Light-assisted charge spreading and charge trapping in 1D organic semiconductor nanocrystals on 2D materials probed by AFM based techniques

Christian Teichert[1], Aleksandar Matković[1], Markus Kratzer[1], Jakob Genser[1], Bernd Kollmann[2], Daniel Lüftner[2], Peter Puschnig[2], Zhongrui Chen[3], Olivier Siri[3], Conrad Becker[3]

[1]Institute of Physics, Montanuniversität Leoben, Franz Josef Strasse 18, 8700 Leoben Austria
[2]Institute of Physics, University of Graz, NAWI-Graz, Universitätsplatz 5. 8010 Graz, Austria
[3]Aix Marseille Université, CNRS, CINaM UMR 7325, 13288 Marseille, France

Crystalline films of small conjugated molecules offer attractive potential for fabricating organic solar cells, organic light emitting diodes (LEDs), and organic field effect transistors (OFETs) on flexible substrates. Here, the novel two-dimensional (2D) van der Waals materials like conducting graphene (Gr), insulating ultrathin hexagonal boron nitride (hBN), or semiconducting transition metal dichalcogenides come into play. Gr for instance offers potential application as a transparent conductive electrode in organic solar cells and LEDs replacing indium tin oxide, whereas hBN can be used as an ultrathin flexible dielectric in OFETs. Recently, we reported on the self-assembly of crystalline nanowires (NWs) composed of rod-like oligophenylene molecules on exfoliated, wrinkle-free Gr [1-2] and hBN [3], both transferred onto SiO_2. The NWs are several 10 nm wide and a few nm high, they can extend to several 10 µm in length. The discrete NW directions with respect to armchair and zigzag directions of the substrates were determined by atomic-force microscopy (AFM) in conjunction with density functional theory calculations.

Here, we study the growth of an oligoacene derivate dihydrotetraazaheptacene (DHTA7), which - due to nitrogen containing groups - forms crystals through H-bonding and dipolar interactions between neighboring molecules. Crystalline NWs of DHTA7 were grown by hot wall epitaxy on the surfaces of Gr and hBN, which act as van der Waals electrodes and gate dielectrics, respectively. Using conductive AFM (C-AFM) and photo-assisted electrostatic force microscopy (EFM), we demonstrate charge trapping and light-assisted charge spreading within the networks of DHTA7 NWs. We found that the NWs are not conductive in the dark, while visible light - linearly polarized parallel to the long axis of the nanowires - allows spreading of the charges across the network for tens of micrometers. The results indicate that - due to light excitation - charges that were trapped in the localized defects can spread through the bands of the organic semiconductor. The charge transport can be described by a simple diffusion model, considering the individual NWs as RC-transmission lines.

[1] M. Kratzer, C. Teichert, "Growth of aromatic, rod-like molecules on graphene", Nanotechnology **27** (2016) 292001.
[2] A. Matković, M. Kratzer, B. Kaufmann, J. Vujin, R. Gajić, C. Teichert, "Probing charge transfer between graphene and molecular semiconductors", Sci. Rep. **7** (2017) 9544
[3] A. Matković, J. Genser, D. Lüftner, M. Kratzer, R. Gajić, P. Puschnig, C. Teichert, "Epitaxy of highly ordered conjugated organic semiconductor crystallite networks supported by hexagonal boron nitride", Sci. Rep. **6** (2016) 38519.