ASSOCIATE CONTENT

Supporting Information

Sensitized Solar Cells with Colloidal PbS/CdS Core/Shell Quantum Dots

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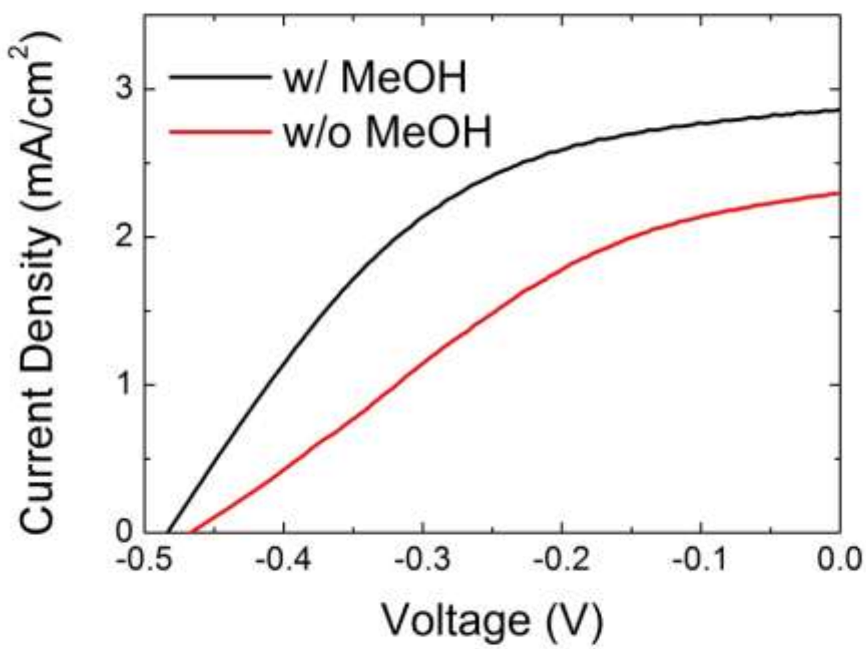

Figure S1. PbS/CdS (1.1 nm) QD sensitized solar cells in the polysulfide electrolyte with and without methanol.

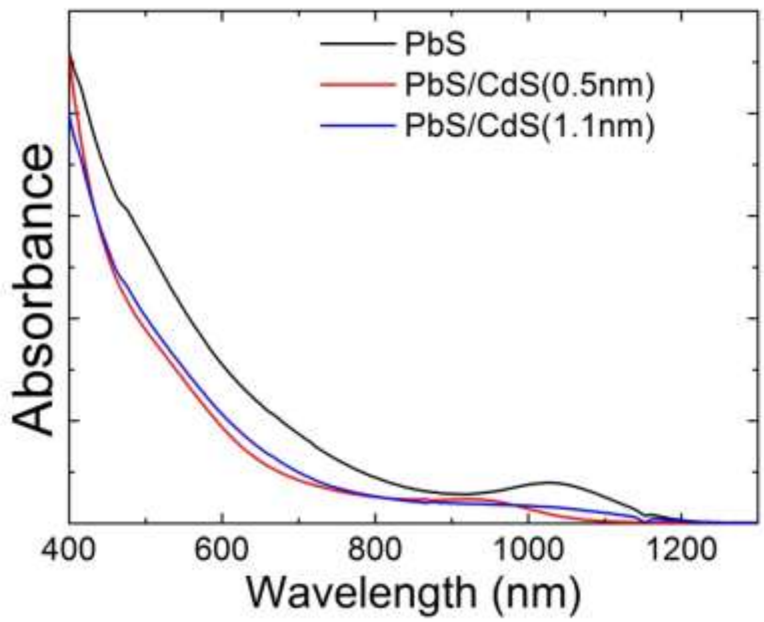

Figure S2. Absorbance of oleic-acid passivated colloidal QDs in chloroform.

