**DEVICE PHYSICS AND STABILITY OF EMERGING SOLAR CELLS**

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***Abstract*** - We report on fundamental electronic properties of the PTB7:PCBM70 bulk heterojunction solar cells: Sub-gap quantum efficiency measurements determine the Urbach energy of tail states (33 meV) and D/A interfacial bandgap (1.34 eV). Density of deep defects is determined by capacitance spectroscopy, and is ~1016 cm-3.eV-1. By photo-current spectroscopy, we assess surface recombination velocity at D/A interface, which translates to a capture cross-section of ~10-16 cm2for deep defects. These properties are then used in our analytical modeling. Using a multiple-level trap model, we compute recombination rates in the cells. The model can predict dark saturation currents and ideality factors, and strongly suggests that band tail recombination is the main limiting factor of open-circuit voltage.

Additionally, we find that, upon light exposure, photo-induced defects lead to increased trap-assisted recombination and photo-voltage instability. To increase photo-stability, we propose a novel n-i-p hybrid device where n+/a-Si:H is used as the front contact of the bulk heterojunction. Highly energetic photons (blue and UV light), which induce defects in the light-absorbing material, are blocked (absorbed) in the n+/a-Si:H layer. This leads to significant reduction of photo-induced damage in the blend, and thereby enhances photo-stability. Some photo-current is, however, lost due to absorption in n+/a-Si:H. In order to overcome this drawback, we present a novel organic-inorganic hybrid tandem solar cell, in which blue photons are harvested by an a-(SiC):H front cell. A PTB7:PCBM70 cell is used as the back cell. Our results demonstrate a VOC of 1.67 V, JSC of 7.3 mA/cm2 and overall efficiency of 7.6%, which is among the highest reported in the literature.

In the last part of this dissertation, we study the electronic properties of methyl-ammonium lead iodide perovskite solar cells. Capacitance spectroscopy shows the existence of a shallow (0.24 eV) and a deep (~0.62 eV) defect band in the bandgap. Moreover, we find that attempt-to-escape frequency is ~1011 Hz. The deeper defect band has a Gaussian distribution with a peak density of ~3×1016 cm-3.eV-1. Ideality factors and dark saturation currents indicate that band-to-band recombination is dominant at high excitation levels, and limits the photo-voltage.