Supplementary Information (SI) for RSC Advances.

Microstructurally Optimizing the Mid-Infrared Optical Modulation Properties of Vanadium Oxide Thin Films via Magnetron Sputtering and Subsequent Annealing

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In this study, all films were deposited under identical sputtering conditions (power 120 W, time 20 min, substrate temperature 60 °C), and therefore possessed a consistent initial thickness in the as-deposited state. The film thickness was measured using a step profiler. The non-annealed film exhibited a thickness of approximately 40 nm (Fig. S1). After annealing at 450 °C, despite grain growth and densification, the thickness remained essentially unchanged (Fig. S2). Notably, the samples annealed at 550 °C and 650 °C developed island-like and lamellar structures, respectively, accompanied by localized melting, which made step-profiler thickness measurements impractical. Therefore, their thicknesses were determined by atomic force microscopy (AFM), yielding values of about 60 nm (Fig. S3) and 12 nm (Fig. S4), respectively.

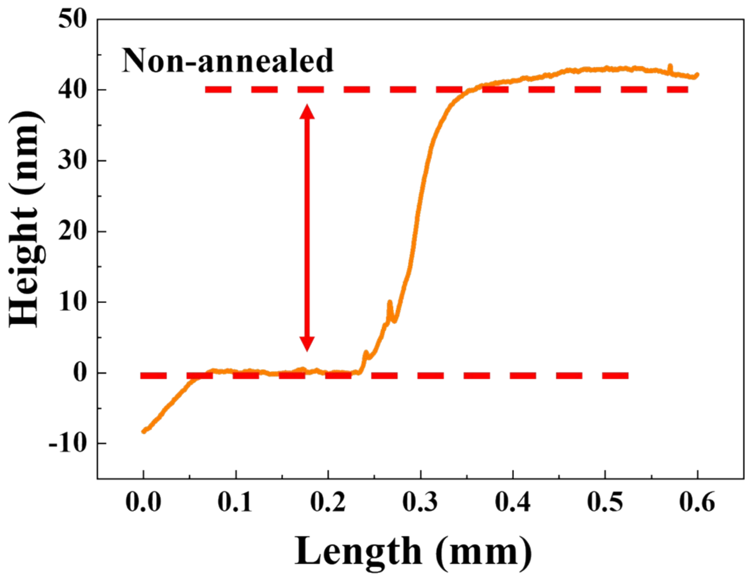

Fig. S1 Thickness of the non-annealed film.

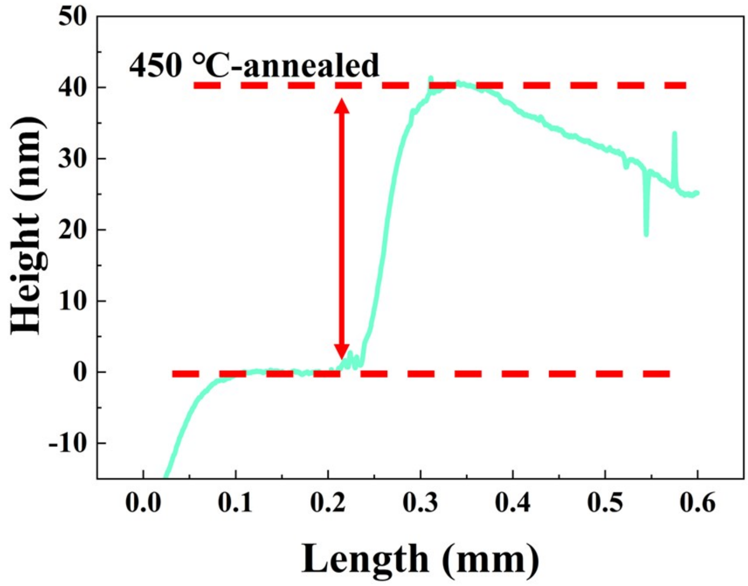

Fig. S2 Thickness of the 450°C-annealed film.

