

Loss mechanisms in Polymer-Fullerene Solar Cells  
Carsten Deibel, Alexander Foertig, Vladimir Dyakonov  
Experimental Physics VI, Julius-Maximilians-University  
of Würzburg  
Am Hubland, 97070 Würzburg, Germany

A combination of transient photovoltage (TPV), voltage dependent charge extraction (CE) and time delayed collection field (TDCF) measurements is applied to Poly[[4,8-bis[(2-ethylhexyl)oxy]benzo[1,2-b:4,5-b']dithiophene-2,6-diyl] [3-fluoro-2-[(2-ethylhexyl)carbonyl] thieno[3,4-b]thiophenediyl]] (PTB7):[6,6]-phenyl-C71-butyric acid (PC71BM) bulk heterojunction solar cells to analyze the limitations of solar cell performance of devices processed from pure chlorobenzene solution or with 1,8-diiodooctane (DIO) as a co-solvent. The dramatic change of the power conversion efficiency from about 3% to about 7% upon adding DIO are investigated in view of the dominating loss processes. While in the devices processed from chlorobenzene solution severe geminate and nongeminate recombination losses are observed, the use of DIO facilitates charge photogeneration and strongly reduces geminate losses. Thus, from the determined charge carrier decay rate under open circuit conditions and the voltage dependent charge carrier densities  $n(V)$  the nongeminate loss current  $j_{\text{loss}}$  of the device allows us to reconstruct the current/voltage characteristics across the whole operational range of PTB7:PC71BM solar cells. In contrast, for the case without DIO the reconstruction deviates from the measured  $j/V$  characteristics. We show that this discrepancy is due to a combination of field dependent photogeneration and trapped charge carriers in isolated domains of pure fullerene phases. The nongeminate recombination dynamics are explained in detail, and are discussed in view of the relative importance of Langevin-like and trap-assisted recombination.