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Supplementary Information for

A flexible, multifunctional, active terahertz modulator with an ultra-low triggering threshold

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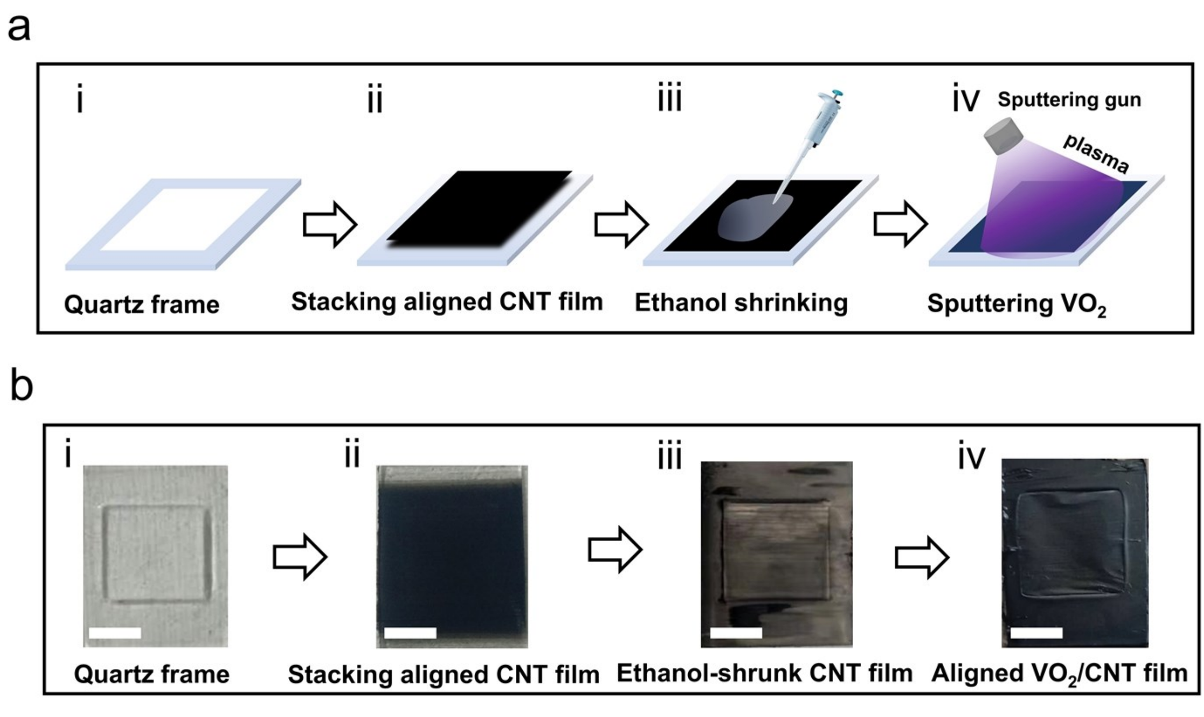

Figure S1. Preparation of VO_2/CNT THz AMs. (a) Schematic of THz AM fabrication using a VO_2/CNT film. (b) Corresponding optical images for process steps i through iv. The scale bar is 5 mm.

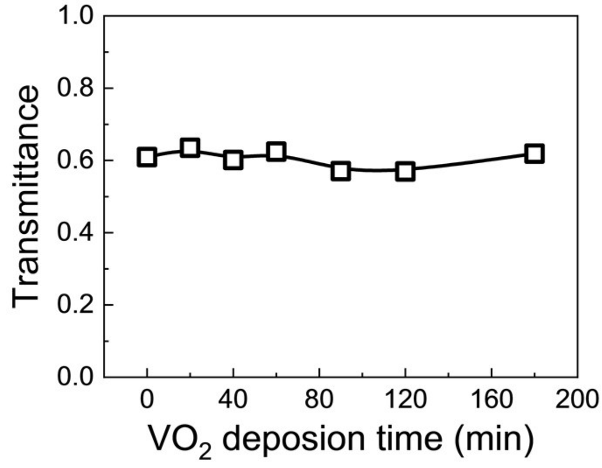

Figure S2. Dependence of the VO_2/CNT THz AM average transmittance on the VO_2 deposition time.

