Supplementary Information

Ligand-modulated electron transfer rates from CsPbBr3 nanocrystals to titanium dioxide

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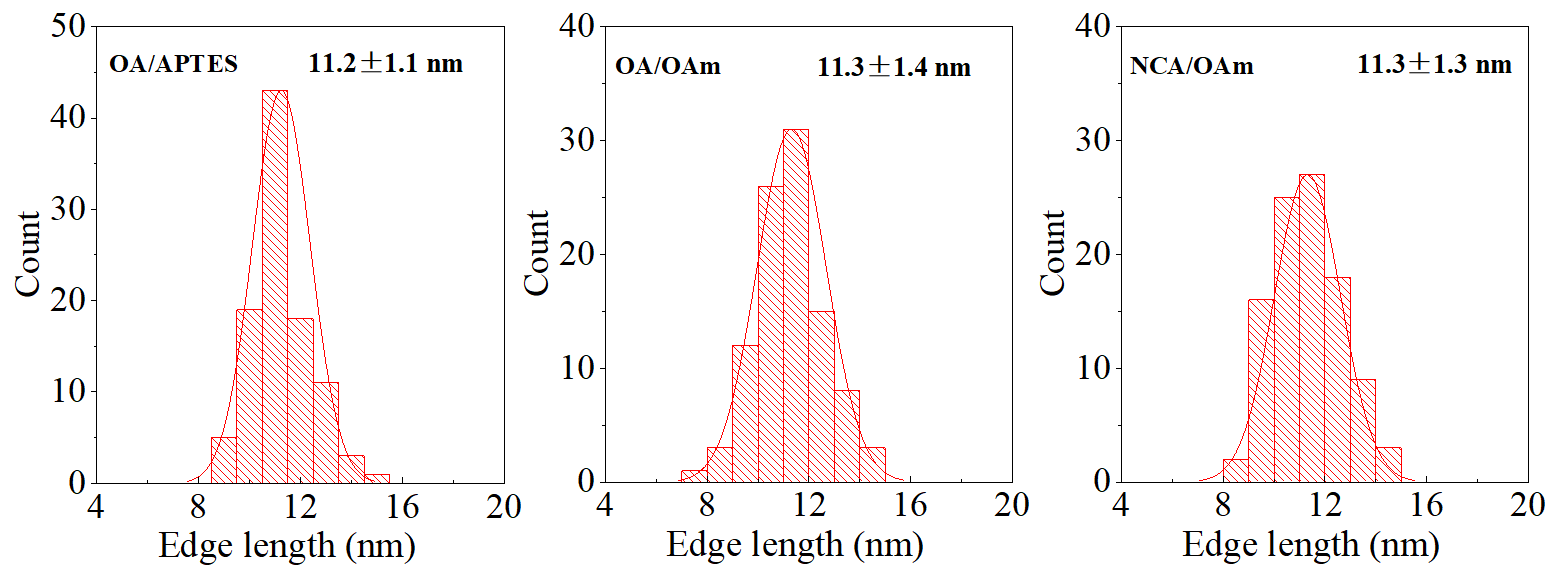
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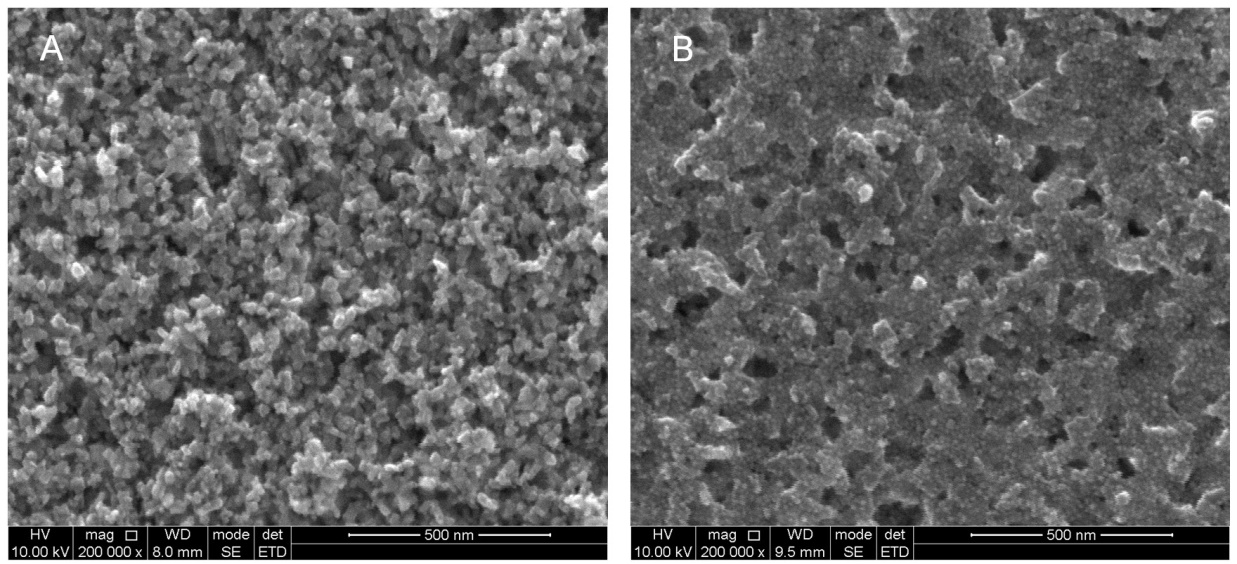
**Figure S1.** TEM image of OA/APTES-CsPbBr3 NCs with scale bars of 50 nm at low concentration. No cross-linking between different NCs is observed, indicating that inter-nanocrystal cross-linking in our APETS-NC systems can be excluded.



