Kirkendall effect induced ultrafine VOOH nanoparticles and its transformation into VO2(M) for energy-efficient smart window

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gradient		specific values for the constant parameters		
		Hydrothermal temperature	Reaction time	The volume of HCOOH
Hydrothermal temperature	80 ℃		6 h	1 ml
	120 ℃			
	160 ℃			
	200 ℃			
Reaction time	1.5 h	120 ℃		1 ml
	6 h			
The volume of HCOOH	0 ml	160 ℃	6 h	
	0.5 ml			
	1 ml			
	1.5 ml			
	2 ml			

Fig. S1. The synthesis parameter for different gradient experiment.

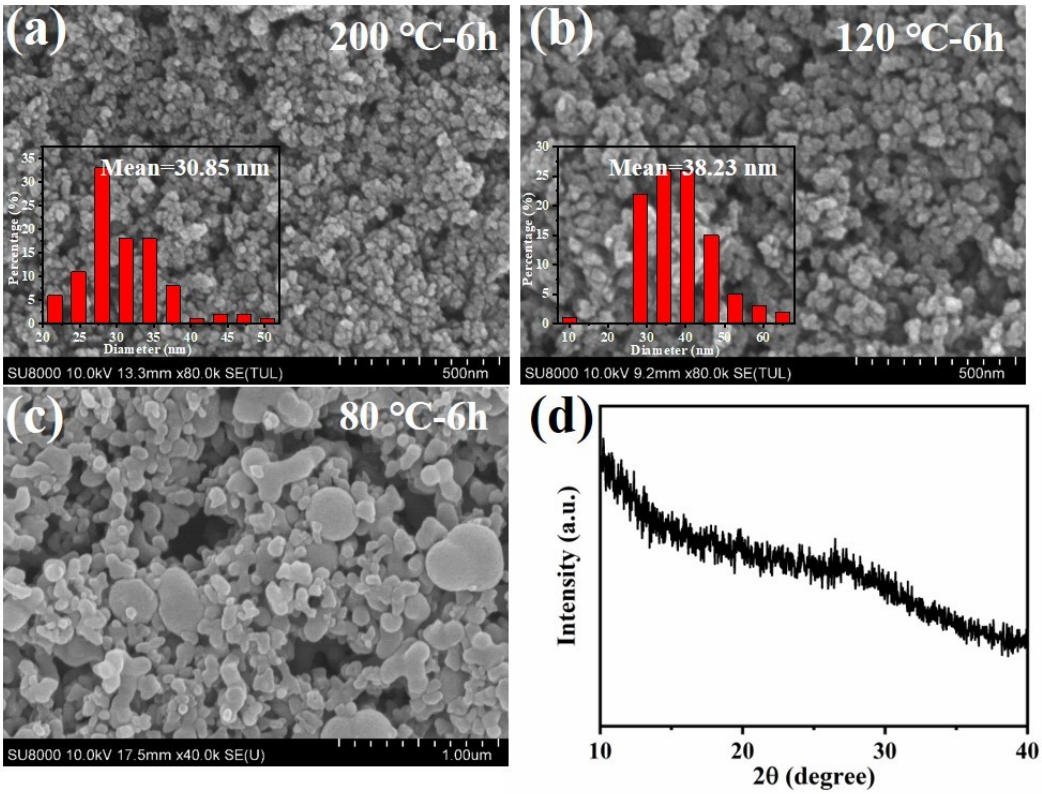

Fig. S2. The SEM images of VOOH nanoparticles prepared with different hydrothermal temperature: (a) 200 ℃ and (b)120 ℃. The SEM image and XRD pattern of hydrothermal product at temperature of 80 ℃. (inset: histogram of size distribution images of the VOOH NPs).

