# Electrons meet holes in organic solar cells: or why and how they don't (so much)

(Traditional title: Charge carrier losses in organic solar cells -- from density of states to recombination rate)

Carsten Deibel, Institut für Physik, Technische Universität Chemnitz, 09126 Chemnitz, Germany

Recombination of already separated charge carriers in organic solar cells is the major loss mechanism, limiting the attainable power conversion efficiencies. This is despite the fact that charge carrier annihilation is often described by the so called reduced Langevin recombination, a rate reduced by orders of magnitude compared to the original theory. While experiments of recombination in organic blend solar cells can be approximated with this model, I will discuss several aspects going beyond its level of detail. I will touch on spatial effects as well as energetic effects. The energetic landscape has an influence on the recombination which can, for instance, be expressed in terms of the order of decay and the ideality factor. I will compare the charge carrier dynamics measured by transient absorption for two model systems, P3HT:PCBM [1] and PTB7:PC70BM, and compare the order of decay to the expectations from the density of trap states meaured by thermally stimulated currents [2]. Concerning the role of spatial effects, I will briefly present two contributions to a reduced recombination rate: by charge carrier concentration gradients [3,4], shown by macroscopic device simulations, and the donor-acceptor phase separation [5,6], based on kinetic Monte Carlo simulations.

While a lot of progress has been made in the last years to understand charge carrier losses in organic solar cells, with the facets I have presented contributing to a more complete picture, not all aspects are well understood yet. Therefore, I hope on a lively discussion, for instance concerning the role of redissociation of bound pairs, doping, band bending in devices (electrodes), polaronic relaxation, etc.

[1] J. Gorenflot, M. C. Heiber, A. Baumann, J. Lorrmann, M. Gunz, A. KaÃàmpgen, V. Dyakonov, and C. Deibel. J. Appl. Phys., 115:144502, 2014
[2] A. Foertig, J. Rauh, V. Dyakonov, and C. Deibel. Phys. Rev. B, 86:115302, 2012
[3] C. Deibel, A. Wagenpfahl, and V. Dyakonov. Phys. Rev. B, 80:075203, 2009
[4] F. Deledalle, P. S. Tuladhar, J. Nelson, J.R. Durrant, T. Kirchartz, J. Phys. Chem. C, 118:8837, 2014
[5] L. J. A. Koster, V. D. Mihailetchi, R. Ramaker, P. W. M. Blom, Appl. Phys. Lett., 86:123509, 2005
[6] M. C. Heiber, C. Baumbach, V. Dyakonov, and C. Deibel. Phys. Rev. Lett., 114:136602, 2015