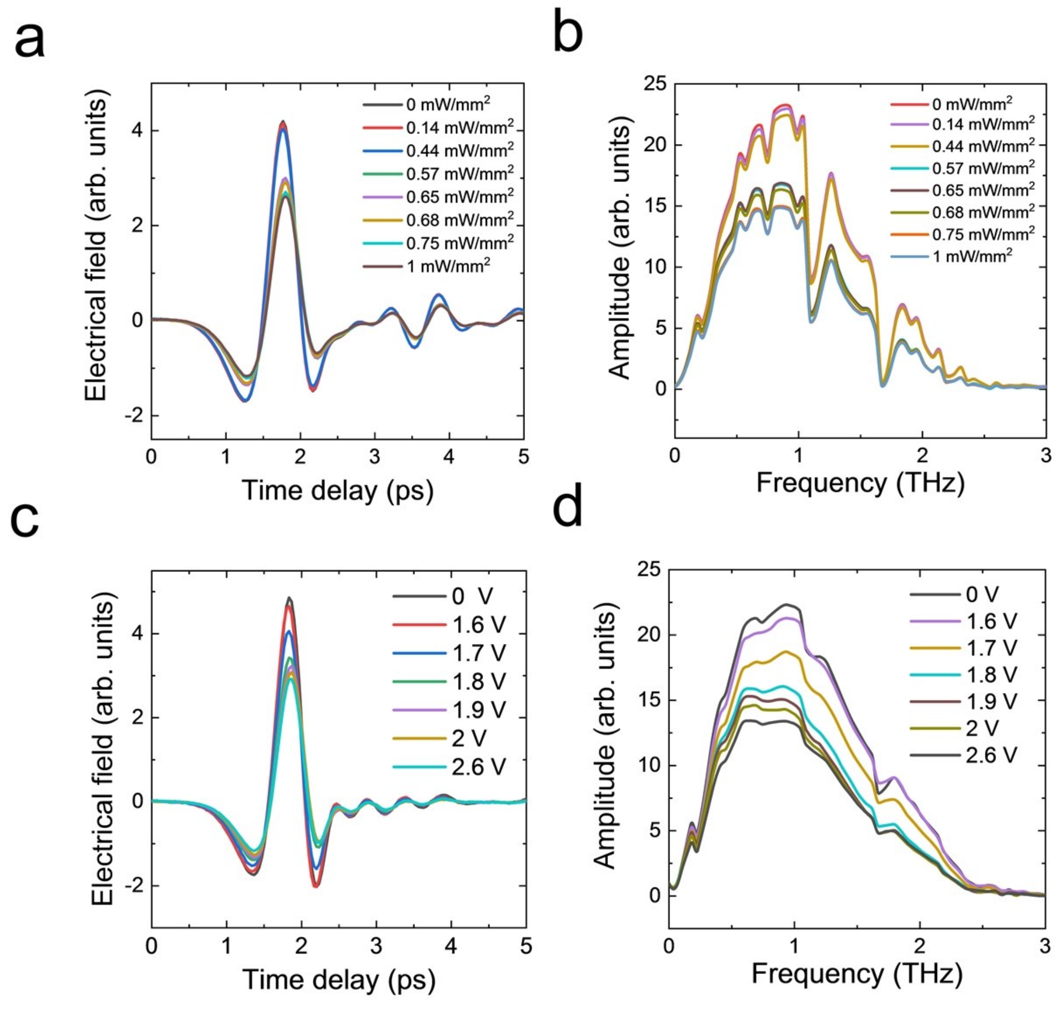

Figure S3. (a) Transmission spectra of VO_2/CNT THz AM in time domain under the light stimulation. (b) Fourier transforms of the time-domain transmission spectra under the light stimulation. (c) Transmission spectra of VO_2/CNT THz AM in time domain under the electrical stimulation. (d) Fourier transform of the time-domain transmission spectra under the laser stimulation. The measurements of photo and electrical stimulations were performed in air and in a nitrogen atmosphere, respectively.

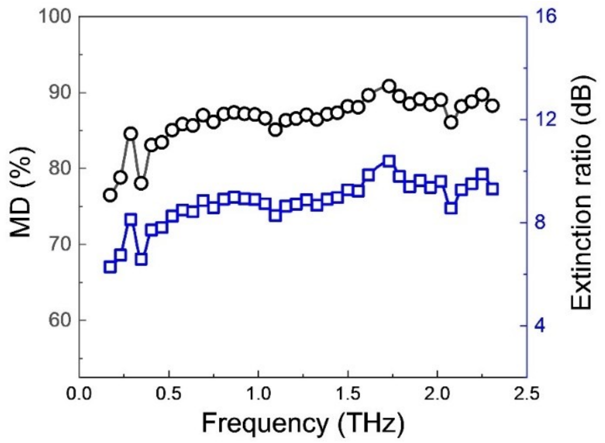

Figure S4. MD and extinction ratio of the VO_2/CNT THz AM (180 min VO_2) in the frequency from 0.2 THz to 2.5 THz.

