operation temperature. Lastly, after steady discharge has been initiated the electric thruster is turned on by applying the required emitter-anode current. The entire thruster ignition duration is usually less than 100 seconds.

Thanks to the fact that HHCs do not incorporate a heater they possess several advantages for micro-propulsion:

(1) Small mechanical design – cathode diameter may be smaller than in conventional cathodes since no space dedicated for heater allocation is needed.
(2) Fast Ignition – Conventional cathodes require ignition time of several minutes in order to prevent thermal stress of the heater. Heaterless cathode, on the other hand, may start within seconds and tens of seconds.
(3) No heater feed – Heaterelss cathode do not need a heater electrical; therefore decreasing the overall size and required power of the power processing unit.

In the past several years Rafael, in cooperation with the physics department at the Technion, conducted fundamental low current heaterless hollow cathode research, followed by full product development [3-9]. The purpose was to fully develop a heaterless hollow cathode that can serve as a low current ion beam neutralizer for either Hall or ion thrusters. The developed cathode requirements are presented in **Table 1**.

This paper presents the heaterless hollow cathode developed at Rafael (Figure 1), its mechanical and electrical features and tests performed on it. In particular a 5,000 hours continuous steady state operation test and 3,500 cold ignition cycle test are presented.

Table 1. Key requirements of the Rafael Heaterless Hollow Cathode (RHHC)

#	Requirement	Value
1	Discharge Current	0.5-1.1 A
2	Xenon Mass Flow Rate	0.2-0.3 mg/s
3	Lifetime	1,100 A×hr
4	No. of Startups	6,000
5	Ignition Voltage	Up to 1,200 V
6	Mass	Up to 200 g

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