

Electronic Supplementary Material

Enhanced charge extraction for all-inorganic perovskite solar cells by graphene oxide quantum dots modified TiO₂ layer

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Table S1. Comparison of CsPbBr₃ PSCs with graphene materials and QDs.

Device structure	PCE/(%)	Ref.
FTO/c-TiO ₂ /m-TiO ₂ /CsPb _{1-x} Ag _x Br ₃ /carbon	6.92%	S1
FTO/c-TiO ₂ /m-TiO ₂ /CsPbBr ₃ : g-C ₃ N ₄ /carbon	8.00%	S2
FTO/TiO ₂ /CsPbBr ₃ /carbon	5.44%	S3
FTO/TiO ₂ /CsPbBr ₃ -CsPb ₂ Br ₅ /Spiro-OMeTAD/Ag	8.34%	S4
FTO/c-TiO ₂ /m-TiO ₂ /CsPbBr ₃ /MoS ₂ QDs/carbon	6.80%	S5
FTO/c-TiO ₂ /m-TiO ₂ /CsPbBr ₃ /BHJ/carbon	8.94%	S6
FTO/ZnO/CsPbBr ₃ -CsPb ₂ Br ₅ /PCBM/Ag	6.81%	S7
FTO/c-TiO ₂ /CsPbBr ₃ /spiro-MeOTAD/Au	8.65	S8
FTO/a-Nb ₂ O ₅ /CsPbBr ₃ /CuPC/carbon	5.74	S9
FTO/c-TiO ₂ /CsPbBr ₃ /carbon	7.81	S10
FTO/c-TiO ₂ /CsPbBr ₃ /buffer layer/P3HT/Au	7.90	S11
FTO/TiO ₂ /CsPb _{0.998} Co _{0.002} Br ₃ /Spiro-OMeTAD/Au	8.57	S12
FTO/Sr-TiO ₂ /CsPbBr ₃ /Carbon	7.22	S13
FTO/c-TiO ₂ /m-TiO ₂ /InBr ₃ :CsPbBr ₃ /carbon	6.48	S14
FTO/SnO ₂ /CsPbBr ₃ @Cs ₄ PbBr ₆ /carbon	9.02	S15
FTO/c-TiO ₂ /m-TiO ₂ /GOQDs/CsPbBr ₃ /carbon	9.16	This work

S1. Chen S L, Liu X L, Wang Z, Li W H, Gu X Y, Lin J, Yang T Y, Gao X Y, Kyaw A K K. Defect passivation of CsPbBr₃ with AgBr for high-performance all-inorganic

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- S10. Liu L L, Yang S E, Liu P, Chen Y S. High-quality and full-coverage CsPbBr₃ thin films via electron beam evaporation with post-annealing treatment for all-inorganic perovskite solar cells. *Solar Energy*, 2022, 232: 320-327
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S15. Liu C B, Zhang T, Li Z, Zhao B H, Ma X T, Chen Y L, Liu Z B, Chen H N, Li X Y. Crystallization kinetics engineering toward high-performance and stable cspbbr₃-based perovskite solar cells. *ACS Applied Energy Materials*, 2021, 4(10): 10610-10617

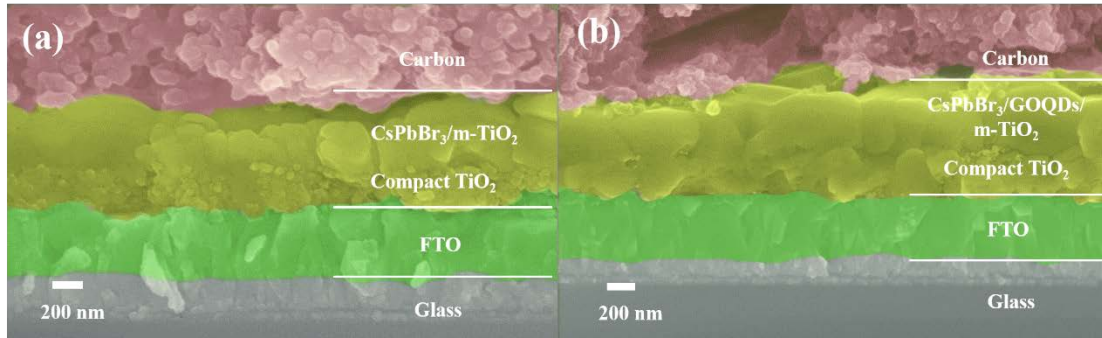


Figure S1. Cross section SEM images of perovskite film (a) without GOQDs and (b) with GOQDs.

