Supporting information for

Improving Anion-Exchange Efficiency and Spectrum Stability of Perovskite Quantum Dots *via* Al^{3+} Bonding-Doping Synergistic Effect

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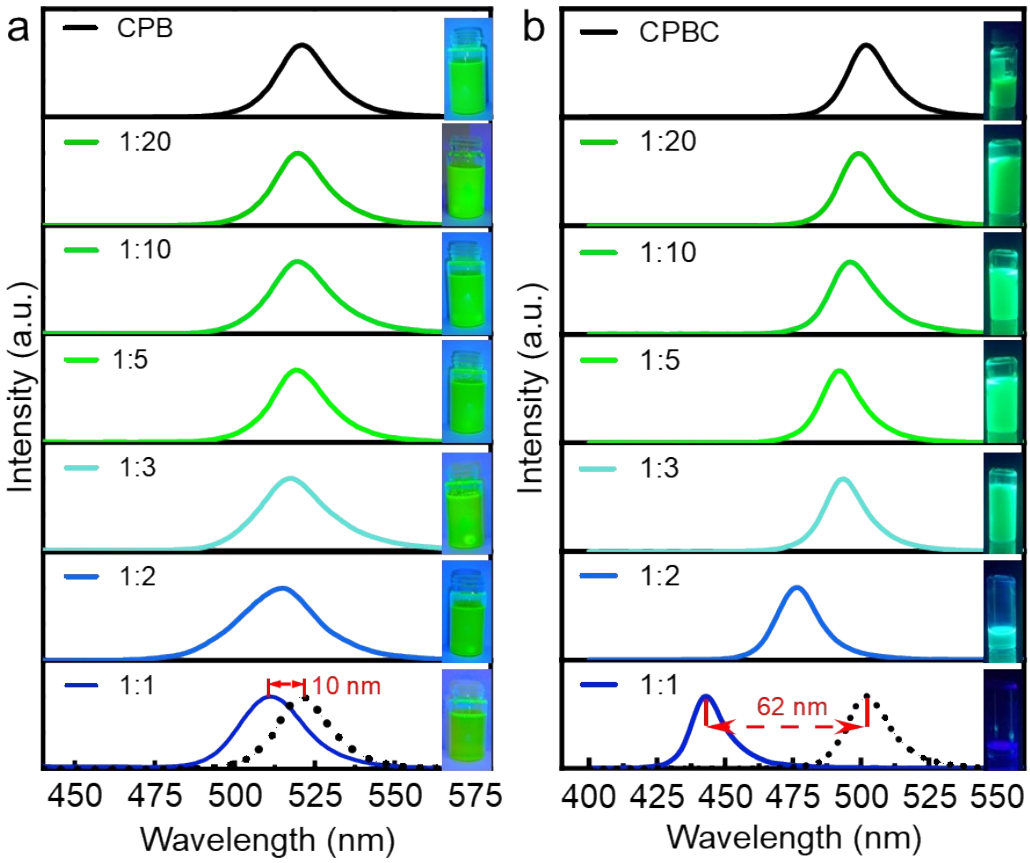

Figure S1. The spectra of CPB, CPBC, ACPB and ACPBC QDs. **a.** The PL spectra of crude solutions (CPB, the ratio of Al:Pb changes from1:20 to 1:1). The illustrations demonstrate samples under ultraviolet (UV) light. **b.** The PL comparison of CPBC and ACPBC QDs (ratio of Al:Pb vary from 1:20 to 1:1). Inserts demonstrates the solutions after anion exchange.

