THERMOCHROMIC MATERIALS FOR REFLECTIVE COATING

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ABSTRACT

Thermochromic materials respond to change in external temperature. There are many thermochromic materials attended in recent years for energy conservation. Vanadium dioxide (VO_2) is a well-known thermochromic materials. The reversible mechanism can be useful for thermal reflective coating of buildings reduces the temperature. This work is to investigate the ability of molybdenum (Mo)-doped VO_2 powder for mixing in paint to be used as thermal reflective coating for concrete surface. Three different powder coatings were used. The effect of different type of surface coating on temperature variation of the surface concrete has been evaluated. This work demonstrates a novel approach that Mo-doped VO_2 can be potentially used to reduce the temperature on the concrete surface and further retains indoor passive thermal comfort.

KEYWORDS: thermochromic materials, vanadium dioxide, reflective coating

1. Introduction

Global warming is the current increase in temperature of the Earth's surface as well as its atmosphere. 20 to 40 percent of energy consumption in developed countries can be attributed to buildings, and 10 to 20 percent of the primary energy usage of buildings account for heating or cooling purposes [1]. Building architecture systems lead to more cooling and heating energy loss in increasing air temperature. Thermochromic materials were used in energy saving solutions. VO_2 is a thermochromic material that undergoes a fully reversible metal-insulator phase transition (MIT) at 68 °C accompanied by structural changes from a monoclinic (semiconductor with high IR transparency) to a rutile (metallic form with IR reflection) phase [2]. Many works to improve the performance of VO_2 as energy saving smart windows with solar heat control [3-7], reversible/tunable IR solar radiation control, air conditioning, VO_2-PVP composite coatings [8], the optical properties of VO_2 films, forming nanoparticle composite foils. The preparation of a film with excellent performance is still a challenge.

In this paper, we report for the first time synthesis of novel Mo-Doped VO_2 powders by a simple solution-based process [9]. The morphology, structure and properties of the powder were investigated by SEM, XRD, DSC and EDX techniques. The different powders loading were mixed in paint and coating on concrete, compared with the uncoated and primer. The concretes were placed at the lamp exposure. The temperature was evaluated at the outer and inner concrete surface. The above techniques breakthrough will play a role in obtaining materials with integrated energy-savings and environmental protection functions for building applications.

2. Materials and Methods

2.1 Preparation of Mo-Doped VO_2 Powders

Thermochromic 12% atom Mo-doped VO_2 powders were prepared by a simple solution-based process, rapid microwave assisted at 300 Watt, and calcination in Nitrogen gas method at 700°C [9]. The phase transition behavior was characterized by differential scanning calorimetry (DSC) (Perkin Elmer DSC7) with a heating rate at 5 ºC min^{-1}. The morphologies and sizes of the structure were characterized by FEI Quanta 400 scanning electron microscope (SEM). The properties of the synthesized Mo-doped VO_2 powders were investigated by X-ray diffraction (XRD). The elemental analysis of the paint was performed by electron dispersive X-ray analysis (EDX).

2.2 Preparation of The paint

There are different percentages of Mo-doped VO_2 powders as 0, 0.5, 1.5 and 3% wt pigments were stirred in 2 ml of water for 5 min, then the mixture was added in 10 g of paint suspension for 10 min during stirring. Pigments have been incorporated and dispersed into paint (commercial paint) media.

2.3 Preparation of specimens for coating of paint film

The specimen for thermal testing is a cube specimen of concrete by size 100 x 100 x 15 mm. The coating was applied on the surface of all the test specimens, was through hand lay-up. This work was to compare the samples as uncoated, primer, 0, 0.5, 1.5 and 3% wt of pigment. Table 1 shows the description of samples for an experiment.

Table 1 Description of samples

Samples no.	Description
1	Uncoated
2	Primer
3	Primer+Paint+0%VO_2
4	Primer+Paint+0.5%VO_2
5	Primer+Paint+1.5%VO_2
6	Primer+Paint+3.0%VO_2

