FY23 Innovative Spontaneous Concepts Research and Technology Development (ISC)

ITO Nanocrystals for Dynamic Thermo-optical Coatings in Spacecraft Environments

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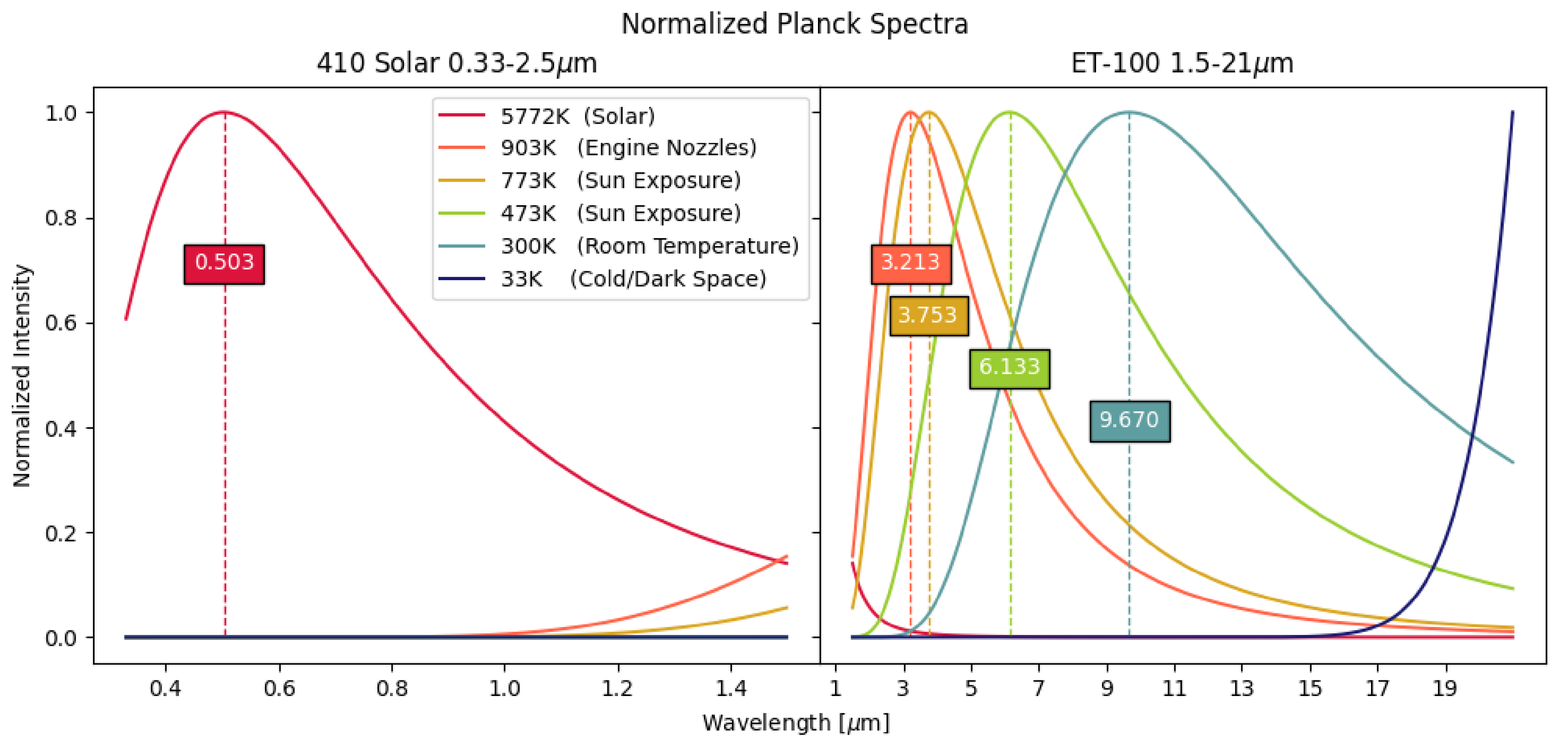
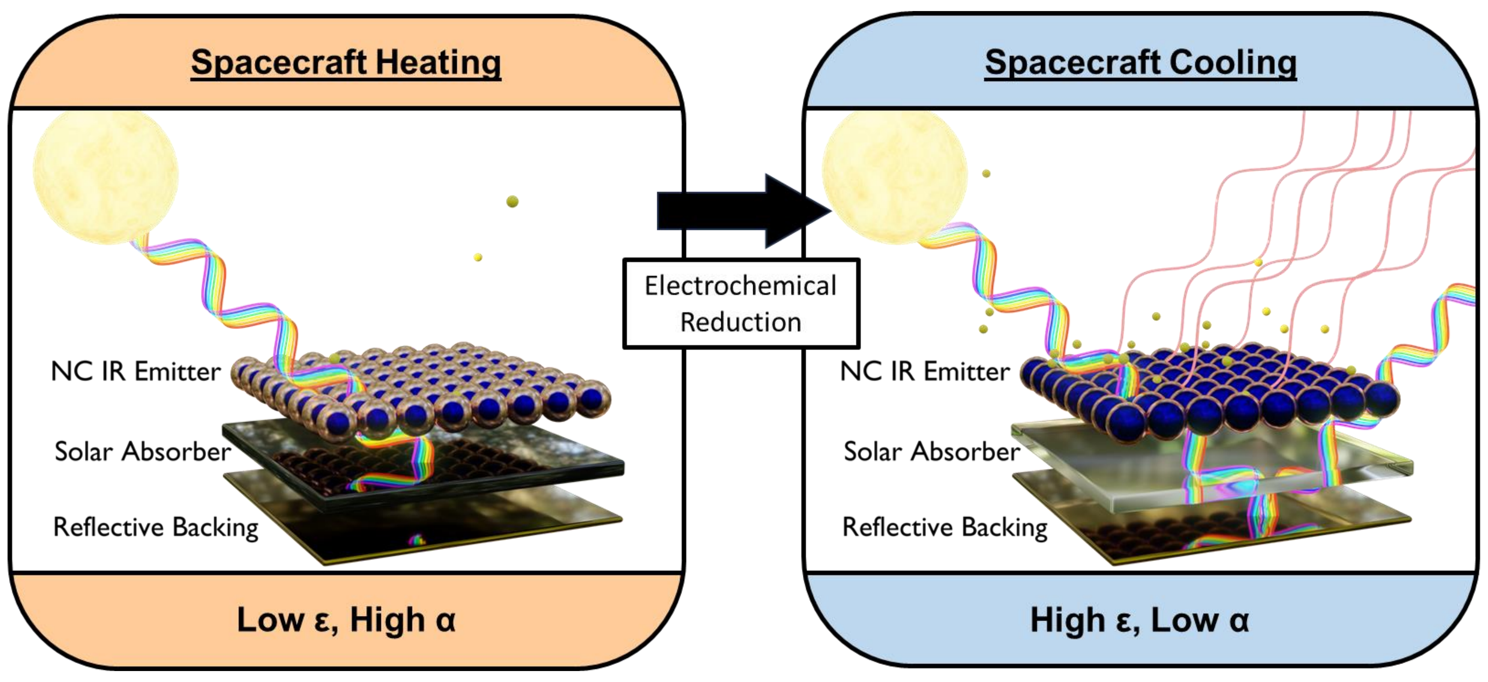
Objectives and Background