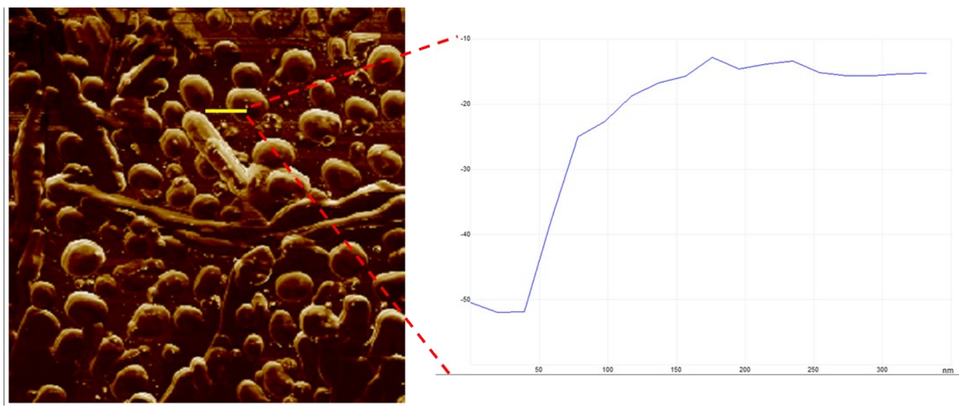

Fig. S3 Thickness of the 550°C-annealed film.

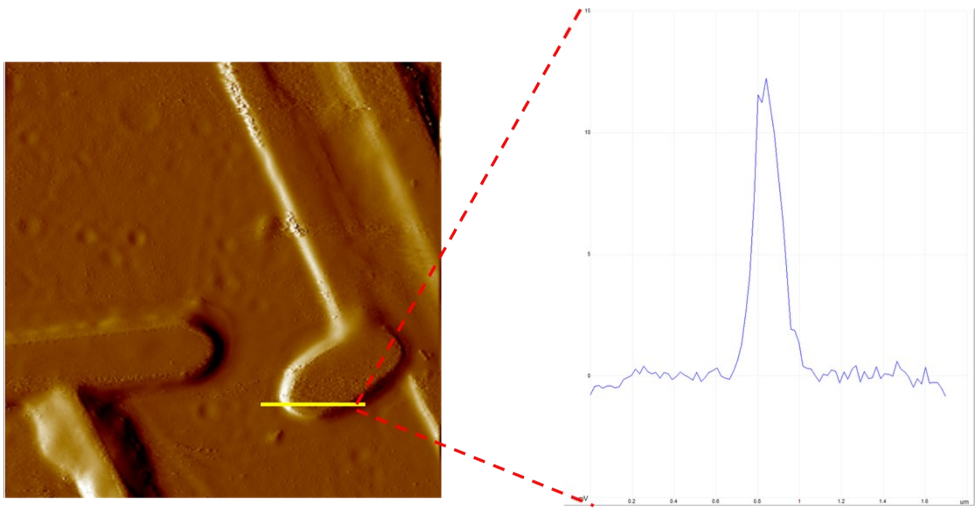

Fig. S4 Thickness of the 650°C-annealed film.

Atomic force microscopy (AFM) was employed to characterize the surface morphology (Fig. S5). The root-mean-square (RMS) roughness of the non-annealed film and the film 450 °C-annealed are 1 nm and 3 nm, respectively.

Notably, after annealing at 550 °C and 650 °C, the films evolve into island-like and platelet/stripe-like structures, respectively, accompanied by partial melting. Under these conditions, the films are no longer continuous, and therefore the surface roughness of a uniform thin film cannot be meaningfully defined or evaluated.

