Thermal Control of CubeSats Utilizing an Electrochromic Variable Emissivity Device

Spacecraft Thermal Management Systems 2020 - 2021

Mechanical Engineering, Chemical Engineering, & Material Science Engineering Department

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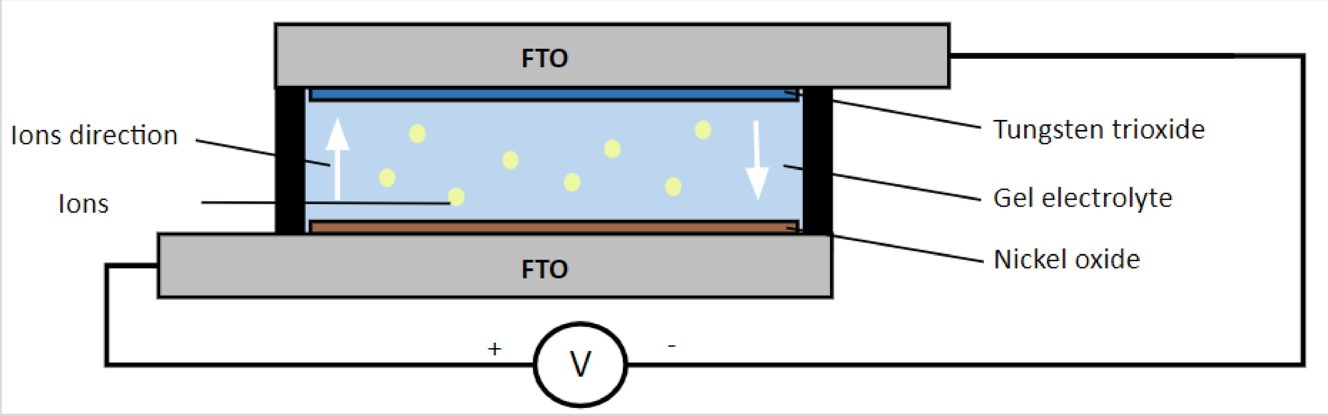
Background

- Spacecraft Thermal Management Systems (STMS) is an undergraduate, interdisciplinary research project that works to develop an electrochromic cell for Cube and Nano Satellites.
- The electrochromic **variable emissivity device (VED)** will act as a method of controlling heat loads on satellites through a color change.
- In its colored or high emissivity state, the VED will prevent a net heat flux into the satellite.
- In its transparent or low emissivity state, the VED will permit heat dissipation from internal electrical components.

Project Significance

- The VED will function as a lightweight and affordable method of thermal management for a 10 cm x 10 cm Cube Satellite.
- Other thermal management methods will incur a large payload and commercial VED's cost $500 per square inch.



