Supporting Information

High Performance PbS Quantum Dot/Graphene Hybrid Solar Cell with Efficient Charge Extraction

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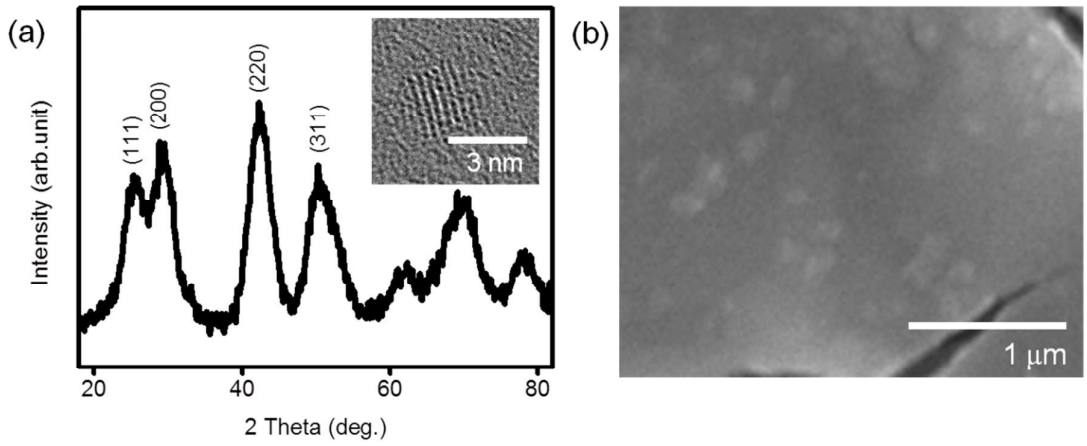

Fig. S1 (a) X-ray diffraction patterns and HRTEM image (inset) of the PbS nanocrystal. (b) Representative SEM image of SG flakes (average lateral size of ~550 nm) homogeneously deposited on PbS QD film.

The crystallinity of the PbS QD film is examined by the XRD measurement as shown in Figure S1a. Well-defined diffraction peaks were assigned to the (111), (200), (220), and (311) planes, respectively. It clearly implies that the PbS in the solid state has a face-center-cubic (fcc) structure. The HRTEM lattice fringe image is taken from a 1.3 eV PbS QD and the diameter of the QD is approximately 2.5 nm (inset).

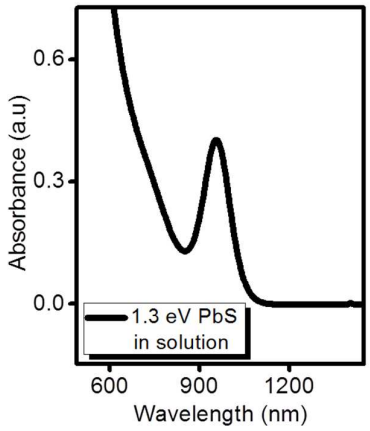

Fig. S2 UV-vis absorption of 1.3 eV PbS QDs capped with oleic acid in solution (peak

around 950 nm). A size distribution of the corresponding PbS QD is obtained with a mean diameter of ~ 2.5 nm.

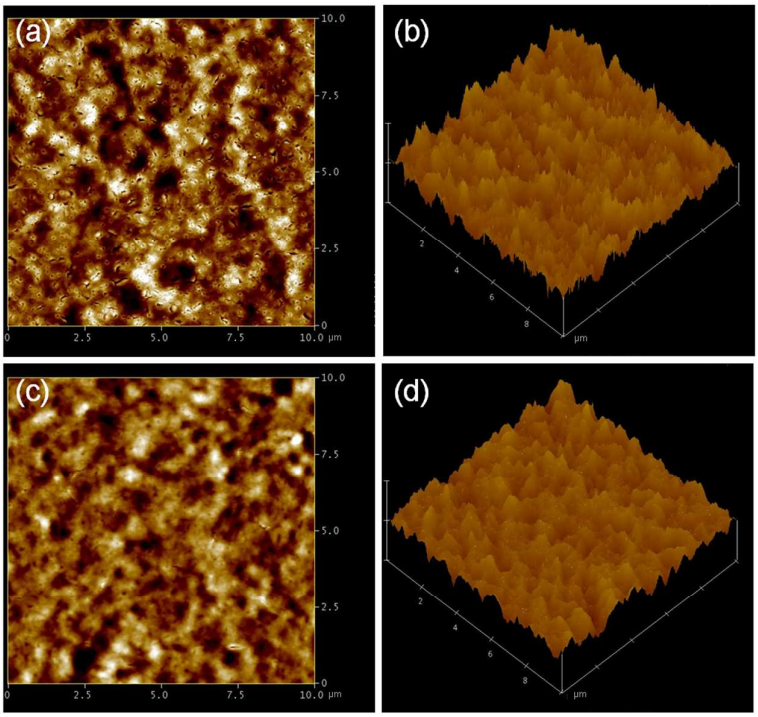

Fig. S3 10 x 10 μm AFM images showing the surface morphologies of (a and b) PbS and (c and d) PbS/SG films. The root mean square (RMS) roughness are 13.204 and 11.641 nm, respectively. The image area is 10 x10 μm.

