

Electronic Supporting Information (ESI)

Anatase TiO₂ Single Crystal Hollow Nanoparticles: Facile Synthesis and High-performance in Dye-Sensitized Solar Cells

Javid Khan,^a Jiuwang Gu,^b Yuying Meng,^a Zhisheng Chai,^b Shiman He,^a Qili Wu,^a Shengfu

Tong,^a Gulzar Ahmed,^c Wenjie Mai^{b,} and Mingmei Wu^{a,*}*

^a MOE Key Laboratory of Bioinorganic and Synthetic Chemistry, State Key Laboratory of Optoelectronic Materials and Technology, Key Laboratory of Environment and Energy Chemistry of Guangdong Higher Education Institutes, School of Chemistry and Chemical Engineering, Sun Yat-Sen (Zhongshan) University, Guangzhou 510275, P. R. China

^b Siyuan Laboratory, Guangzhou Key Laboratory of Vacuum Coating Technologies and New Energy Materials, Department of Physics, Jinan University, Guangzhou, Guangdong 510632, P. R. China

^c School of Material Science and Engineering, South China University of Technology, Guangzhou 510640, P. R. China.

*Email: - ceswmm@mail.sysu.edu.cn (M.M. Wu) and wenjiemai@email.jnu.edu.cn (W.J. Mai)

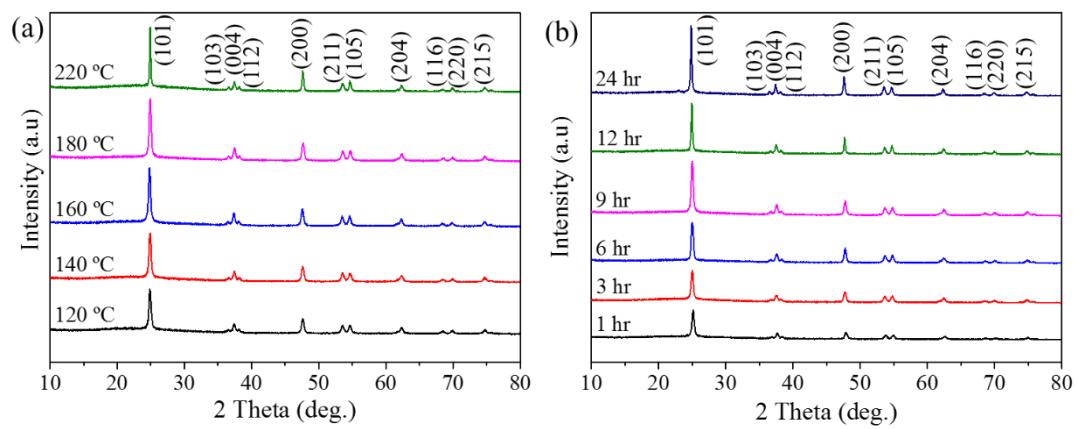


Fig. S1. XRD patterns of the anatase hollow single crystals synthesized with 100 μL HF (a) at various hydrothermal temperature and (b) with different hydrothermal time.