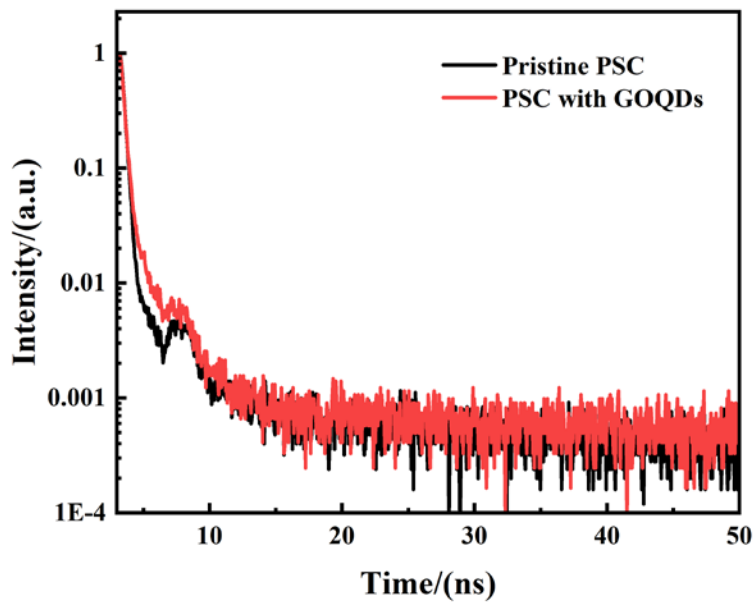


Figure S2. TRPL spectra of the PSCs with and without GOQDs.

Table S2. TRPL key parameters of the PSC with and without GOQDs

PSC devices	$\tau 1/(\text{ns})$	$f1/(\%)$	$\tau 2/(\text{ns})$	$f2/(\%)$	$T_{\text{ave}}/(\text{ns})$
Pristine	0.27	93.62	4.20	6.38	4.29
PSC with GOQDs	0.29	86.17	2.55	13.83	1.79

Table S3. Hall Effect parameters of the CsPbBr₃ film with and without GOQDs

PSC devices	Resistivity $/(\Omega \cdot \text{cm})$	Bulk concentration $/(\text{cm}^{-3})$	Mobility/ $(\text{cm}^2\text{V}^{-1}\text{s}^{-1})$
Pristine	2.48×10^3	2.45×10^{16}	9.65
PSC with GOQDs	7.13×10^2	5.48×10^{19}	15.97

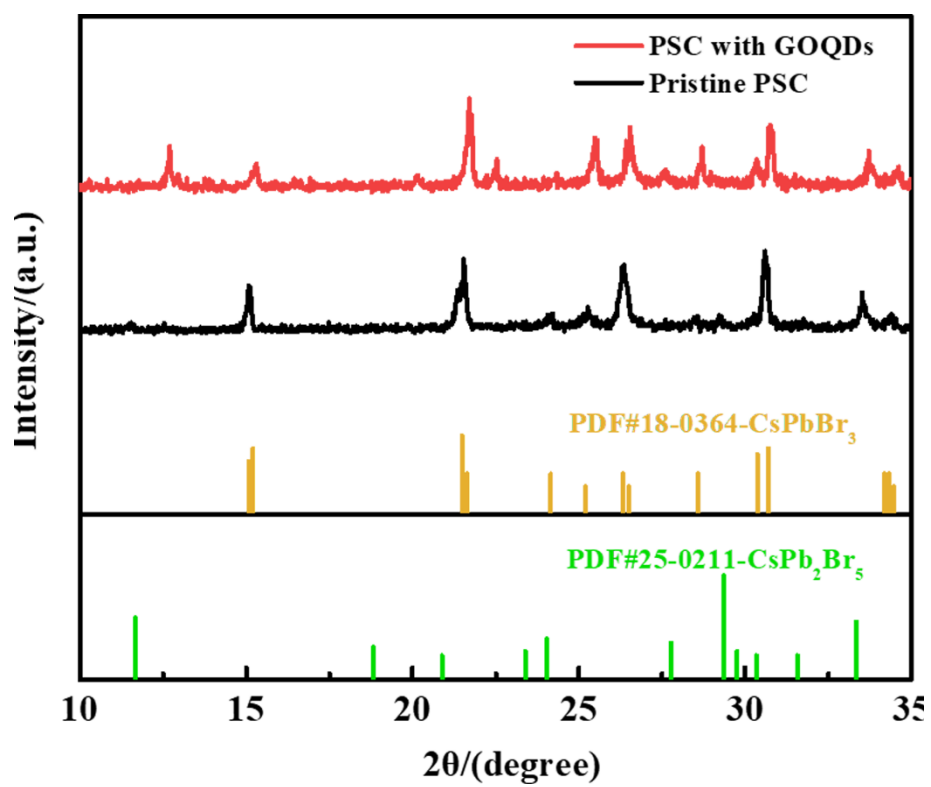


Figure S3. XRD patterns of the PSCs with and without GOQDs.