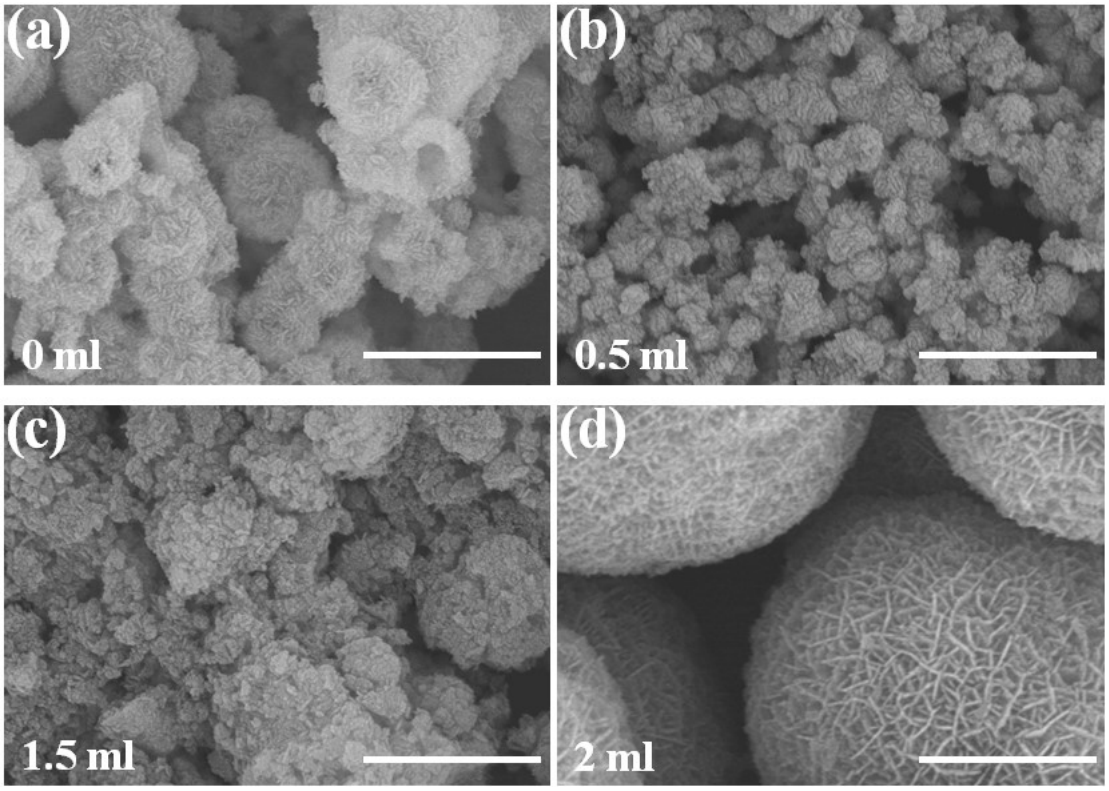

Fig. S3. The SEM images of hydrothermal products with different volume of HCOOH: (a) 0 ml, (b) 0.5 ml, (c) 1.5 ml and (d) 2 ml. (Scale bar: 1 μm)

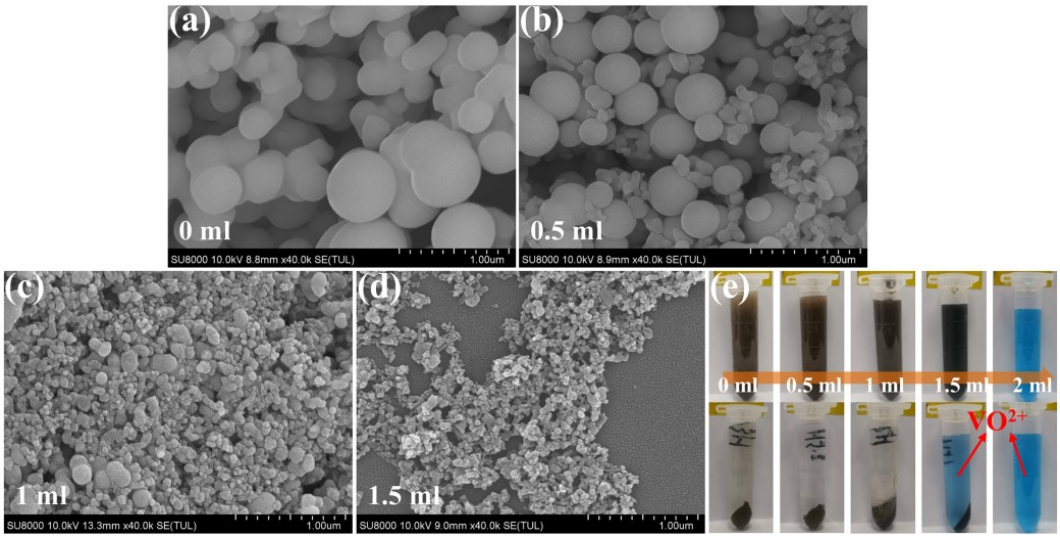

Fig. S4. The SEM images of hydrothermal precursors with different volume of HCOOH: (a) 0 ml, (b) 0.5 ml, (c) 1 ml and (d) 1.5 ml. (e) Digital images of hydrothermal precursors before (top) and after centrifugation (down).

