Krūvininkų generacija, pernaša ir rekombinacija puslaidininkiniame anglies nanovamzdelių tinkle

Carrier photogeneration, drift and recombination in a semiconducting carbon nanotube network

Vidmantas Jašinskas[1], Valentas Bertašius[1], Angela Eckstein[1], Imge Namal[2], Tobias Hertel[2], Vidmantas Gulbinas[1,3]
[1]Center for Physical Sciences and Technology, Saulėtekio al. 3, LT-10257 Vilnius, Lithuania
[2]University of Würzburg, Physical Chemistry Department, Am Hubland, 97074 Würzburg, Germany
[3]Vilnius University, Department of General Physics and Spectroscopy, Saulėtekio al. 9-III, LT-10222 Vilnius, Lithuania
vidmantas.jasinskas@ftmc.lt

The fact that single-wall carbon nanotubes (SWNTs), depending on diameter and chirality may be either metallic or semiconducting is of particular interest for many technological applications. Semiconducting nanotubes have potential for use as photoactive material in solar cells or light detectors [1]. The photoresponse in the IR spectral region also makes SWNTs particularly well suited for IR or photothermal detectors [2]. SWNTs were also tested for application in organic solar cells to enhance charge transport [3], as electron acceptors in blend with conjugated polymers [4], or as electron donors in heterojunctions with fullerene derivatives [5].

In many potential applications carbon nanotubes are expected to be used in the form of thin film percolation networks, forming conductive or semiconducting layers. The photoconductivity of such SWNT layers is a key for the performance of SWNT-based optoelectronic devices.

We used a combination of the steady state and transient photocurrent with time-delayed-collection field technique for an investigation of charge carrier generation, drift and recombination processes in networks of polyfluorene-wrapped (6,5) SWNTs blended with PCBM, following their optical excitation. Charge carrier generation takes place spontaneously by electron transfer from excited SWNT to PCBM. Generated holes create a transient photocurrent in SWNT network, which is controlled by the morphology of the network, rather than by carrier recombination or extraction. The transient photocurrent (Fig. 1) shows three characteristic decay regimes. An ultrafast phase, lasting less than 2 ns is attributed to hole transfer within single SWNTs while hole jumps between SWNTs take a few microseconds. The slowest photocurrent component is observed only at high PCBM concentrations and is attributed to electron transfer via PCBM. Electrons and holes residing on the same nanotube recombine within about 1 µs. In contrast, carriers located on different SWNTs can survive hundreds of microseconds.

The clear identification of several photocurrent phases in SWNT systems provides broader perspectives for their application in photoelectrical devices while providing new leads for the optimization of photocurrents. The ultrafast photocurrent component, which may be particularly useful in designing new ultrafast photodetectors may be further optimized by increasing nanotube lengths and by making networks with higher degree of nanotube alignment orientation. Additional improvements might be achieved if SWNTs were better isolated from one another so as to prevent intertube carrier jumps. Improvement of the SWNT network percolation, on the other hand, is a crucial requirement for the maximization of steady state photocurrents.

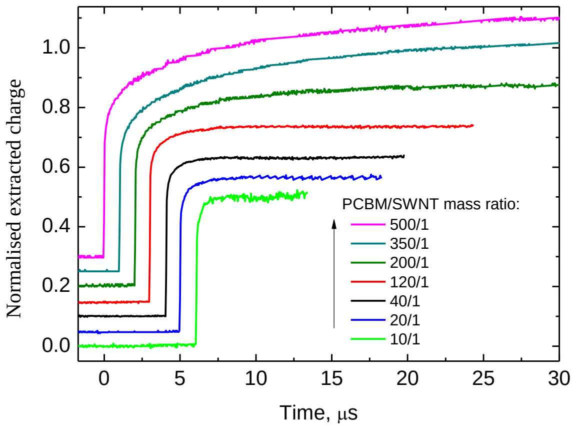

Fig. 1. Charge extraction kinetics from samples with different PCBM to SWNT ratios measured under excitation at 1064 nm by 16 µJ/cm^2 energy pulse under 2V applied voltage. For more clear presentation they are normalized to the equal intensity of the fast growth component and shifted vertically and horizontally

Keywords: carbon nanotube, PCBM, kinetics, photogeneration, recombination, charge extraction.

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