Applied Ion Systems
AIS-TR-025

AIS ADAMANT Series Development
Preliminary Sublimation and Ionization Test #4 of Adamantane Fuel for Ultra-Low Power Micro-Ion Thruster Systems - 01/21/2021

Test Report and Summary
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I. BACKGROUND

The AIS ADAMANT Series thrusters leverages Adamantane, a diamandoid hydrocarbon which exhibits many unique properties allowing for the potential of extreme power and size miniaturization of conventional gas-fed electric propulsion systems, with significantly reduced toxicity and no known corrosion issues like its similar and highly explored cousin Iodine. Currently, the ADAMANT Series is focusing on the development of highly integrated and modular micro-Hall thrusters run purely on sublimated Adamantane fuel. Total system power depending on the thruster is currently aimed from 5W up to 20W for the smallest class systems, with the ability to scale up to more conventional 50W class systems. Despite its unique potential as an alternative molecular propellant for conventional gas-fed EP, little work has been done on Adamantane for use as a fuel in the field.

While Adamantane has been tested a couple of times in literature, this has only been done at much higher power levels in larger gridded ion thrusters at hundreds of watts to kW class systems. Despite successful operation at higher power levels, with performance similar to Xenon, Krypton, and Iodine, Adamantane has been largely dismissed in literature without custom modifications to the chemical composition to overcome some of the inefficiencies inherent to the fuel, and overall testing in the field has been practically non-existent otherwise. Due to its many attractive properties however, such as solid storage, ease of sublimation, high ionization cross-section, high molecular weight, low cost, non-corrosiveness, and low-toxicity, Adamantane has been identified as a key technical enabler in meeting the unique challenges being addressed and inherent limitations in funding and infrastructure at AIS, and fully embraced as the central focus of new development efforts at AIS through the ADAMANT Series, which leveraging the unique properties of Adamantane to overcome conventional scaling limitations in EP technology such as Hall thrusters.

II. OVERVIEW

The goal of the fourth preliminary sublimation and ionization test was to explore the potential of low-power positive and negative beam extraction from an Adamantane plasma using the sublimation and ionization test cell from the prior three tests.

The first three preliminary tests have successfully validated that Adamantane can be sublimated at very low temperatures and heater power levels, as well as very easy to ionize at moderate voltages and very low discharge power levels, demonstrated from 0.75W to 2W. Basic plasma formation as well as plume extraction have been observed. In order to run ion thrusters as well as neutralizers, both positive and negative charge extraction must be demonstrated. This test aimed to attempt to measure charge extraction with both polarities from the test cell. In prior tests, only visual confirmation of plasma was observed, but no quantitative measurements of extraction have been made.

Looking at currently available limited data, and drawing extrapolations from these test results and basic principles of related EP systems and other alternative fuels, AIS proposes that Adamantane can allow for unprecedented scaling of conventional gas-fed EP technologies, allowing for low-power operation and unpressurized feed for the smallest class of satellites in the field. With significantly less toxicity, and no corrosion issues like Iodine, Adamantane has further potential for much greater total system cost reduction using conventional materials in the design of the Hall thruster, neutralizer, and propellant feed system. AIS is also taking a radically unconventional approach towards cathode design to leverage these advantages to create the smallest fully integrated Hall thruster systems ever developed in the field. AIS is currently the first and only EP company in the world specifically developing Adamantane-fueled EP systems through its AIS ADAMANT Series development initiative.

III. PRELIMINARY SETUP

For this test, the system was set up with the same configuration as Test 3, however the polarities on the plates were changed. In this test, a positive discharge was established between the bottom (grounded) and center plate (+HV), and a negative voltage applied to the uppermost extractor plate (-HV). A +3.5kV, 2W power supply was used for the +HV, and a -3.5kV, 2W supply was used for the -HV. Whereas Test 3 aimed to look at operation similar to a hollow-cathode neutralizer, this test aimed to extract ions from the plasma in either polarity.

Due to the vertical orientation of the test cell, the Faraday cup could not be lined up with the output of the test cell to measure any extracted beam. As such, the high vacuum chamber was floated, and the chamber itself was used as one large Faraday collector, with a wire connected to the micro-ammeter to read any beam current extracted from the test cell. Finally, the test would be conducted without any heater power applied, relying on passive sublimation in vacuum.