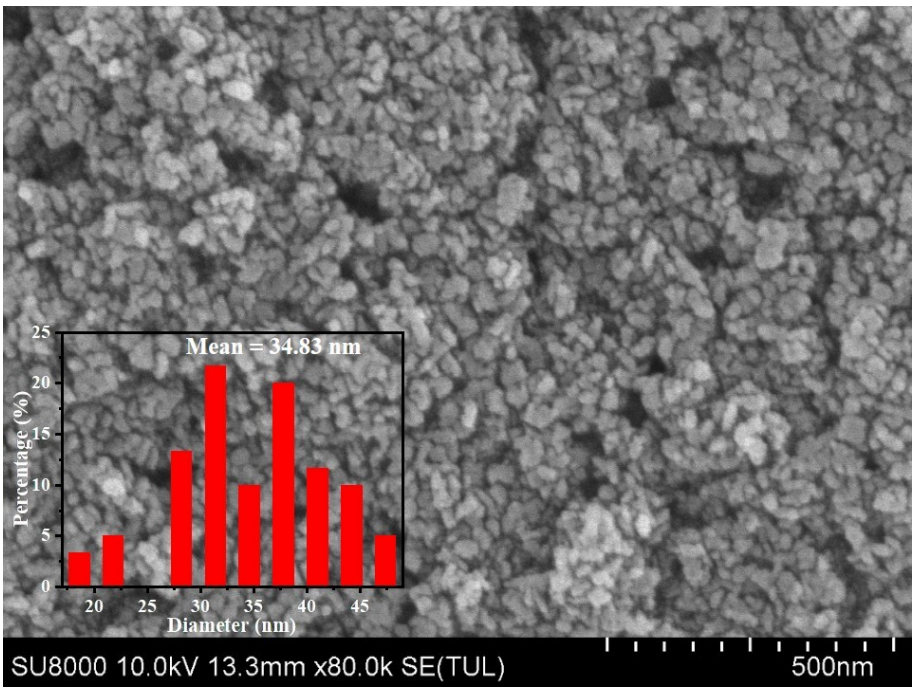

Fig. S5. The SEM image of VOOH nanoparticle prepared at 200 ℃, 12 h. ((inset: histogram of size distribution images of the VOOH NPs).

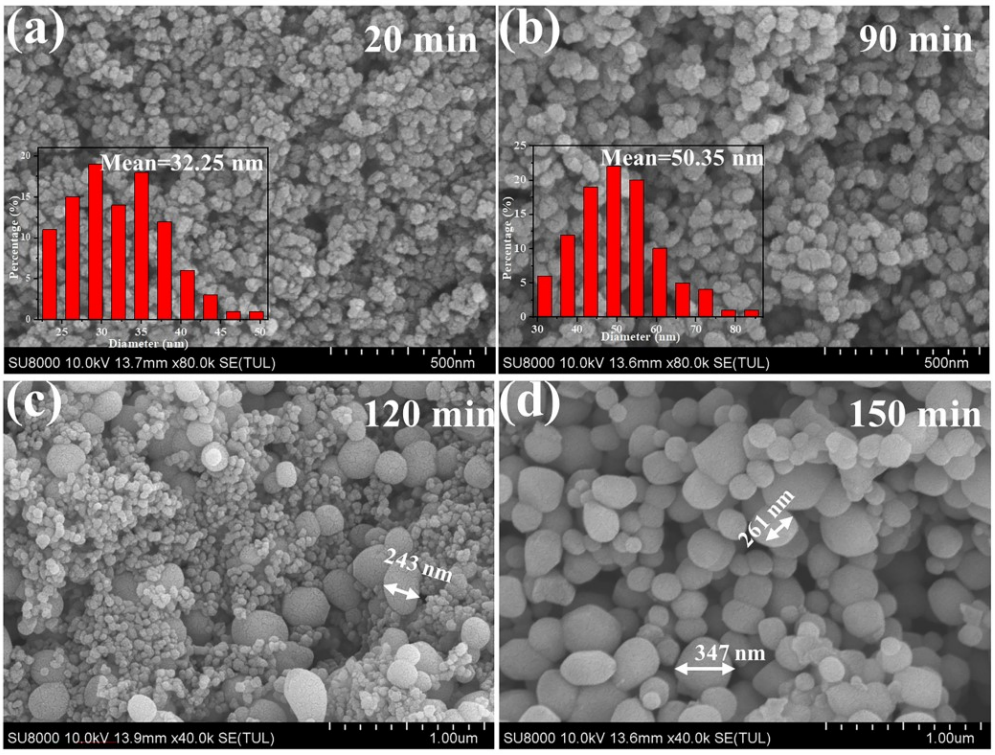

Fig. S6. SEM images of VO_2 with different annealing times: (a) 20 min, (b) 90 min, (c) 120 min and (d) 150 min. (inset: histogram of size distribution of the VO_2 nanoparticles).

