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Electron-Phonon and Electron-Electron Interactions in Individual Suspended Carbon Nanotubes

STEPHEN CRONIN, University of Southern California

The fabrication of pristine, nearly defect-free, suspended carbon nanotubes (CNTs) enables the observation of several phenomena not seen before in carbon nanotubes, including breakdown of the Born-Oppenheimer approximation[1], mode selective electron-phonon coupling[2], and a Mott insulator transition[3]. Raman spectroscopy of these nanotubes under applied gate and bias potentials reveals exceptionally strong electron-phonon coupling, arising from Kohn anomalies, which result in mode selective electron-phonon coupling, negative differential conductance (NDC), and non-equilibrium phonon populations[2,4]. Due to the extremely long electron lifetimes, we observe a breakdown of the Born-Oppenheimer approximation, as deduced from the gate voltage-induced changes in the vibrational energies of suspended carbon nanotubes[1]. We also report strikingly large variations in the Raman intensity of pristine metallic CNTs in response to gate voltages, which are attributed to a Mott insulating state of the strongly correlated electrons[3]. As will be shown, preparing clean, defect-free devices is an essential prerequisite for studying the rich low-dimensional physics of CNTs. (1.) Bushmaker, A.W., Deshpande, V.V., Hsieh, S., Bockrath, M.W., and Cronin, S.B., "Direct Observation of Born-Oppenheimer Approximation Breakdown in Carbon Nanotubes." Nano Letters, 9, 607 (2009). (2.) Bushmaker, A.W., Deshpande, V.V., Bockrath, M.W., and Cronin, S.B., "Direct Observation of Mode Selective Electron-Phonon Coupling in Suspended Carbon Nanotubes." Nano Letters, 7, 3618 (2007) (3.) Bushmaker, A.W., Deshpande, V.V., Hsieh, S., Bockrath, M.W., and Cronin, S.B., "Large Modulations in the Intensity of Raman-Scattered Light from Pristine Carbon Nanotubes." Physical Review Letters, 103, 067401 (2009). (4.) Bushmaker, A.W., Deshpande, V.V., Hsieh, S., Bockrath, M.W., and Cronin, S.B., "Gate Voltage Controlled Non-Equilibrium and Non-Ohmic Behavior in Suspended Carbon Nanotubes." Nano Letters, 9, 2862 (2009)