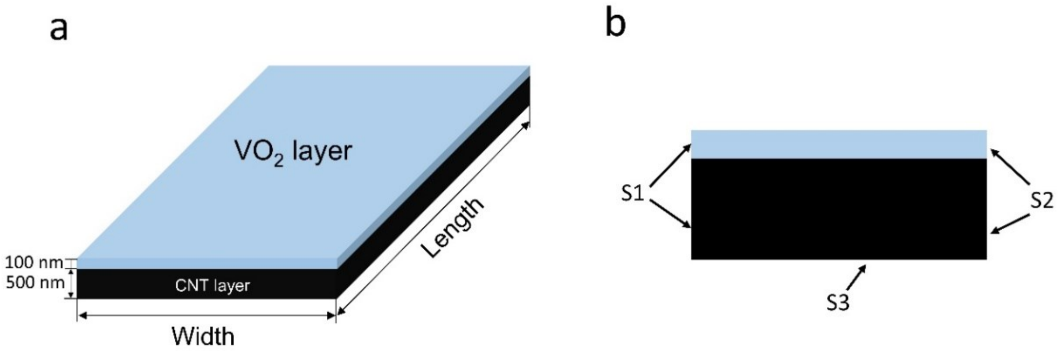

Figure S5. (a) Geometrical model of the VO_2/CNT film in the transient thermal transfer model. (b) Front view of the geometrical model.

The geometrical model of VO_2/CNT film in the transient thermal transfer model is shown in Figure S5a. The 3D transient thermal transfer equation $\rho C_p \frac{\partial T}{\partial t} + \nabla \cdot (-k\nabla T) = Q$ is solved by the COMSOL Multiphysics software, where ρ is the density, C_p is the specific heat capacity at constant stress, k is the thermal conductivity, and Q is the heat source. In our model, the density of the CNT film[1] is 300 kg/m^3, the C_p of the CNT film[2] is 710 J/(kg·K), the thermal conductivity of the CNT film[3] is 136 W/(m·K), the density of VO_2 is 4600 kg/m^3, the C_p of the VO_2[4] is 690 J/(kg·K), and the thermal conductivity of the VO_2[4] is 5 W/(m·K). Thicknesses of the VO_2 layer and the CNT layer are fixed at 100 nm and 500 nm, respectively. The width and the length of the VO_2/CNT film are equal and are varied together. The boundary conditions are as follows. As shown in Figure S5b, the temperature of two side surfaces (S1 and S2) is set to 298 K. The underside surface (S3) is irradiated by laser and thus an inward heat, which energy (W/m^2) is equal to the laser power, is set on this surface. For other surfaces, the boundary conditions are $-n \cdot \nabla(-k \cdot \nabla T) = h(T - T_0)$, where h is the heat transfer coefficient of air (20 W/m^2/K), T_0 is the environmental temperature (298K).