Our objective was to assess a new electrochromic (EC) material, Indium Tin Oxide (ITO) nanocrystals (NCs), for dynamic thermo-optical control coatings that could enable new or more efficient (lighter, cheaper, and more reliable/robust) spacecraft architectures in challenging space environments. To achieve this we collected thermo-optical property data (absorptivity and emissivity) on ITO nanocrystal samples that had been fabricated and initially measured (specular reflectance) by the Milliron Group at University of Texas at Austin (UTA), and a baseline thermal model was constructed to understand the potential impact of implementing these developments for current and future JPL missions.



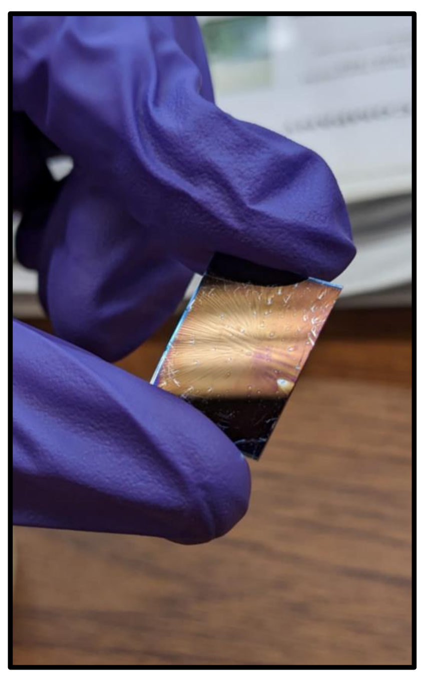
Extreme thermal environments are a limiting factor in mission selection and spacecraft design. Louvers, featuring reflective vanes that cover an emissive base plate, are the current state-of-the-art for tunable thermal control. Louvers are passively controlled to allow for the thermal emittance of spacecraft surfaces, but i) impose restrictions on spacecraft design due to their size and weight, and ii) offer no means for active control of emittance. **Electrochromic (EC) materials dynamically modulate wavelengths for light and heat management via the application of a small electrical bias, and offer a number of advantages over current technologies for thermal control as a lightweight, conformal, low power coating.**

