Evidence for Strong Electronic Correlations and Band-Gap Renormalization in Doped Single-Wall Carbon Nanotubes

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We have investigated the photophysical properties of chemically and of gate-doped semiconducting single-wall carbon nanotubes (s-SWNTs) using stationary [1] and femtosecond time-resolved spectroscopy [2]. The continuous wave (CW) measurements have focussed on doping induced changes of exciton oscillator strengths and their spectroscopic quantification as well as on the appearance of trion-like absorption and emission features below the first subband exciton transition. Time-resolved spectroscopy has aimed at elucidating the coupling between trion- and exciton-states in moderately charged SWNTs.

Stationary measurements revealed that the first subband exciton oscillator strength - as obtained from absorption spectra - can be used for assessment of carrier densities and that they provide evidence for band-gap renormalisation (BGR) in (6,5) SWNTs. We predict that BGR of one-dimensional gate doped semiconductors is accompanied by a stepwise increase of the carrier density by $\Delta n = 32 m_{eff}\, b/(\pi\hbar)^2$ once the electrochemical potential reaches the valence or conduction band offset with b = (0.15 ± 0.05) eV nm (m_{eff} - effective carrier mass). Moreover, we show that the width of the spectroelectrochemical window of the first subband exciton of (1.55±0.05) eV corresponds to the fundamental band gap of the undoped (6,5) SWNTs in our samples and not to the renormalized band gap of the doped system. We also compare spectral changes in gate doped SWNTs with those of chemically doped SWNTs.

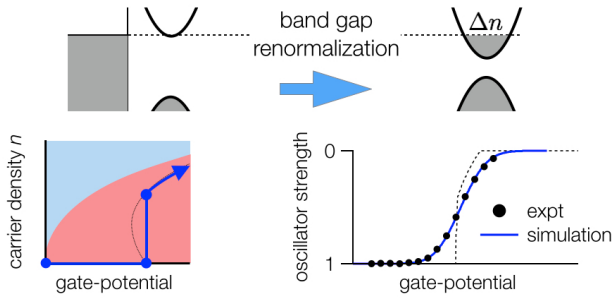

Figure 1. Schematic illustration of gate doping and band gap renormalization in a 1D semiconductor.

Femtosecond time-resolved pump-probe spectroscopy of chemically doped SWNTs provides evidence of strong exciton-trion coupling. These observations as well as a previously unidentified absorption band emerging at high doping levels in the Pauli-blocked region of the single-particle Hartree band structure, provide clear evidence for strong electronic correlations in the optical spectra of SWNTs.

[1] H. Hartleb, F. Späth and T. Hertel *Evidence for Strong Electronic Correlations in the Spectra of Gate-Doped Single-Wall Carbon Nanotubes*, ACS Nano, **9**, 10461 (2015).
[2] K. Eckstein and T. Hertel (in preparation).