Electronic Supplementary Information

Quantum Dots-Silica Composite as an Efficient Spectral Converter in a Luminescence Down-Shifting Layer of Organic Photovoltaic Devices

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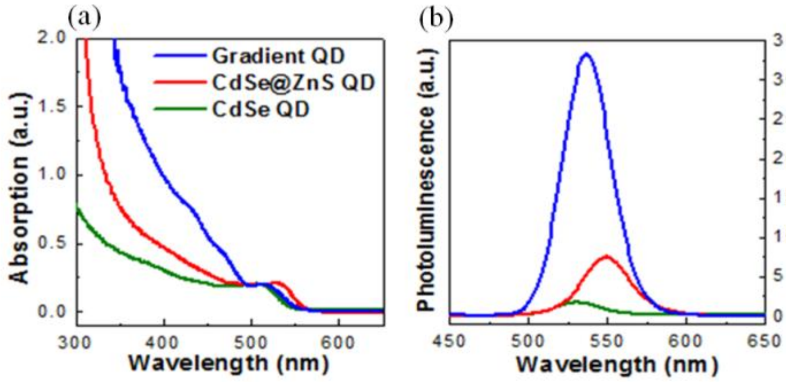

Fig. S1. (a) UV-Vis absorption and (b) PL emission spectra of CdSe (green), CdSe@ZnS (red), and gradient QDs (blue).

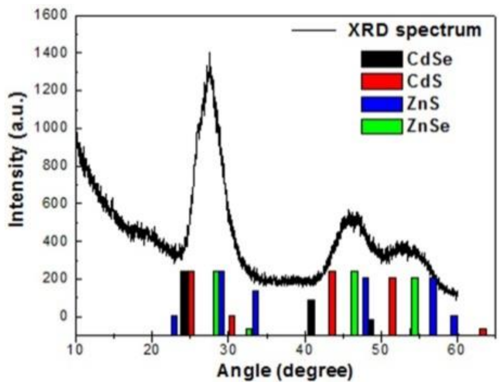

Fig. S2. XRD spectrum of OA-coated gradient QDs (black solid line) (inserted reference of bulk CdSe (black bar), CdS (red bar), ZnS (blue bar), and ZnSe (green bar)).

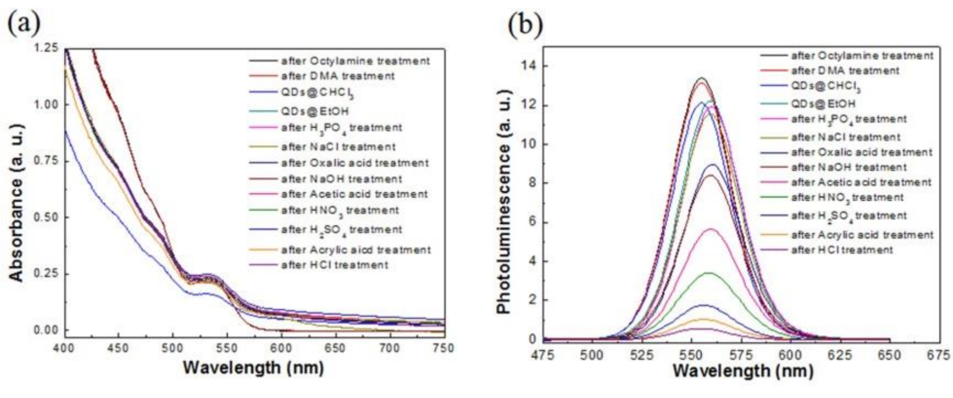

Fig. S3. Changes of (a) UV-Vis absorption, and (b) photoluminescence intensity after acid or base treatment of QDs. We injected 1 ml acid or base solution into QDs and then measured optical properties after 1 h.