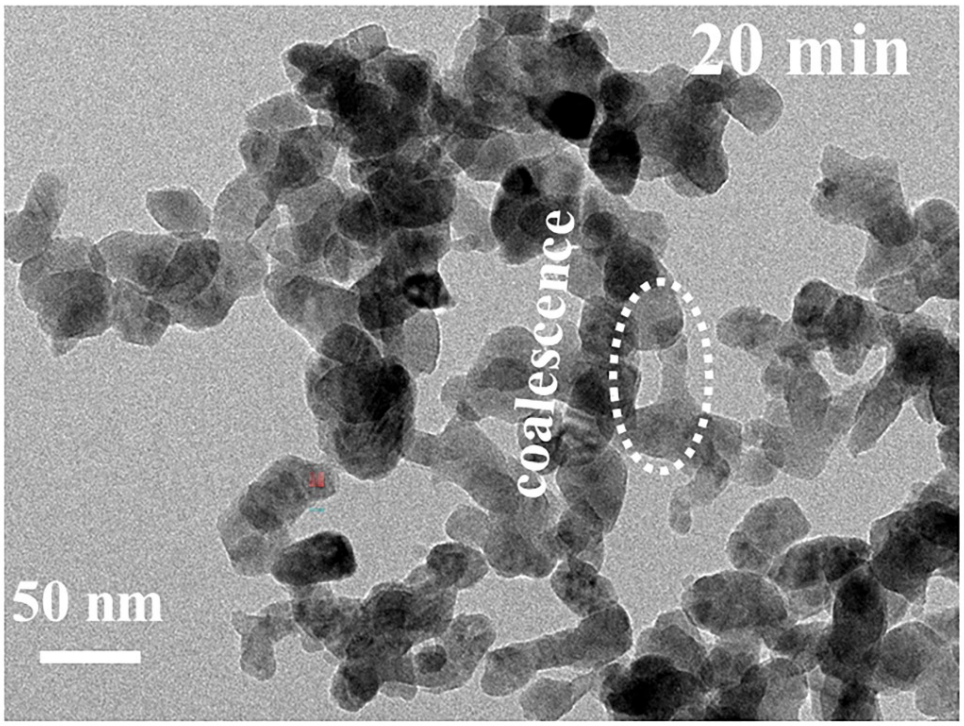

Fig. S7. TEM images of VO_2 with annealing time of 20 min.

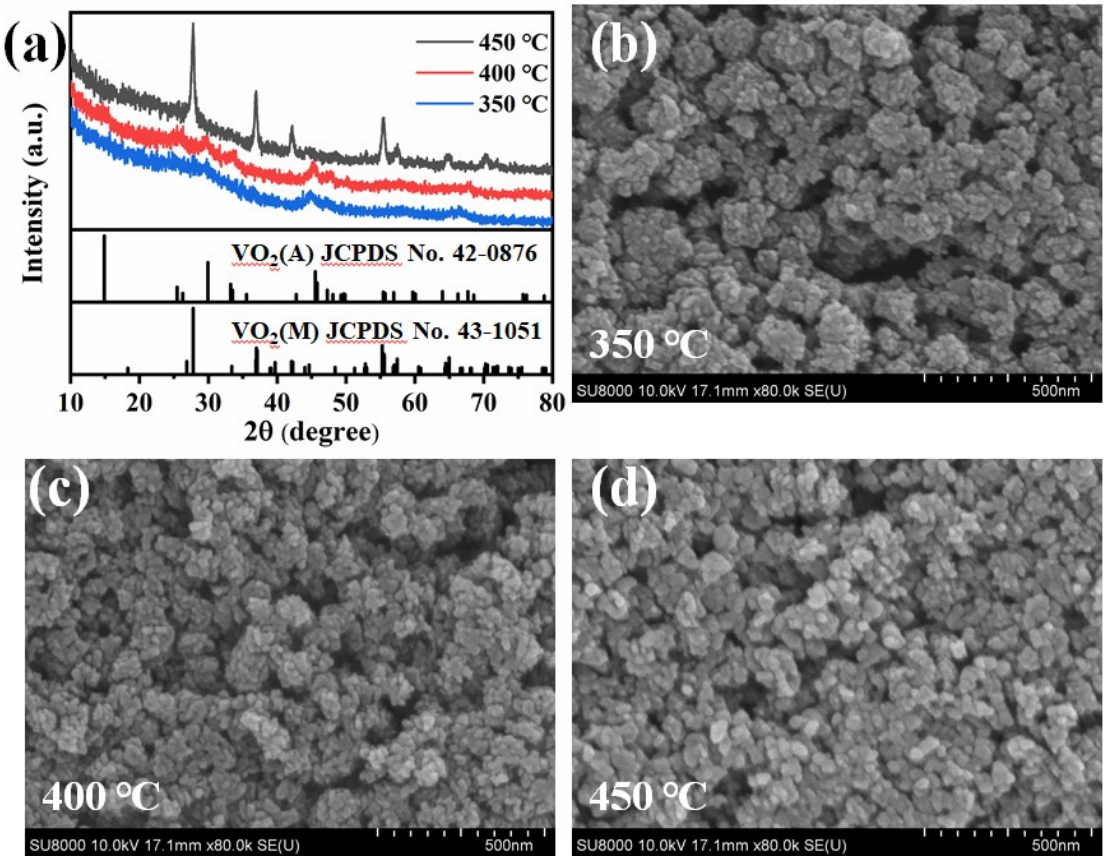

Fig. S8. (a) The XRD patterns of VO_2 with different annealing temperature. The SEM images of annealed samples at temperature of (b) 350 ℃, (c) 400 ℃ and (d) 450 ℃.

