Description of the Thermal Control using Metamaterials Project

CNF Project Number: 2527-17

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Primary Source(s) of Research Funding: National Science Foundation (NSF)

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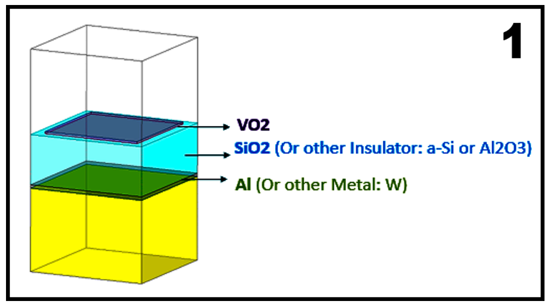
Primary CNF Tools Used: AJA sputter deposition, plasma enhanced chemical vapor deposition (PECVD)

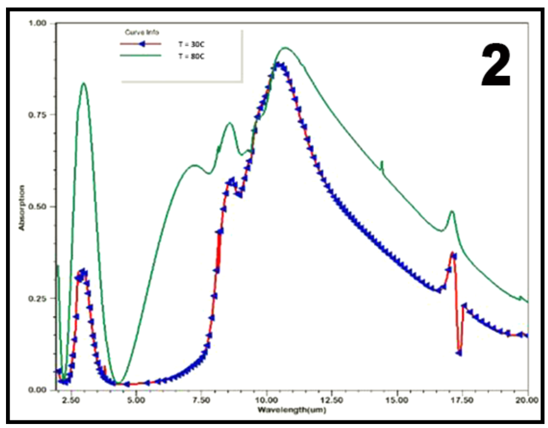
Abstract:

In this project, we are going to fabricate a temperature-based metamaterial structure composed of vanadium oxide (VO_2) grating with the benefit of semiconductor to metal phase change. The thermochromic VO_2 is transparent, which acts as semiconductor in temperatures lower than critical temperature, but emits the light in higher temperature as a metal. The deposition of VO_2 film is under investigation by changing the oxygen and argon pressure along with applying temperature changes *in situ* in a sputtering chamber and also, by changing annealing methods.

Project Description:

In this project we show the capabilities of metamaterials-based thermal controlling films. The metamaterial structure composed of VO_2 grating on top of SiO_2/Al substrate can retain heat when desired, while dissipate heat at other times, shown in Figure 1. VO_2 as a thermochromic material undergoes a semiconductor (monoclinic structure) to metal (rutile structure) transitions at a critical temperature of 68°C, accompanied by change in IR reflectivity and in resistivity, shown in Figure 2. The technology is unique such that it allows for passive thermal control of space-based instruments. We also developed a fabrication plan at the Cornell NanoScale Science and Technology Center (CNF) that allows for large-area fabrication of films, and designed the lithography mask for grating layer of the filter. If methods are developed to develop large-area films, then the technology can coat space-based instruments, as optical solar reflector (OSR), shown in Figure 3. The optical setup and reflector in addition to thermal control device is already accomplished to measure the reflection of filter at different temperatures in Clarkson University lab. Current thermal control systems require onboard electronics that add weight, size, complexity (i.e., SWaP-C).





References:

[1] K. Sun, C. Riedel, A. Urbani, M. Simeoni, S. Mengali, M. Zalkovskij, B. Bilenberg, C. d. Groot and O. L. Muskens, "VO_2 Thermochromic Metamaterial-Based Smart Optical Solar Reflector," American Chemical Society Photonics, vol. 5, p. 2280-2286, 2018.

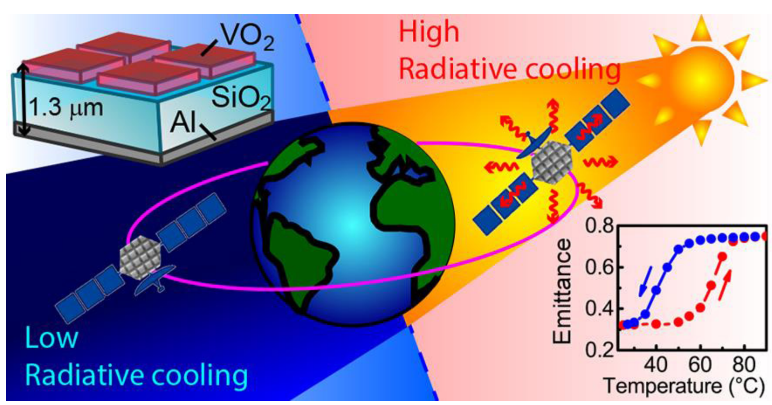


Figure 1, top: Metamaterial structure composed of VO_2 grating on top of insulator/metal substrate. Figure 2, middle: Absorption spectra of VO_2 increased in higher temp in comparison with lower temp. Figure 3, right: VO_2 based metamaterial structure as OSR shows the phase transition above and below 68°C critical temperature [1].