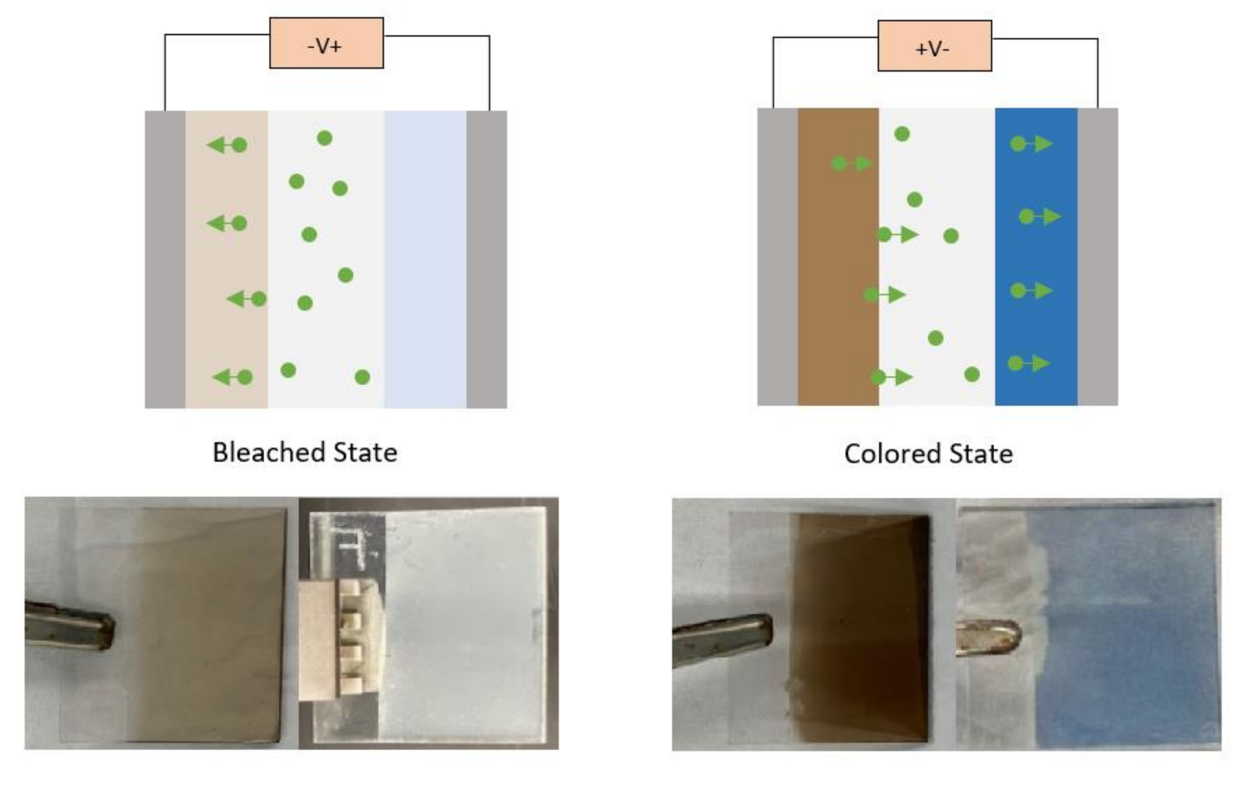
Requirements

The objective is to create a VED that:

- Can withstand 6 months in orbit and is capable of 3,000+ life cycles at an altitude of 500 km - 800 km.
- Has an emissivity modulation value of 0.5.
- Has a gel-electrolyte that has a conductivity value of > 10^-5 S/cm.
- Can function effectively in low pressure vacuum conditions of 10^-10 mbar.

Chemical Division

The objective of the Chemical and Material Science Division is to create, develop, and test the chemical and material properties of the VED device.



Tungsten Trioxide:

- Magnetron sputtered WO_3 thin film created to compare results to chemical bath deposition method.
- Measured film thickness using FIB-SEM (~170 nm) (Fig. A).

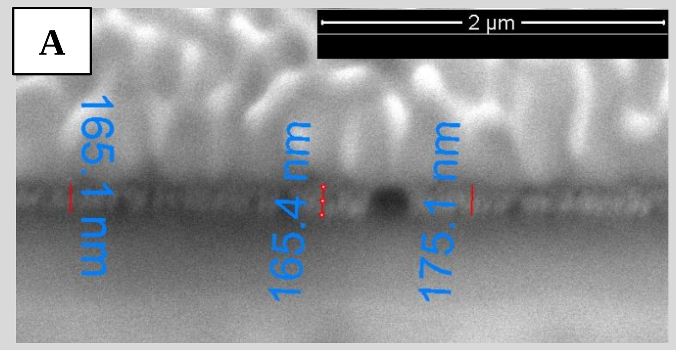
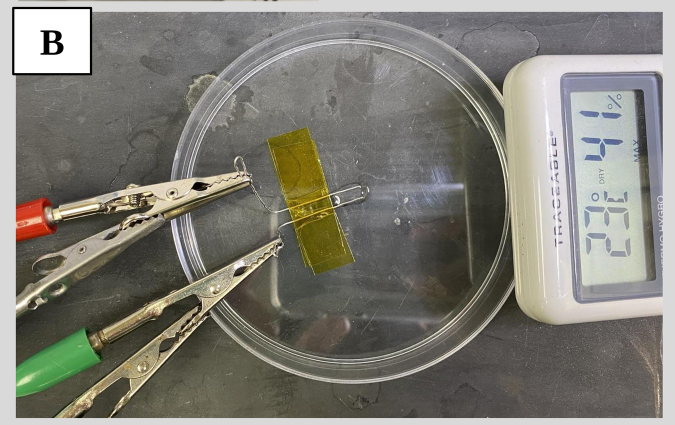


Image of gel-electrolyte

Nickel Oxide:

- Investigated sol-gel and dip-coating as alternative deposition techniques.
- Surveyed film degradation factors.