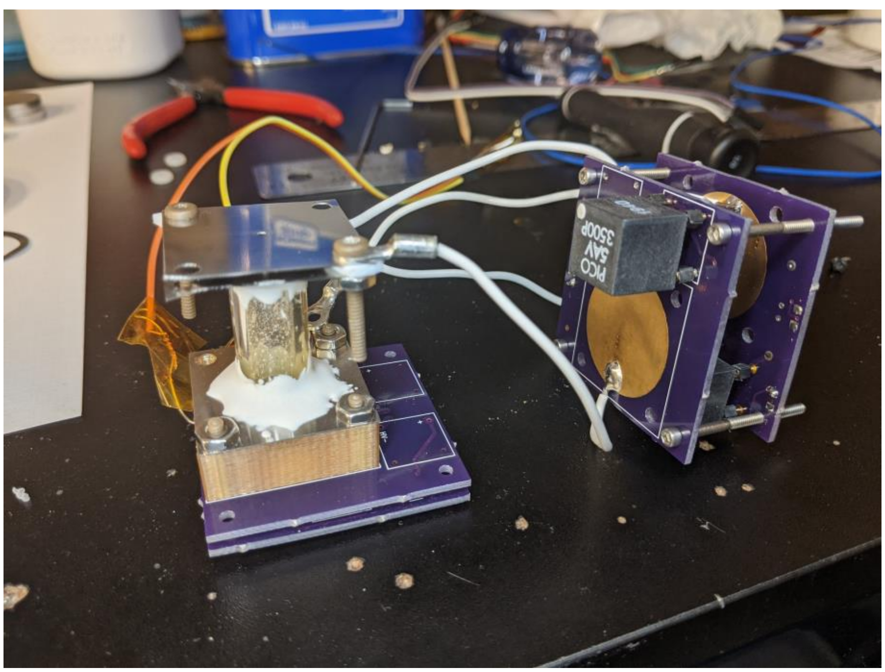

FIGURE 1: *Test cell and power supply assembly*

The assembly was fueled and bolted together like in the prior three tests. The entire assembly was then wired up and mounted in the vacuum chamber.

