

Topology of exciton in artificial structure

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Topology of an electron wavefunction in artificial structures are determined by the structural parameters if the disturbance of the electron can be neglected. The topology of an exciton wavefunction, however, heavily depends on the delocalized feature of the relative motion of an electron-hole pair making an exciton as well as the structural parameters. We focused our eyes to this situation and have investigated the topological aspects of the exciton in nanotube structure theoretically.

By employing a variational method, we have calculated the excitonic properties of thin nanotube structures. The exciton wavefunctions show variety of spatial distribution patterns depending on the structural parameters of the nanotube structure. We found that the change of the exciton wavefunction by controlling the tube circumference length is strongly related to the topology of the wavefunction. The kinetic energy of the ground state exciton in nanotubes decreases monotonically when the circumference length decreased. This is a curious behavior because smaller confinement region yields larger confinement kinetic energy in conventional artificial structures. The exciton wavefunction is delocalized and connected in the case that the circumference of nanotube is small, while the exciton wavefunction is localized for large circumference nanotube. The connected wavefunction has ring-like topology and it yields the constant like wavefunction for the ground state electron and hole reducing the confinement energy of the exciton.

We have also found that the topological transition can be controlled even by changing the barrier dielectric constant of the nanotubes. This implies that we can control the topology of the exciton wavefunction simply by changing the dielectric constant or other material parameters. We expect the control of the artificial structure providing a novel guiding principle for creating functional devices through the topological control of excitons.