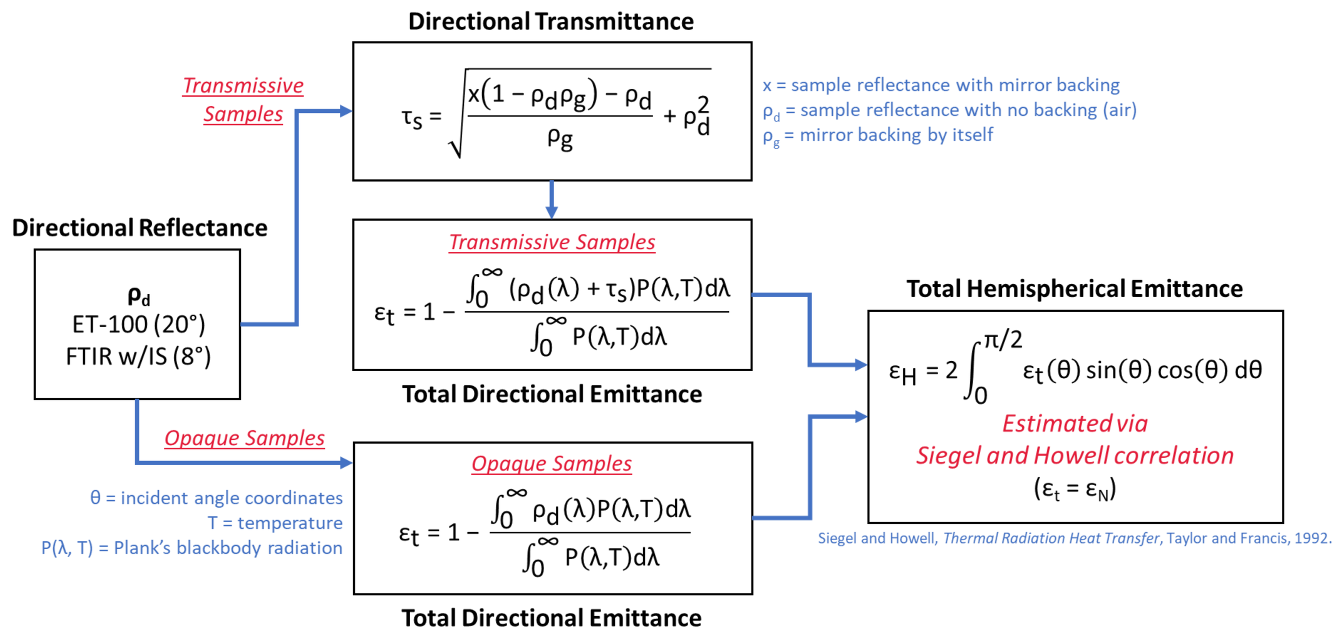


Significance/Benefits to JPL and NASA

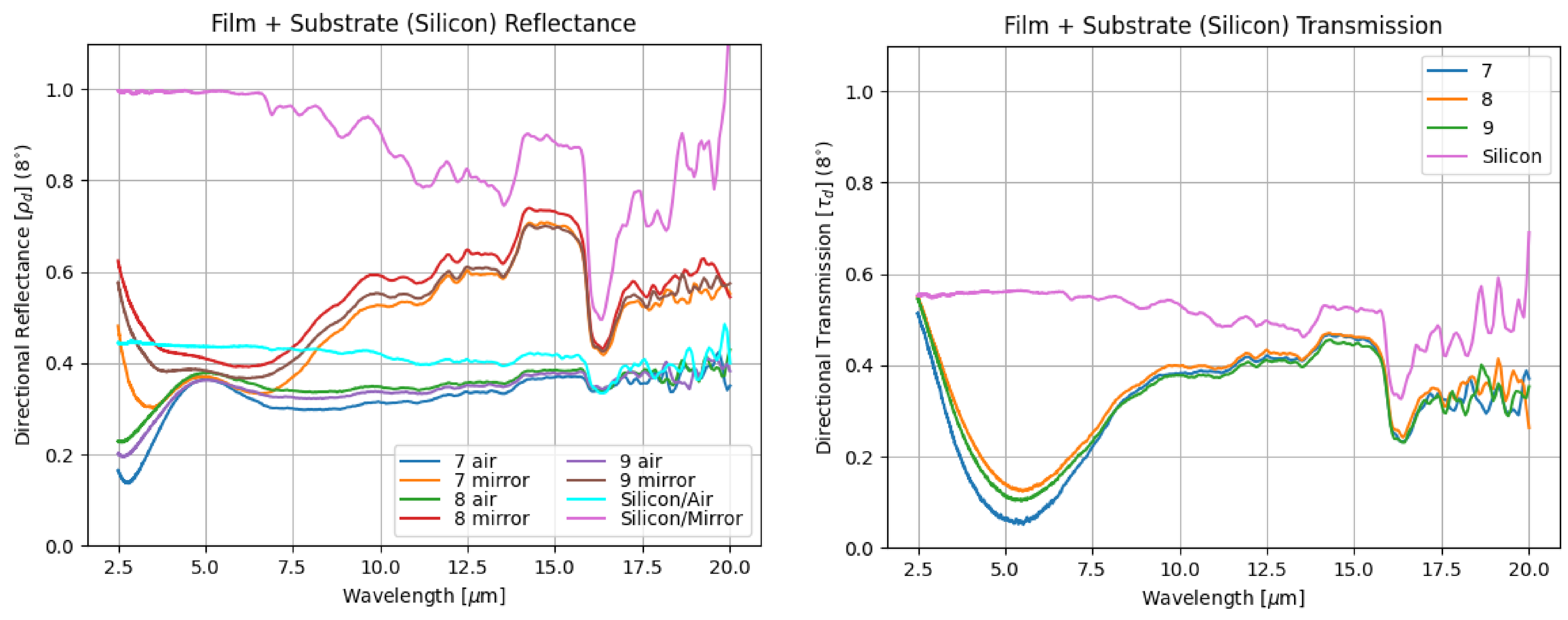
The heat rejection capability and emittance modulation range of literature-based EC films show the potential to rival a standard louver system for typical spacecraft operations. The current work with ITO nanocrystals shows a degree of tunable emittance at IR wavelengths, and further development of ITO nanocrystal materials could produce tunable EC films that equate to or outperform louver-based systems, with benefits including lower mass imposition and fewer restrictions in spacecraft design inherent to louver standard sizes. The active thermo-optical property control capabilities and higher effective emission modulation (thermo-optical contrast) associated with EC films would allow for missions to more extreme environments, greater flexibility in spacecraft design, thermal control options for small satellites (CubeSats), and larger instrument payloads as a result of mass-savings. Future work will aim to improve device-level thermo-optical contrast, and develop a full system with environmental and life-cycle testing to understand performance in spacecraft applications.

