Synthesis and Characterization of Vanadium Oxide Film by Sparking Method for Thermochromic Application

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Abstract

Vanadium dioxide (VO_2) has a great potential to be utilized as thermochromic glazing for improving the energy efficiency of buildings. The famous semiconductor-to-metal phase transition (SMT) property of VO_2 shows the reversible optical properties when the temperature is above the critical point at 68 °C. In this work, VO_2 films were prepared by sparking method on glass substrates and annealed for 2 – 6 h at 300 – 500 °C. Thickness of VO_2 films was varied by increasing the sparking cycles. The surface morphology of samples was analyzed by atomic force microscopy and scanning electron microscopy. The solar reflectance and transmittance were investigated by UV-Vis-NIR spectroscopy. The results show that the roughness of the films was decreased by rising the annealing temperatures and the near-infrared transmittance trend of products were dropped down when annealing in vacuum with pressure at 5x10^{-3} Torr.

Introduction

Renewable sources of energy have much interest widely study because energy is highly used, around 30–40% of the primary energy that used for consumption are due to heating, cooling, ventilation, lighting and appliances in buildings [1]. Smart windows can exhibit automatic heat control in response to environmental without the use of any external switching device. For examples *photochromic* controlling by using ultraviolet irradiation, *electrochromic* controlling optical transmittance by using electrical charging, and *thermochromic* transmittance depends on temperature [2]. Window coatings are considered to be the first step in reducing heat transfer between the inside and outside environments of buildings.

This research focuses on VO_2-based thermochromic materials prepared by sparking method is generally advantageous for practical use because its lower cost and simplicity on thin film coating process in ambient condition.

Materials and Methods

Synthesis of vanadium oxide films

VO_2 thin films were deposited on a substrate by sparking method using vanadium wire tip of 0.25 mm in diameter, 99.8% purity. Glasses (10 × 10 × 1 mm^3), treated by ultrasonically cleaned in acetone, water and ethanol for 30 minutes respectively, were used as substrates. Vanadium oxide films were coated by sparking method in air at room temperature and film thickness was varied by number of sparking circles. The coated materials were annealed from 300 to 500 °C for 2 to 6 hours under pressure at 5x10^{-3} Torr.

Measurements

Optical transmittances were measured using UV-Vis-NIR spectroscopy. The surface morphologies, root-mean-square (rms) roughness, and film thickness of the films were observed by atomic force microscopy and scanning electron microscopy. X-ray photoelectron spectroscopy was used to determine oxidation state of vanadium.

Results and Discussions

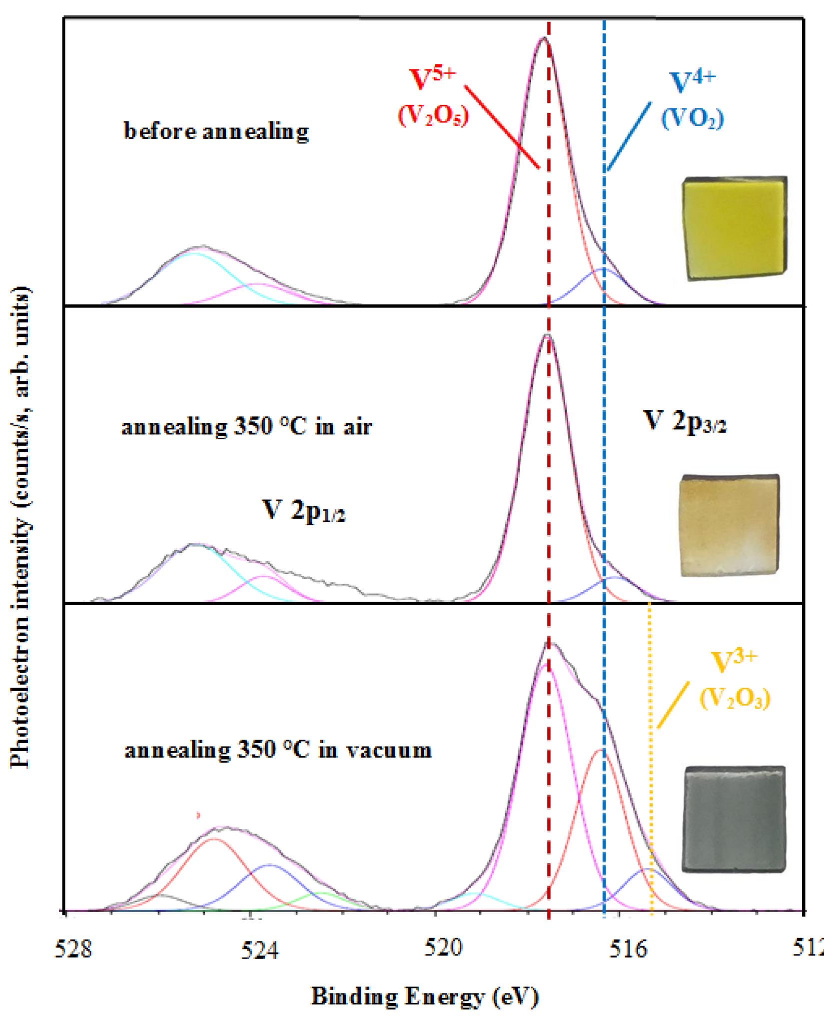

Fig. 1. V 2p XPS spectra of the vanadium oxide films by sparking method. Red, blue and yellow lines indicate V^{5+}, V^{4+} and V^{3+} peaks in the spectra, respectively.

Phase of vanadium oxide by XPS

The V^{5+} oxidation state was generally occurred in as prepared and 350 °C air annealing products. However, with annealed at 350 °C in vacuum pressure 5x10^{-3} Torr, the intensity of V^{5+} peaks was decreased related to the V^{4+} oxidation state, which also confirms the phase transition from V_2O_5 to VO_2 on the samples. Nevertheless, VO_2 is still a minor phase.