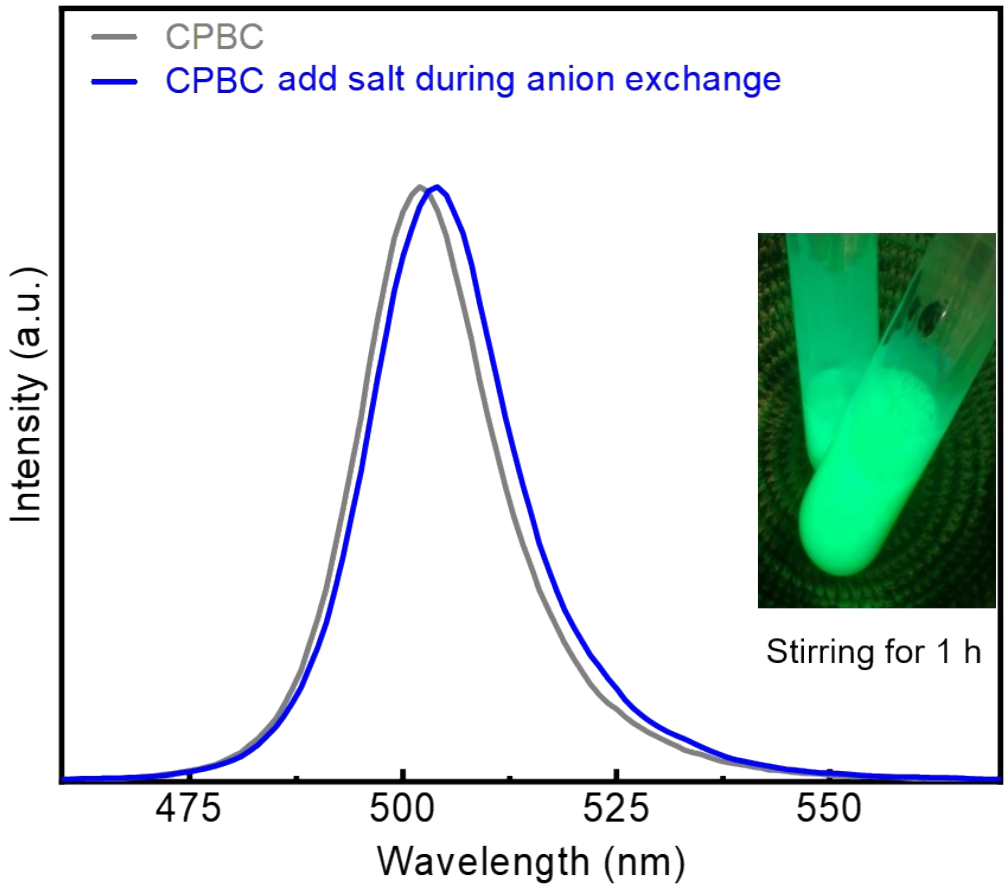

Figure S2. The PL spectra of CPB QDs without and with Al-salt added during anion exchange. The ratio of Al/Pb and the amount of DDAC is fixed as 1:1 and 0.1 mmol.