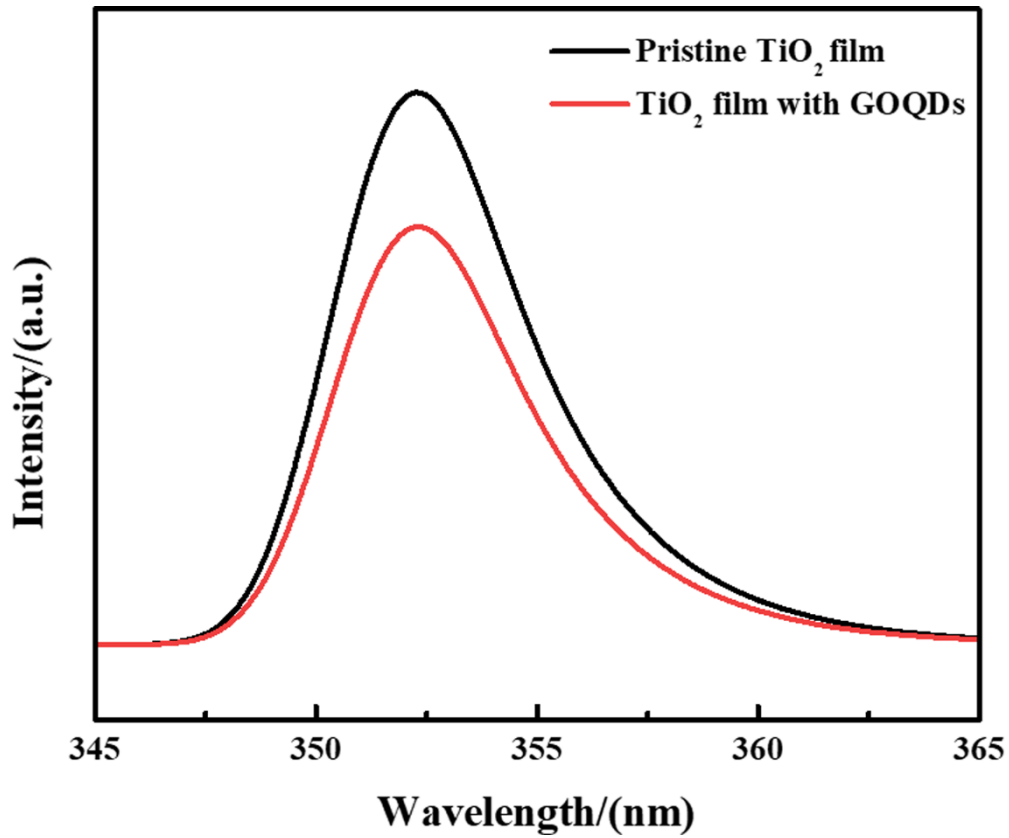


Figure S4. PL spectra of TiO₂ films with and without GOQDs.

Table S4. Hall Effect parameters of the TiO₂ film with and without GOQDs.

TiO ₂ film	Resistivity /(Ω·cm)	Bulk concentration /(cm ⁻³)	Mobility /(cm ² V ⁻¹ s ⁻¹)
Pristine TiO ₂ film	4.46×10 ³	2.07×10 ¹²	66
TiO ₂ film with GOQDs	1.04	9.01×10 ¹⁶	67

