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Probing the unique electrical and optical properties in one-dimensional carbon nanotubes and nanoribbons

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Abstract

Electrons confined in one-dimension (1D) show distinct behavior from their higher-dimensional counterparts: these confined electrons form a strongly correlated system described by a Luttinger liquid which exhibits a unique power-law decay of correlation functions and spin-charge separation; they exhibit divergence in the density of states (DOS) known as a van Hove singularity. 1D quantum conductor such as metallic single-walled carbon nanotubes (SWNTs) has provided a rich playground to explore the Luttinger liquid physics featuring the power-law decay of electron tunneling probability and plasmons excitation and propagation with remarkable spatial confinement of the optical field. On the other hand, 1D quantum semiconductor such as semiconducting SWNTs and atomically precise graphene nanoribbons (GNRs) has revealed the extremely strong excitonic effect and polarization sensitivity spanning the entire UV-vis-NIR spectral range, making it attractive in the study of fundamental science and optoelectronic applications.

In this talk, I will describe our recent effort in probing the interesting 1D physics in SWNTs and atomically precise armchair GNRs (AGNRs) [1-3]. We have combined the electron tunneling spectroscopy and scanning near-field optical nanoscopy to carry out an ultimate experimental test of Luttinger liquid theory in the unique junctions formed by two crossed SWNTs. We have also observed the sequential band-to-band resonant tunneling processes over a large spectral window (~ 2 eV) by electron tunneling spectroscopy, which was realized in the unique carbon nanotube/hexagonal boron nitride/carbon nanotube heterojunctions. A polarization spectroscopy technique in the visible and near-IR has been successfully employed to measure the optical absorption spectra of 7-AGNRs and 9-AGNRs that were transferred onto an insulating substrate, whose optical bandgaps agree well with the GW-BSE calculated results. If time allows, I will also discuss the unique opportunity that the combined electrical and optical probes promise in the experimental exploration of exotic physical phenomenon in two-dimensional materials.

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