Area: Perovskite Solar Cells

TOWARDS HOT CARRIER PEROVSKITE SOLAR CELLS

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Perovskite solar cells have achieved unprecedented efficiencies of ~22% efficiencies. This outstanding performance stems from their novel properties of large absorption coefficients, long balanced electron-hole diffusion lengths[1], inherently low defect densities[2] *etc*. For any further substantial gains in perovskite solar cell performance, it is imperative that we leverage on novel photovoltaic concepts like hot carriers where these perovskites possess a unique slow hot carrier cooling phenomena that was first reported by Xing *et. al.* in 2013.[1] This phenomena could potentially be exploited for developing hot carrier perovskite solar cells. Hot carrier solar cells offer a tantalizing prospect of transcending the Shockley-Queisser limit by harvesting the excess energy from hot carriers that would be otherwise lost as heat in conventional solar cells. Theoretical limits up to 66% efficiency are possible with hot carrier solar cells. However, suitable materials are few and far between. Inorganic semiconductor quantum dots were once considered as potential candidates due to their perceived hot phonon bottleneck under quantum confinement. Regrettably, harvesting of their hot carriers was compromised by the highly competitive relaxation pathways that breached their phonon bottlenecks. Herein, we reveal that colloidal perovskite nanocrystals can overcome these challenges. Our findings show that these perovskite nanocrystals exhibit around two orders slower hot-carrier cooling times and around four times larger hot-carrier temperatures than their bulk-film counterparts.[3] Under low intensity photoexcitation, a phonon bottleneck mediates the cooling of hot carriers, which is surprisingly slower in smaller nanocrystals in contrast to conventional inorganic semiconductor nanocrystals. Under high intensity photoexcitation, Auger heating mediates the hot-carrier cooling, which is slower in larger nanocrystals and was not observed in conventional semiconductor nanocrystals. Importantly, we achieved highly efficient room temperature hot-electrons extraction (~83%) from surface-treated perovskite nanocrystal thin films to an energy-selective electron acceptor layer. These new insights would allow the development of extremely thin absorber and concentrator-type hot-carrier perovskite solar cells.

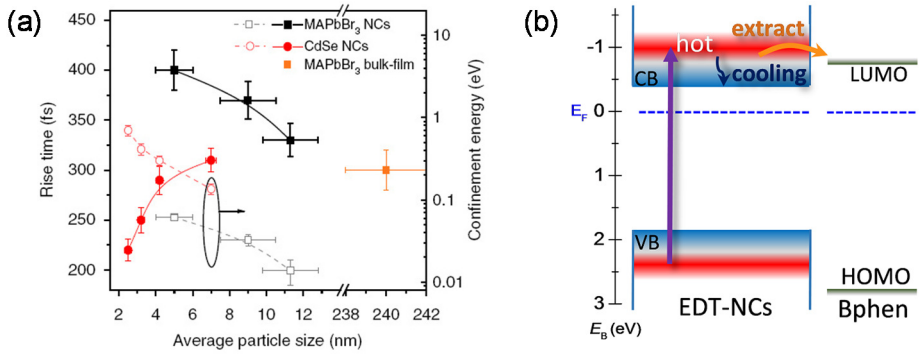

Figure 1: **(a)** Unlike CdSe nanocrystals (NCs) (red solid line), the cooling (i.e., rise times) of perovskite (methyl ammonium lead bromide (or $MAPbBr_3$) NCs (black solid line) become slower as particle size decreases. **(b)** Schematic of highly efficient hot carrier extraction with an energy selective layer Bphen. Images adapted from reference 3.

References

1 Xing, G. *et al.* Long-range balanced electron-and hole-transport lengths in organic-inorganic $CH_3NH_3PbI_3$. *Science* **342**, 344-347 (2013).

2 Xing, G. C. *et al.* Low-temperature solution-processed wavelength-tunable perovskites for lasing. *Nature Materials* **13**, 476-480, doi:10.1038/Nmat3911 (2014).

3 Li, M. *et al.* Slow cooling and highly efficient extraction of hot carriers in colloidal perovskite nanocrystals. *Nature Communications* **8**, 14350, doi:10.1038/ncomms14350 (2017).