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REACTIVE HIGH-POWER IMPULSE MAGNETRON SPUTTERING OF THERMOCHROMIC VO_2 FILMS ON SILICON SUBSTRATE AT LOW DEPOSITION TEMPERATURES

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1 Introduction

Vanadium dioxide is the most interesting thermochromic material due to its reversible phase transition from semiconducting IR transparent state (monoclinic structure) to metallic IR reflective state (tetragonal structure) at around 68 °C. High infrared transmittance modulation in thin films makes the VO_2 based films a suitable candidate for optical switching applications, such as self-tunable infrared filters, temperature sensing devices and smart windows for automatic solar transmission. Current drawbacks surrounding the commercialization of VO_2 include a high transition temperature, high deposition temperatures (> 400 °C) required for synthesizing the crystalline VO_2 thin films as well as a low visible transmittance (typically 50 %) S.-Y. Li et al. (2012), J.-P. Fortier et al. (2014).

2 Experimental details and Results

High-power impulse magnetron sputtering with a pulsed reactive gas (oxygen) flow control was used for depositions of thermochromic VO_2 films (75 - 100 nm thick) onto floating Si substrates at the temperatures, T_s, of 250 - 400 °C. Note that using the floating potential improves the application potential of the films due to a simplified deposition process and a decreased ion-induced compressive stress. The depositions were performed using a strongly unbalanced magnetron with an indirectly water-cooled planar vanadium target (50.8 mm in diameter) in argon-oxygen gas mixtures at the argon pressure of 1 Pa. The duty cycle was set to a constant value of 1%, the voltage pulse durations were 50 and 80 μs, and the corresponding repetition frequencies were 200 and 125 Hz, respectively. The deposition-averaged target power density was 12 - 14 Wcm^{-2}. The target-to-substrate distance was 150 mm. The phase composition of the VO_2 films was determined by X-ray diffraction and Raman spectroscopy. The thermochromic behaviour of the VO_2 films was investigated using a spectroscopic ellipsometer equipped with a heat stage. The ellipsometric measurements were performed in the range of 300 - 2000 nm and 25 - 100 °C. The optical constants (refractive index, n, and extinction coefficient, k) were obtained from the ellipsometric data

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using a description of VO_2 by the Cody-Lorentz oscillator combined with Lorentz oscillators. Moreover, the optical constants (measured on Si substrates) were used to predict transmittance of the same materials on glass substrates. The VO_2 films prepared at the voltage pulse duration of 80 µs exhibit very low room-temperature k (down to 0.11 at 550 nm; applies also to the lowest T_s = 250 °C), leading to a high predicted transmittance in the visible region (e.g. up to 65% for a 100 nm thickness). The films exhibit a high infrared modulation, perfect reversibility of the thermochromic behaviour and a lower transition temperature (48 ˚C) than the bulk VO_2 (68 ˚C).

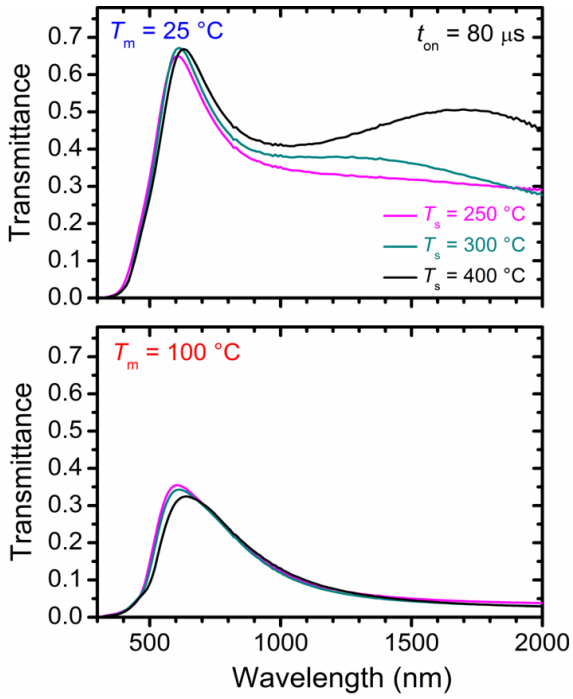

Figure 1: Calculated spectral transmittances from refractive index and extinction coefficient of the samples prepared at the voltage pulse length of 80 µs and substrate temperature of 250, 300 and 400 °C in the case of 1 mm thick glass substrate.

References

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