Spacecraft Thermal Management Systems

Interdepartmental Senior Design Project offered by: Mechanical and Aerospace, Chemical Engineering and Materials Science Departments

by

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Background Summary

The environmental conditions experienced by orbiting spacecraft are extreme due to the wide temperature range and vacuum conditions. These environmental variations pose a demanding design constraint on the engineers creating the thermal management systems for spacecraft. Most operating satellites today come equipped with radiators to reject heat from onboard electronics into space. A radiator that rejects heat efficiently into the cold vacuum of space, consequently will absorb radiation as heat very readily when exposed to direct sunlight. These are two key situations in which the satellite radiator must successfully operate.

The primary function of the satellite radiator is to reject the heat generated by the electronic components through infrared radiation to space. The heat generated by the electronic components is conducted through the structures of the satellite, then rejected by radiation from the outer surface using a high-emissivity material. The problem occurs when this surface is exposed to direct sunlight; it will readily absorb the Sun's radiation and transfer it back into the satellite, heating the internal components. The Variable Emissivity Radiator being researched and designed at UCI provides control to lower the outer surface emissivity during sunlight exposure, and increase it again to dissipate internal heat, all while using minimal power and no moving components.

The second requirement of the radiator design is to protect it against variety of ion particles in the environment. The environment surrounding a satellite from Earth to Low Earth Orbit altitude ~300km is filled with charged ions and debris that will consistently impact the radiator. The Variable Emissivity Radiator material must be designed to protected against these charged ions by spacecraft grounding system.

Description

There are various materials that exhibit a change in thermal infrared emissivity when a small voltage difference is applied. There were two space tests conducted in recent years that evaluate such materials.

Currently, Eclipse Energy Systems in St. Petersburg, FL and Ashwin-Ushas Corporation in Marlboro, NJ have obtained patents for successful fabrication of variable emissivity devices (VEDs). Only Eclipse Energy System Inc. has tested their Electrochromic Device (ECD) aboard the MidSTAR-1 satellite in March 2007. The results were showed some promise. A second test of the same VED was done in May 2011, the Air Force Research Laboratory (AFRL) on board STS -134 (last mission of Space Shuttle Endeavor). The results were disappointing with the VEDs showing little or no change is emissivity. Data presented by the AFRL at Aerospace Corporation in March 2012 indicate that insufficient pre-launch vacuum tests were performed on ground. Including lack of humidity and contamination tests may be responsible for on orbit failure.

The UCI Spacecraft Thermal Management Systems project will not be using these materials that have been previously tested because the cost is approximately \$100/cm^2; a prototype for testing would cost upwards of \$10,000. However, one square samples of Ashwin's are available for lab test comparison with UCI VED's. Student project will explore much less expensive designs and methods of controlling the emissivity using a nickel oxide (NiO), tungsten oxide (WO_3), titanium dioxide (TiO_2), and oxide mixture films. These films are based upon a design which has been successfully used by the UCI Chemical Engineering & Materials Science Department to build Sol Gel and Chemical Bath Deposition (CBD) techniques. Mechanical and Aerospace

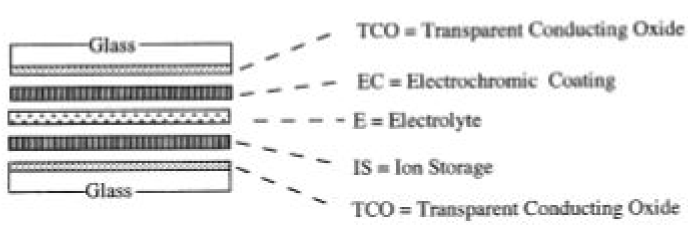

Figure 1. Typical Electro-chromic composite cell arrangement

Engineering students will design and build electrochromic (EC) films and composite cells for space application shown in Figure 1.

EC Film Testing

The UCI Thermal Management Systems students will perform on prototype samples produced and compare them with Off the Shelf samples. Currently the world leader in variable emittance is a company called Ashwin-Ushas Electrochromic Devices. UCI has acquired a sample of their emissive device and plan to use it for benchmark comparison.