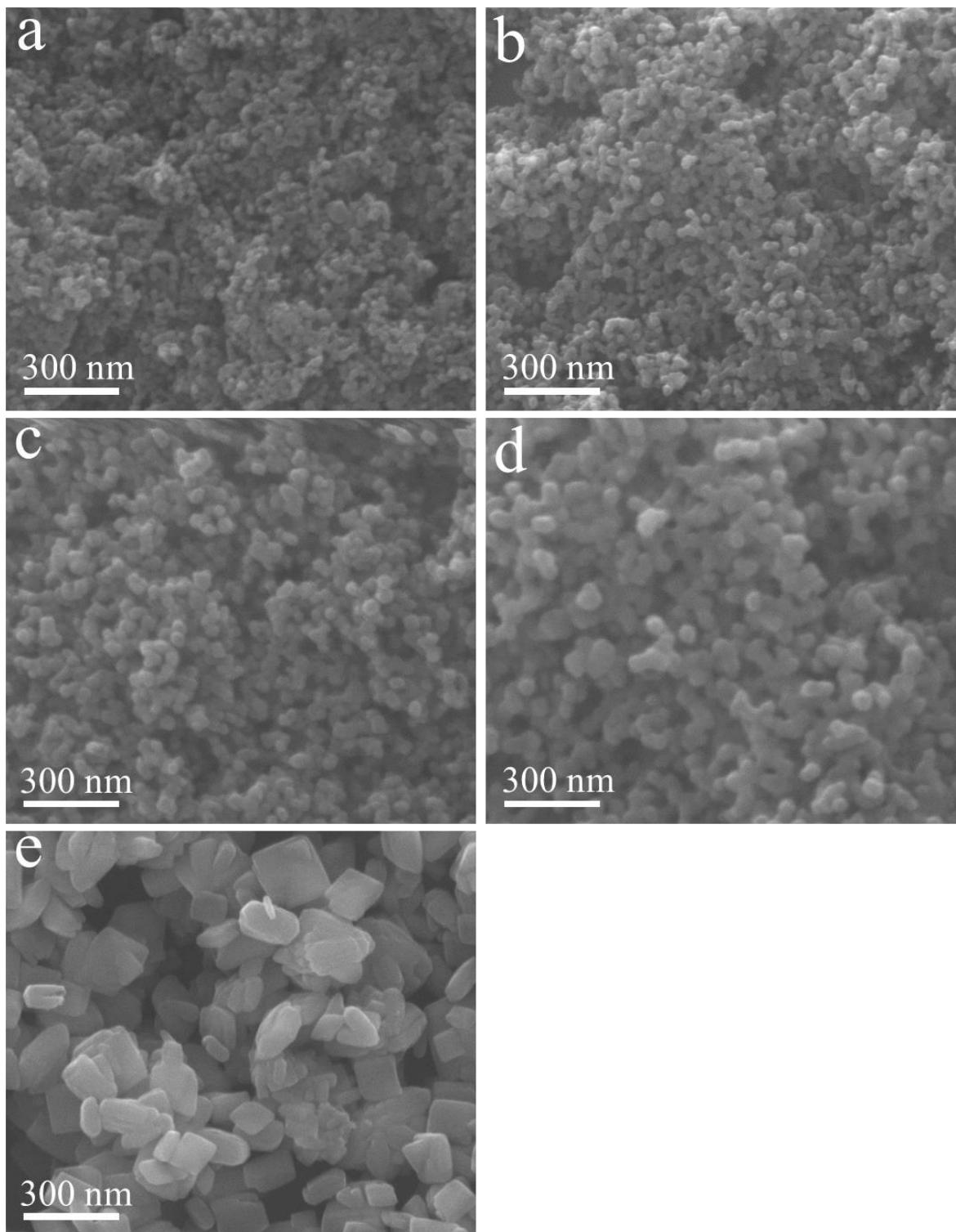


Fig. S2. FE-SEM images of anatase hollow TiO_2 nanoparticles (S100) at different hydrothermal temperature for 6 h, (a) 120 °C, (b) 140 °C, (c) 160 °C, (d) 180 °C and (e) 220 °C.

