Electronic Transport Behavior in High-Quality Twisted Bilayer Graphene Nanoribbons

Haoliang Shen,[1,2] Alessandro Cresti,[3] Fabrice Iacovella,[2] Walter Escoffier,[2] Yi Shi,[1]
Xinran Wang,[1] Bertrand Raquet [2]

[1] National Laboratory of Solid State Microstructures and School of Electronic Science and Engineering, Nanjing University, 22 Hankou Road, Nanjing 210093, P. R. China
[2] Laboratoire National des Champs Magnétiques Intenses, INSA UPS UJF CNRS, UPR 3228, Université de Toulouse,143 av. de Rangueil, 31400 Toulouse, France
[3] IMEP-LAHC (UMR CNRS/INPG/UJF 5130), Grenoble INP Minatec, 3 Parvis Louis Néel, BP 257, F-38016 Grenoble, France
xrwang@nju.edu.cn, bertrand.raquet@lncmi.cnrs.fr

By scaling down the width of 2D material Graphene, a new 1D carbon system rises up, well-known as Graphene Nanoribbon (GNR). Besides the many merits inherited from its ancestor-Graphene, GNR has one exceptional advantage over the zero-gap material graphene: a bandgap is arisen due to the transverse confinement, which makes GNR more promising for logical devices and electrical application. Therefore, it is essential to understand the electronic property of GNR.

Theoretical work have revealed that the band structure of GNR is highly dependent on its width and edge geometry (chirality) [1,2]. Recently several experimental work have stressed on this issue[3-5]: lithography made GNR is proved to have rough edges, thus introducing a "transport gap" other than the intrinsic confinement gap [3]. The charge transport is more dominated by the edge disorder, therefore making it less ideal to study the intrinsic effects of confinement. R. Ribeiro et al. firstly made efforts to study the quantum transport in lithographically patterned GNR with width around 70-100nm [4]. The results unveil the onset of magnetoelectronic subbands, edge currents and quantized hall conductance, also bringing the evidence of the valley degeneracy lifting due to the electronic confinement. However, the width of the studied ribbons is so wide that the confinement effect is less significant and bulk effect still exists. In this region, chirality plays feeble impact. Another work is done on chemically derived GNRs [6] with width around 11nm [5]. However, for this study, the conductance is far away from the supposed value in quasi-ballistic regime, probably due to the underlying disorders inside this kind of GNR. And here the magnetoconductance is not able to reach the quantum hall regime.

In this work, we start with sonochemical derived graphene nanoribbons, originally unzipped from multi-wall carbon nanotubes, with width around 20nm exhibiting ultra-smooth edges [7-10]. Noteworthily, it has been reported that 70% of the final products with this unzipping method are twisted bilayer GNRs [8], and the twist angle is randomly distributed. By probing the two-terminal magnetoresistance of the as-made GNRs under pulse magnetic field up to 55T, un unusual reproducible quantized conductance value shows up and we bring the evidence that the carrier transport in twisted bilayer GNR is ruled by two parallel layers both conducting with very close carrier densities. The two layers both enter into quantum hall regime at almost the same magnetic field. And the total magnetoconductance is contributed by the two "independent" layers, with each layer still behaving like one monolayer GNR's spectrum. We are now attempting to unveil the magnetic band structure on each layer.

References:

[1] K. Nalada et al., Phys. Rev. B **54,** 17954 (1996)

[2] K. Wakabayashi et al., Phys. Rev. B **59,** 8271 (1999)

[3] M.Y. Han et al., Phys. Rev. Lett. **104,** 056801 (2010)

[4] R. Ribeiro et al., Phys. Rev. Lett. **107,** 086601 (2011)

[5] J. Poumirol et al., Phys. Rev. B **82,** 041413(R) (2010)

[6] X. Li et al., Science **319,** 1229 (2008)

[7] L. Jiao et al., Nature Nanotech. **5,** 321 (2010)

[8] L. Xie et al., J. Am. Chem. Soc. **133,** 10394 (2011)

[9] C. Tao et al., Nature Phys. **7,** 616 (2011)

[10] X. Wang et al., Nature Nanotech. **6,** 563 (2011)

Figures:

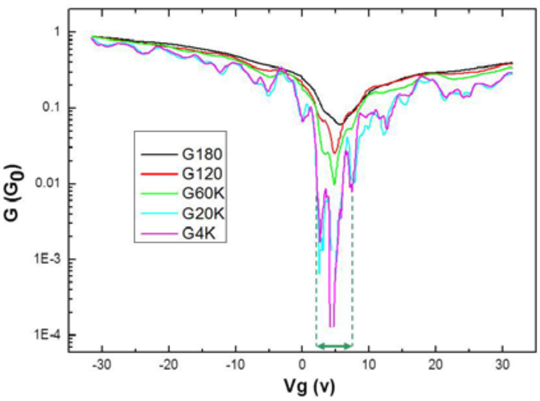

Fig 1. Conductance versus back-gate voltage of one typical sample device during the cooling process. $G_0=2e^2/h$. The sharp dip around the charge neutrality point indicates the transport is dominated by confinement, other than edge disorder.

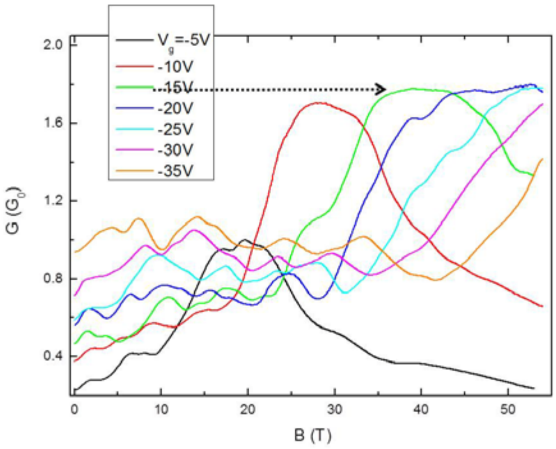

Fig 2. Magneto-Conductance of the same device at 4.2K in p-doped region. At high doping level, the magneto- conductance shows a plateau around 3.5 e^2/h (Contact resistance still included).