MASTER'S THESIS

Defect characterization of organic/inorganic semiconductors using photothermal deflection spectroscopy and thermal admittance spectroscopy

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Abstract

Traps are ubiquitously present in semiconductors. Their presence results in ineffective charge transport and thus limited the device performance. For organic semiconductors, traps can present intrinsically via structural disorder or extrinsically during synthesis or device fabrication. A thorough understanding of traps is important to optimize the device performance and material design. This thesis employs two trap measurement techniques, photothermal deflection spectroscopy (PDS) and thermal admittance spectroscopy (TAS), to investigate the trap density in the materials.

The subgap optical absorptions of several high performance bulk-heterojunction (BHJ) systems for organic solar cells have been studied by PDS. The charge transfer (CT) states are, in particular, looked into detail. CT states are intermediate bound electron-hole pairs at the donor/acceptor (D/A) interface of an organic solar cell. The dynamics and energetics of CT states are crucial to free charge generation and recombination processes. With the help of PDS and external quantum efficiency (EQE) measurements, the CT states the delocalized CT states (hot) from the localized CT states (cold) are observed and differentiated directly. It is discovered that the localized CT states are more pronounced when the acceptor concentration reaches its percolation limit. As the acceptor concentration reaches its optimized composition, the intensity of these CT states is significantly reduced due to the reduced recombination. Using the CT

energies measured from PDS, the open-circuit voltage losses from the BHJs are determined.

Besides PDS, thermal admittance spectroscopy (TAS) is employed as an alternative method to measure the trap densities. TAS measures the frequency dependent capacitance response of a semiconductor under a small ac signal excitation. This technique is useful to measure the trap depth and trap density of a semiconductor. The defect profiles in two classes of materials are investigated, they are perovskite compounds and an organic hole transporter with an intentional dopant. The trap density are determined by TAS is compared with that obtained by PDS.

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