3. Results and discussions

3.1 Structure and morphological properties

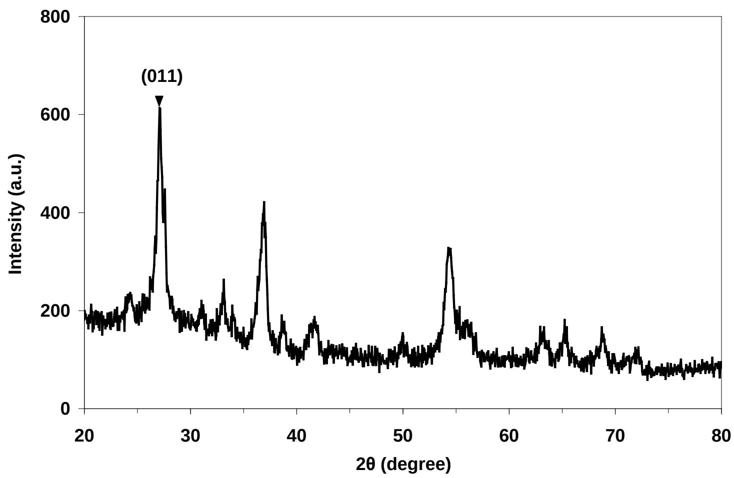

Figure 1 XRD patterns of 12% atom Mo-doped VO_2 powders was calcined at 700°

XRD patterns of 12% atom Mo-doped VO_2 powders was calcined at 700°C (Figure 1) can be indexed as the monoclinic crystalline phase of VO_2 (M) which corresponds to VO_2 (M) (JCPDS 01-082). XRD patterns show a sharp fraction peak at about $2\Theta = 27.08$, which corresponds to the (011) plane of monoclinic VO_2.

The morphology of the Mo-doped VO_2 powders is presented in Figure 2. The Mo-doped VO_2 particles agglomerate, with particle sizes at the micrometer level.

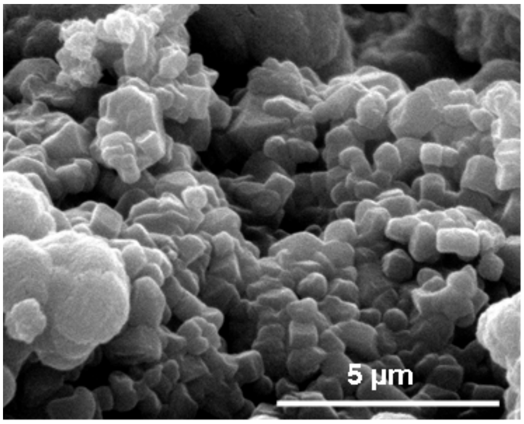

Figure 2 SEM image of VO_2 powders with 12% atom of Mo content.

3.2 Thermal analysis

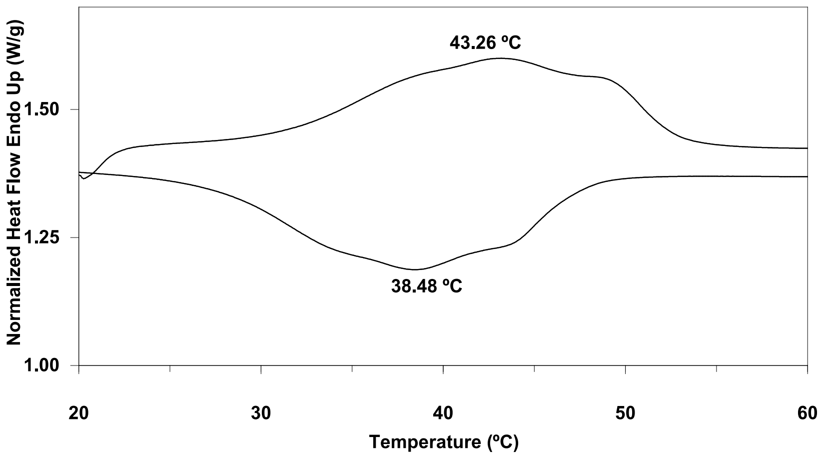

Figure 3 DSC curves of 12% atom Mo-Doped VO_2 powders was calcined at 700°C.

Figure 3 exhibits the DSC curves of 12% atom Mo-Doped VO_2 powders was calcined at 700°C. The transition temperature peak of the endothermic and exothermic peaks is at 43.26 and 38.48°C, respectively. It could be ascribed to the phase transition from monoclinic to tetragonal.

3.3 The thermal performance of the pigmented coatings

Figure 4 Inset shows the equipment of testing temperature difference of the two coatings.