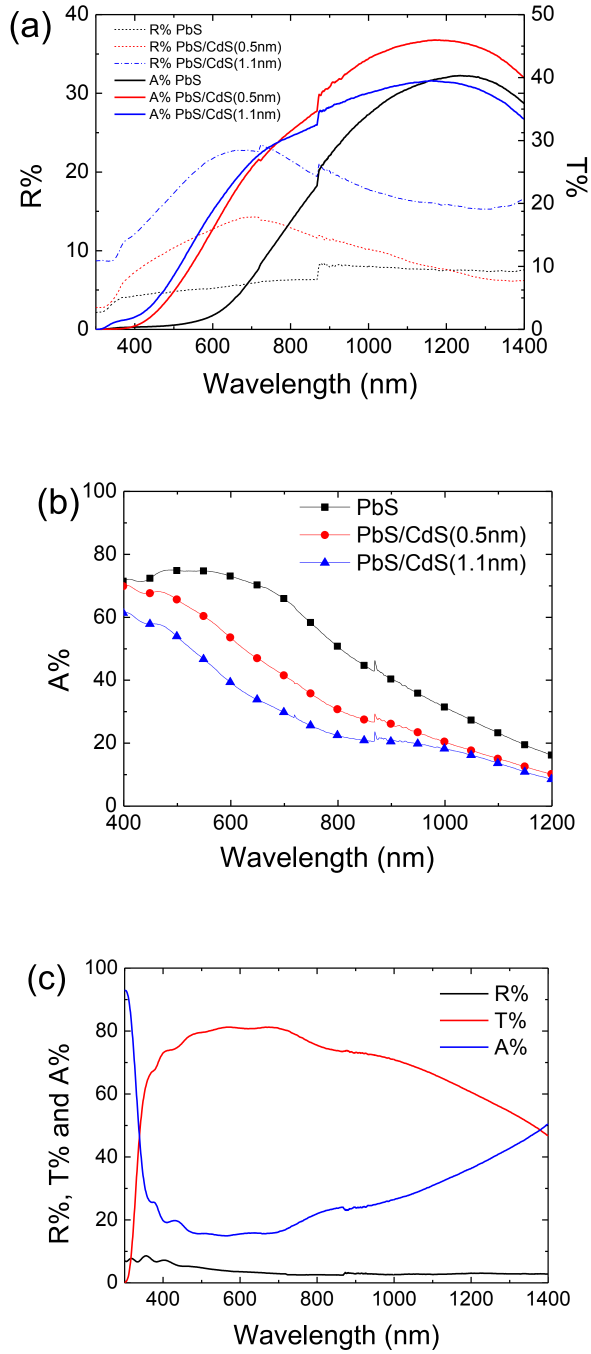

Figure S3. (a) Reflectance and transmittance of QD sensitized electrodes (Glass/FTO/TiO_2/QDs) (b) Absorbance spectra of QD sensitized electrodes (TiO_2/QDs) (c) Reflection, transmission and absorption of Glass/FTO substrate.