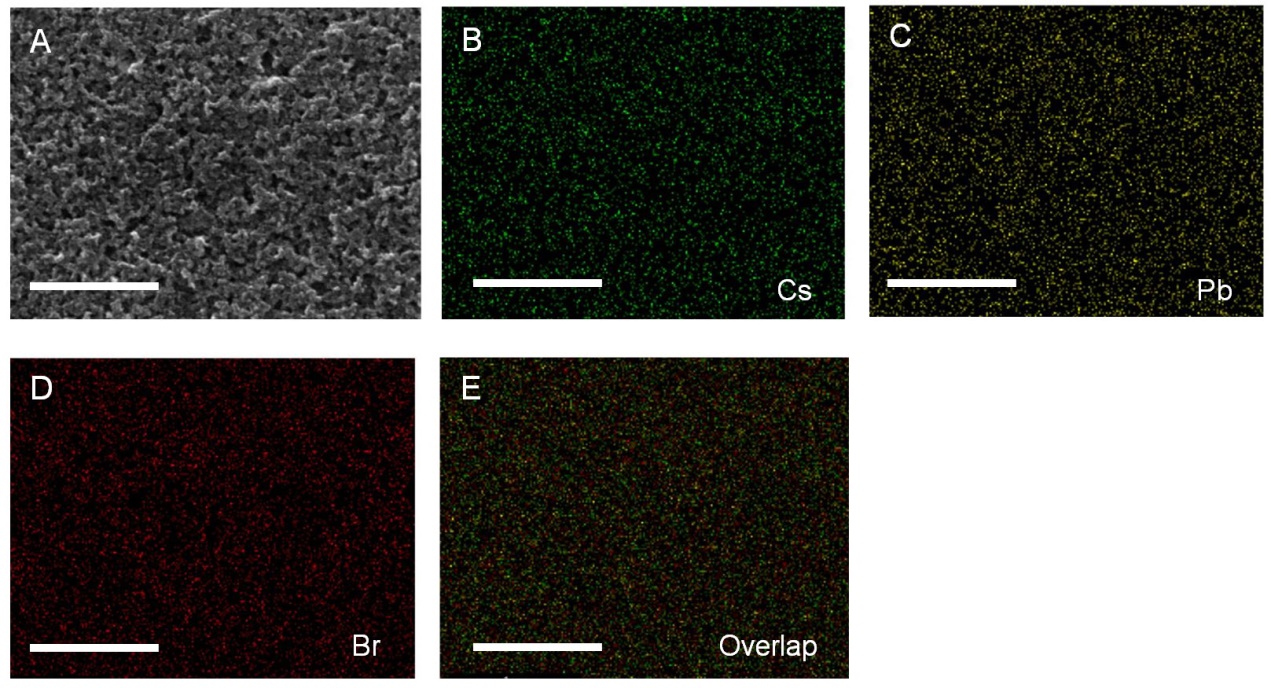
**Figure S2.** Size distribution of the synthesized OA/APTES-CsPbBr3, OA/OAm–CsPbBr3 and NCA/OAm–CsPbBr3 nanocrystals.