Approach and Results



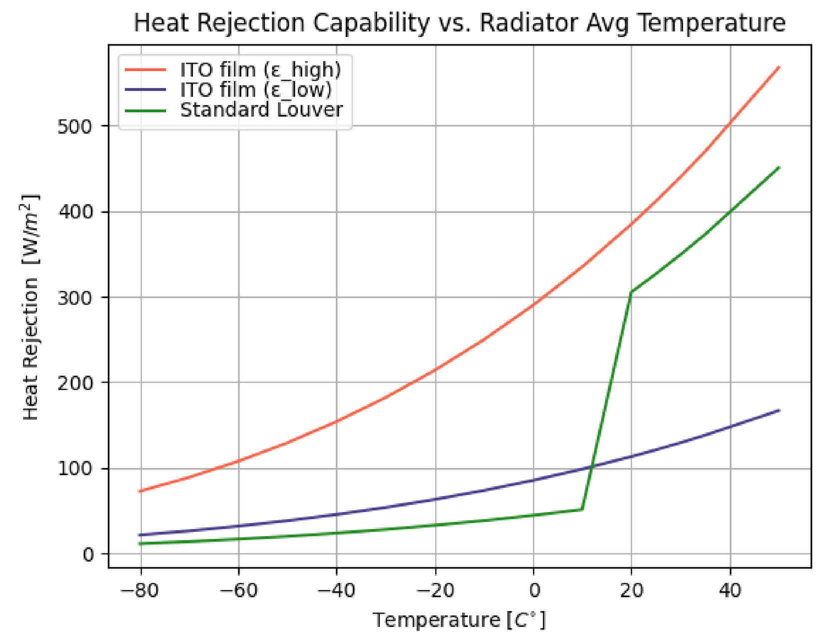


The Milliron Group synthesized two batches of ITO nanocrystal samples using a hot injection method, with control over both nanocrystal diameter and level of tin oxide doping. Spin coating or solution printing techniques were used to apply the ITO nanocrystals at a controlled thickness onto quartz and silicon substrates. A computer program was written to calculate the total hemispherical emissivity (IR) and absorptivity (UV-Vis-NIR) using the raw reflectance data and compare performance among the ITO nanocrystal samples.



Thinner ITO nanocrystal films (order of nm) showed moderately increased absorptivity relative to silicon standards, and increasing the thickness of the films (order of microns) greatly improved the magnitude of broadband absorbance. **The highest total hemispherical emittance achieved for Batch 1 and Batch 2 samples on silicon substrates was 0.21 (ID = C2) and 0.39 (ID = 7-9), respectively (cf. 0.06 for silicon substrate reference).**

The EC coating has potential advantages over standard louver assemblies. Assuming a required rejection of 100W at an average radiator temperature of 30C, the radiator size would have to be ca. 0.29 m^2 if emittance is based on standard louver performance. **The pre-set size of louvers requires two 18 blade louvers (2 kg) and a radiator of 0.33 m^2. The same radiator using the EC film coating would only require 0.23 m^2 (0.9/1.8 kg) (maximum emittance).**



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