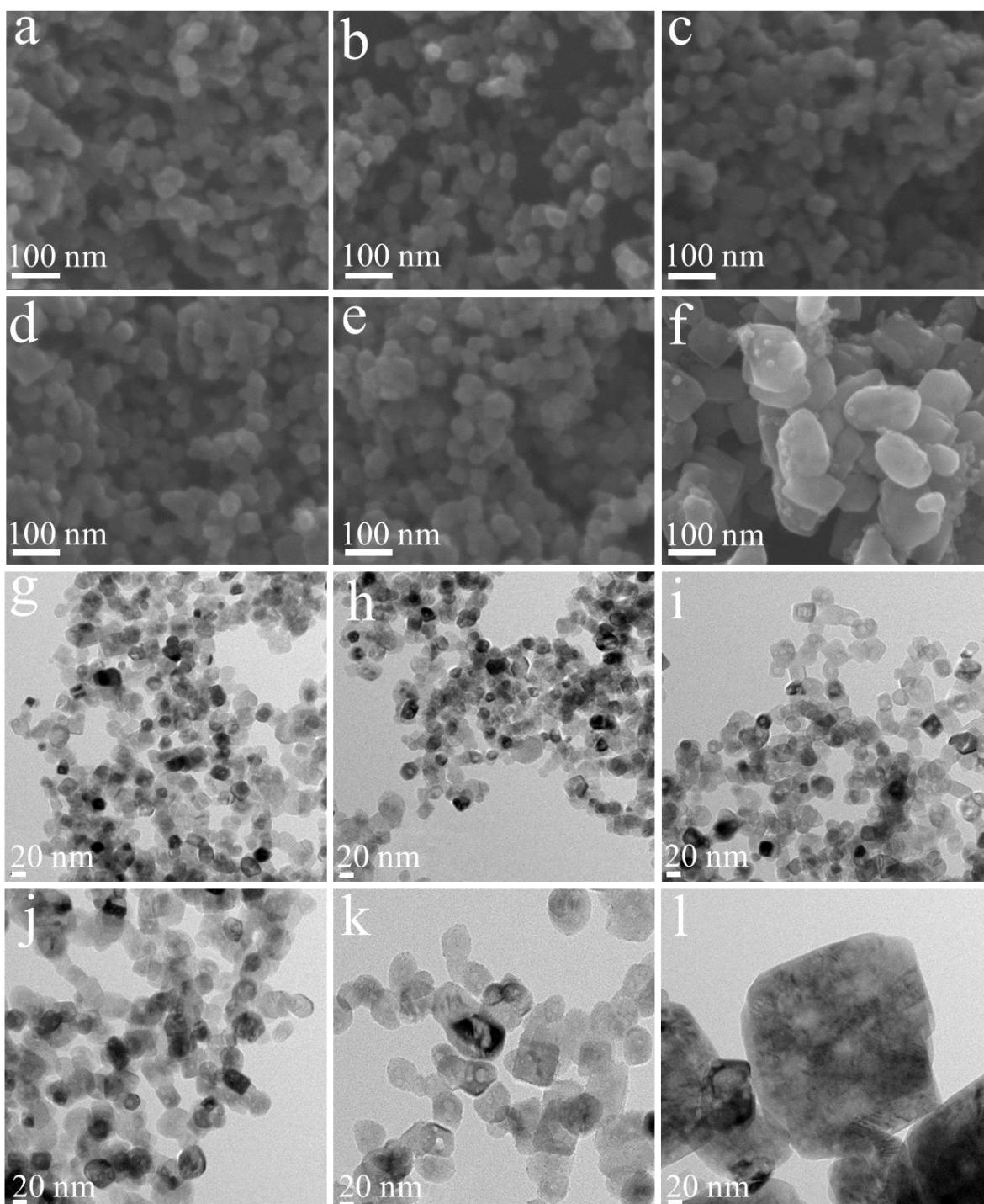


Fig. S3. FE-SEM and TEM images of anatase hollow TiO₂ nanoparticles (S100), synthesized at hydrothermal temperature of 160 °C with different reaction times: (a, g) 1 h, (b, h) 3 h, (c, i) 6 h, (d, j) 9 h, (e, k) 12 h, and (f, l) 24 h.