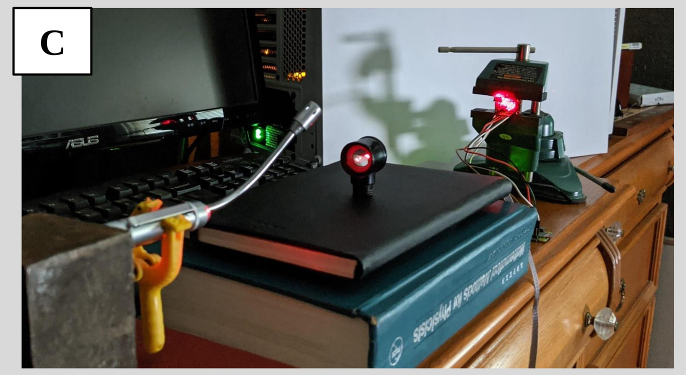


Gel Electrolyte:

- Performed Electrical Impedance Spectroscopy (EIS) to characterize electrical properties of 15 wt% PMMA gel electrolyte (Fig. B).
- Determined resistance to be 1.7kΩ.

Spectro-Volt:

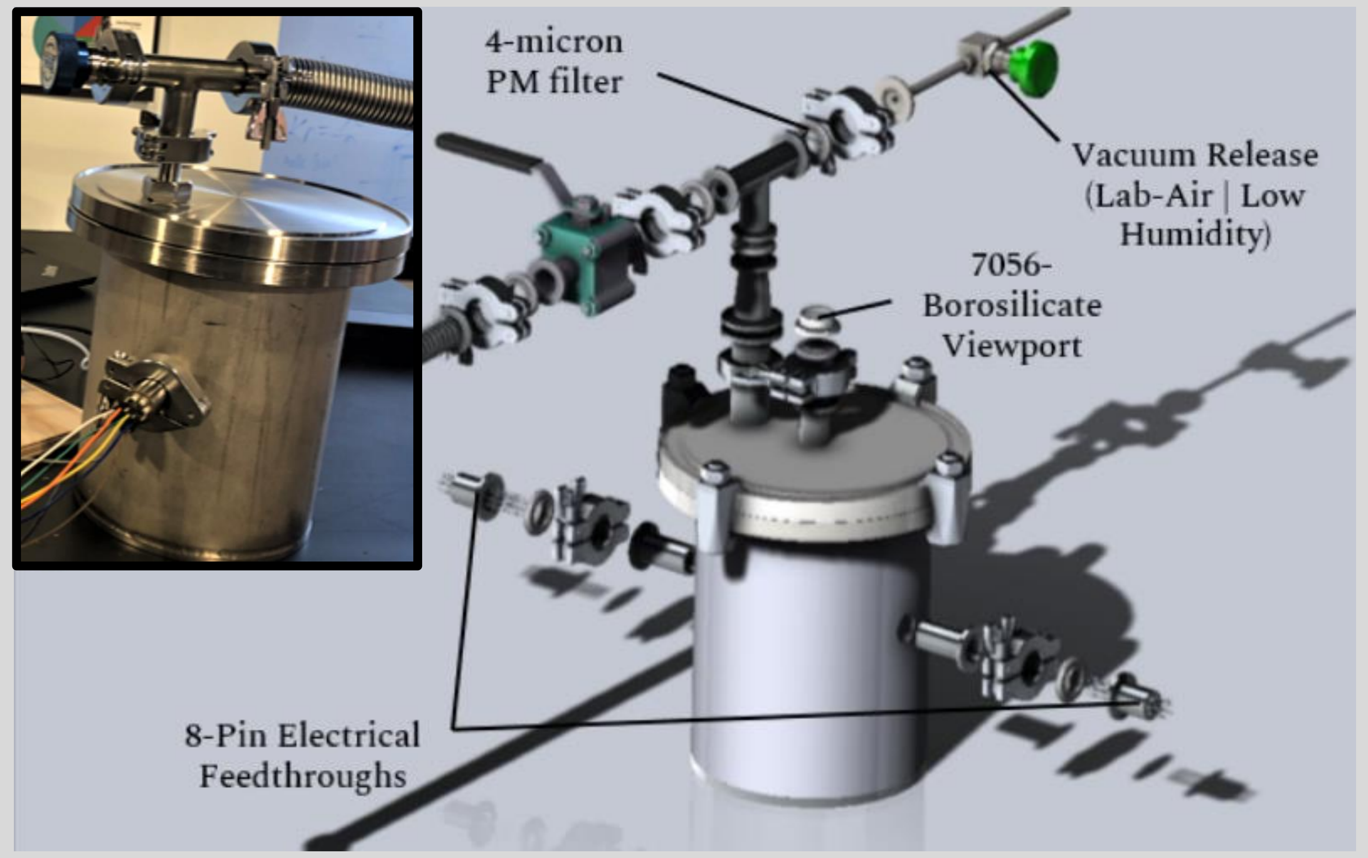
- Completed proof of concept design for an in-situ photodetector set up to measure transmission (Fig. C).

