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High-Performance Thermochromic YSZ/$V_{0.986}W_{0.014}O_2$/YSZ Coatings for Energy-Saving Smart Windows

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1 Introduction

The reversible semiconductor-to-metal transition of vanadium dioxide (VO_2) makes VO_2-based coatings a promising candidate for thermochromic smart windows, reducing the energy consumption of buildings. We report on a scalable sputter deposition technique for fast preparation of strongly thermochromic YSZ/$V_{0.986}W_{0.014}O_2$/YSZ coatings, where YSZ denotes Y-stabilized ZrO_2, on conventional soda-lime glass at a relatively low substrate surface temperature (350 °C) and without any substrate bias voltage. The thermochromic $V_{0.986}W_{0.014}O_2$ layers and the antireflection YSZ layers were deposited using a controlled high-power impulse magnetron sputtering of a single V-W and Zr-Y target, respectively.

A coating design utilizing a second-order interference in the YSZ layers was applied to increase both the integral luminous transmittance (T_{lum}) and the modulation of the solar energy transmittance (ΔT_{sol}). The YSZ/$V_{0.986}W_{0.014}O_2$/YSZ coatings exhibit a transition temperature of 33-35 °C with T_{lum} = 64.5 % and ΔT_{sol} = 7.8 % for a $V_{0.986}W_{0.014}O_2$ thickness of 37 nm, and T_{lum} = 46.1 % and ΔT_{sol} = 13.2 % for a $V_{0.986}W_{0.014}O_2$ thickness of 67 nm. The results constitute an important step to a cost-effective and high-rate preparation of large-area thermochromic VO_2-based coatings for future smart-window applications.

2 Results

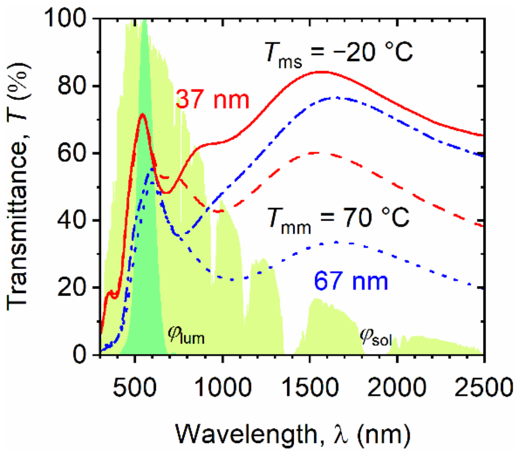

Figure 1: Spectral transmittance (T) for the YSZ (170 nm)/ $V_{0.986}W_{0.014}O_2$ (37 nm)/YSZ (179 nm) coating (full and dashed lines) and the YSZ (172 nm)/ $V_{0.986}W_{0.014}O_2$ (67 nm)/YSZ (182 nm) coating (dash-dotted and dotted lines) on 1 mm thick glass substrates

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The spectral transmittance of YSZ/$V_{0.986}W_{0.014}O_2$/YSZ coatings is shown in Figure 1, which allows one to note numerous features. First, there is the desired interference maximum in the visible, maximizing T_{lum}. Second, this second-order maximum in the visible is accompanied by a first-order maximum in the infrared (at roughly 3 times longer wavelength), leading to enhanced ΔT_{sol}. Third, there is the first fingerprint of the trade-off between T_{lum} (higher $T(\lambda)$ in the visible at h = 37 nm) and ΔT_{sol} (higher $T(\lambda)$ modulation in the infrared at h = 67 nm).

Figure 2 compares the performance of both presented sputtered coatings with that of other VO_2-based thermochromic coatings prepared by various sputtering techniques in various laboratories. Let us emphasize that the figure captures all the key criteria of success: T_{lum}, ΔT_{sol}, T_{tr} and maximum substrate temperature. It can be seen that the presented coating design and the industry-friendly low-temperature high-rate deposition technique allowed us to achieve further progress and to move the line representing the h-induced trade-off between T_{lum} and ΔT_{sol} further toward the area of required values denoted in the top right corner.

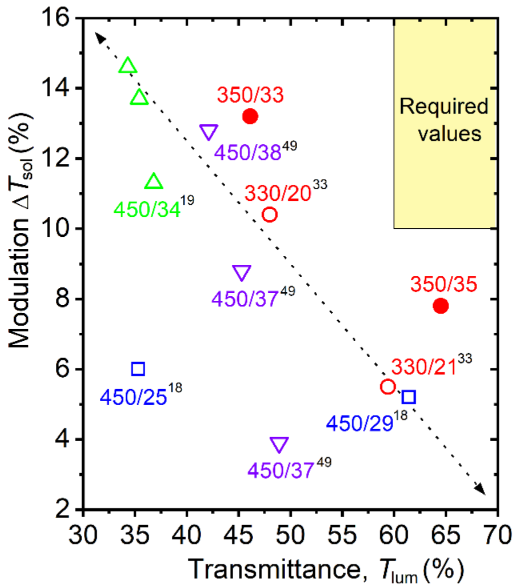

Figure 2: T_{lum} and ΔT_{sol} achieved in this work (full circles) and reported in the literature (empty symbols) for VO_2-based coatings with a transition temperature $T_{\text{tr}} \leq 38$ °C. The labels denote a maximum substrate temperature during the preparation of the coatings and their transition temperature (both in °C), with the reference number in the superscript (more specified in the article cited at the end of this page).

Acknowledgement

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References

Kaufman, M., Vlček, J., Houška, J., Čerstvý, R., Farrukh, S., Chargaoui, M., Haviar, S., Jiang, J.C., Meletis, E.I. and Kos, Š. (2023) High-Performance Thermochromic YSZ/$V_{0.986}W_{0.014}O_2$/YSZ Coatings for Energy-Savings Smart Windows. *ACS Applied Materials & Interfaces* (submitted)