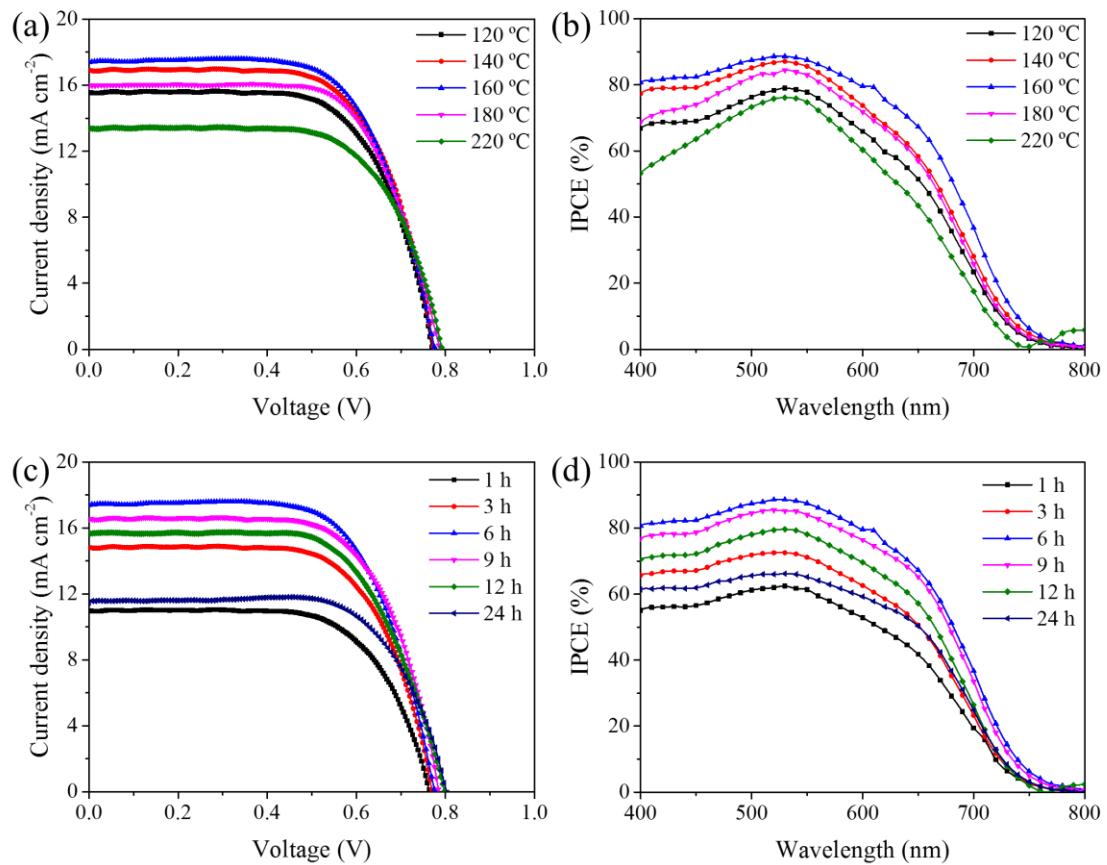


Fig. S4. (a, c) J–V curves (b, d) EQE spectra of DSSCs based on anatase hollow TiO_2 nanoparticles (S100) prepared at different hydrothermal temperatures and reaction times, respectively.