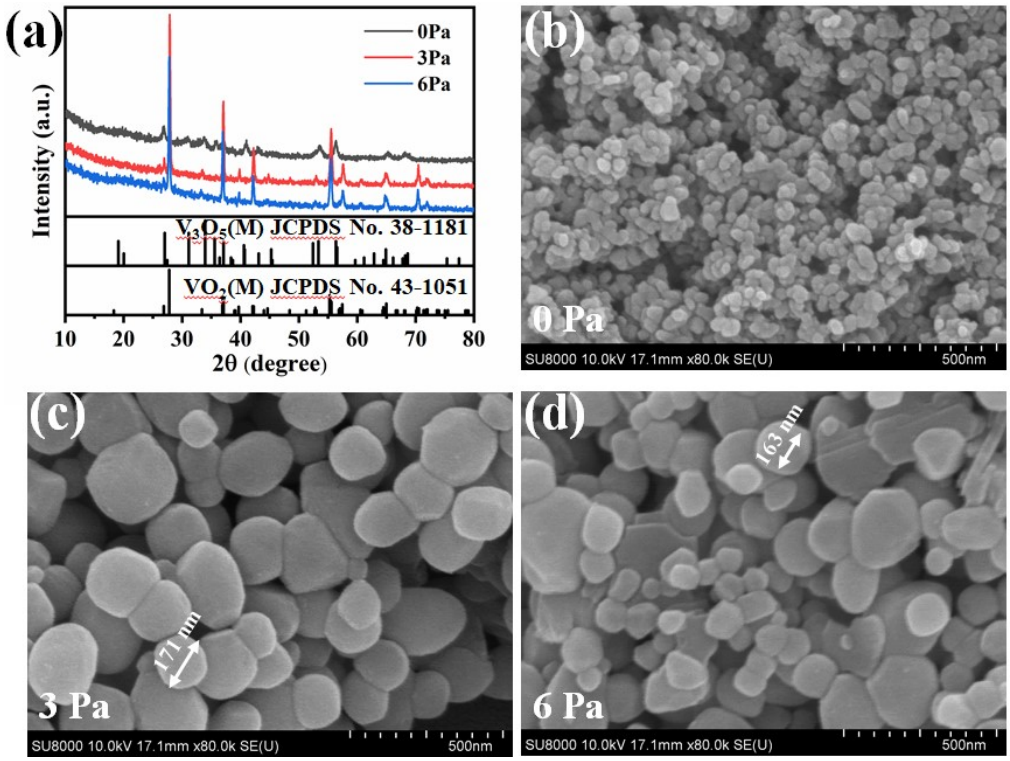

Fig. S9. (a) The XRD patterns of VO_2 with different vacuum degree. The SEM images of annealed samples at vacuum degree of (b) 0 Pa, (c) 3 Pa and (d) 6 Pa.

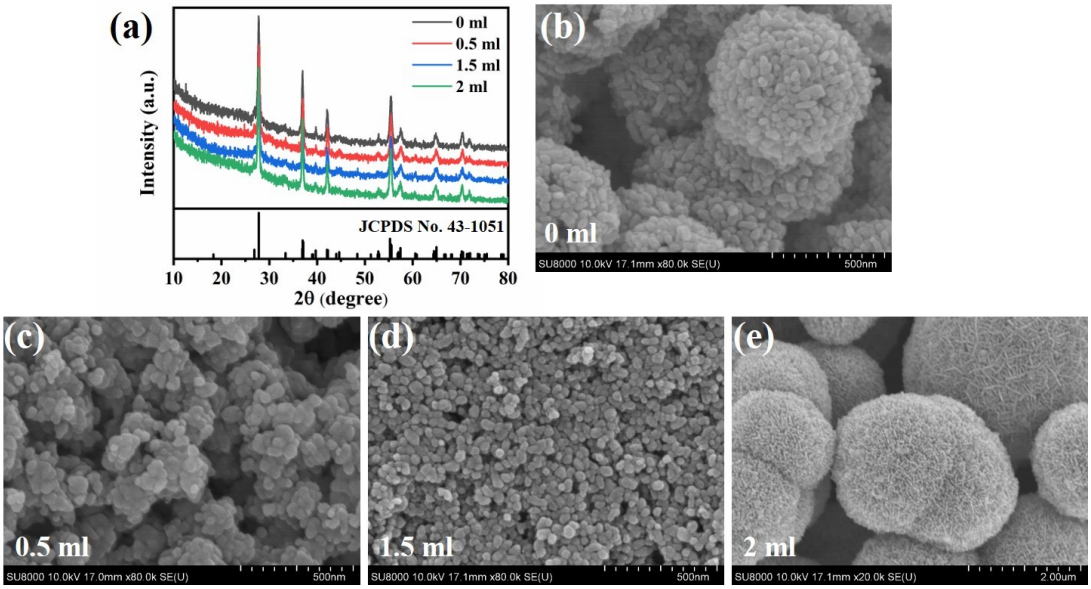

Fig. S10. (a) The XRD patterns of VOOH precursors after annealing treatment. The SEM images of VOOH precursors after annealing treatment with different volume of HCOOH: (b) 0 ml, (c) 0.5 ml, (d) 1.5 ml and (e) 2 ml.