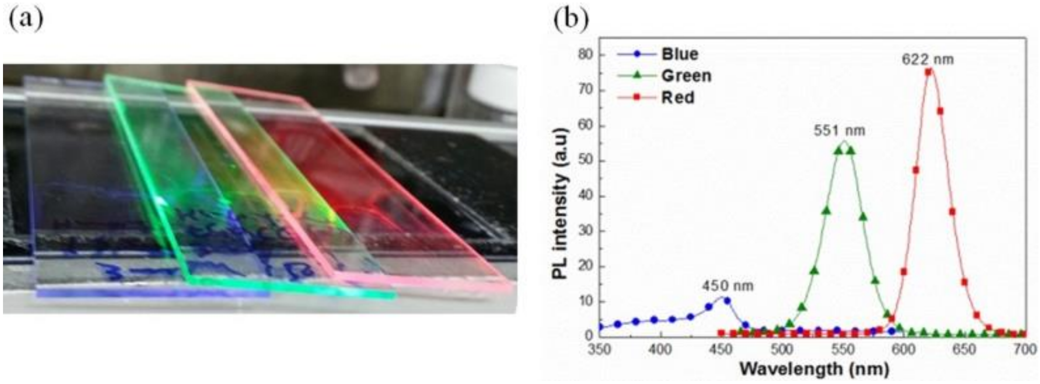

Fig. S4. (a) Photograph of blue, green and red light emission (b) PL emission spectra from QDs-silica composite films on a slide glass.

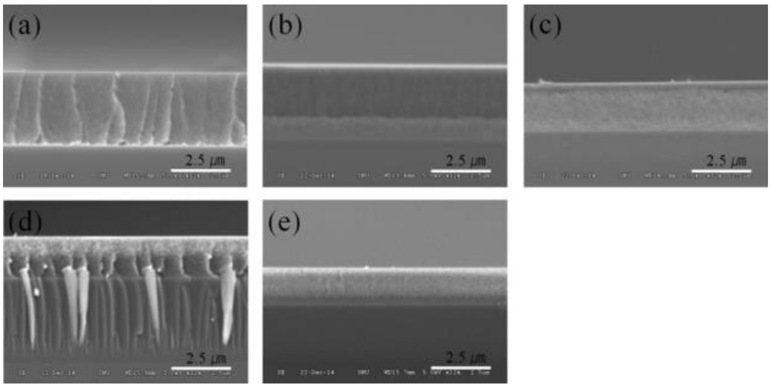

Figure S5. SEM images of (a) 3.1 μm, (b) 3.0 μm, (c) 2.0 μm, (d) 1.7 μm, (e) 1.5 μm thickness of 0.1 wt% QDs-silica thin films as a luminescent down-shifting layer.

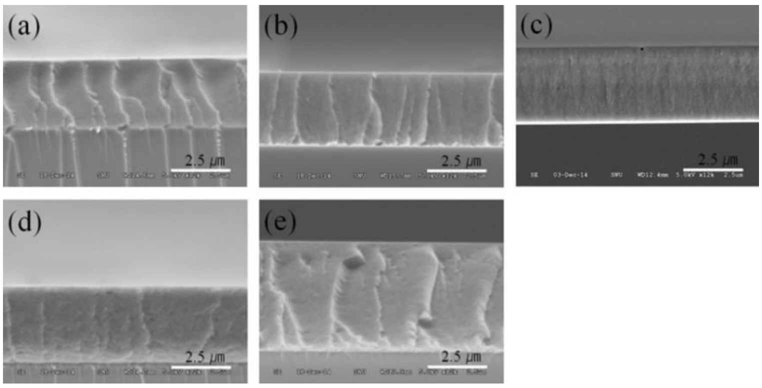

Figure S6. SEM images of (a) 0 wt%, (b) 0.1 wt%, (c) 0.2 wt%, (d) 0.3 wt%, and (e) 0.5 wt% of QDs-silica thin films.