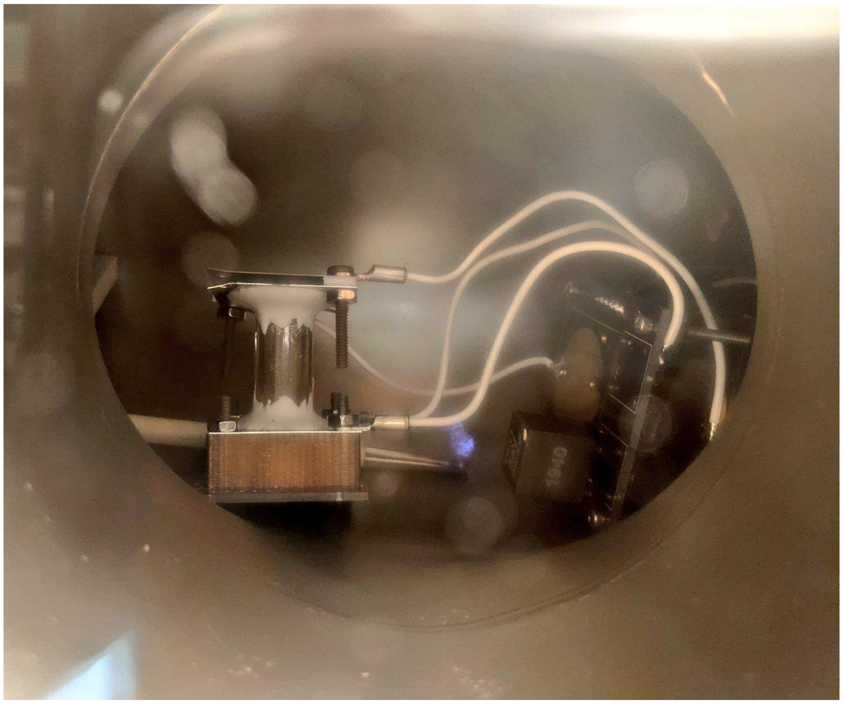

FIGURE 2: *Mounting of the test cell in the high vacuum chamber for testing*

IV. TESTING

Pumpdown behavior was the same as the prior tests, slowly reaching an ultimate vacuum level around 7.5x10^-4 Torr prior to ignition attempts. Once at vacuum, positive HV was applied to initiate the discharge, and negative HV applied to the extractor. A stable pale green plasma discharge was initiated at less than 1W of power. Background temperature during the test started at 11C, eventually settling to 15C by the end of the test. Unlike the prior test however, there was no visible plume or beam extraction. Despite the clear lack of plume, beam current was being measured on the galvanometer readout.

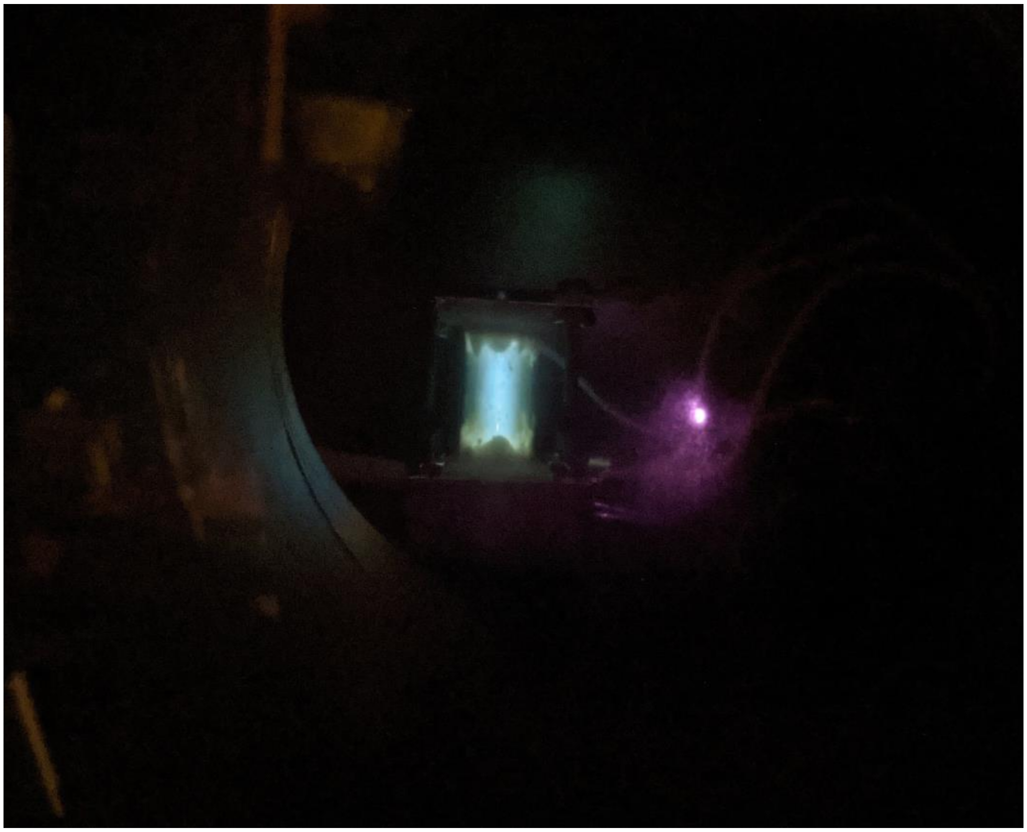

FIGURE 3: *Low power Adamantane plasma discharge at 1W for positive and negative charge extraction.*

With only the +HV discharge power applied, a current of -100uA was read, indicating some negative charge extraction. With just the -HV extractor plate power, +20uA was read. However, with both +HV discharge power and -HV extractor power, a total of -80uA of current was read. Adjusting both supplies, a net 0uA charge balance could be achieved.

After beam current measurements were taken, discharge power was increased to the full 2W. A noticeable shift in plasma color and brightness was observed. This discharge remained stable until the end of the test, which concluded from the depletion of the Adamantane fuel charge and reduction in background pressure.