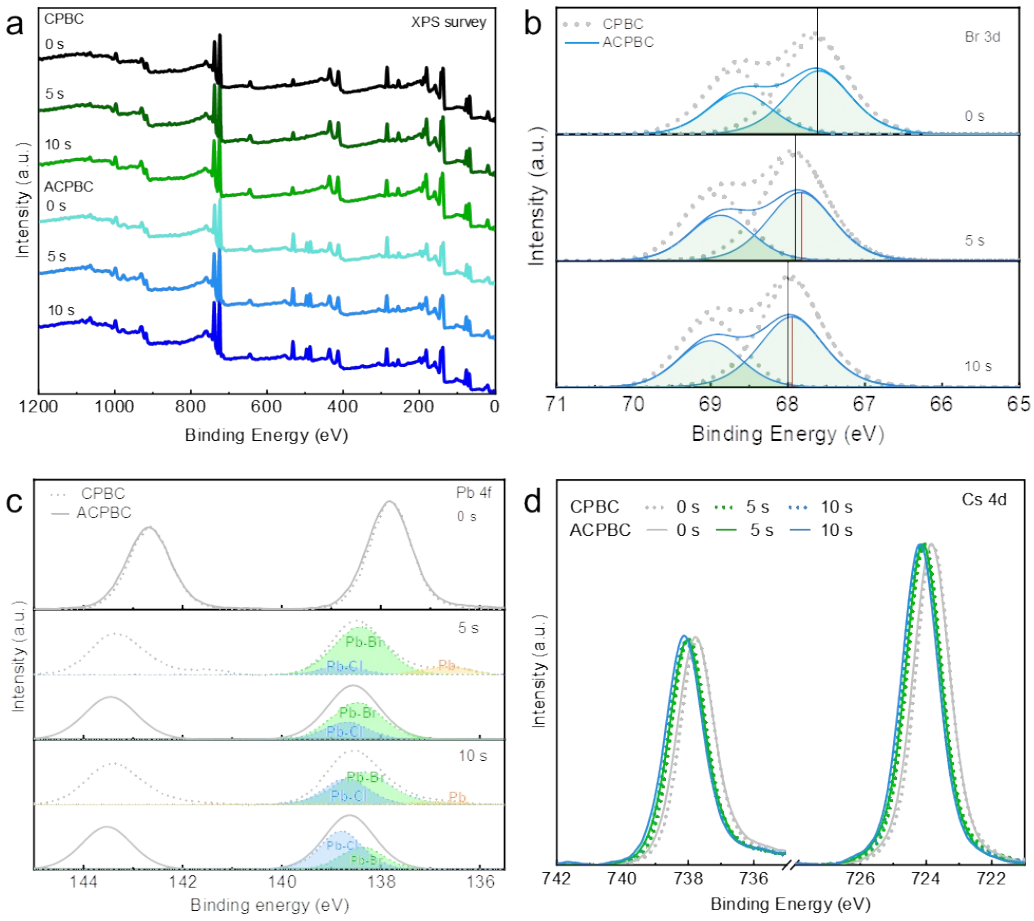

Figure S3. XPS spectra of CPBC and ACPBC QDs. **a.** The survey spectra of CPBC and ACPBC QDs under etching for 0s, 5s and 10s. **b.** The Br XPS spectra of CPBC and ACPBC QDs, the binding energy shift to higher level. **c.** The Pb XPS spectra of CPBC and ACPBC QDs. The peaks of Pb-Br and Pb-Cl can split two characteristic peaks (shaded area). **d.** The Cs XPS spectra of CPBC and ACPBC QDs under etching for 0s, 5s and 10s, the binding energies of two sample are approximate.

