Exploring the Magnetically Induced Field Effect in Carbon Nanotube Based Devices

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The exceptional low-dimensionality and symmetry of carbon nanotubes (CNT) are at the origin of their spectacular physical properties governed by quantum effects. Ajiki and Ando [1] predicted that an axial magnetic field would tune the band structure of a CNT between a metal and a semiconductor, owing to the modulation of the Aharonov-Bohm (AB) phase of the electronic wave functions. Here we report on a high magnetic field study of the AB-effect on transport properties of gated (quasi)-metallic single wall carbon nanotubes (SWCNTs) [2].

The magnetotransport measurements were conducted using devices made in the configuration of a standard CNT field-effect transistor (CNFET), as shown in Fig. 1. The conductance characteristics $G(V_g)$ were recorded at temperatures from 1.5 K to 290 K and in magnetic fields up to 30 T.

Figure 2. (a) Plot of the sample 1 conductance versus the gate voltage and the axial magnetic field. A dark arrow indicates the value of $B_0$, where $\varepsilon_g(B)$ has a minimum. (b) Off-state magnetoconductance of sample 1.

Figure 1. (a) Schematic of a CNFET type device. (b), (c) AFM images of two studied CNFET devices. White arrows indicate direction of the magnetic field.

To summarize, we report on observation of a magnetic field induced conversion of initially metallic carbon nanotube devices into carbon nanotube field effect transistors. Strong exponential magnetoresistance observed up to room temperature is the ultimate consequence of the linear increase of the band gap with a magnetic field. The magnetic field controlled Schottky barriers significantly contribute to the CNT magnetoconductance, which may suggest new routes to engineer CNT-based devices characteristics. Moreover, this study reveals the temperature-dependent CNT magnetotransport as a new tool to explore the symmetries of carbon nanotubes.

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References