ELECTRON-HOLE SYMMETRY IN A SEMICONDUCTING CARBON NANOTUBE QUANTUM DOT

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The drive towards the development of molecular electronics and quantum information technology has boosted in recent years the study of nanoscale systems both from the fundamental as well as the applied point of view. Among these systems, quantum dots (QDs) have received particular attention. Quantum dots formed in two-dimensional electron gases[1] have been intensively studied for over a decade and more recently metallic nanotubes[2-4] and individual molecules[5] have also been subject of intensive research. Few electron QDs in vertical semiconductor heterostructures have been very successful in extending the physics of atoms to 2-D systems and a wide range of novel phenomena have been realized[1]. QDs in the few hole regime have been much less explored. Natural candidates for few electron and hole QDs are semiconducting carbon nanotubes[6]. Despite some studies at intermediate temperatures, semiconducting nanotube single QDs have been proven difficult to realize at low temperatures[7], and usually the tube is divided into multiple islands preventing, for example, the observation of the electronic spectrum. Here we show that semiconducting individual single-walled carbon nanotubes can behave as fully coherent single QDs operating both in the few-electron and few-hole regime. We find that the discrete excitation spectrum for a nanotube with N holes is strikingly similar to the corresponding spectrum for N electrons. The data indicate a near-perfect electron-hole symmetry as well as the absence of scattering in semiconducting carbon nanotubes.

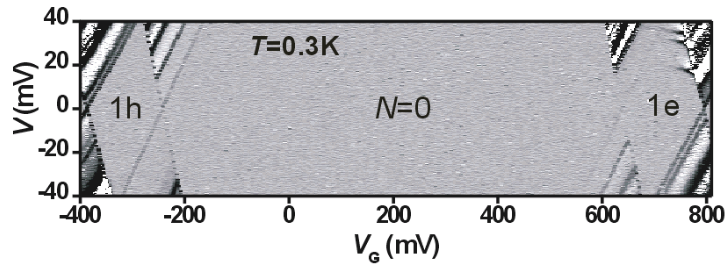

Figure 1. Carbon nanotube quantum dot operating both in the single hole and single electron regime.

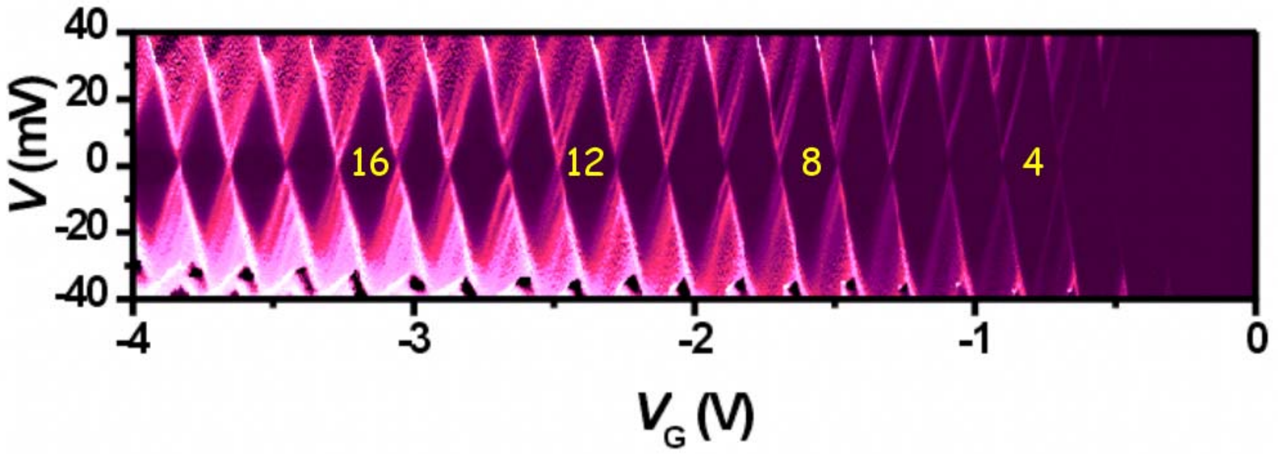

Figure 2. The number of holes in the quantum dot can be changed one by one. The regularity indicates a nanotube free of disorder.

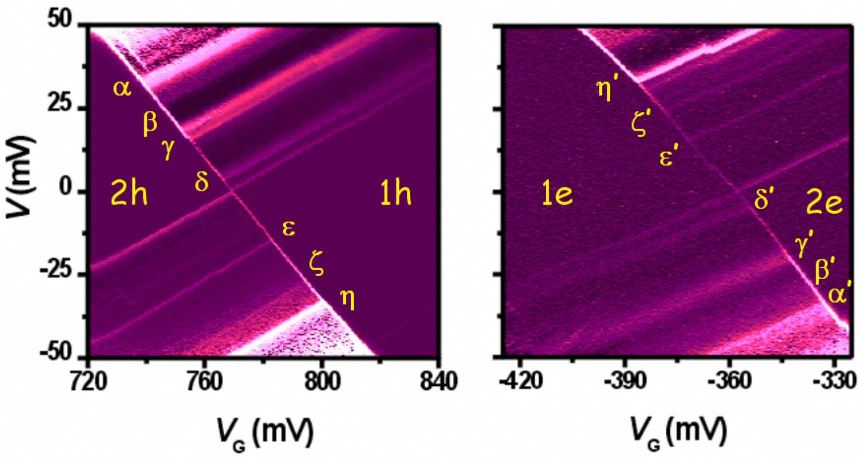

Figure 3. The spectrum of electrons and holes is symmetric.

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