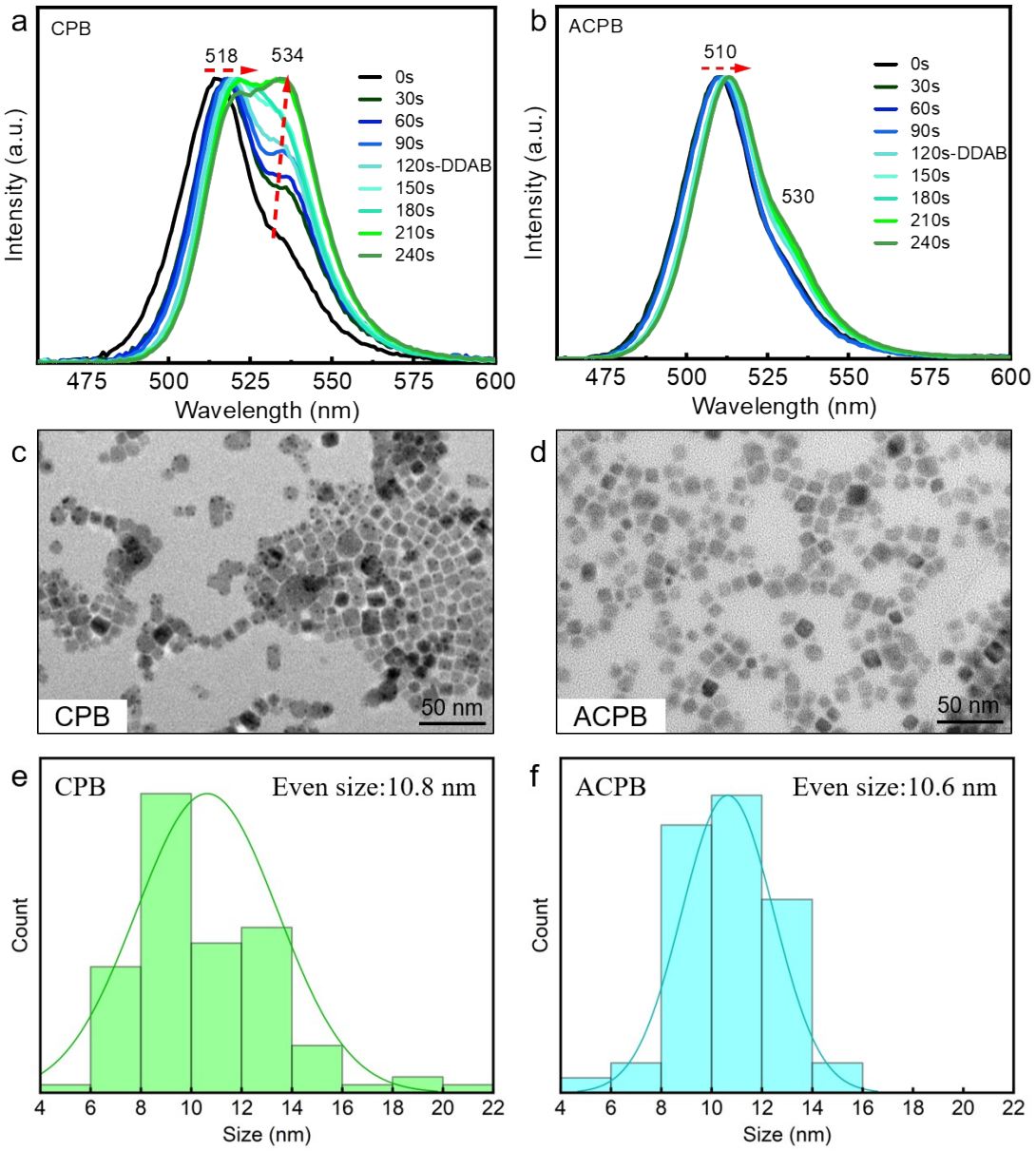

Figure S4. The in-situ PL spectra of CPB **(a)** and ACPB **(b)** QDs. the Cs-precursor is injected to Pb-precursor at 0 s, and DDAB solution is injected at 120 s. **c.** and **d.** The TEM graphs of CPB and ACPB QDs. **e.** and **f.** The size distribution of CPB and ACPB QDs, the later indicates a more uniform distribution, while there are individual large grains for the former.

