

Electronic Supplementary Information

Titanium Oxide Morphology Controls Charge Collection Efficiency in Quantum Dot Solar Cells

Ankita Kolay, P Naresh Kumar, Sarode Krishna Kumar, Melepurath Deepa*

Fluorescence decay analysis of TiO₂/CdS films

The emission decay plots of CdS, TiO₂ NSHs/CdS, TiO₂ PNPs/CdS, TiO₂ NPs/CdS and TiO₂ NWs/CdS films (in Figure 2d) were fitted into bi-exponential functions based on χ^2 values. The emission average life times, and fitted parameters are tabulated in the Table S1.

$$f(t) = B_1 e^{-t/\tau_1} + B_2 e^{-t/\tau_2} \quad (1)$$

$$\langle \tau \rangle = \frac{\sum B_i \tau_i^2}{\sum B_i \tau_i} \quad (2)$$

In (1) and (2), B_i is the decay amplitude, t is the time after excitation, τ is the electron lifetime and $\langle \tau \rangle$ is the average electron lifetime.

Table S1 Kinetic parameters of emission decay analysis of photosensitizer films deduced from double exponential fits.

Sample	B_1	τ_1 (ns)	B_2	τ_2 (ns)	$\langle \tau \rangle$ (ns)	χ^2
CdS	19.46	0.00944	80.54	4.77	4.77	1.04
TiO ₂ NSHs/CdS	97.82	0.00615	2.18	1.41	1.182	1.13
TiO ₂ PNPs/CdS	99.38	0.00623	0.62	1.78	1.145	0.95
TiO ₂ NPs/CdS	20.45	0.0379	79.55	1.14	1.135	0.97
TiO ₂ NWs/CdS	19.64	0.00354	80.36	0.553	0.552	1.04

Surface area and porosity studies

Brunauer-Emmett-Teller (BET) surface area analysis and Barrett-Joyner-Halenda (BJH) pore size and volume analysis were performed under Nitrogen at 77.3 K, after degassing at 300 °C for 3 h. Figure S1 shows the BET analysis plots, and from the analysis it is deduced that TiO₂ NSHs have the highest surface area, followed by TiO₂ PNPs, TiO₂ NPs and TiO₂ NWs. The data for surface area, and pore volume of the TiO₂ morphologies are listed in Table S2. CdS QDs are incorporated within these morphologies, depending on the size and volume of the pores, and the effective available surface area of TiO₂.

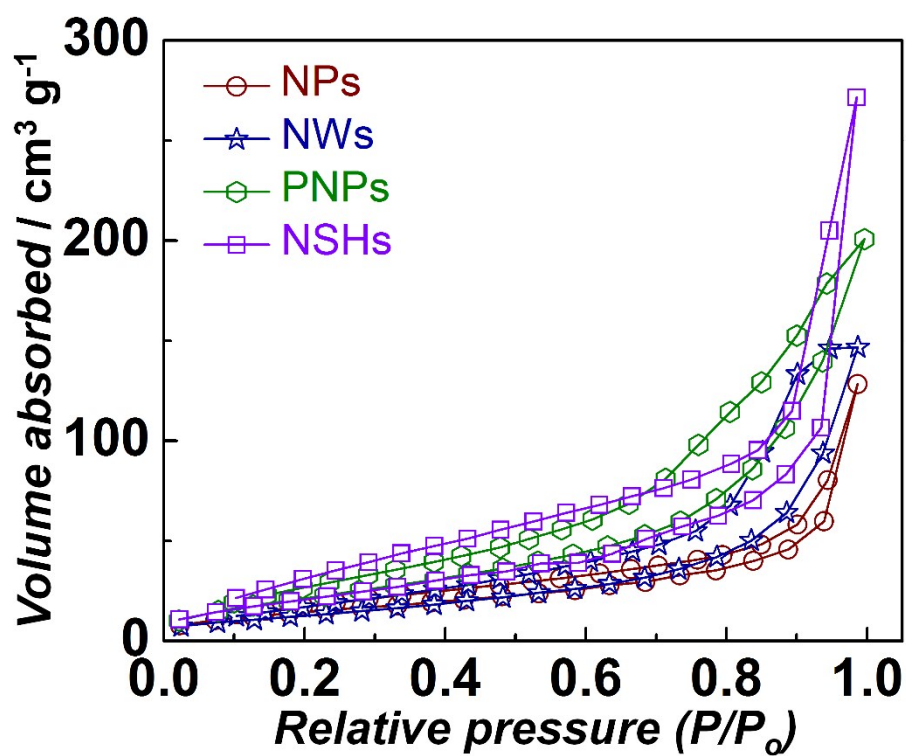


Figure S1 Adsorption-desorption isotherms of different TiO₂ morphologies.

Table S2 BET and BJH analysis data for different TiO₂ morphologies.

Morphology	Surface area (m ² g ⁻¹)	Pore volume (cm ³ g ⁻¹)
TiO ₂ NPs	64.304	0.198
TiO ₂ NWs	61.82	0.227
TiO ₂ PNP	102.359	0.3107
TiO ₂ NSHs	111.968	0.42

J-V characteristics

Table S3 Solar cell parameters of the 5-cells for each TiO₂ morphology measured using carbon fabric as the counter electrode in a 0.1 M Na₂S electrolyte (in 3:7 v/v of water:methanol), under 1 sun illumination (AM 1.5, 100 mW cm⁻²).