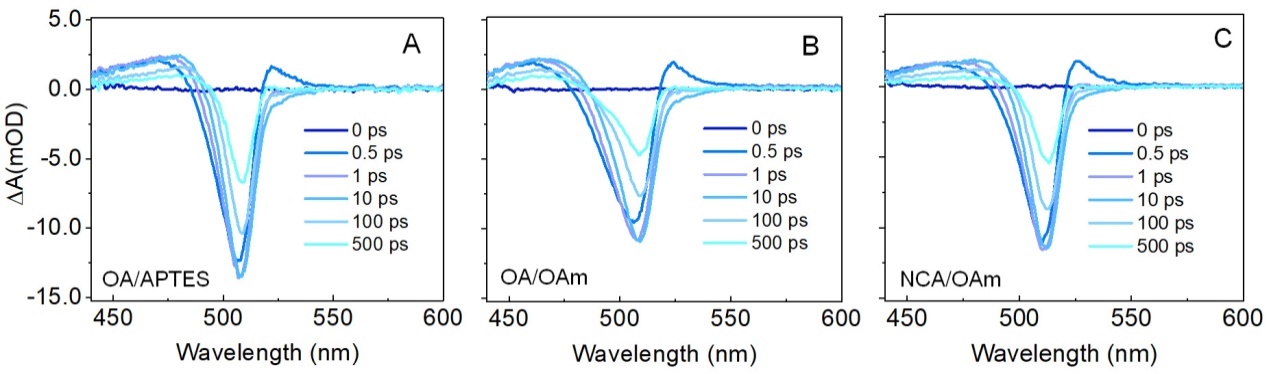
**Figure S3.** UV-Vis absorption spectra of APTES, OA, OAm and NCA solution in ethanol.



**Figure S4.** Top view SEM images of mesoporous TiO2 with (A) and without (B) OA/APTES-CsPbBr3 nanocrystals spin coated onto the surface under electron energy of 10 kV. The [homodisperse](javascript:;)d tiny particles can be clearly seen on surface of mesoporous TiO2 in (B), highlighting that CsPbBr3 nanocrystals have been successfully adsorbed onto the surface of mesoporous TiO2 without aggregation occurred.



**Figure S5.** (A) SEM image of OA/APTES-CsPbBr3 nanocrystals attached to mesoporous TiO2. The corresponding elemental mapping images of (B) Cs (green), (C) Pb (yellow), (D) Br (red) and (E) overlapped image of OA/APTES-CsPbBr3 nanocrystals attached to mesoporous TiO2. Scale bars are 1 µm.



**Figure S6.** (A-C) TA spectra of OA/APTES-CsPbBr3, OA/OAm-CsPbBr3 and NCA/OAm-CsPbBr3 nanocrystals at indicated time delays following 400 nm pump excitation.

**Figure S7.** Normalized decay-associated spectra of OA/APTES-CsPbBr3, OA/OAm-CsPbBr3 and NCA/OAm-CsPbBr3 nanocrystals attached to PMMA and mesoporous TiO2.



**Figure S8.** Kinetics of photoinduced bleach signal at 510 nm for (A) OA/APTES-CsPbBr3, (B) OA/OAm–CsPbBr3 and (C) NCA/OAm-CsPbBr3 nanocrystals dispersed in octane.

**Determination of the average number of excitons per nanocrystal.**

Based on a basic assumption that the distribution of excitons in a nanoparticle conforms to Poisson distribution:

P(N)=<N>Nexp(-<N>)/N! (1)

where <N> is the average number of excitons per nanoparticle, the normalized transient bleach signal amplitude at early delay time immediately after the intraband relaxation can be given by [1]:

Here, the fraction 0.5 results from the fraction bleaching of the 2-fold degenerate band edges of CsPbBr3 nanocrystals [2]. At very low pump fluence (<N> far less than 1), normalized transient bleach signal can be approximated by |∆A|/A ∝ <N>. Therefore, the average number of excitons per nanoparticle can be estimated by knowing the transient and steady state absorbance, |∆A| and A. In this work, for all three CsPbBr3 nanocrystal samples dispersed in octane, steady state absorbance A=0.2, the maximum bleach signal amplitude |∆A| ≈ 0.014 (Figure S8), thus we have <N> less than 0.14, within the linear dependence as discussed above. The pump fluence 16 nJ/pluse for transient measurements can avoid any multiple exciton induced effects.

**Reference**

[1] Aneesh J, Swarnkar A, Ravi VK, Sharma R, Nag A, Adarsht KV. Ultrafast exciton dynamics in colloidal CsPbBr3 perovskite nanocrystals: Biexciton effect and auger recombination. J Phys Chem C 2017;121:4734-4739.

[2] Swarnkar A, Chulliyil R, Ravi VK, Irfanullah M, Chowdhury A, Nag A. Colloidal CsPbBr3 perovskite nanocrystals: Luminescence beyond traditional quantum dots. Angew Chem Int Edit 2015;54:15424-15428.