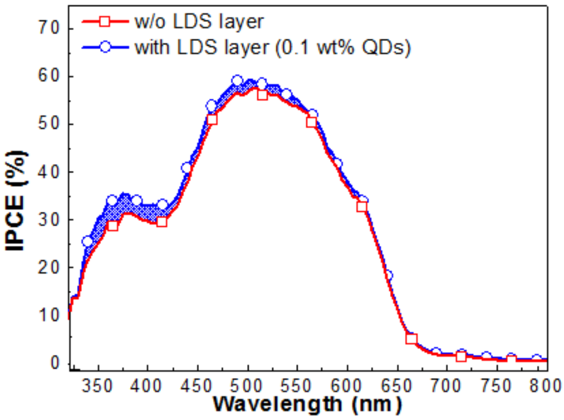

Figure S7. IPCE data of BHJ OPV devices. (line with open circle: with the LDS layer of 0.1 wt% QDs, line with open rectangle: without the LDS layer).

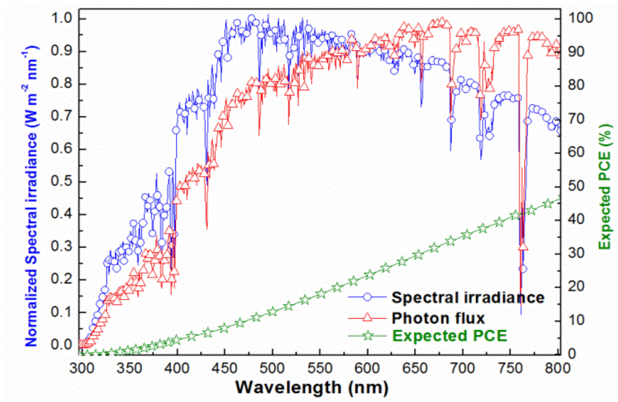

Figure S8. Theoretically expected PCE values of solar cells calculated from NREL (National Renewable Energy Laboratory) data.

