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Abstract

Structure-Dependent Electrical Conductance of Suspended Graphene Nanoribbon by In-situ Transmission Electron Microscopy Observation

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In this thesis, the structure-dependent electronic properties of suspended graphene nanoribbons (GNRs) are investigated by in situ transmission electron microscopy (TEM) observation to obtain structural information and simultaneous current-voltage (I-V) curve measurements.

The suspended GNR devices are fabricated with the width from ca. 100 to 800 nm. After careful cleaning by current annealing, the suspended ribbon sculpt by convergent electron beam followed by a high bias annealing. During the thinning process, the measured I-V curves indicate that the electrical conductivity of ribbon change from metallic to semiconducting behavior, with the reduction of GNR width. When the width become very narrow (usually < 4 nm), the energy gap start to be opened. A transport gap of 300 and 700 meV is estimated for 1.5 nm wide AGNR and ZGNR, respectively. Most of important, the I-V curves for the zigzag edge GNRs (ZGNRs) are obviously different from those for the armchair edge GNRs (AGNRs) and mixture of both zigzag and armchair edges GNRs (MGNRs) as follows. (1) The ZGNRs showed a sharp increase at the threshold voltage in differential conductance-voltage curves. (2) The band gaps measured for ZGNRs were smaller than the band gaps calculated using the GW approximation. (3) The threshold voltage increased with the GNR length. These features support the previously simulated current-driven magnetic-insulator and nonmagnetic-metal nonequilibrium phase transitions by the application of a bias voltage.

In addition, we also carefully observe the restructure of monolayer and few layer GNRs under different applied bias voltage. When a stable 1.0 V bias voltage is applied on monolayer GNR, it only affect the edge structure; the rough and curve edge restructure into straight and smooth edge, without changing the width of ribbon. However, when the bias voltage is increased, it not only affect edge structure, but also width and layer number of GNR. Under a high bias voltage, the thickness and width of ribbon shrinks sharply with the edge restructure at the same time. Moreover, we found that the conductance improve by structure recrystallization during reconstruction process, even with the decrease of ribbon width.

In conclusion, our ability to fabricate ultra-narrow GNRs with controlled width, layer number and edge structure opens a door systematic investigation the structure dependent electrical property of GNR. The unique I-V characterization of narrow and short ZGNR represents the potential for further nanosized switching devices.

Keywords: structure-dependent electronic properties, suspended graphene nanoribbons, in-situ TEM observation, nonequilibrium phase transitions, restructure