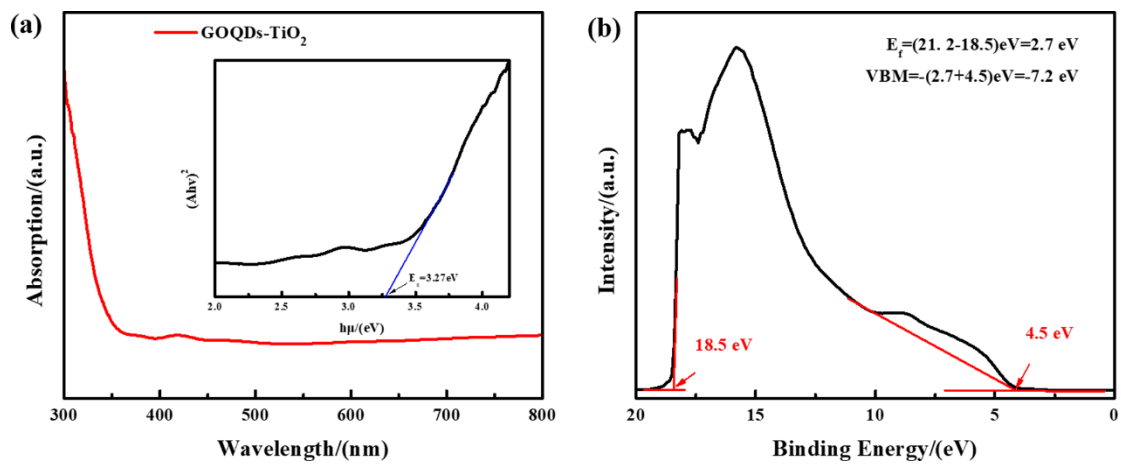


Figure S5 (a) The absorption spectrum of TiO₂ electron transport layer with GOQDs and its corresponding Tauc plot (Inset). (b) The UPS characterization of TiO₂ electron transport layer with GOQDs.

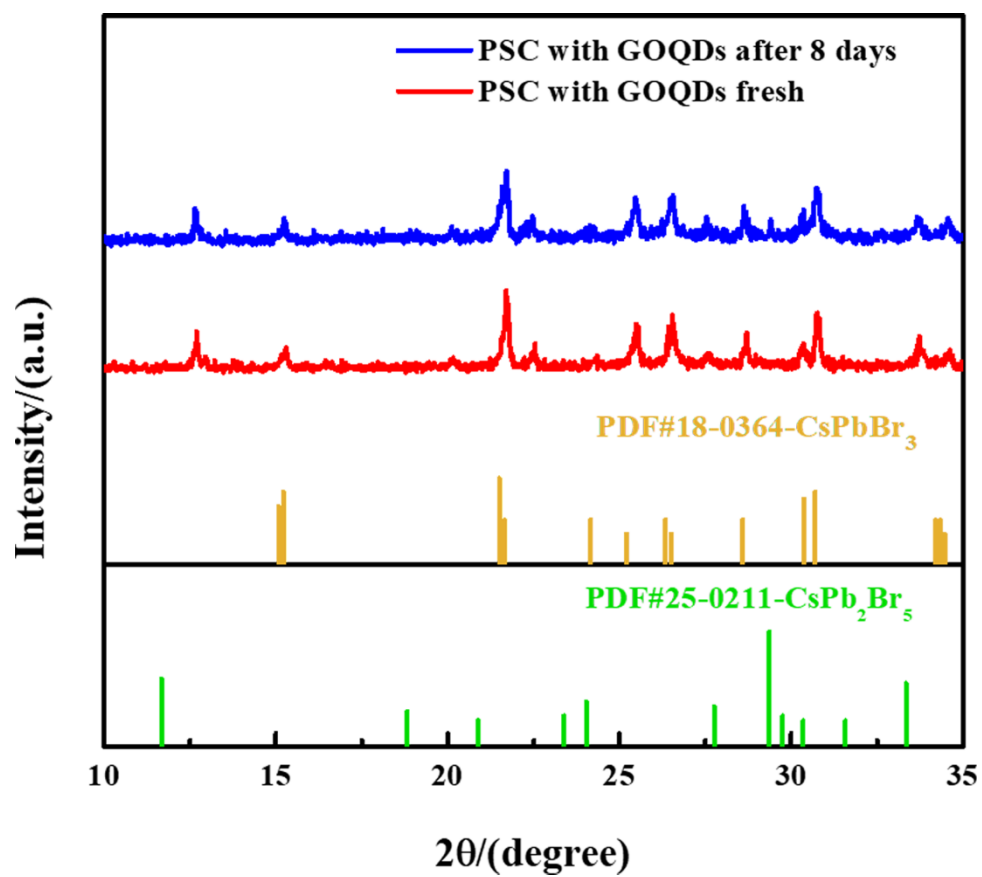


Figure S6. XRD patterns of the PSCs with GOQDs freshly made and after storing in atmosphere for 8 days.