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Case ID:M21-227P^
Published: 2/22/2022

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Spectrally-Selective Vanadium Dioxide–Based Variable-Emittance Coating for Dynamic Radiative Cooling

-Background Recently there has been significant interest in selective radiative cooling coatings for passive thermal control applications, and tremendous progress has been made with static thermal control coatings. However, a tunable radiative coating with variable emittance could help to reduce energy consumption in buildings by limiting heat loss in cold weather with low emittance or promoting heat dissipation in warm weather by selectively emitting heat within the 8–13 μm atmospheric window to outer space. Spectral selectivity can be achieved through a variety of nanostructures, while switchable radiative properties can be provided by incorporating a thermochromic material into the coating. One such material is vanadium dioxide (VO2), which exhibits an insulator-to-metal transition and a dramatic change in infrared optical properties near a temperature of 68 °C.

Although results from theoretical studies show great promise for dynamic radiative cooling with VO2 thin films, several challenges exist with the fabrication and experimental demonstrations of these devices. Current devices require either many layers or thick layers that are difficult to fabricate. Further, Hendaoui et al. fabricated a Fabry-Perot emitter with an SiO2 spacer that achieved excellent performance for dynamic spacecraft thermal control, however the phonon modes in the spacer material prevented the device from achieving spectral selectivity in the atmospheric window. Invention Description Researchers at Arizona State University have developed a VO2-based tunable metafilm coating with variable emittance that decreases thermal emission at low temperatures and increases thermal emission at higher temperatures. The emitter sample consists of an aluminum mirror, a silicon spacer, and a VO2 thin film, respectively fabricated using electron beam evaporation, RF magnetron sputtering, and a furnace oxidation technique. The high refractive index of the silicon enables a much smaller spacer thickness to be used, while the lack of strong phonon modes in the infrared regime makes it possible to achieve spectral selectivity in the atmospheric window. Sputtering is also employed in industry to fabricate coatings on large areas and nonplanar geometries. The VO2 and silicon layers can be applied to both aluminum structures and flexible foils with vapor deposited aluminum, which are extensively used in the aerospace industry. Potential Applications • Radiative cooling • Terrestrial and extraterrestrial craft • Thermal control for aerospace applications • Energy conservation in buildings Benefits and Advantages • Tunable metafilm emitter achieves a significant total emittance increase from 0.14 at room temperature to 0.60 at 100 °C • Demonstrates a pronounced emission peak around 10 μm wavelength, corresponding to the peak thermal emission of a body at room temperature, and which is within the desired 8–13 μm atmospheric infrared window • Fabricated with techniques and materials common to the aerospace industry Related Publication: Spectrally-Selective Vanadium Dioxide Based Tunable Metafilm Emitter for Dynamic Radiative CoolingResearch Homepage of Professor Liping Wang