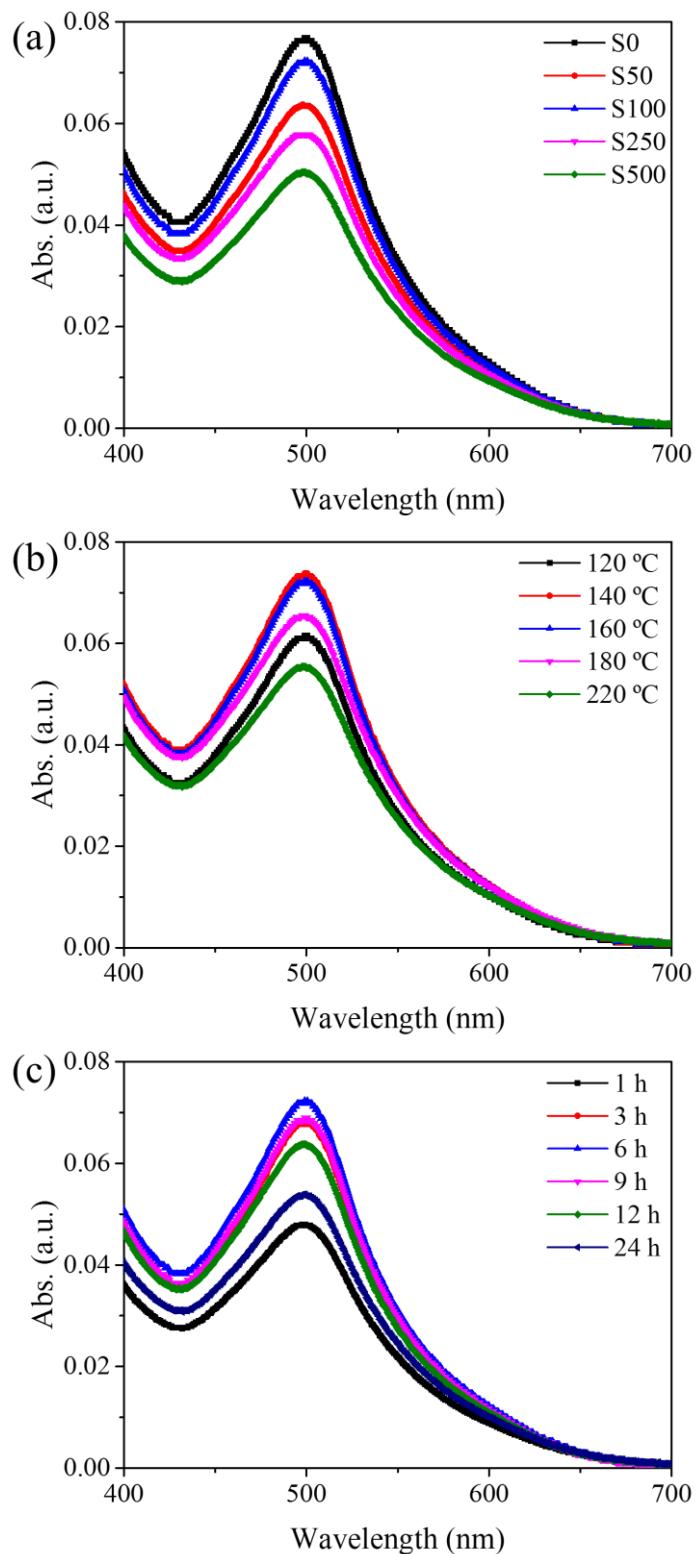


Fig. S5. UV-Vis spectra of solutions containing N719 desorbed from sensitized TiO₂ photoelectrodes: (a) different amounts of HF, (b) temperature dependent and (c) time dependent.

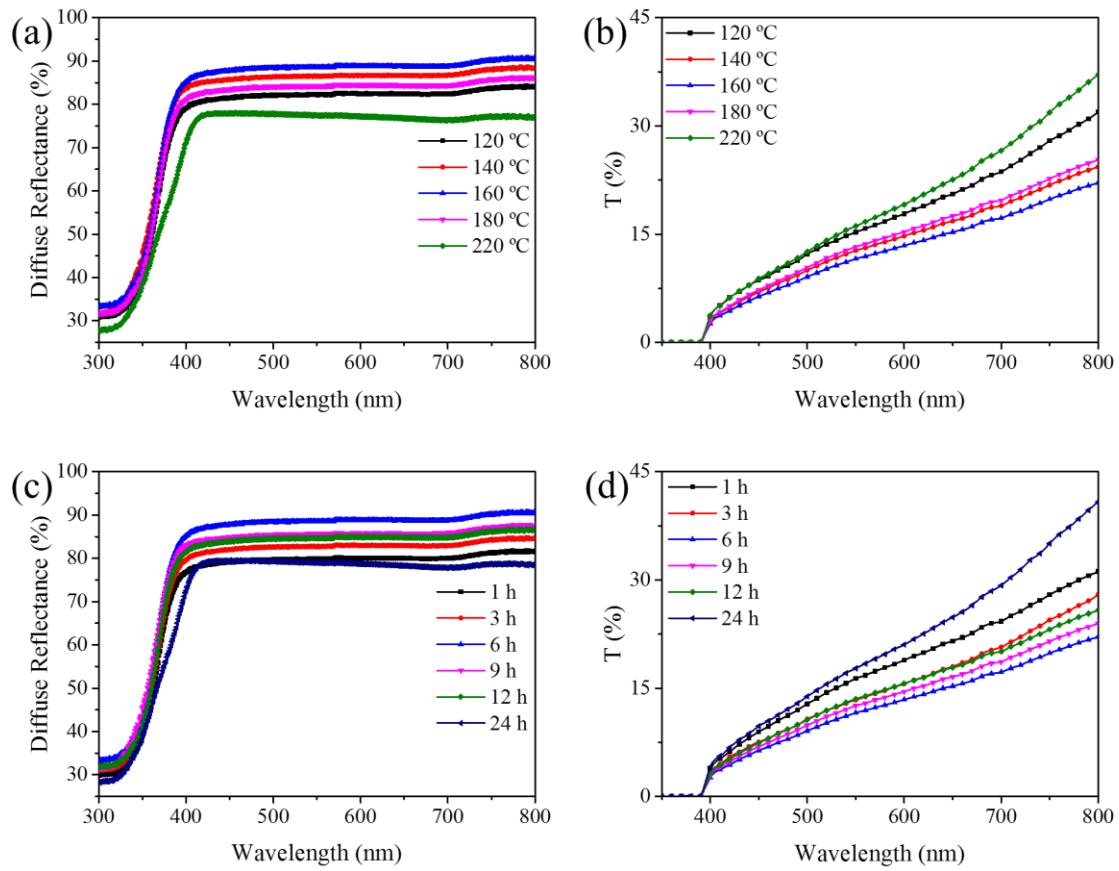


Fig. S6. (a, c) Diffuse reflectance (b, d) Transmittance spectra of DSSCs based on S100, synthesized at different temperatures and reaction times, respectively.