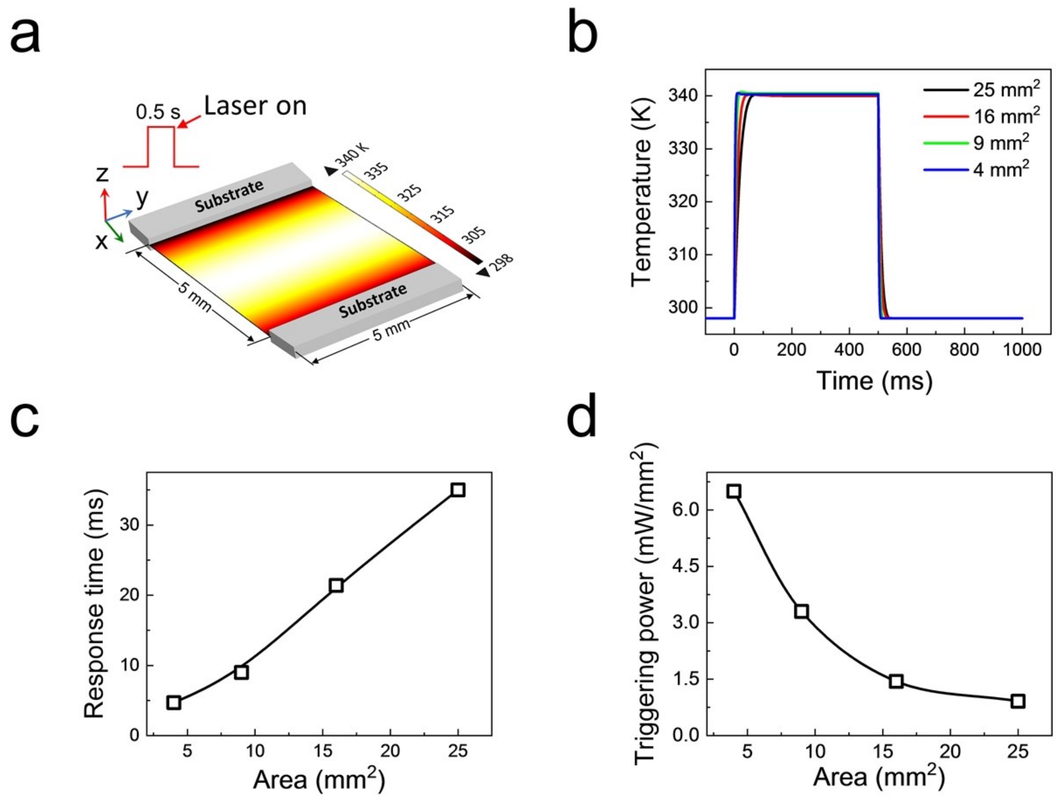

Figure S6. Simulated dynamic response of a VO_2/CNT THz AM to a laser pulse. (a) Temperature distribution on a VO_2/CNT THz AM with an area of 25 mm^2 at 300 ms. (b) Dynamic responses of VO_2/CNT THz AMs of various sizes. Dependences of (c) the response time and (d) the triggering power on the device area.

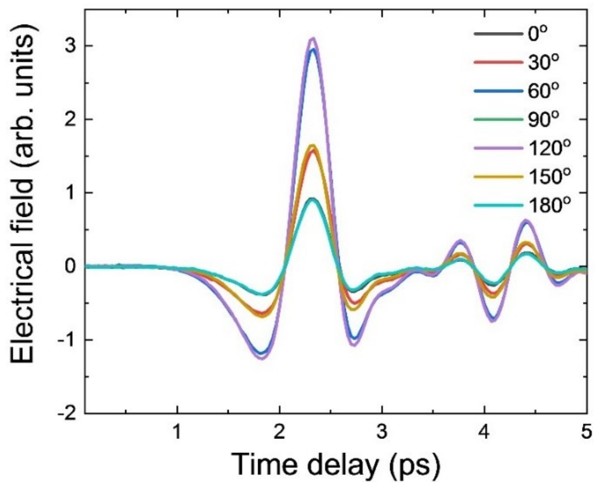

Figure S7. Transmission spectra of VO_2/CNT THz AM in the time domain at different polarizing degrees. The measurement was performed in air.

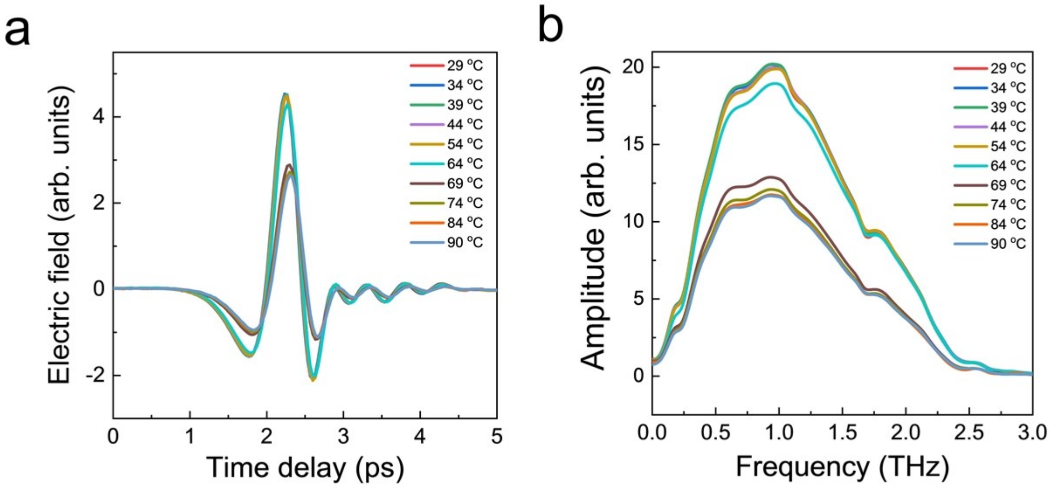

Figure S8. (a) Transmission spectra of VO_2/CNT THz AM in time domain under different temperatures. (b) Fourier transforms of the time-domain transmission spectra. The measurement was performed in a nitrogen atmosphere.

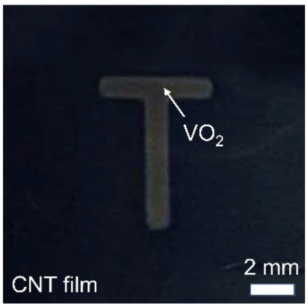

Figure S9. Optical image of the pattern VO_2/CNT AM.

References

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