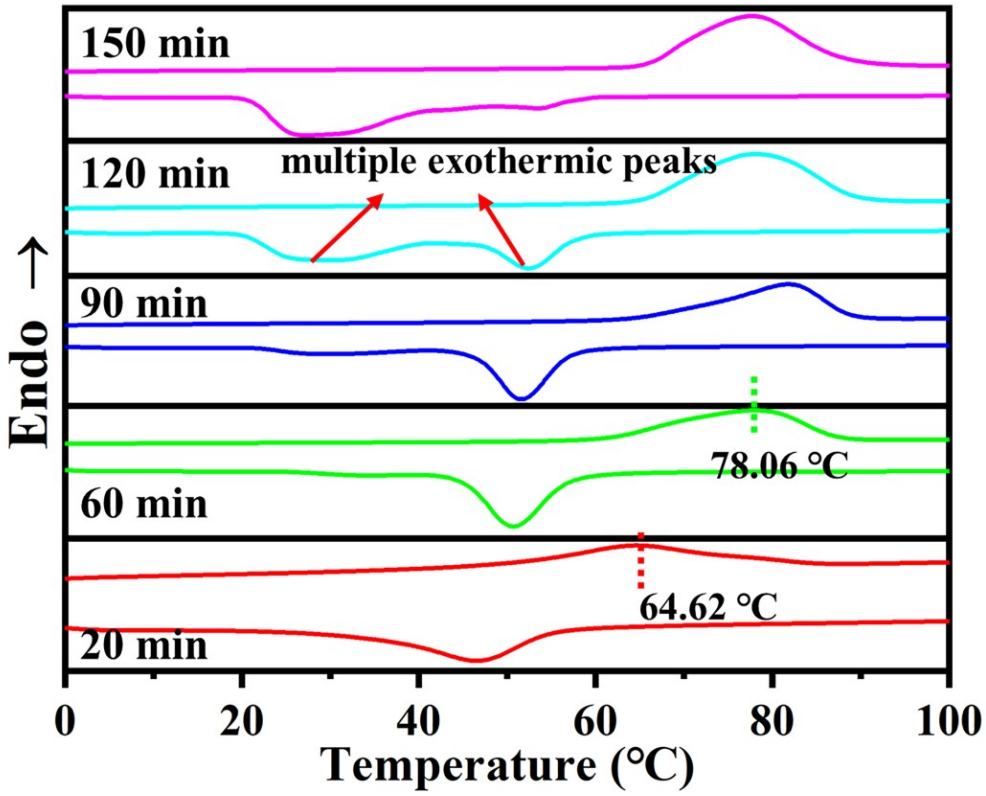

Fig. S11. DSC curves of VO_2 with different annealing times.

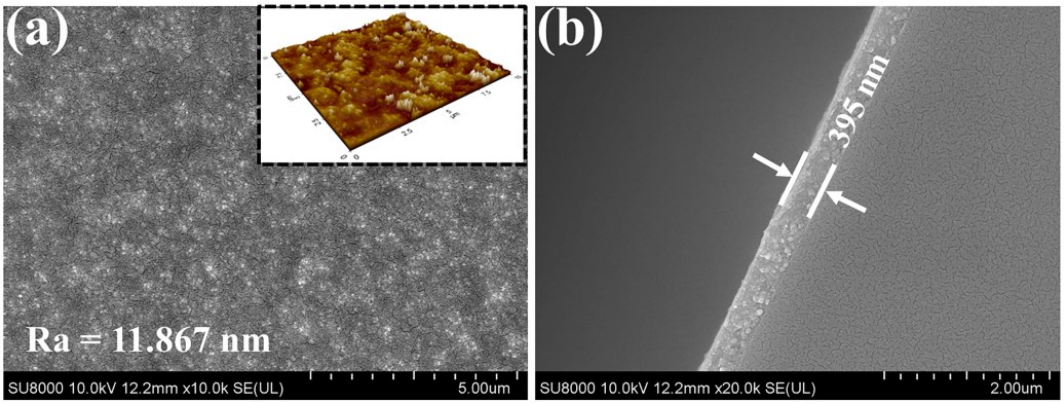

Fig. S12. (a) SEM, AFM images and (b) cross section image of VO_2/PVP-60 min film with spinning coating time of 3

