Excitons and trions in hole-doped single-walled carbon nanotubes

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Semiconducting single-walled carbon nanotubes have attracted great interests over the past decade, because of their unique electric and optical properties [1]. In one-dimensional structures such as carbon nanotubes, a strong Coulomb interaction between electrons and holes causes the formation of stable excitons with huge binding energies. Exciton dynamics govern the optical responses of carbon nanotubes, and the unique exciton-related phenomena, such as exciton-exciton annihilation (or exciton Auger recombination) and the formation of positive trions (three-body complexes of one electron and two holes), are observed [2]. In this work, we study the dynamical behaviors of excitons and trions in undoped and hole-doped carbon nanotubes, and discuss the effect of exciton-hole interactions on the exciton formation and recombination dynamics in single-walled carbon nanotubes.

Single-walled carbon nanotube samples used in this study were dispersed in toluene solutions with 0.9 wt.% poly(9,9-dioctylfluorenyl-2,7-diyl) (PFO). 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F_4TCNQ) was used as a *p*-type dopant. By hole doping, new photoluminescence and absorption peaks appear below the E_{11} (the transition between first electron and first hole subbands) bright exciton peak. We conclude that the new peak is attributed to trions, which are stable even at room temperature, because of their large binding energies due to the strong electron-hole exchange interaction [3]. Here, we study the exciton and trion dynamics in undoped and hole-doped nanotubes studied by femtosecond transient absorption spectroscopy.

In hole-doped carbon nanotubes, fast decay components appear in decay curves. The lifetime of the fast components is a few picoseconds. We found that the recombination process between an exciton and holes shows a quantized behavior as a function of the doped hole [4]. Therefore, the number of holes in carbon nanotubes can be evaluated on the basis of the exciton decay dynamics. We also study the excitonic fine structures and high Rydberg states of one-dimensional exciton in undoped and hole-doped carbon nanotubes by two-photon excitation spectroscopy. The energy shifts of Rydberg states of excitons in hole-doped carbon nanotubes were observed, indicating that the Coulomb interaction between electrons and holes is strongly modulated by doped holes. We will present a global feature of excitons and trions in hole-doped single-walled carbon nanotubes.

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