Tests will be performed in the visible and infrared (IR) wavelength range For IR testing it is important to remove all modes of heat transfer except thermal radiation. Introduction of vacuum can minimize convection. Conduction losses can be reduced by thermal design. A typical test set-up is shown in figure 2. Figure 3 shows the exiting equipment fabricated by previous MAE department students.

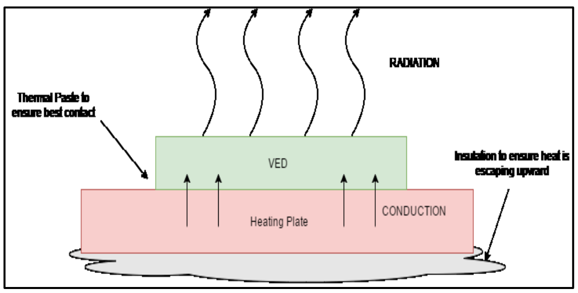

Figure 2 Typical Infrared Emissivity Test Set-Up

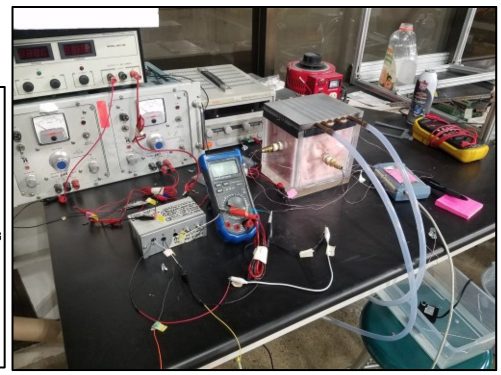

Figure 3 Existing available equipment's

EC Film Testing Results in visible range

Students from 2016-2017 successfully built a NiO thin film using chemical bath deposition technique. The film showed electrochromic behavior in the visible range when a voltage ~o(+/-1volt) was passed through it. See Figures 4 and 5 below. For more details and joining the project contact Dr. Khalid Rafique (krafique@uci.edu)

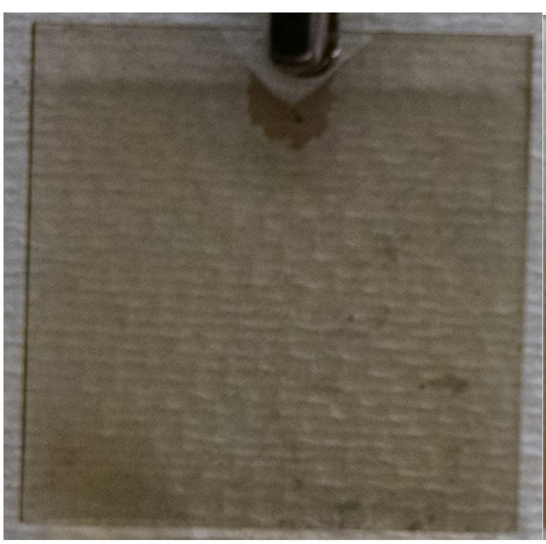

Figure 4: Bleached NiO Film

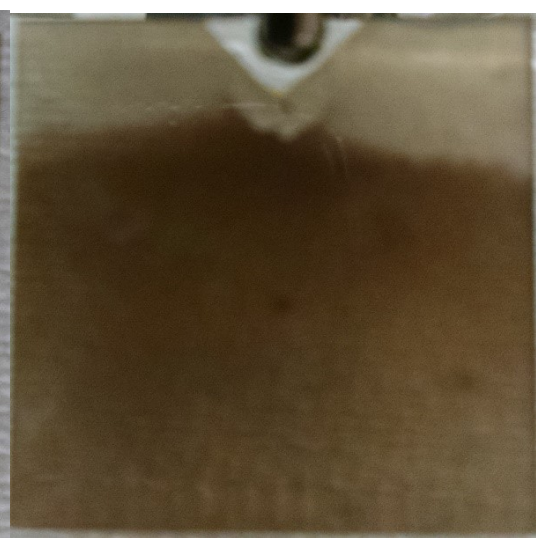

Figure 5: Colored NiO Film