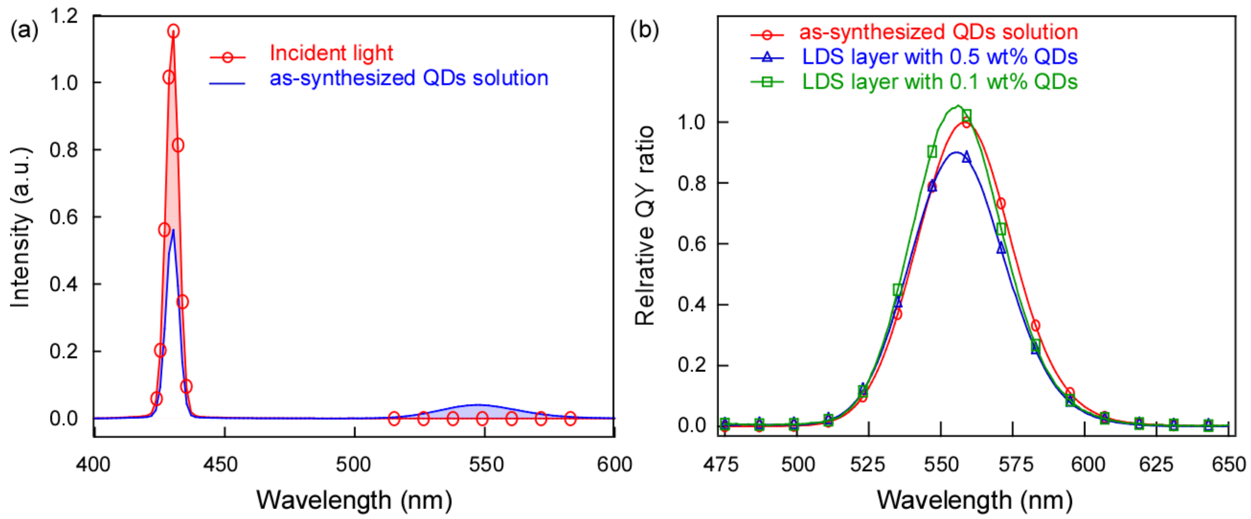

Figure S9. (a) Photoluminescence quantum yields (PLQYs) of the as-synthesized QDs solution in hexane (excitation: 430 nm). The PLQY was calculated to be 52.1 %. (b) PLQY ratios of the QDs solution, the LDS layer with 0.1 wt% QDs, and the LDS layer with 0.5 wt% QDs. The QYs of the LDS layers with 0.1 wt% QDs and 0.5 wt% QDs were calculated to be 53.7 and 46.7%, respectively. (line with open circle: as-synthesized QDs solution, line with open rectangle: LDS layer with 0.1 wt% QDs, and line with open triangle: LDS layer with 0.5 wt% QDs)

Quantum yield (QY) of QDs solution was measured to be 52.1% (Figure S9 (a)). Based on this result, the relative QYs of the LDS layers with 0.1 wt% and 0.5 wt% were estimated by *eq* 1 and *eq* 2, respectively.[1]

$$QY_{LDS\ layer\ with\ 0.5\ wt\%\ QDs} = QY_{reference} \times \frac{Abs_{reference}}{Abs_{LDS\ layer\ with\ 0.5\ wt\%\ QDs}} \times \frac{PL_{LDS\ layer\ with\ 0.5\ wt\%\ QDs}}{PL_{reference}} \times \frac{{n_{LDS\ layer}}^2}{{n_{reference}}^2} \quad \ldots\ldots(1)$$

$$QY_{LDS\ layer\ with\ 0.1\ wt\%\ QDs} = QY_{LDS\ layer\ with\ 0.5\ wt\%\ QDs} \times \frac{PL_{LDS\ layer\ with\ 0.1\ wt\%\ QDs}}{PL_{LDS\ layer\ with\ 0.5\ wt\%\ QDs}} \times \frac{Conc._{LDS\ layer\ with\ 0.5\ wt\%\ QDs}}{Conc._{LDS\ layer\ with\ 0.1\ wt\%\ QDs}} \times \frac{Thickness_{LDS\ layer\ with\ 0.5\ wt\%\ QDs}}{Thickness_{LDS\ layer\ with\ 0.1\ wt\%\ QDs}} \ldots\ldots(2)$$

Where reference is QDs solution, QY is PLQY, Abs is absorption, PL is photoluminescence, and *n* denotes refractive index. The values of parameters were summarised below.

$\frac{Abs_{reference}}{Abs_{LDS\ layer\ with\ 0.5\ wt\%\ QDs}}$	$\frac{PL_{LDS\ layer\ with\ 0.5\ wt\%\ QDs}}{PL_{reference}}$	$\frac{PL_{LDS\ layer\ with\ 0.1\ wt\%\ QDs}}{PL_{LDS\ layer\ with\ 0.5\ wt\%\ QDs}}$	$PL_{LDS\ layer\ with\ 0.5\ wt\%\ QDs}$
1.98	0.44	0.14	431.99
$PL_{LDS\ layer\ with\ 0.1\ wt\%\ QDs}$	$PL_{reference}$	$Thickness_{LDS\ layer\ with\ 0.5\ wt\%\ QDs}$	$Thickness_{LDS\ layer\ with\ 0.1\ wt\%\ QDs}$
60.52	982.89	4.6 *um*	2.8 *um*
$Conc._{LDS\ layer\ with\ 0.5\ wt\%\ QDs}$	$Conc._{LDS\ layer\ with\ 0.1\ wt\%\ QDs}$	$n_{LDS\ layer}$	$n_{reference}$
0.5	0.1	1.40	1.38

Reference

1. J. Laverdant, W. D. de Marcillac, C. Barthou, V. D. Chinh, C. Schwob, L. Coolen, P. Benalloul, P. T. Nga and A. Maître, *Materials*, 2011, **4**, 1182-1193.