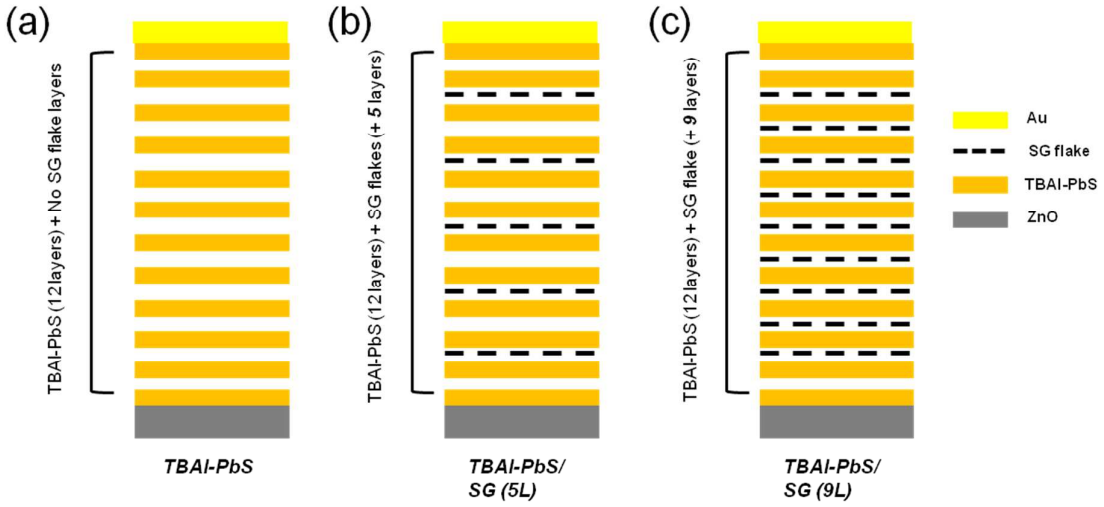

Fig. S4 Schematic of devices of (a) TBAI-PbS, (b) TBAI-PbS/SG (5L), and (c) TBAI-

PbS/SG (9L). All devices are fabricated under the same conditions and consist of 12 layers of TBAI-PbS with 0, 5, and 9 layers of SG flake. For the hybrid cell fabrication, 5 and 9 layers of SG flake were symmetrically inserted in the TBAI-PbS layers as seen in Fig. S4 (b) and (c).

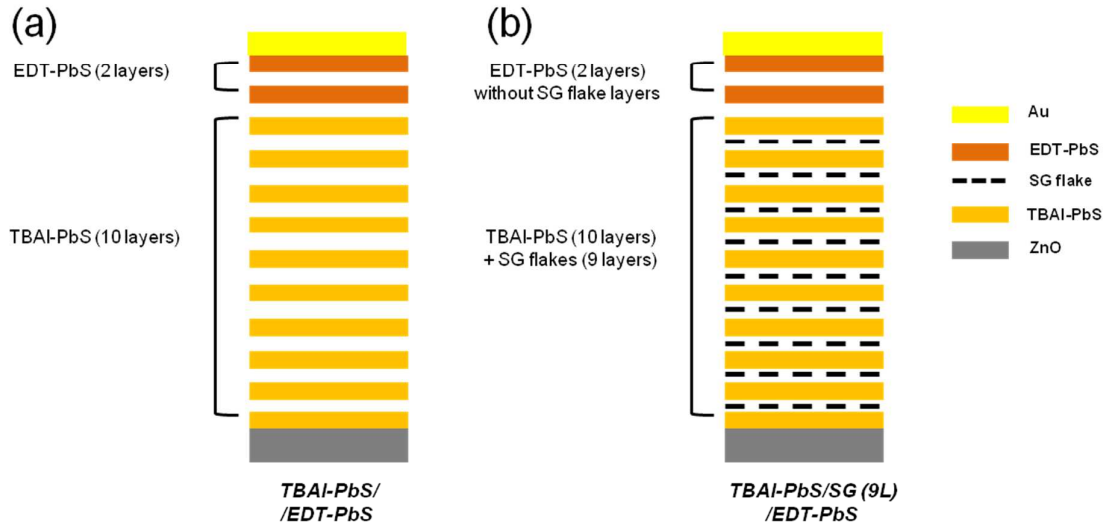

Fig. S5 Schematic of (a) TBAI-PbS/EDT-PbS and (b) TBAI-PbS/SG (9L)/EDT-PbS junction solar cells. They consist of 10 layers of TBAI-PbS and 2 layers of EDT-PbS on ZnO/ITO/glass substrates. For the hybrid cell fabrication, 9 layers of SG flake were inserted in TBAI-PbS CQD layers.

Table S1 Photovoltaic performance of TBAI-PbS/EDT-PbS and TBAI-PbS/SG (9L)/EDT-PbS junction structure. Average values of each device with standard deviations were collected from four devices.

	V_{oc} (V)	FF	J_{sc} (mA/cm^2)	R_s (Ω)	PCE (%)
TBAI-PbS /EDT-PbS	0.51±0.01	0.62±0.02	23.61±0.10	2.10±0.28	7.53±0.18
TBAI-PbS/SG (9L) /EDT-PbS	0.48±0	0.61±0.03	29.81±0.66	1.47±0.78	8.82±0.55
TBAI-PbS/SG (9L) /EDT-PbS [a]	0.48	0.63	30.34	1.46	9.18

[a] Best performance of TBAI-PbS/SG (9L)/EDT-PbS junction device.

Table S2 Photoresponse characteristics of PbS and PbS/SG devices.

	off state (pA)	on state (nA)	on-off ratio	Rise time (τ, msec)
PbS	310	8.91	28.74	3.3
PbS/SG	272	10.6	38.97	2.1