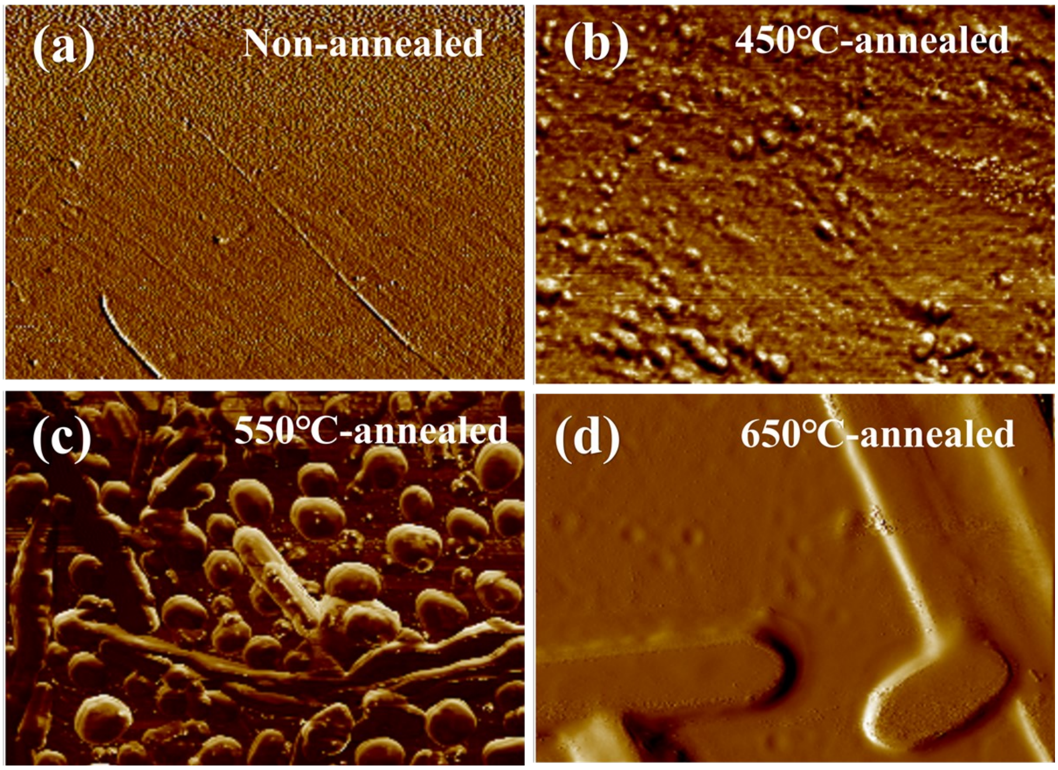

Fig. S5 AFM images of the (a) non-annealed, (b) 450 °C annealed, (c) 550 °C annealed, and (d) 650 °C annealed film specimens.

The thermochromic performance data of the samples within the solar spectral range (200-2500 nm) (Fig. S6).

