Elucidating the long-range charge transport in metal halide perovskite semiconductors

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Many different standard spectroscopic measurements have been employed for precise quantification of key optoelectronic properties (i.e. light absorption strength, bandgap, charge carrier lifetime and radiative efficiency) of metal halide perovskites. It has been greatly beneficial for rapidly advancing the quality of perovskite thin films and ensuing solar cell efficiency.

In contrast, charge carrier mobility (ratio between the drift velocity and the electric field), has proven to be much more challenging to quantify. In addition to mobile electrons and holes, the mobile ions in metal halide perovskites redistribute in an applied electric field. It negates many benefits of standard spectroscopic techniques to quantify mobility, such as nanosecond to millisecond transient methods, time-of-flight and space charge limited current measurements. Indeed, an accurate estimation of charge carrier density is hindered by early-time recombination, the branching ratio of excitons to free-carriers and sensitivity to short-range conductivity unlikely influenced by scattering events at grain boundaries and charge trapping. It is, therefore particularly more important to understand the long-range charge transport within the metal halide perovskite for optimisation of operating devices, where the charges have to travel over on the order of microns, and if these properties change in different carrier density regimes, or through different methods of processing the films.

Here the present talk introduces a new methodology and also highlights an advanced optical and electrical methodologies: Photoinduced transmission and reflection (PITR), Transient photo-conductivity (TPC), Pulsed-voltage space charge limited current (PV-SCLC), Linear-tracking Time-of-flight (LTOF). With these methods, we accurately estimated the internal free-carrier density during photo-excitation, accounting for both early-time recombination and exciton-to-free-carrier branching ratios to determine long-range charge carrier mobility in metal halide perovskite thin films and single crystals, to be invariant over many orders of magnitude of charge density. We also demonstrate that the processing method of perovskite layer has a strong influence on the long-range charge transport. We believe this study is the first accurate evaluation of photo-induced long-range mobility of metal halide perovskites, and therefore represents a new handle for future optimisation of perovskite solar cells and optoelectronic devices. Moreover, we expect our methodology to be especially useful for polycrystalline and nanostructured semiconductor materials, where the long-range mobility is expected to vary considerably in comparison to the short-range mobility, such as quantum dots, carbon materials, semiconducting organic molecules and metal oxides.

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