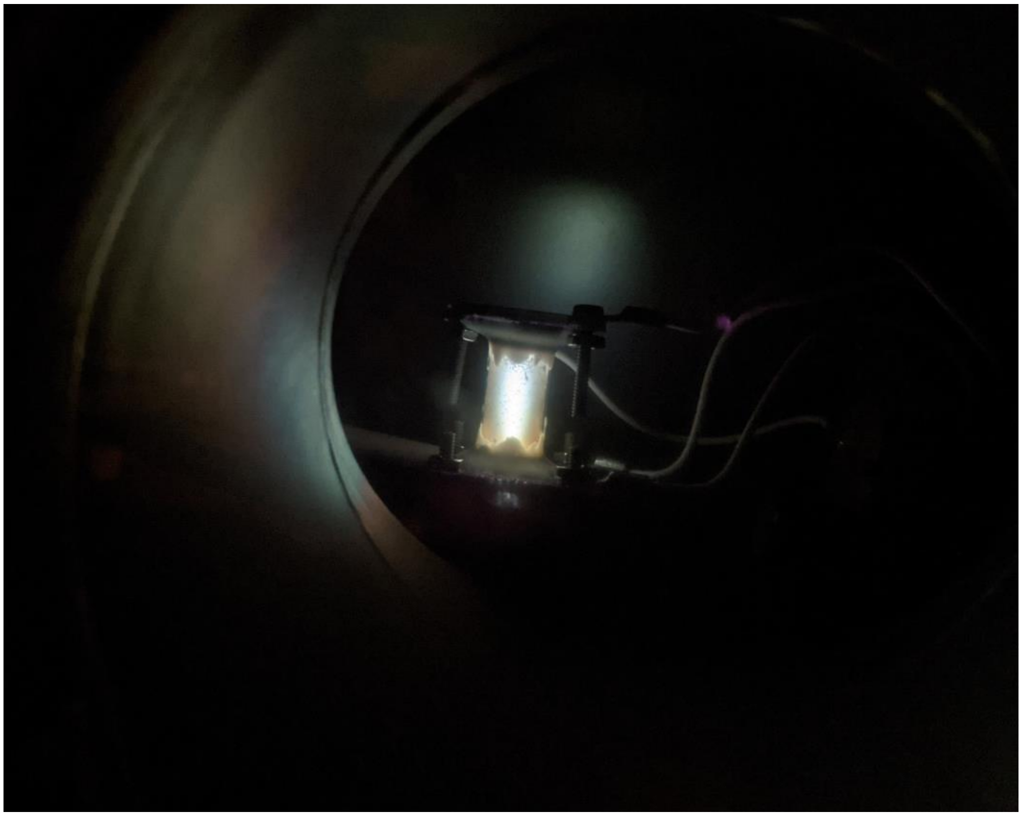

FIGURE 4: *Full power Adamantane plasma discharge at 2W sustained on passively sublimated fuel.*

V. CONCLUSION AND FUTURE DEVELOPMENTS

The fourth preliminary sublimation and ionization test of Adamantane fuel in vacuum has been successfully completed. In this test, ionization was successfully demonstrated on purely passively sublimated Adamantane vapors at chamber background temperatures from 11C to 15C, at discharge power levels from less than 1W to 2W. A noticeable shift in plasma color was observed, from low to full power, and like the prior tests, the plasma discharge was stable for the duration of the test and easily ignited. During the test, both positive and negative charge was extracted from the plasma, which tracked with the opposite polarity applied. Adjusting the power supplies, extracted charge was nulled. For the +20uA beam, this made sense for ion extraction given that the -HV extractor voltage was applied. However, it is unclear for the -100uA current when applying the +HV power whether electron beam current or negative ion beam current was being extracted. While there is very little data on Adamantane discharges in literature, there have been observations of negative ion formation within the plasma. This could be immediately verified with something like time of flight analysis in future tests.

Based on this and the prior test results, AIS will be continuing to move forward and dedicated its currently available resources to the first prototype build of the EHT1 Micro End-Hall Thruster and GDN1 Low-Power Glow Discharge Hollow Cathode Neutralizer.