Asymmetric Charge Carrier Transfer and Transport in Planar Lead Halide Perovskite Solar Cells

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Introduction

Understanding the extraction of charge carriers from perovskite photoactive layer is critical to optimizing the design of perovskite solar cells. Herein we focus on using a simple time-resolved photoluminescence (TRPL) method to characterize charge transport across bulk perovskite and charge transfer from perovskite to interlayers, elucidating their dependence on film thickness, boundary (GB) and interlayers. Particularly, with asymmetric laser excitation, we selectively probe charge transport by generating charges away from heterojunction interface and charge transfer by generating charges near the interface, ultimately correlate these properties with device performance. We observed that whilst both kinetics affected by film thickness and GBs, there is an asymmetry between electron and hole transport across bulk perovskite as well as electron and hole transfer from perovskite to interlayers.

Asymmetric excitation of perovskite samples with 404nm laser

1. Neat MAPI films do not show much difference in long time decay meaning they have same majority of bimolecular recombination kinetics. However, the first fast decay associated to the defects illustrates that the films have a different trap densities. AAS: Aerosol assisted solvent annealing treatment.

Device performance and morphology: Evidence of grain boundaries

By making perovskite thick, V_{oc} is increased but FF is dropped due to the formation of GBs in the vertical way. After AAS, GBs are removed, V_{oc} and especially FF are further increased.

Steady-state PL measurement of neat perovskite films: film property

Non-radiative recombination loss: 250nm-750nm neat perovskite on glass substrate. Indicative of the same order in terms of trap density

1-D diffusion mode is used to calculate the mobility

Conclusion:

In summary, by simply growing perovskite thicker, traps can be largely reduced therefore contributing to a huge improvement in V_{oc}. However, by using asymmetric excitation in surface quenching TRPL method, we found thick MAPI suffers from imbalanced charge transport within the bulk between electron and hole due to GBs hinders more on hole transport rather than electron. By employing AAS, GBs in the thick MAPI can be effectively eliminated, a more balanced and faster charge transport is obtained. These properties facilitate charge extraction in total, though slow hole transfer still limits the efficiency. Finally, PSC with 20% is achieved mainly due to the increase in FF.