

Directional exciton diffusion in pentacene-decorated carbon nanotubes

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1. Introduction

Semiconducting carbon nanotubes are photoluminescent in the telecommunication wavelength at room temperature and can be readily integrated into Si-based devices [1-3]. They are a promising candidate for room-temperature single-photon sources that are applicable in quantum information processing [4].

The optical processes in carbon nanotubes are dominated by the so-called excitons [5-7], whose binding energies are sensitive to the surrounding dielectric environment [8]. To modify the exciton properties in carbon nanotubes, noncovalent functionalization by molecules has been proven as an effective approach [9-11]. Not only are novel functionalities achieved, the excellent optical properties of carbon nanotubes can also be preserved due to the fact that the interactions between the molecules and the carbon nanotubes are less perturbative compared to covalent functionalization.

To generate single photons in carbon nanotubes by utilizing noncovalent functionalization, suitable molecules need to be carefully chosen, so that isolated adsorbed sites on the nanotube can be formed, and excitons nearby can diffuse to and accumulate at such sites. As a result, efficient exciton-exciton annihilation is expected, which is a crucial step towards single-photon emission in carbon nanotubes [12, 13].

2. Results

Here, by decorating individually suspended single-walled carbon nanotubes with isolated pentacene particles, we demonstrate tuning of the excitonic energies and directional exciton diffusion induced by molecular screening. Pentacene particles with controllable sizes in the range of tens of nanometers are deposited onto the nanotubes via thermal evaporation. Bright photoluminescence is observed, and the location of the pentacene-adsorbed site on the nanotube can be identified by photoluminescence imaging. Furthermore, location-dependent photoluminescence excitation spectroscopy is performed along the tube, and distinct peaks corresponding to the pristine region and the adsorbed site on the nanotube can be distinguished in the resulting spectra. The excitonic energies are lowered at the adsorbed site compared to that in the pristine region as evidenced by the redshifted emission wavelengths. Importantly, directional exciton diffusion is achieved, where excitons transfer from the pristine region to the adsorbed site due to the energy difference. Time-resolved photoluminescence measurements reveal the exciton lifetimes, and photon antibunching is demonstrated in the adsorbed region.

3. Conclusions

We have achieved the formation of pentacene particles on individually suspended carbon nanotubes. Modulation of excitonic energies and directional exciton diffusion have been shown by photoluminescence excitation spectroscopy. Photon antibunching observed in the pentacene-adsorbed region verifies the possibility of using molecules to induce single-photon emission in carbon nanotubes.

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