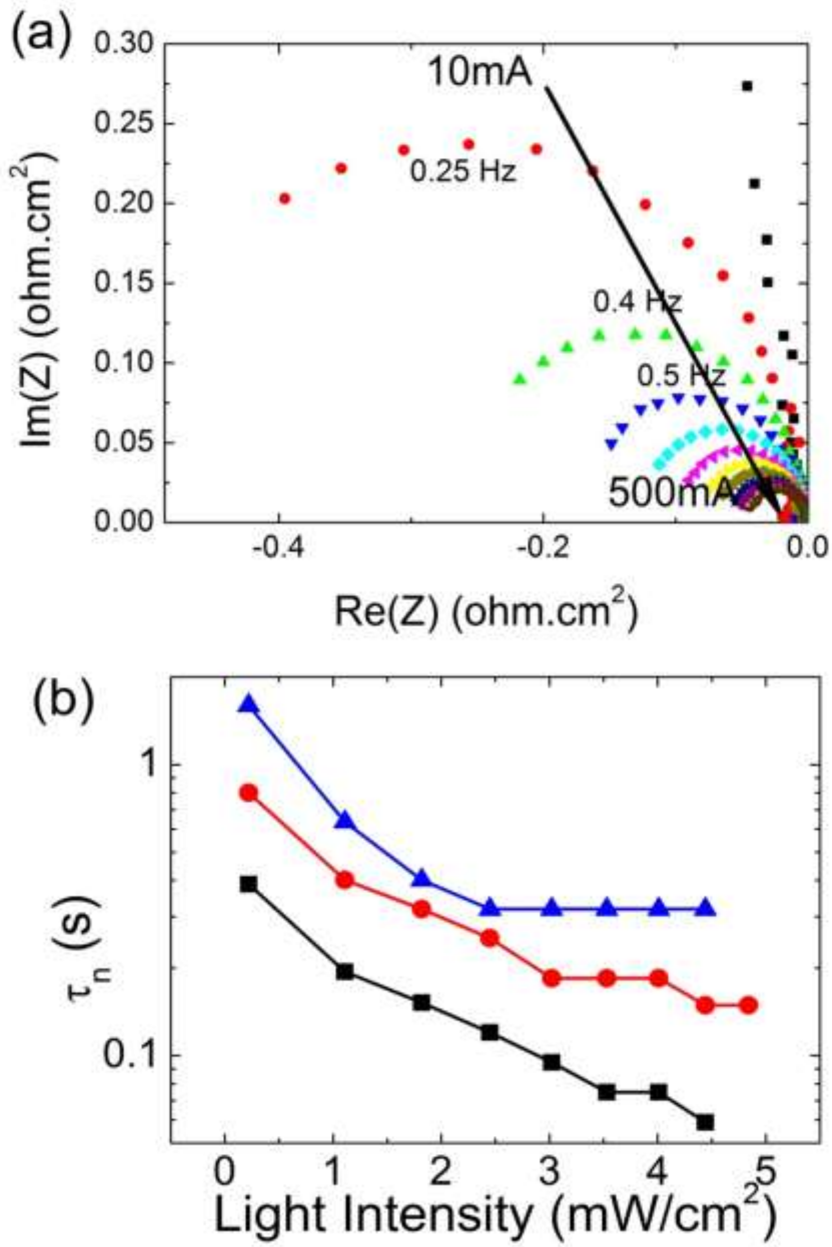

Figure S4. (a) Nyquist plot of IMVS spectra of PbS/CdS(1.1nm) QD sensitized solar cells, measured by employing a 528 nm LED, scanned from 10 mA (corresponding to 0.22mW/cm^2 light intensity) to 500 mA (corresponding to 5.57 mW/cm^2 light intensity). (b) Light intensity dependent mean electron lifetime determined by IMVS measured under 528 nm LED illumination.

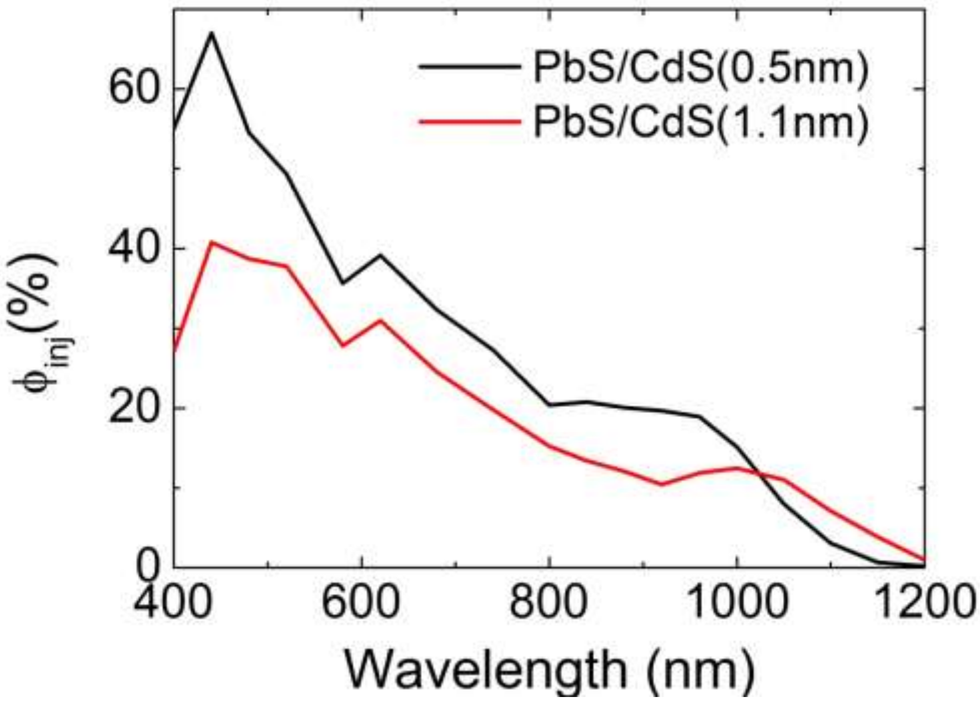

Figure S5. Charge injection efficiencies for cells with different CdS shell thicknesses. The charge injection efficiency is obtained by $\phi_{inj} = IQE/\eta_c$, where the η_c is measured at 10 mW/cm^2 (Table S1) is used.

Table S1. Equivalent circuit fitting results and other parameters of cells [a]

