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VANADIUM DIOXIDE-BASED VARIABLE REFLECTIVITY RADIATION COATINGS FOR OPTICAL PROPULSION APPLICATIONS

Abstract

An original dynamic radiation coating design is developed which can actively control the reflectivity of spacecraft exterior surfaces to modulate solar radiation pressure for use in propulsion and attitude control applications. This design presents an advantage over alternative forms of micropropulsion because it is fuel-free and requires minimal allotment for mass and volume. The solar radiation pressure and corresponding optical force will be maximized when the variable reflectivity coating has high reflectivity over the solar spectrum. When the coating has low reflectivity the optical force is reduced.

Vanadium dioxide is an insulator-to-metal transition material which undergoes a dramatic shift in optical properties during transition. This characteristic of vanadium dioxide has been investigated as a means to provide switchablility to radiation coatings. The transition of vanadium dioxide can be actuated thermally or electrically. This study considers a four layer thin film stack, which is comprised of a Fabry-Perot cavity with a vanadium dioxide anti-reflection coating. The top and bottom mirrors of the Fabry-Perot resonator are gold and tungsten respectively. When the vanadium dioxide is dielectric it provides the cavity for Fabry-Perot absorption enhancement, significantly reducing the reflectivity. When the vanadium dioxide is metallic the combined thickness of the metallic layers maximizes the reflectivity for all wavelengths.

We introduced a uniaxial transfer matrix method to calculate the reflectivity of a preliminary multilayer thin film coating with both metallic and insulating vanadium dioxide. For the insulating vanadium dioxide, the visible reflectivity is less than 20%, the near-infrared reflectivity is below 40% for wavelengths smaller than 1.2 m. For metallic vanadium dioxide, the reflectivity is over 85% throughout the visible and near-infrared regimes, and increases to over 95% for the mid and far infrared. This performance is shown to be independent of angle for incident angles less than 60 degrees. To evaluate the performance of the coating, we developed a figure of merit based on the variance of solar radiation pressure from the insulating phase to the metallic phase. The layer thicknesses will be optimized by minimizing the figure of merit via a genetic algorithm approach. Based on these results, the proposed structure could be useful for applications in optical propulsion and attitude control.

This work has not been published or presented at a previous meeting.