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Vanadium Dioxide: a reconfigurable disordered metamaterial[1]

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In VO_2 thin films, the Insulator-to-Metal transition occurs gradually with increasing temperature: Nanoscale inclusions of the metallic phase emerge in the surrounding insulating-phase VO_2, which grow and these metallic inclusions are much smaller than the scale of the wavelength at infrared frequencies, and thus VO_2 can be viewed as a natural, reconfigurable,disordered metamaterial with variable effective optical properties across the phase transition. connect in a percolation process, eventually leading to a fully metallic state at the end of the transition. In Ref. [1], this unique temperature-dependent dispersion of the effective medium was used to demonstrate that a film of VO_2, with thickness ($\cong$ 150 nm) much smaller than the wavelength, deposited on sapphire can operate as a temperature tunable absorber; in particular, nearly perfect absorption was achieved at a particular temperature for a narrow range of infrared wavelengths. The reflectivity of such a device varies dramatically and non-monotonically across the phase transition, with the strong absorption feature appearing during an intermediate state of VO_2 as a result of coupling to an "ultra-thin-film resonance" [2]. Since the emissivity of an object is equal to its frequency-dependent absorptivity (Kirchoff's law) such a thin-film VO_2-sapphire structure is expected to have an emissivity that also depends strongly and non-monotonically on temperature. This structure displays "perfect" blackbody-like thermal emissivity over a narrow wavelength range (approximately 40 cm^{-1}), surpassing the emissivity of our black-soot reference [3]. We observed large broadband negative differential thermal emittance over a >10 C range: Upon heating, the VO_2-sapphire structure emits less thermal radiation and appears colder on an infrared camera [3]. Our experimental approach allows for a direct measurement and extraction of the wavelength- and temperature-dependent thermal emittance. Collaborations with M. A. Kats, S. Ramanathan, D. Sharma, R. Blanchard, P. Genevet, J. Lin, S. Zhang, C. Ko, Z. Yang, M. M. Qazilbash, D. N. Basov are gratefully acknowledged.

[1] M. A. Kats et al. Appl. Phys. Lett. 101,221101 (2012).
[2] M. A. Kats, R. Blanchard, P. Genevet, and F. Capasso, Nat. Mater. 12, 20 (2012).
[3] M. A. Kats et al. PRX 3, 041004 (2013).

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