The thermal performance evaluated the difference of interior temperature of the pigmented coatings used as building box. Figure 4 shows the equipment of examination. The results of experiments, conducted under the same condition. The results for each sample are demonstrated in Figure 5 which presents a 60-min distribution of the outer and inner surface temperature of the concrete coating. The 1.5% pigment sample presents lower outer and inner surface temperatures than others sample.

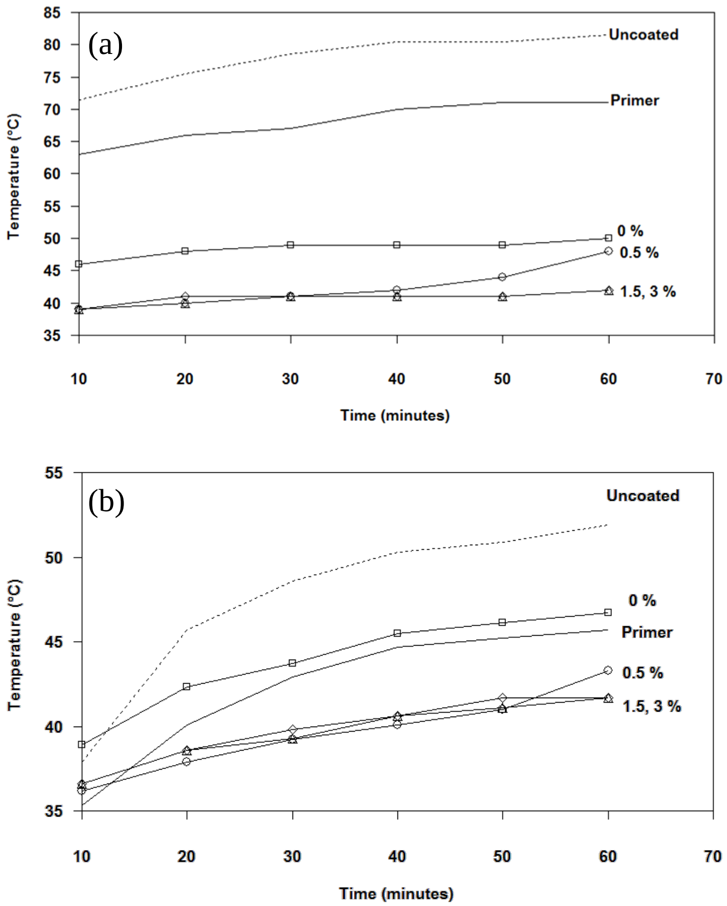

Figure 5 **The outer (a) and inner surface (b) temperature of the concrete coating with different pigment dosage.**

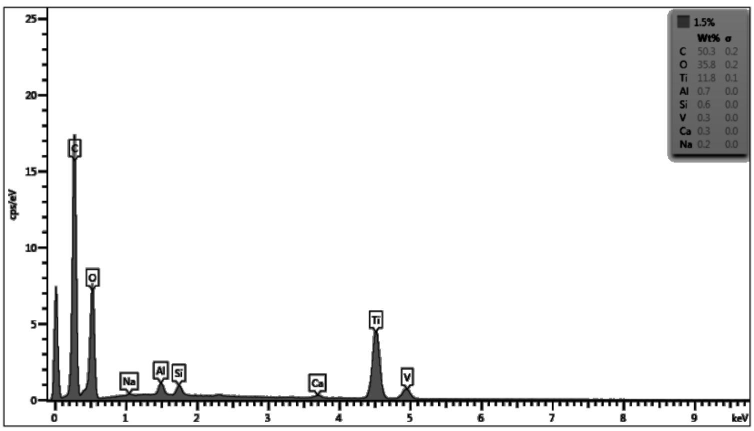

Figure 6 **Analysis of 1.5% wt pigment by energy dispersive X-ray analyser (EDX).**

EDX analysis of the paint is show in Figure 6. The paint compositions contain C, O, Ti, Al, Si, V, Ca and Na.

4. Conclusions

The properties of the paint impact thermal reflective. The thermal performance of the pigmented coatings was also evaluated. The outer surface temperature difference between without coating and coating around 40˚C and the inner surface temperature difference between without coating and coating around 10˚C. This study indicates that 1.5% wt pigment show the best potential to be used as a pigment in paints. The coating colored with the pigment we prepared reflects more thermal portion and decreases the heat transferred into indoor space, which in turn reduces energy consumption for cooling [10]. These properties benefit for the development and application of thermochromic materials.

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