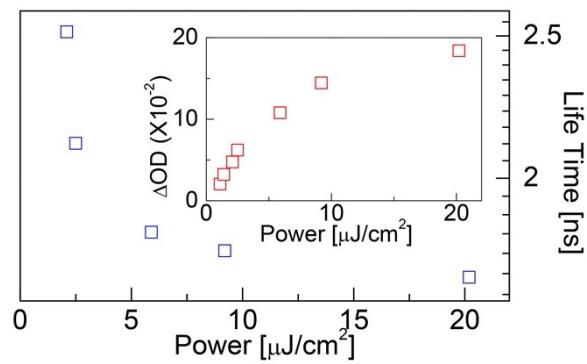


**PHYSCHEMCHMOPHY**

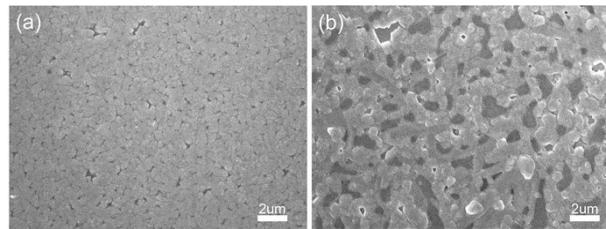
Supporting Information

**Elucidating the Band Structure and Free Charge  
Carrier Dynamics of Pure and Impurities Doped  
 $\text{CH}_3\text{NH}_3\text{PbI}_{3-x}\text{Cl}_x$  Perovskite Thin Films**

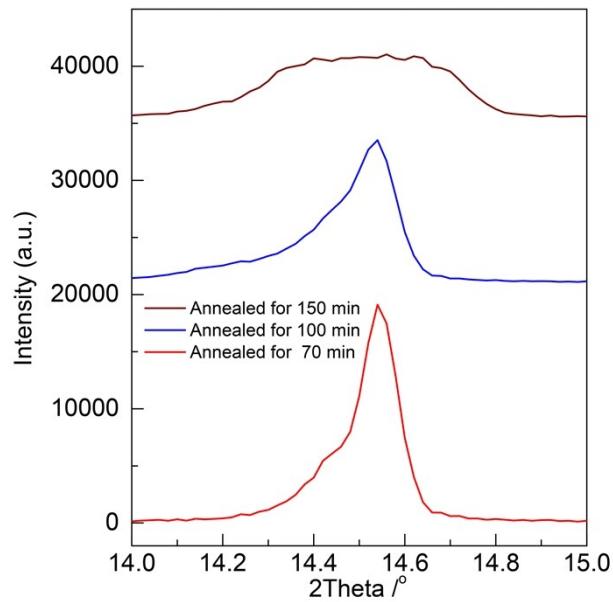
Zhen-Yu Zhang,<sup>[a]</sup> Xin Chen,<sup>[a]</sup> Hai-Yu Wang,<sup>\*[a]</sup> Ming Xv,<sup>[a]</sup> Bing-Rong Gao,<sup>[a]</sup> Qi-Dai Chen,<sup>[a]</sup> and Hong-Bo Sun<sup>\*[a]</sup>



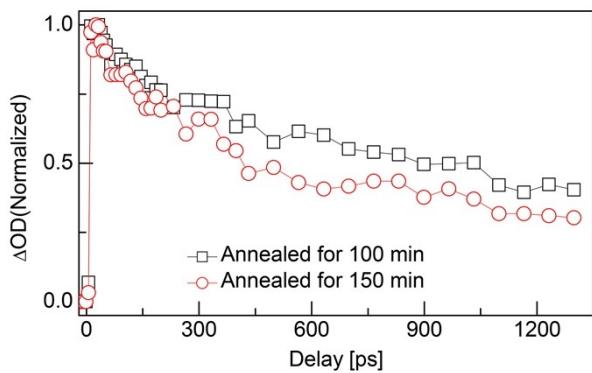
**Figure S1** The free carrier lifetime showing the faster excited-state recombine rate with increased pump intensity, and the inset displays that the signal/carrier intensity shows the positive relationship with the increased pump intensity.



**Figure S2** The SEM images of precursor films thermal annealed under different time at  $\sim 80$   $^{\circ}\text{C}$  in a nitrogen filled glove box. (a) Thermal annealed for 70 min, (b) thermal annealed for 150 min. The SEM image shows us that the perovskite film under the proper thermal conditions (time and temperature) exhibits well compactness with rare interspace. The excessive thermal annealing time will results to the decomposition of the perovskite film. As shown in the image (b), the interspace dramatically increased, corresponding, the defect-state come to play a role, reducing the performance of the perovskite-based device. The scale bar is 2 $\mu\text{m}$ .



**Figure S3** The detailed spectra FWHM of perovskite crystalline orientation (110), the FWHM increased with the excessive thermal decomposed process, and this is the indicative of the decreased perfection of perovskite lattice.



**Figure S4** The kinetic profiles of 485 nm bleaching signal under identical pump intensity of perovskite films under different annealing time (square: 100 min, circle: 150 min). The longer excessive thermal annealing time induced more defect-related recombination channel, and it accelerated the recombination rate.