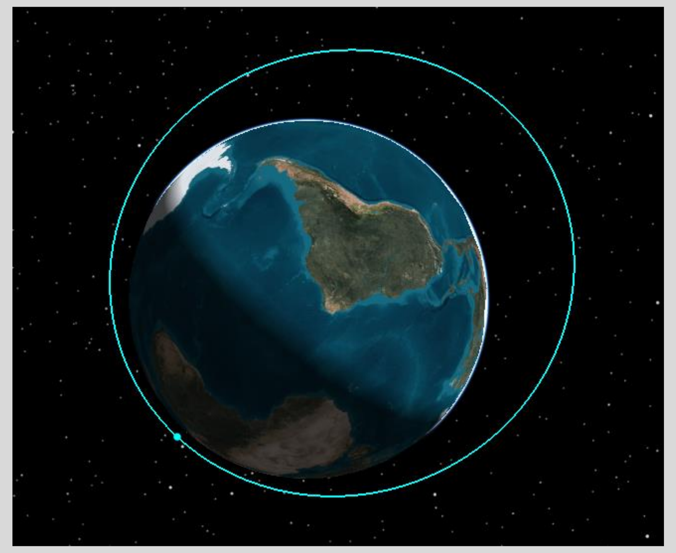


Mechanical Division

The objective of the Mechanical Division is to assist the Chemical Division by providing services such as VED control, orbital simulations, and environmental testing for the device.

- Performed vacuum environmental testing on thin films for 30 minutes at a temperature of 80 °C.
- Achieved thermal vacuum pressure of 17 mbar.
- Achieved orbital trajectory simulation for various types of orbits.





$$T_{ambient} = 279\sqrt[4]{(\frac{s*(1-\alpha)}{2a}(1-\sqrt{1-\frac{1}{(1+\frac{H}{R})^2}})}$$

$$\therefore \quad T_{MINambient} = 195.82(^{\circ}K)$$

$$T_{averageambient} = 302.21(^{\circ}K)$$

Smart Window	Thermal Conductivity, $k_{sw}\left[\frac{W}{m \cdot K}\right]$
Opaque State	0.445
Transparent State	0.607

Other Achievements

- Characterized the new sputtered film using SEM and XRD.
- Determined the thermal conductivity value of the smart window and absorbance of the electronic paper display (EPD).
- Simulated CubeSat model in orbit on STK.
- Determined method to control voltage application to the smart window.
- Theoretically determined best pump arrangement to obtain lowest pressure for the thermal vacuum.

Future Work

- Perform life cycle tests on the thin films and smart window.
- Determine emissivity of the smart window and thin films.
- Complete combination set-up to analyze electrochromic ability during electrochemical life cycle tests .
- Begin synthesis of new gel-electrolyte samples.
- Achieve satellite temperature difference between 15 °C - 30 °C in Sun Synchronous Orbit (SSO) simulations.
- Test new pump arrangement to obtain a lower vacuum pressure.

Contact Information

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