Light Intensity	c_μ' [b]	r_{ct}' [c]	r_r' [d]	τ_n [e]	τ_d [f]	D_e [g]	μ_e [h]	L_d [i]	η_c [j]
$mWcm^{-2}$	$\mu Fcm^{-2}\mu m^{-1}$	$\Omega\ cm^2\mu m^{-1}$	$\Omega\ cm^2\mu m$	ms	ms	m^2s^{-1}	$cm^2V^{-1}s^{-1}$	μm	%
PbS									
100.0	358.08	32.19	109.68	39.27	5.94E+02	2.69E-11	1.05E-05	1.0	31.7
91.2	170.53	31.38	155.68	26.55	3.36E+02	4.76E-11	1.85E-05	1.1	34.2
79.4	166.65	38.34	158.96	26.49	4.02E+02	3.98E-11	1.55E-05	1.0	31.7
50.1	180.79	63.98	199.20	36.01	6.76E+02	2.37E-11	9.21E-06	0.9	29.0
31.6	189.94	103.13	291.92	55.45	9.42E+02	1.70E-11	6.61E-06	1.0	31.7
10.0	132.69	161.50	960.00	127.38	2.69E+03	5.94E-12	2.31E-06	0.9	29.0
PbS/CdS(0.5nm)									
100.0	315.79	1.58	130.00	41.05	4.90E+01	3.27E-10	1.27E-04	3.7	75.6
91.2	316.45	1.33	139.00	43.99	3.86E+01	4.15E-10	1.62E-04	4.3	82.3
79.4	314.59	1.87	208.00	65.43	4.55E+01	3.51E-10	1.37E-04	4.8	84.5
50.1	361.82	1.39	155.00	56.08	7.21E+01	2.22E-10	8.64E-05	3.5	74.2
31.6	356.04	2.41	292.00	103.96	8.36E+01	1.91E-10	7.45E-05	4.5	83.1
10.0	367.23	3.30	610.00	224.01	1.10E+02	1.46E-10	5.68E-05	5.7	88.2
PbS/CdS(1.1nm)									
100.0	892.45	0.26	195.20	174.21	2.13E+01	7.50E-10	2.92E-04	11.4	96.6
91.2	891.09	0.38	222.40	198.18	3.48E+01	4.60E-10	1.79E-04	9.5	95.2
79.4	880.38	0.42	253.76	223.41	3.38E+01	4.74E-10	1.84E-04	10.3	95.9
50.1	847.88	0.45	397.84	337.32	3.65E+01	4.38E-10	1.71E-04	12.2	97.0
31.6	817.18	0.51	606.40	495.54	4.29E+01	3.73E-10	1.45E-04	13.6	97.6
10.0	718.56	0.56	1312.80	943.32	4.28E+01	3.74E-10	1.45E-04	18.8	98.7

[a] values are determined based on the data measured at open-circuit condition under different light intensity by transmission line model fitting as the equivalent circuit shown in Fig. 3a.

[b] the chemical capacitance per cm^2 produced by the accumulation of electrons in the TiO_2 and interface, C_μ' (= c_μ'L), where L is the thickness of the TiO_2. $C_\mu = Q(2\pi f_p)^{\alpha-1}$, where Q is constant phase element (CPE), α is a constant, and f_p is the peak frequency of Nyquist impedance plots.

[c] electron transport resistance, R_{ct}' (= r_{ct}'L)

[d] interfacial charge recombination resistance, R_r' (= r_r'/L)

[e] the average electron lifetime in TiO_2, $\tau_n = C'_{\mu} R'_r$

[f] the average electron transit time, $\tau_d = L^2/D_e$

[g] electron diffusion coefficient, $D_e = (r_r / r_{ct}) L^2 / (2\pi\tau_n)$

[h] electron mobility, $\mu_e = D_e / k_B T$

[i] electron diffusion length, $L_d = (\tau_n D_e)^{0.5}$

[j] charge collection efficiency[S1-S3], $\eta_c = \frac{\left(-L_d\alpha\cosh\left(\frac{L}{L_d}\right)+\sinh\left(\frac{L}{L_d}\right)+L_d\alpha e^{-\alpha L}\right)L_d\alpha}{(1-e^{-\alpha L})(1-L_d{}^2\alpha^2)\cosh\left(\frac{L}{L_d}\right)}$, where α is the extinction coefficient of quantum dot-sensitized TiO_2 film. Here we assume the αL equals to 1 for the calculation. Another well-adopted formula for the charge collection efficiency is $\eta_c = 1 - \left(\frac{L}{L_d}\right)^2$. However, it is only valid when the cell active layer is thin enough so that the photo-generated electrons either immediately transport to the electrodes or recombine. In the case $L=L_d$ results in $\eta_c = 0$, indicating this formula obviously deviates the real situation of the quantum dot-sensitized solar cells.

Supplementary References

S1. J. Halme, P. Vahermaa, K. Miettunen and P. Lund, *Adv Mater*, 2010, **22**, E210-234.

S2. X. Dang, H. Yi, M. H. Ham, J. Qi, D. S. Yun, R. Ladewski, M. S. Strano, P. T. Hammond and A. M. Belcher, *Nature nanotechnology*, 2011, **6**, 377-384.

S3. L. Bertoluzzi, S. Ma, *Physical chemistry chemical physics : PCCP*, 2013, **15**, 4283.