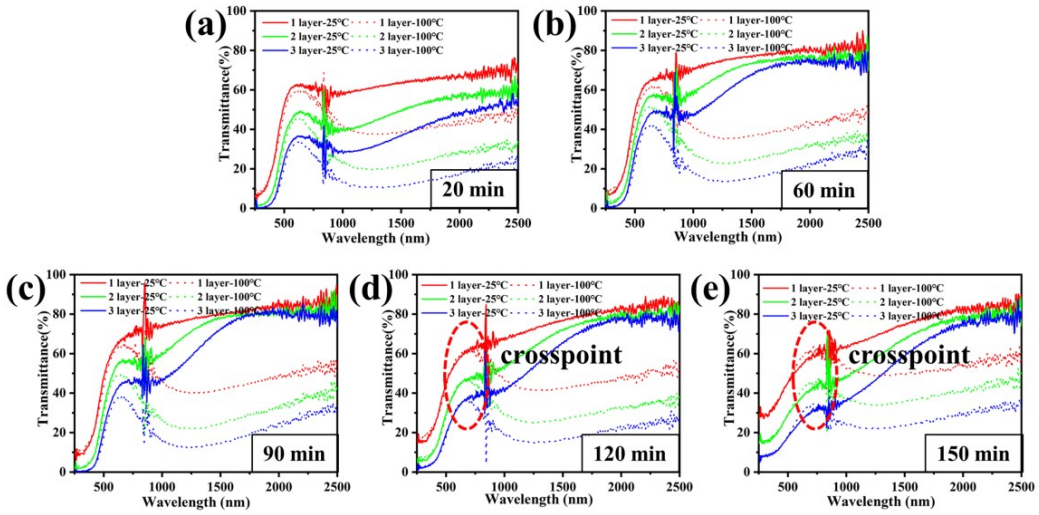

Fig. S13. The transmittance spectra of VO_2/PVP films with different spin coating times: (a) 20 min, (b) 60 min, (c) 90 min, (d) 120 min and (e) 150 min.

Annealing time	Spin coating times	T_{lum} (%)			T_{sol} (%)		
		20 ℃	100 ℃	T_{lum} (%)	20 ℃	100 ℃	ΔT_{sol} (%)
20 min	1	59.10	55.65	57.38	54.97	45.97	9.00
	2	43.50	40.56	42.03	40.05	29.62	10.43
	3	32.04	29.07	30.55	29.10	19.67	9.43
60 min	1	58.29	54.61	56.45	60.23	45.27	14.95
	2	48.48	44.41	46.45	50.85	33.70	17.15
	3	38.80	34.73	36.77	42.66	24.58	18.08
90 min	1	57.97	55.49	56.73	62.27	48.22	14.05
	2	45.17	41.40	43.29	50.29	31.84	18.45
	3	33.66	29.75	31.71	40.81	22.00	18.81
120 min	1	52.37	52.71	52.54	58.07	48.20	9.88
	2	38.02	38.24	38.13	45.24	42.43	12.81
	3	27.59	27.77	27.68	36.28	22.61	13.67
150 min	1	50.01	52.15	51.08	56.88	51.85	5.03
	2	33.72	35.73	34.73	42.56	35.88	6.68
	3	22.23	24.47	23.35	31.57	24.47	7.10

Fig. S14. Summarized optical performances of VO_2/PVP films.

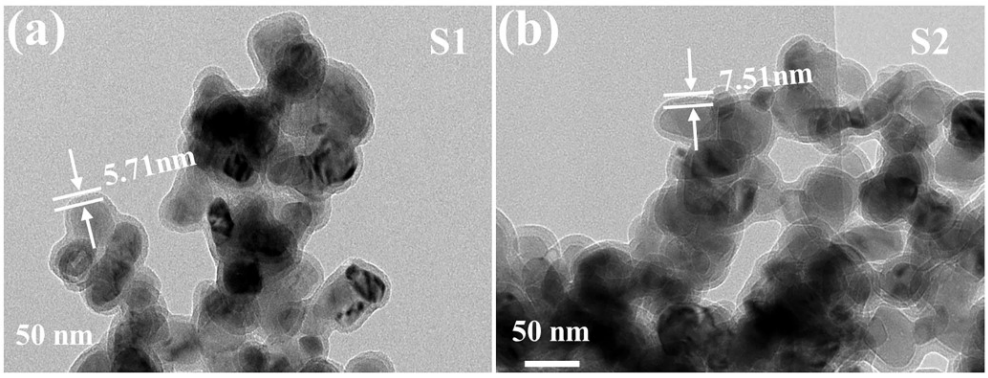

Fig. S15. TEM images of (a) S1, (b) S2.

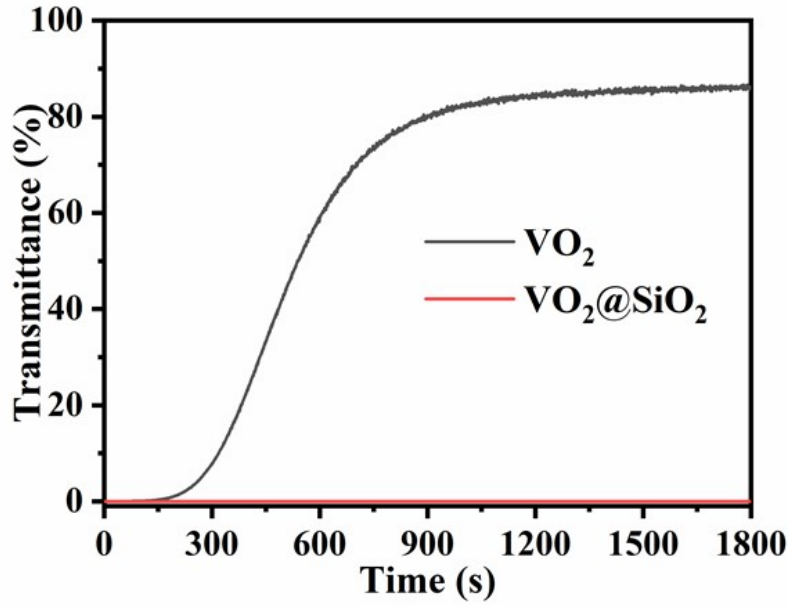

Fig. S16. The time-dependent transmittance at 550 nm of VO_2 and $VO_2@SiO_2$.

