# Artificial Atom in Carbon Nanotubes and their Quantum Response to THz Wave

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Single-wall carbon nanotubes (SWCNTs) are attractive building blocks of quantum-dot (QD) based nanodevices because of their extremely small diameter (~1nm) [1]. The single electron transport measurements at low temperatures have revealed that the charging energy for single electron ($E_c$) and the spacing of discrete confined levels ($\Delta E$) are ~10meV and a few meV with a length of a few hundred nms, which reflects the small size of the material. We demonstrate that the SWCNT QD behaves as a one-dimensional artificial atom even with many electrons in a QD because $\Delta E$ is much larger than the electron-electron interaction energies [2]. In fact, we show 1) four or two electron shell structures, 2) Zeeman splitting of the single particle quantum states, 3) singlet-triplet splitting at B=0 with two electrons in a shell.

The energy scales associated with the SWCNT QD, which ranges from submillimeter to THz frequencies, may make strong interaction possible with THz wave. In fact, we show experimental results on the quantum response of the SWCNT QD to the THz wave at 1.5K [3]. When the THz wave was irradiated to the SWCNT QD, new side-peaks appeared in Coulomb oscillations. In the course of a quantitative analysis based on Coulomb diamond results, from which we can obtain various energy parameters of the QD, we could conclude that the new side-peaks originate from the photon assisted tunneling (PAT) of an electron in a QD to the drain electrode.

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