Abstract / 論 文 の 内 容 の 要 旨

論文題目

Screening effects on excitons in air-suspended carbon nanotubes

（架橋カーボンナノチューブにおける励起子の遮蔽効果に関する研究）

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The unique optical properties of single-walled carbon nanotubes make them a promising material for nanoscale photonic and optoelectronic devices. The optical transitions are dominated by tightly bound excitons even at room temperature, as the limited screening in the one-dimensional systems results in an enhancement of the Coulomb interactions.

Here we show that the screening effects on excitons are particularly limited in air-suspended nanotubes. We examine electric field effects on various excitonic states by simultaneously measuring both photocurrent and photoluminescence. As the applied field increases, we observe an emergence of new absorption peaks in the excitation spectra. From the diameter dependence of the energy separation between the new peaks and the ground state of E_{11} excitons, we attribute the peaks to the dark excited states which became optically active due to the applied field. Field-induced exciton dissociation can explain the photocurrent threshold field, and the edge of the E_{11} continuum states has been identified by extrapolating to zero threshold. By taking the energy difference between the E_{11} continuum edge and ground state of E_{11} excitons, we have obtained exciton binding energies of 0.6 eV. The binding energy is 1.5 times larger than that of micelle-wrapped tubes, showing that the pronounced effects of environmental screening on excitons in carbon nanotubes.

We also show that the large screening effects on excitons give rise to all-optical memory functionality in individual carbon nanotubes. Excitation power and energy resolved PL microscopy reveals that energy shifts induced by molecular adsorption and desorption leads to optical bistability. We demonstrate reversible and reproducible optical memory operation, and further perform time-resolved measurements to

determine the rewriting speed. Our results underscore the impact of molecular-scale screening effects on optical properties of nanomaterials, offering new design strategies for photonic devices that are a few orders of magnitude smaller than the optical diffraction limit.