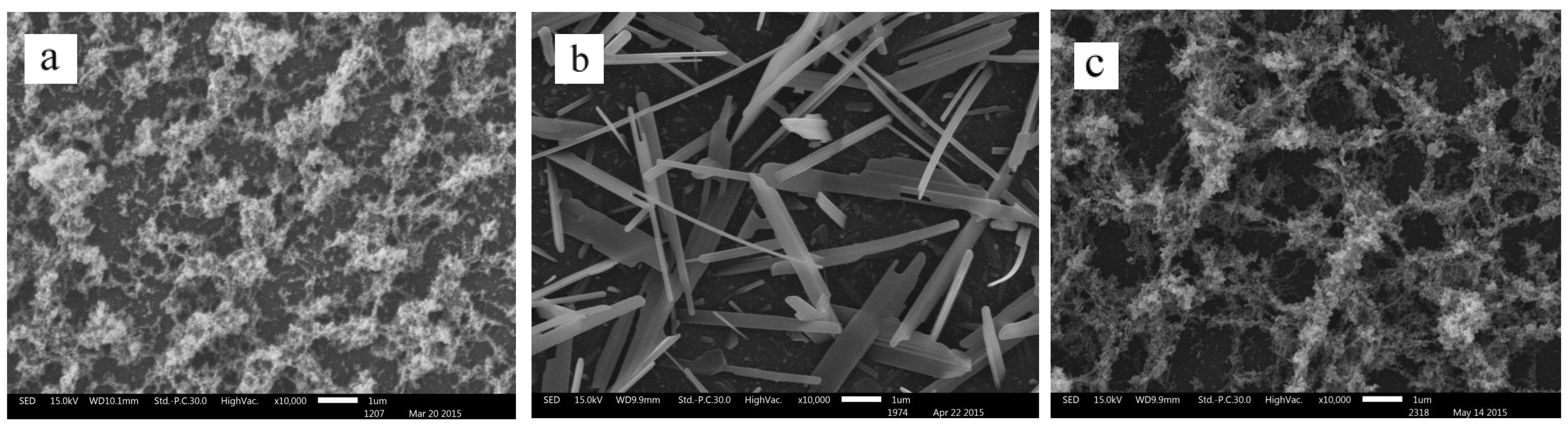

Fig. 2. SEM images of the samples before annealing (a); after annealing 350 °C in air (b); and in vacuum at 5x10^{-3} Torr (c).

Surface morphology image by SEM were shown in Fig. 2 and the transmittance spectra of the films was measured by UV-Vis-NIR spectrometer were shown in Fig. 3.

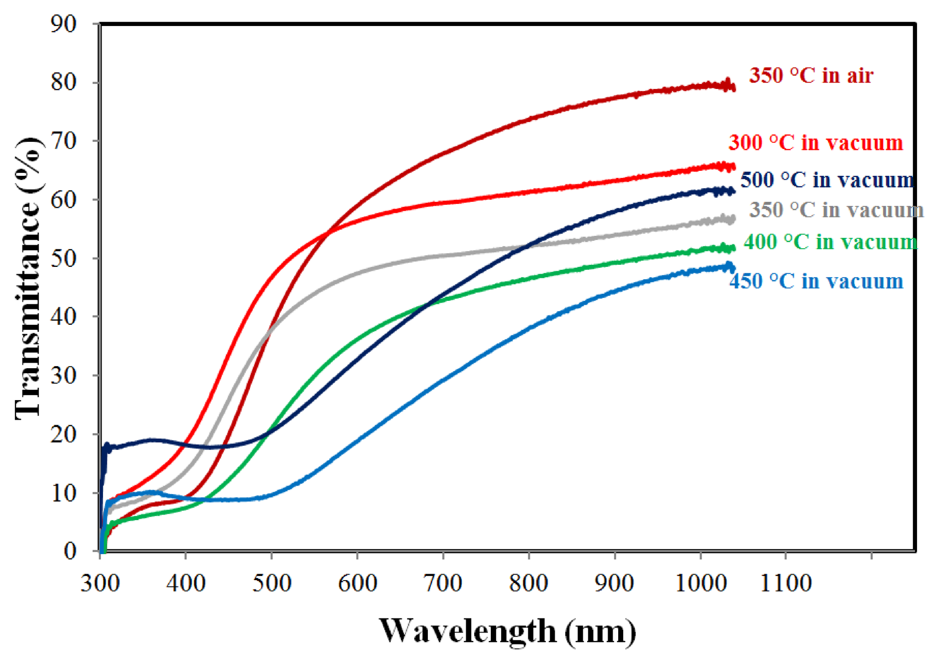

Fig. 3. The transmittance spectra of films with annealed at 350 °C in air and annealed in vacuum from 300 to 500 °C with pressure at 5x10^{-3} Torr.

Shows that the near infrared transmittance of vacuum annealed films is lower than other air annealed sample due to VO_2 forming. The appearance of VO_2 decreased the near infrared transmittance depended to temperature rising up to 450 °C.

Conclusions

Vanadium oxide thin films were successfully coated on glass substrates by sparking method. Phase transition of V_2O_5 to VO_2 by annealed in vacuum at pressure 5x10^{-3} Torr was confirmed by XPS results. Near infrared transmittance of vacuum annealed films is lower than other air annealed sample due to VO_2 forming that observed by UV-Vis-NIR spectroscopy. In this research, the proper condition was annealed in vacuum at 450 °C with pressure 5x10^{-3} Torr which near infrared transfer around 48%.

Acknowledgments

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