Study of the Phase Transition of Vanadium Dioxide by Radiative Emission in the Mid-Infrared

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The optical and infrared properties in thermochromic materials have been deeply investigated in the last years due to the large variety of photonic devices that can be realized thanks to the metal/insulator phase transition: "smart" windows, thermally controllable localized-plasmon, hysteresis enhancement of a phase transition by nanoparticulation, optical memory by the means of phase transition, and ultrafast switching of the photonic stop band in photonic crystals. Among the thermocromic materials, vanadium dioxide (VO2) represents the most widely used for many applications [1,2]. Its crystalline lattice exhibits an abrupt semiconductor-to-metal phase transition at a temperature of about TC≈68 °C, characterized by a change of the crystalline cell from monoclinic to tetragonal, and consequently by an ultrafast change in the optical and IR properties (i.e. reflectivity and emissivity). In this paper we studied the phase transition of a thin vanadium dioxide film deposited on a silicon substrate in the infrared range. We show that the thermal hysteresis strongly depends on the specific spectral band used for the detection in the mid-infrared: two spectral bands are chosen in the atmospheric transparency infrared windows (SWIR 2.5-5 µm, and LWIR 8-12 µm). The sample emissivity shows a strong thermal hysteresis when the sample is heating up and cooling down. It shows also an anomalous increase of emissivity for all the infrared ranges related to the coexistence of the metal and dielectric states in the disordered metamaterial phase during the semiconductor metal transition (SMT). We have applied the main theories of the effective medium during the phase transition (Maxwell Garnett and Bruggeman effective medium approximation) in order to explain the emissivity behavior as a function of the temperature in both spectral bands SWIR and LWIR [3,4]. The result of such a study is useful for many applications: in the field of camouflage, in the aerospace field for the design of engineer smart radiator devices, and for smart windows for reducing energy consumption.

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References:

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