Ultrafast Photoconductivity of Graphene, Graphene Nanoribbons and Carbon Nanotubes

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We present a comparative study of ultrafast photoconductivity in graphene[1] and two different forms of one-dimensional (1D) quantum-confined graphene nanostructures[2]: structurally well-defined semiconducting graphene nanoribbons (GNRs), and semiconducting carbon nanotubes (CNTs) with a similar bandgap. Transient photoconductivities of both materials were measured using time-resolved terahertz spectroscopy, allowing for contact-free measurements of complex-valued photoconductivity spectra with sub-picosecond time-resolution. We show that, while the photoconductivity response seems very different for the three systems, a single model of free carriers experiencing backscattering when moving along the long axis of the CNTs or GNRs provides a quantitative description of both sets of results, revealing significantly longer carrier scattering times for CNTs (ca. 150 fs) than for GNRs (ca. 30 fs) and in turn higher carrier mobilities. While the scattering rate for charge carriers in graphene is of similar magnitude, the mobility in the nanostructures is much reduced due to the presence of the bandgap, which leads to a dramatic increase of charge carrier effective mass. The marked difference between carrier mobility in the nanostructures can be explained by differences in band structures and phonon scattering and the greater structural rigidity of CNTs as compared to GNRs, minimizing the influence of bending and/or torsional defects on the electron transport.

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[1] Nature Physics 9, 248 (2013).

[2] Nano Letters doi: 10.1021/nl402978s (2013).