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Reactive High-Power Impulse Magnetron Sputtering of Thermochromic VO₂ Films at Low Deposition Temperatures

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High-power impulse magnetron sputtering with a pulsed reactive gas (oxygen) flow control was used for depositions of thermochromic VO₂ films (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 40 and 100 μ s, and the corresponding repetition frequencies were 250 and 100 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 VO₂ films was determined by X-ray diffraction and Raman spectroscopy. The thermochromic behaviour of the VO₂ 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 using a description of VO₂ 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 VO₂ films prepared at the voltage pulse duration of 80 μ s 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 VO₂ (68 °C).

Keywords

Reactive HiPIMS

Pulsed reactive gas flow control

VO₂ films

Thermochromic films