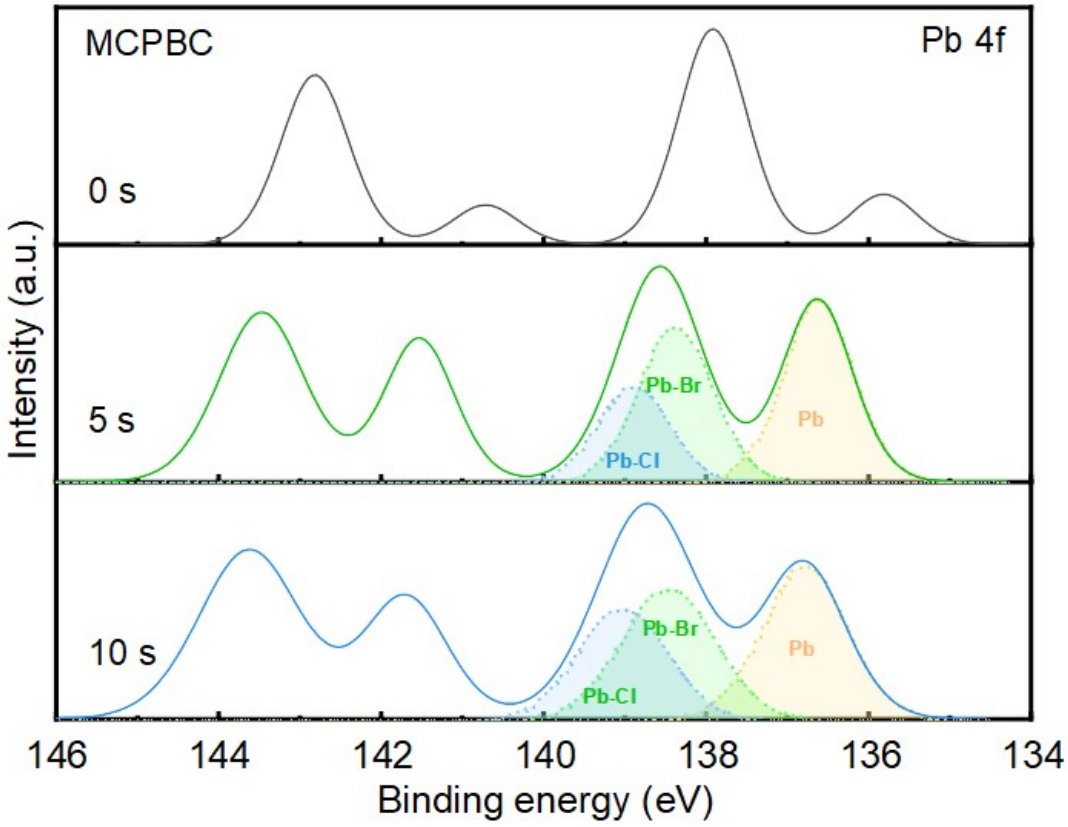

Figure S5. The XPS data of Pb in MCPBC QDs, the gray, green and blue respectively represent etching for 0, 5 and 10 s. There has a more obvious peak attribute to Pb^0 than that of CPBC and ACPBC (**Figure S3c**), demonstrating weaker stability of lattice structure.

