DESIGNING AN ELECTROLYTIC CELL USING CARBON NANOPAPER FOR CUBE SATELLITE PROPULSION.

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Introduction: Since 1999, over twenty one foreign and domestic universities have created cube satellite programs because of their lower fabrication and launch costs as opposed to conventional small satellites as secondary payloads. Cube satellites, nanosats, have dimensions of 4X4X4 inches (10X10X10 mm), costing between 40 and 60 thousand dollars to construct. One cube, which is shown in Figure 1, can carry one or two scientific instruments, but some cubesats are constructed as many cubes sharing a common longitudinal axis therefore allowing larger payloads.

Figure 1: Nanosat Ref. 1

However, propulsion systems are still in early development, leaving the existing Cal Polytech's PPod launcher, shown in Figure 2, as the only standard means to deploy a cube satellite to its desired orbit.[1]

Figure 2: PPod Launcher Ref. 1

Previously NASA explored the possibility of electrolyzing a water payload to generate hydrogen and oxygen propellants for large scale spacecraft because of water's ease of storage and low cost.[2] The goal of this project was to design a small electrolytic cell to investigate whether is could be adapted for nanosats. Carbon nanopaper was selected due to its high surface area. The cell was designed hypothetically for a 1 netwon thruster.

Design: The initial design of the cell is shown in Figure 3.

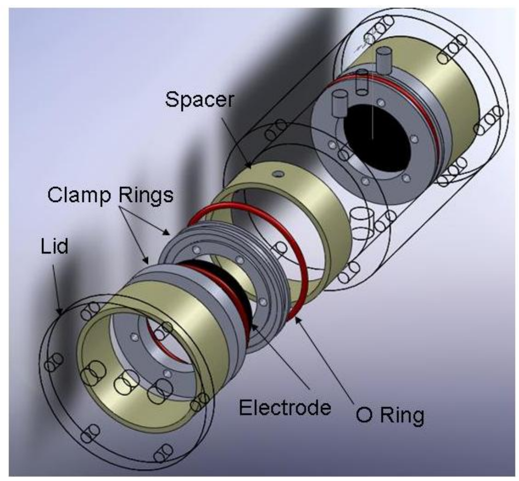

Figure 3: Initial Design

The main body of the cell is a transparent acrylic tube being two inches in diameter and 2.5 inches long. The wall thickness is a quarter inch. Four holes were drilled on the sides of the tube: one for the incoming water, another for exiting air, and two for bolts that are connected to the power supply. The lids were constructed from Plexiglas, which was 3/16 inches thick. Three holes were drilled on each lid: one for the pressure transducer, another for the thermocouple, and last for the release valve. Pertatex Ultra Blue Gasket Maker would be applied between the tube and the lids to supplement the bolts. Two aluminum clamp rings held the carbon nanopaper in place while making contact with screws connected to a DC power supply; therefore, allowing electricity to reach the nanopaper. O ring glands were cut along the outer diameter and the inside face of the centermost clamp rings where silicone o rings were installed to prevent water leaks.

Spacers, constructed using a 3-D printer, held all components in place.

The carbon nanopaper is a product of Marketech International and manufactured using sol-gel technology. Its density, surface area, and average pore size are 0.4-0.5 g/cc, 600 m^2/g, and 0.7 nm/g. For its electrical properties, its resistance, conductivity, and capacitance are 0.01-0.04 ohms/g, $1x10^6$ S/m, and 28-30 F/m. The graphite nanopores are hydrophobic.[4]

Experimental Setup: The setup is based of the experiments conducted previously by NASA.[3] In Figure 4, the measured properties of current, voltage, pressure, temperature, and flow rate are measured to evaluate the cell's performance.

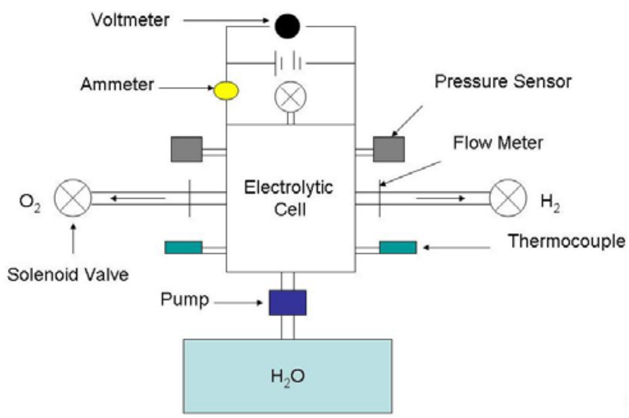

Figure 4: Experimental Setup

The pressure transducers have a range of 100 psi. The pump that will be used is a Range 9 12 volt fuel pump. Initially the cell's center will be filled with water and air will escape through the top duct, where the solenoid valve will be closed prior to the experiment. All data will be recorded using LabView software, and the resulting gases will be vented into the atmosphere after the experiment is completed.

Preliminary Results: After completing construction of the initial design, the cell was filled with water to test the o ring seals. The center spacer was omitted to better observe the cell's interior. The interior o rings seal failed most likely due to improper o ring gland dimensions. Water was also found be drawn through by the pressure exerted by aluminum rings, accumulating further due to aluminum's hydrophilic property.

Redesign: For the redesign, the o rings seals were removed. The clamp rings were reconstructed without o ring glands. To prevent leaks, three possibilities were proposed as shown in Figure 5.

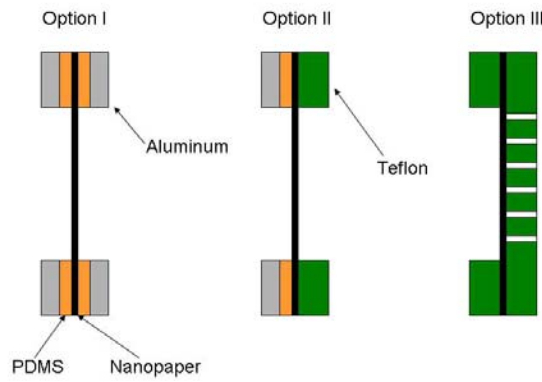

Figure 5: Alternative Water Seal Options

The first is to create polydimethylsilxane (PDMS) gaskets, a hydrophobic organic polymer. The second option is to omit an aluminum ring, replacing it with a solid Teflon and PDMS gaskets. The last option is to flush the carbon nanopaper against two Teflon layers: one gasket and a porous membrane. However, this option will greatly inhibit gas flow and another means of conducting the electricity to the electrode would have to be designed.

Conclusion: Currently no standard propulsion system exists for nanosats. Based on previous work by NASA, a small electrolytic cell was designed to ascertain whether a water electrolysis based propulsion system could be scaled for a nanosat. Carbon nanopaper was selected as the electrode due to its high surface area and hydrophobic nature. The initial design was built and filled with water to test the o ring seals; however, water leaked throughout the unit. Three alternatives were proposed to solve the leak problem, and currently a second unit is being constructed to test the three options. After the water is fully sealed in the center of the unit, the cell may be tested to evaluate its performance.

References:

[1] Huang, Adam. "MEMS-based Warm Gas Thruster System for CubeSat Orbital Maneuver Applications" Powerpoint Presentation.

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[3] Papale, William. "A Water-Based Propulsion System for Advanced Spacecraft" AIAA Guidance, Navigation, and Control Conference. San Jose: AIAA 2006, pg 426-438.

[4] Carbon Nanofoam. 18 Jun 2009. < http://www.mkt-intl.com/aerogels/pages/carbon.html.>