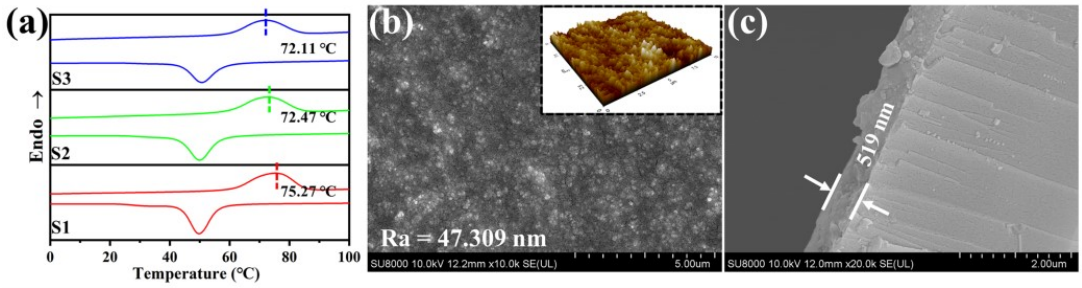

Fig. S17. (a) DSC curves of VO_2@SiO_2 nanoparticles. (b) SEM, AFM images and (c) cross section image of VO_2@SiO_2/PVP film with spin coating time of 3.

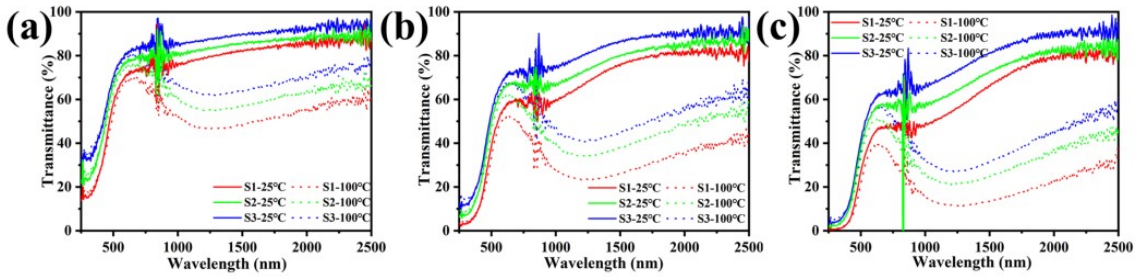

Fig. S18. The transmittance spectra of VO_2@SiO_2/PVP films with different spin coating times: (a) 1 layer, (b) 2 layer and (c) 3 layer.

Annealing time	Spin coating times	T_{lum} (%)			T_{sol} (%)		
		20 ℃	100 ℃	T_{lum} (%)	20 ℃	100 ℃	ΔT_{sol} (%)
S1	1	66.26	63.33	64.79	67.71	55.00	12.71
	2	49.96	45.50	47.73	52.70	34.77	17.92
	3	37.79	32.62	35.20	42.33	22.85	19.48
S2	1	73.36	70.72	72.04	73.63	63.23	10.40
	2	59.79	55.94	57.87	60.80	45.35	15.45
	3	48.81	44.15	46.48	50.53	33.45	17.09
S3	1	77.05	75.19	76.12	78.62	68.65	9.97
	2	63.95	60.64	62.29	66.32	51.40	14.91
	3	52.69	48.69	50.69	57.32	39.02	18.30

Fig. S19. Summarized optical performances of VO_2@SiO_2/PVP films with various spin coating times.

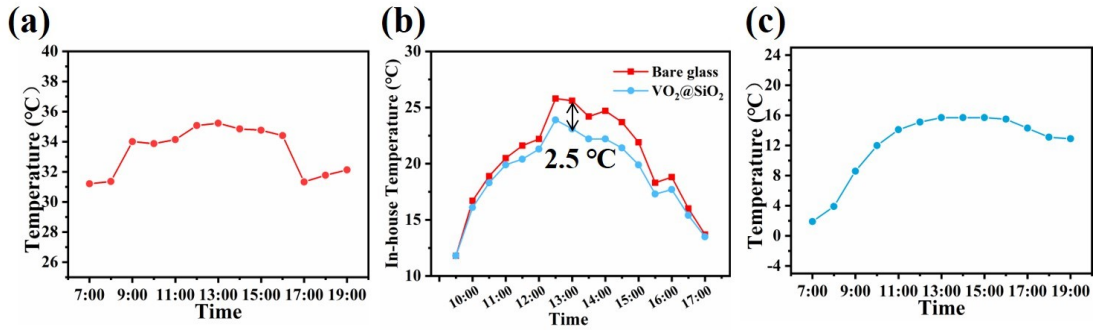

Fig. S20. (a) Temperature change curve in Hefei on 11 July 2023. (b) Temperature vs. time data tested in winter of the model house and (c) temperature change curve in Hefei on 15 November 2023.