Edge dependence of electrical conductance of graphene nanoribbon

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The electronic properties of graphene nanoribbon (GNR) have been studied by both first principle calculation and experiments, which are expected for application to electronic devices and sensors [1]. Theoretically, both zigzag (ZGNR) and armchair GNR (AGNR) exhibit the opening of the energy gap when reducing their width below several nm. However, the origin of their band gaps is different, which has not been clarified in experiment due to the difficulty in fabricating narrow GNR with specific edge structures.

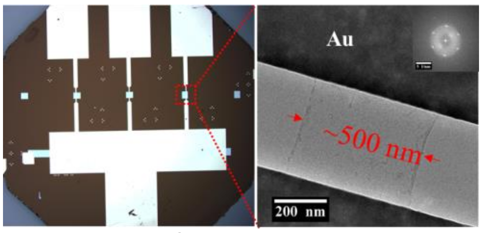

Fig. 1: The fabricated GNR device.

In this study, we clarify the relationship between the electrical conduction of suspended GNRs and their edge structures. As shown in Fig.1, a special suspended GNR device was fabricated for sculpting the width by electron beam and observing the edge structure directly in aberration-corrected transmission electron microscopy (TEM). By using our developed holder, we can measure the electrical conductance properties of GNR simultaneously with observing its structure.

Fig. 2a and 2b show the fabricated 1.5 nm wide GNR with either armchair or zigzag edge, respectively. These narrow GNRs were sculpted from an initial 500 nm wide GNR by convergent electron beam in TEM. Although these two GNRs have the same width, the electrical conductance show obvious difference between the AGNR and ZGNR. The energy gap for ZGNR is more than two-fold larger than that of AGNR. In addition, the dI/dV–V curve for the AGNR shows a parabolic pattern near the origin (0 V), while the curve for the ZGNR shows an abrupt increase above the critical bias voltage [2]. The unique electrical conductance of ZGNR can be explained by theoretical prediction of magnetic-insulator and nonmagnetic-metal nonequilibrium phase transition [3], which can be applied as the smallest devices in the world.

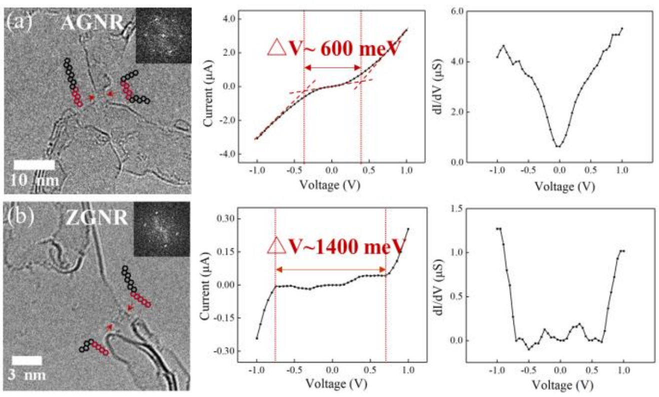

Fig 2. Images of an ultra-narrow AGNR (a) and ZGNR (b) and their electrical conductance

[1] G.Z. Magda, X. Jin, et al., Nature 514, 608 (2014).
[2] C. Liu, J. Zhang, et al., Nanotechnology 32, 205710 (2020).
[3] C. Liu, J. Zhang, et al., Carbon 165, 476 (2020).