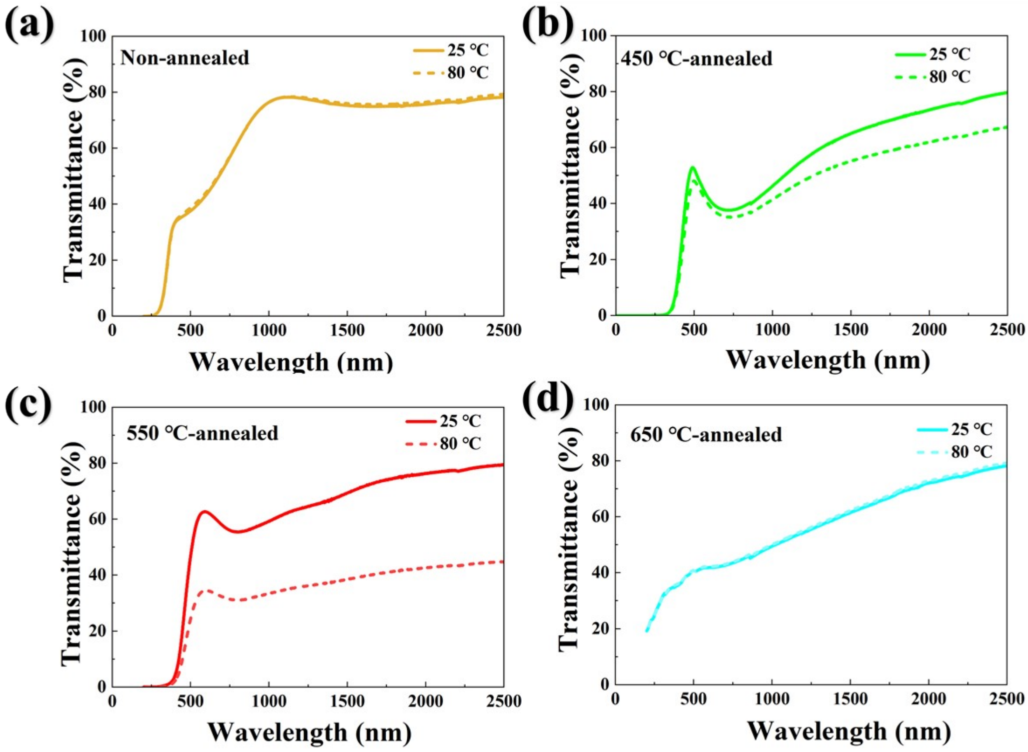

Fig. S6 Optical modulation performance (200 nm~2500 nm) of the (a) non-annealed, (b) 450 °C annealed, (c) 550 °C annealed, and (d) 650 °C annealed VO_2 film specimens.

A thermal imager was included in the optical test setup to monitor the temperature at the laser spot in real time. As shown in Fig. S6, the thermal imaging results indicate that during laser irradiation, the temperature at the center of the spot can exceed 400 °C, far surpassing the temperature required to induce phase transitions in both VO_2 and V_2O_5. The high-energy laser not only triggers the thermally induced phase transition of VO_x but also activates the nonlinear absorption mechanisms characteristic of wide-bandgap semiconductor VO_x.

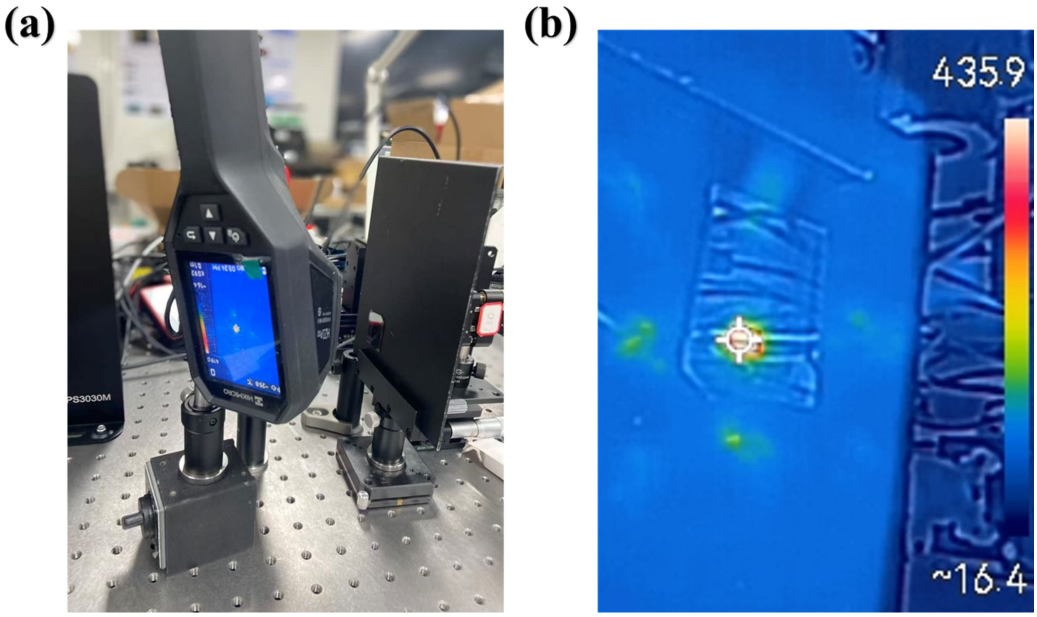

Fig. S7 Laser-induced local thermal effect diagram.