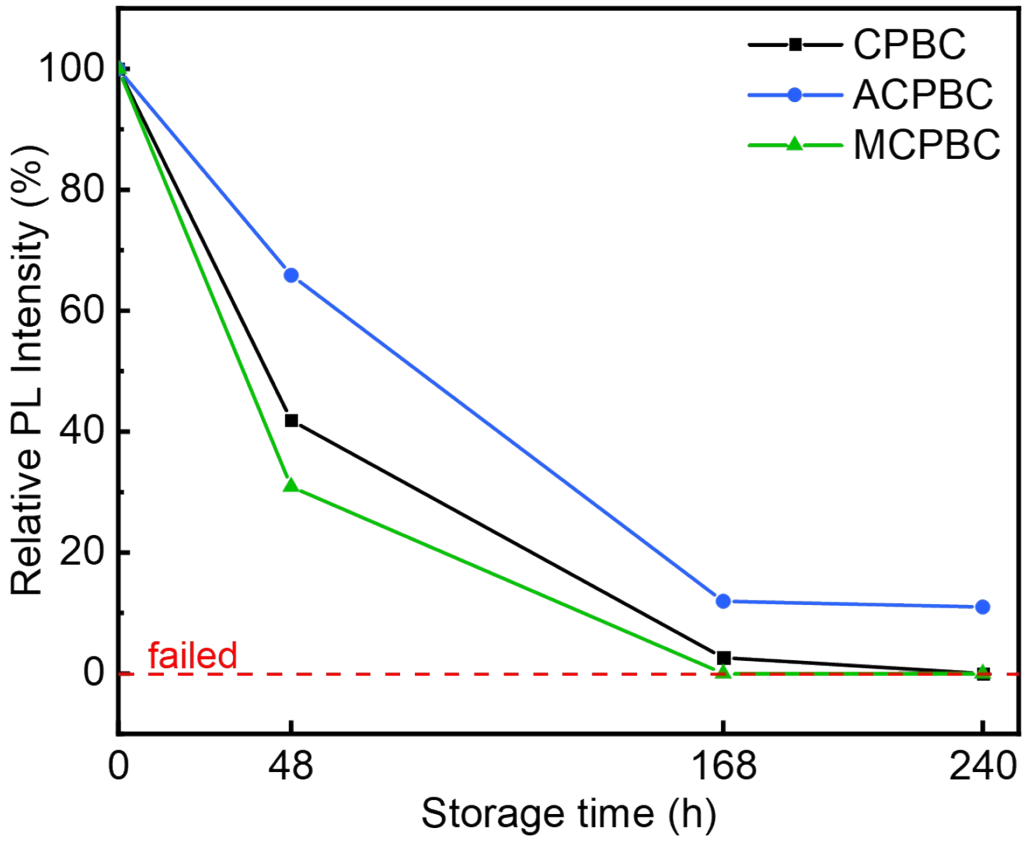

Figure S6. The decline of relative PL intensity among QDs with different storage time. ACPBC (blue) QDs demonstrate a better stability against moisture than CPBC (black) and MCPBC (green).

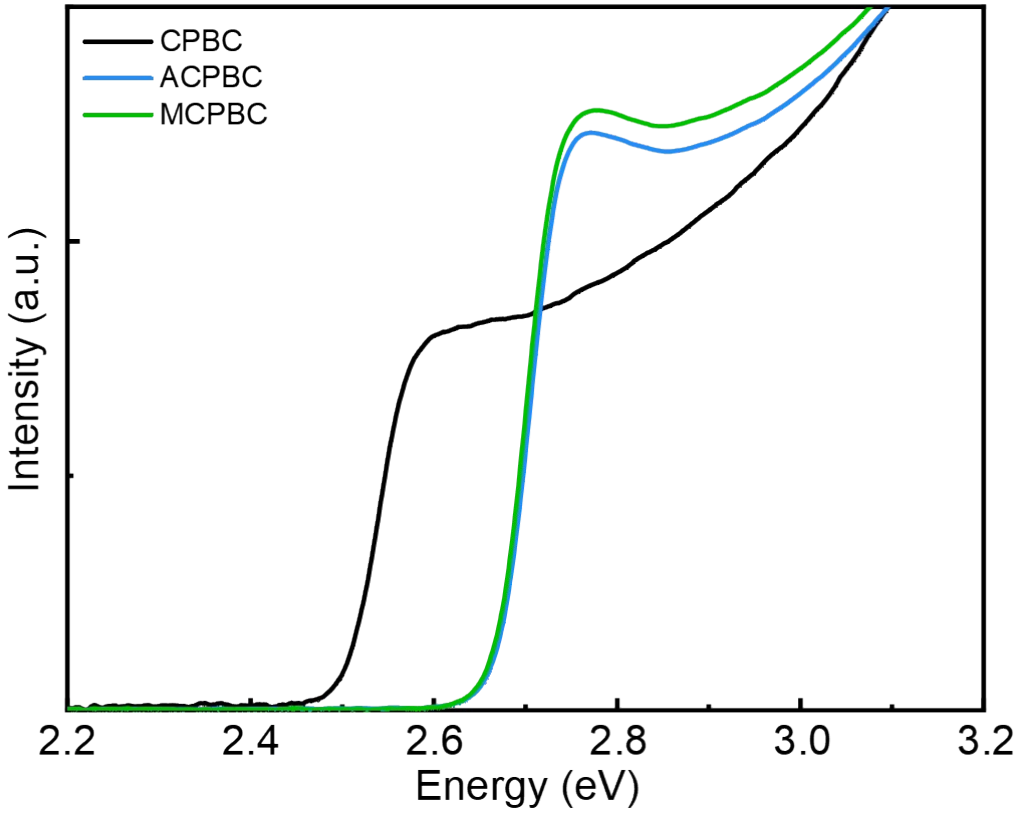

Figure S7. The bandgap curves of CPBC, ACPBC and MCPBC QDs, which are obtained from the absorption curves.

Table S1. The fitting of TRPL of QDs, a dual-exponential fitting method is adapted to calculate the average lifetime.

QDs	A_1 (%)	τ_1 (ns)	A_2 (%)	τ_2 (ns)	τ_{avg} (ns)
CPBC	61.0	11.72	39.0	41.55	32.43
ACPBC	41.8	8.10	58.2	61.82	57.21
MCPBC	45.6	8.40	54.4	40.91	36.14