Structure Dependent Electrical Properties of Suspended Graphene Nanoribbon

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The electrical structure of graphene nanoribbons (GNRs) have been systematically investigated through both first principle calculation and experiments [1-3]. Theoretically, it has reported that both zigzag and armchair GNRs exhibit semiconducting behavior below several nm in width, although the origin of the energy gap is different. However, experimentally, the edge structure dependence has not been clarified yet due to difficulty in the controllable of GNR's structure.

For solving this problem, we established to fabricate a suspended GNR device, which enables us to fabricate GNR controllably by electron beam and observe the structure directly in aberration-corrected transmission electron microscopy. By using our home-made holder, we can measure the electrical conductance properties of GNR simultaneously with observing its structure. As shown in Fig.1a, the suspended GNR device was fabricated on a custom Si/SiN chip with electron-transparent windows. The Au/Cr electrodes and pads were deposited on the chip, then nano-gaps were made by using focused ion beam. Finally, monolayer graphene grown by chemical vapor deposition was transferred onto the prepared chip and patterned using electron beam lithography.

The suspended GNR fabricated across the gap is shown in the TEM image of Fig.1b, which has a width about 250 nm. The corresponding FFT pattern shows that the GNR is monolayer. Then, this ribbon was cleaned by current annealing, and sculpted by a convergent electron beam as shown in Fig.2a to make very narrow GNR. We found that the electrical conductance of GNRs with a zigzag edge structure (ZGNRs) abruptly increased above the critical bias voltage [4]. This result can be explained by theoretical prediction of magnetic-insulator and nonmagnetic-metal nonequilibrium phase transition [5], as shown in Fig. 2b and 2c. This finding is worth noting because the abrupt change in these GNRs can be applied to switching devices, as the smallest devices in the world.

References:

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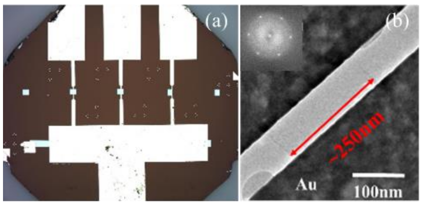

Fig 1. (a) The fabricated GNR device, (b) TEM image of suspended GNR, the inset is corresponding FFT pattern.

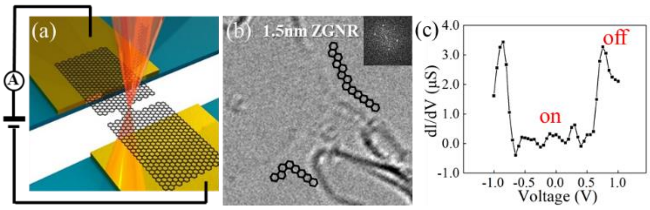

Fig 2. (a) The schematic illustration of nanosculpting technique in TEM by converged electron beam. (b) TEM image of 1.5 nm wide ZGNR. (c) dI/dV-V curves for a 1.5 nm wide ZGNR.