Cells	J _{sc} (mA cm ⁻²)	V _{oc} (V)	FF	Efficiency (η, %)
TiO ₂ NWs/CdS				
Cell 1	14.856	0.978	43.27	6.288
Cell 2	14.856	0.978	43.18	6.275
Cell 3	14.256	0.912	44.98	5.849
Cell 4	13.731	0.973	43.23	5.776
Cell 5	13.726	0.958	42.67	5.611
Average	14.285	0.959	43.46	5.959
TiO ₂ NPs/CdS				
Cell 1	14.645	0.978	38.79	5.557
Cell 2	14.219	0.988	38.67	5.433
Cell 3	13.59	0.933	36.6	4.641
Cell 4	13.279	0.943	37.03	4.637
Cell 5	13.951	0.882	36.4	4.48
Average	13.936	0.944	37.49	4.949
TiO ₂ PNPs/CdS				
Cell 1	16.439	0.857	38.33	5.401
Cell 2	15.322	0.852	39.36	5.139
Cell 3	14.947	0.862	39.43	5.081
Cell 4	11.731	0.923	40.32	4.366
Cell 5	11.00	0.938	41.5	4.282
Average	13.8878	0.8864	39.788	4.854
TiO ₂ NSHs/CdS				
Cell 1	5.839	0.963	47.69	2.682
Cell 2	5.713	0.928	47.26	2.506
Cell 3	5.215	0.938	50.57	2.474
Cell 4	5.109	0.953	50.42	2.455
Cell 5	5.702	0.933	45.65	2.429
Average	5.5156	0.943	48.318	2.509

Electrolyte effect on photovoltaic performance of TiO₂ NPs based cells

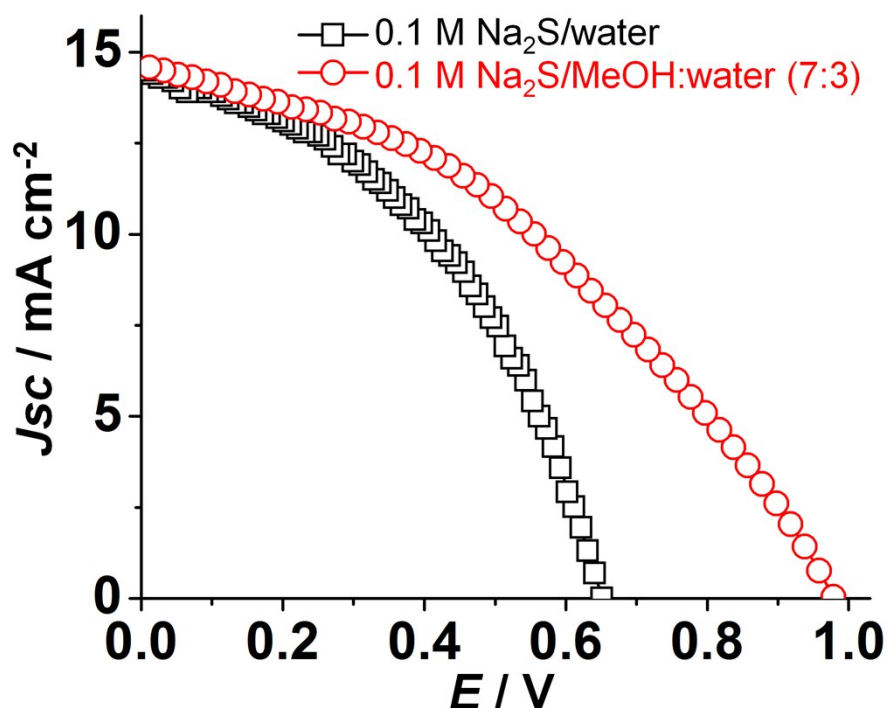


Figure S2 J-V characteristics for cells with a TiO₂ NPs/CdS photoanode and a carbon fabric as the counter electrode with two different electrolytes (under 1 sun illumination, AM 1.5).

Table S4 Solar cell parameters of cells with a TiO₂ NPs/CdS photoanode and a carbon fabric as the counter electrode with different listed electrolytes. Exposed cell area is 0.06 to 0.08 cm² and measurements are performed under 1 sun illumination (100 mW cm⁻²).

Electrolyte	V _{OC} (mV)	J _{SC} (mA cm ⁻²)	FF	η _{champion} (%)	η _{avg} (%)
0.1 M Na ₂ S solution in water	651	14.49	0.44	4.18	3.72
0.1 M Na ₂ S in MeOH:water (7:3)	978	14.645	0.38	5.557	4.949

Table S5 Comparison of J_{SC} and J_{IPCE} values for cells with different TiO₂ morphologies.

Photoanode	J _{SC} (mA cm ⁻²) from J-V	J _{IPCE} (mA cm ⁻²) from IPCE
TiO ₂ NSHs/CdS	5.84	5.70
TiO ₂ PNPs/CdS	16.43	15.97
TiO ₂ NPs/CdS	14.22	14.1
TiO ₂ NWS/CdS	14.85	14.4