Infrared emissivity of vanadium dioxide thin films coated on cotton fabrics

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In the last years there has been an increasing interest in the realization and characterization of innovative smart textiles for several applications such as thermal radiation control as well as infrared (IR) radiation manipulation. Their promising properties, such as flexibility, light weight and cost effectiveness, enable the realization of smart, adaptive clothes. However, component materials, fiber-woven characteristics and structure are important factors affecting the thermal physical properties of the resulting textile [1-4].

Vanadium dioxide of monoclinic structure VO_2 is regarded as the most important and promising material, since it exhibits phase transition at the temperature T_C=68 °C, with dramatic changes of optical properties in the IR range. Below the transition temperature, monoclinic VO_2 is a semiconductor, while above T_c, it switches to metallic state with a rutile structure [5]. Such a phase transition is fully reversible and associated with dramatic changes in electrical, magnetic and optical properties [6-8]. Therefore, with such properties, VO_2 can be considered as a promising candidate for a variety of potential applications such as energy efficient window coatings [9], thermal sensors [10], cathode materials for reversible lithium batteries [11], electrical and infrared light switching device [12-14]. However, there were few reports about the infrared stealth property of VO_2 in the literatures. Among them, Guinneton pointed out there was a fall of 60% in normal integrated emissivity of VO_2 thin film between 8 and 12 μm, which made it possible to be a kind of potential material for infrared stealth [6,7,15-17]. The adaptive infrared camouflage property of VO_2 coated fabric was reported in several recent scientific papers [18]. Results showed that infrared emissivity in the range 8–12 μm of 300 □m VO_2 coated fabric decreases by only about 0.1 during the phase transition. In this paper we wish to study, optimize and experimentally measure the infrared emissivity dynamic range of vanadium dioxide thinner films on cotton fabrics.

Different solutions of VO_2 powder with polyurethane (PU) have been prepared with several concentrations. The solution has been deposited with a blade and spread homogeneously on the fabric. Subsequently, by applying hot air on the sample, the cotton fabric is brought to the maximum temperature of 90/100 °C for a few seconds and then kept at the constant temperature of 60 °C for 5 minutes, so to allow the PU polymerization and drying. Optical images show the homogeneity of a thin coating of about 40□m over a large area at macroscopic range.

The infrared stealth performance was investigated by Infrared Thermography in the infrared range 8 - 14 μm, and in the temperature range from 40 °C to 80 °C. The thickness of the dry vanadium dioxide coating is around 40 μm, that is enough to produce a measurable change of the emissivity properties of the cotton fabric.

The infrared emissivity of the pure cotton (without vanadium dioxide) is ε=0.86, and temperature independent. On the contrary the coated sample exhibits a lower emissivity ε=0.82 already at room temperature (20 – 40 °C), with a drastic decrease to ε=0.72 at 80 °C, after the vanadium dioxide phase transition to metallic state.

The infrared properties of the coated fabric samples at a macroscopic scale have been tested again by infrared thermography in the range 8-14 m. The samples have been placed in thermal contact with a suitable heater with a Peltier temperature control system so to produce continuous heating/cooling cycles from 40 °C to 80 °C with a quasi-static temperature scan of 1°C /min.

Thermal infrared images of coated fabric after undergoing several cycles of heating and cooling process has been used to test the excellent durability of vanadium dioxide phase transformation. The apparent temperature taken by the thermal infrared images together with the real temperature measured by the thermocouples, are processed so to obtain the emissivity map of the coated textiles.

These preliminary results opens a new strategy to design, optimize smart textiles using the natural infrared stealth property of VO_2 so to manipulate the infrared emission and the infrared signature of large size objects.

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