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Electron-phonon interaction and excited states relaxation in carbon nanotubes

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We will discuss the role of electron-phonon interaction on excited states relaxation and phonon spectra in carbon nanotubes (CNTs). The electron-phonon interaction leads to the polaronic effects of the charge carriers, but it also renormalizes the energy and the lifetime of phonons. We present a theoretical model that predicts the changes induced in the phonon modes of CNTs as a function of the charge carrier doping, i.e. position of the Fermi level. In agreement with the predictions, our experiments show sharpening and blue shifts of the G-phonons of metallic CNTs, but only blue shifts for semiconducting CNTs, making the Raman scattering a useful probe of local doping of CNTs [1]. The non-equilibrium dynamics of charge carriers under external electric field is determined by the electron-phonon scattering. The hot carriers under unipolar transport conditions can be produced, leading to the strong impact excitation and light emission, which intensity is determined by electric field, phonon scattering, and impact excitation cross section [2, 3]. In the reverse process of photoconductivity, light is absorbed creating excited states. We will discuss electronic relaxation of high energy excited states leading to the free carriers, contributing to the photoconductivity, and phonon relaxation, leading to the bound excitons [4]. The later can contribute to the photocurrent only after ionization by the external field [5]. Finally, we will discuss the role of phonons in the long puzzling question regarding the nature of the dominant decay channel of the low energy excited states and the potential of optoelectronic applications of CNTs. [1] J.C. Tsang, M. Freitag, V. Perebeinos, J. Liu, and Ph. Avouris, Nature Nanotechnology 2, 725 (2007); [2] J. Chen, V. Perebeinos, M. Freitag, J. Tsang, Q. Fu, J. Liu, Ph. Avouris, Science 310, 1171 (2005); [3] V. Perebeinos and Ph. Avouris, Phys. Rev. B. 74, 121410(R), (2006); [4] T. Hertel, V. Perebeinos, J. Crochet, K. Arnold, M. Kappes, Ph. Avouris, arXiv:0710.3154; [5] V. Perebeinos and Ph. Avouris, Nano Lett. 7, 609 (2007)