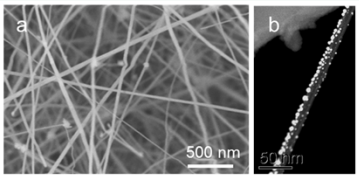
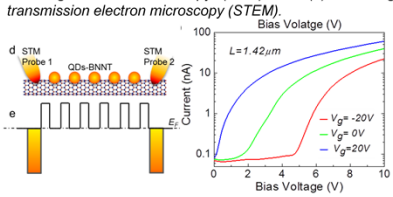
CNMS User Project Highlight

Room Temperature Tunneling Behaviors of Boron Nitride Nanotubes Functionalized with Gold Quantum Dots



Microscopic images of QDs-BNNTs obtained by (a) scanning electron microscopy (SEM) and (b) scanning transmission electron microscopy (STEM).



Left: Schematic of a QDs-BNNT in contact with two scanning tunneling microscope (STM) probes and the corresponding energy diagram. Right: Transport properties of a QDs-BNNT under the modulation of gate voltages (Vg) near the thresholds.

Work was performed at the CNMS and MSTD at ORNL and at the Michigan Technological University

Scientific Achievement

A novel method was demonstrated to form tunneling field effect transistors (TFETs) without using semiconductors. Insulating boron nitride nanotubes (BNNTs) were decorated with gold quantum dots (QDs). The conduction channel is based on quantum tunneling between gold QDs.

Significance and Impact

Conventional electronic devices are based on semiconductors. Here, a new quantum tunneling route to transistors without a semiconductor is demonstrated, with suppressed leakage current and reduced power consumption.

Research Details

Cryogenic four-probe STM has enabled probing individual nano-conduction channels with variable probe spacing and at different temperatures. Boron nitride nanotubes are grown by growth vapor trapping in a tube furnace, then used as substrates for the deposition of gold nanodots by pulsed-laser deposition.

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Highlight Narrative

Silicon-based transistors have been the key components in electronic devices for half a century. Further miniaturization of electronic devices is stymied by various issues including short channel effects and high heat dissipation. The use of carbon nanotubes, nanowires, and graphene in switching devices encounters similar issues as electron transport is based on tuning of conduction channels of these semiconducting materials. Here a new class of room temperature tunneling field effect transistors (FETs) is experimentally and theoretically investigated. It is shown that quasi-one-dimensional arrays of gold quantum dots (QDs) deposited on insulating boron nitride nanotubes (BNNTs) can become the tunneling channels of these FETs. These tunneling behaviors, by-passed many fundamental limits of current electronic devices include the short channel effects, current leakages, and high contact resistances of the semiconducting channels. The turn-on voltages of these FETs can be reduced by shortening channel lengths and applying gate voltages. Basically, a new paradigm of room temperature electronics is demonstrated by creatively combining metallic and insulating nanostructures without the use of semiconductors.

Reference:

Room Temperature Tunneling Behaviors of Boron Nitride Nanotubes Functionalized with Quantum Dots

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