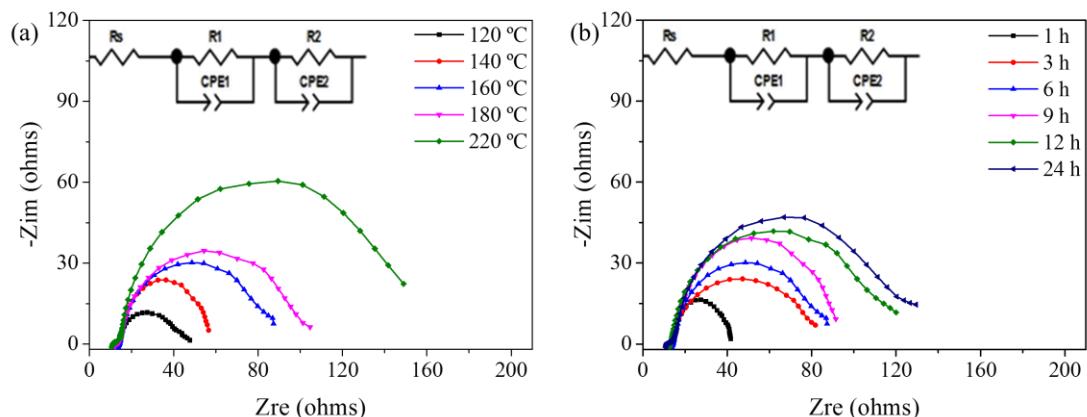


Fig. S7. Nyquist plots from electrochemical impedance spectroscopy of the S100 based DSSCs, (a) temperature dependent and (b) time dependent. Insets are the simulated equivalent circuits.

Table S1. Summarized photovoltaic performance parameters of DSSCs fabricated with DSSCs

based on anatase hollow TiO₂ nanoparticles (S100) prepared at different temperatures, measured under one sun AM 1.5 G illumination (100 mW cm⁻²).

DSSCs	J_{sc} (mA cm ⁻²)	V_{oc} (mV)	η (%)	FF	adsorbed dye (nmol cm ⁻²)
120 °C	15.53	771	7.95	0.66	108
140 °C	16.87	774	8.72	0.66	130
160 °C	17.39	778	8.94	0.66	127
180 °C	15.95	789	8.47	0.67	116
220 °C	13.36	793	7.04	0.66	98

Table S2. Summarized photovoltaic performance parameters of DSSCs fabricated with DSSCs

based on anatase hollow TiO₂ nanoparticles (S100) prepared at different reaction times, measured under one sun AM 1.5 G illumination (100 mW cm⁻²).

DSSCs	J_{sc} (mA cm ⁻²)	V_{oc} (mV)	η (%)	FF	adsorbed dye (nmol cm ⁻²)
1 h	10.96	766	5.57	0.66	83
3 h	14.79	771	7.57	0.66	119
6 h	17.39	778	8.94	0.66	127
9 h	16.53	786	8.63	0.66	121
12 h	15.66	798	8.11	0.64	113
24 h	11.55	801	6.40	0.69	95

Table S3. Simulated values of resistance R_1 and R_2 from the EIS spectra of concentration dependent TiO_2 hollow nanoparticles.

Sample	R_1 (Ω)	R_2 (Ω)
S0	5.94	152.09
S50	1.72	176.36
S100	1.54	72.38
S250	3.21	83.97
P25	1.72	121.98

Table S4. Simulated values of resistance R_1 and R_2 from the EIS spectra of temperature dependent TiO_2 hollow nanoparticles.

Sample	R_1 (Ω)	R_2 (Ω)
120 °C	1.55	33.14
140 °C	1.59	41.56
160 °C	1.54	72.38
180 °C	3.00	89.57
220 °C	3.28	135.6

Table S5. Simulated values of resistance R_1 and R_2 from the EIS spectra of time-dependent TiO_2 hollow nanoparticles.

Sample	R_1 (Ω)	R_2 (Ω)
1 h	1.25	27.44
3 h	1.49	68.14
6 h	1.54	72.38
9 h	2.16	76.83
12 h	1.42	105.94
24 h	3.25	115.22