Magnetotransport Properties of Graphene Nanoribbons with Zigzag Edges

Shuang Wu,[1,4,*] Bing Liu,[1,4] Cheng Shen,[1,4] Si Li,[2] Xiaochun Huang,[1,4] Xiaobo Lu,[1,4] Peng Chen,[1,4] Guole Wang,[1,4] Duoming Wang,[1,4] Mengzhou Liao,[1,4] Jing Zhang,[1,4] Tingting Zhang,[1,4] Shuopei Wang,[1,4] Wei Yang,[1,4] Rong Yang,[1,4] Dongxia Shi,[1,4] Kenji Watanabe,[3] Takashi Taniguchi,[3] Yugui Yao,[2] Weihua Wang,[1,4] and Guangyu Zhang[1,4,5,6,†]

[1]*Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China*
[2]*School of Physics, Beijing Institute of Technology, Beijing 100081, China*
[3]*National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan*
[4]*School of Physical Sciences, University of Chinese Academy of Sciences, Beijing 100190, China*
[5]*Collaborative Innovation Center of Quantum Matter, Beijing 100190, China*
[6]*Beijing Key Laboratory for Nanomaterials and Nanodevices, Beijing 100190, China*

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Yemliha Bilal Kalyoncu

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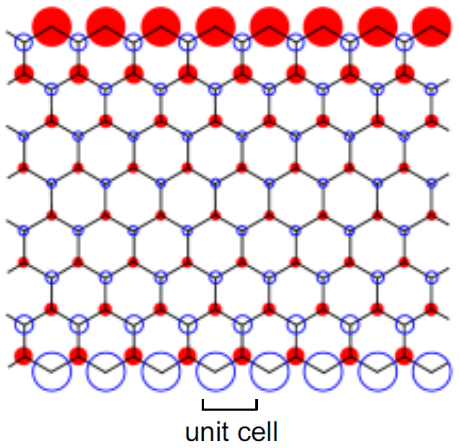
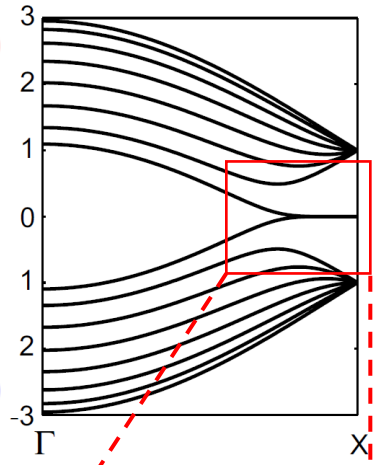
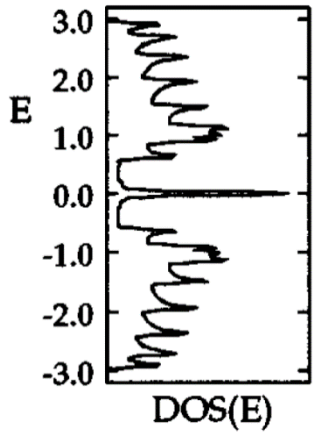
Motivation



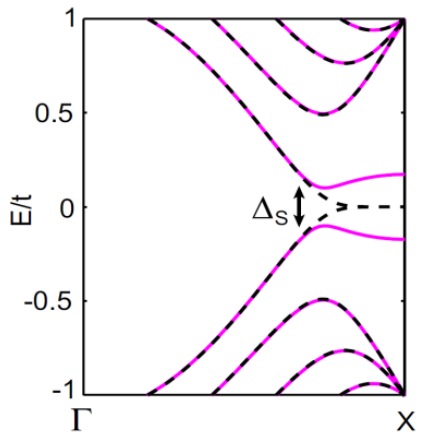


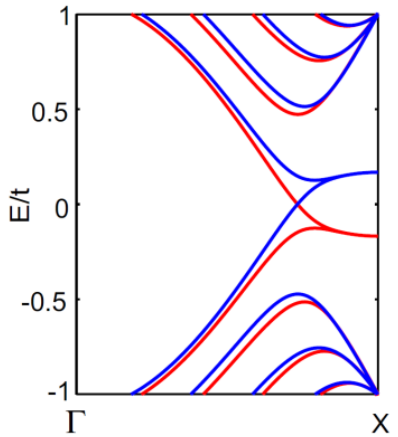
Flat bands
Near
Fermi Energy



Wave
functions
Localized
at the Edge

Localized
Magnetic
Moments





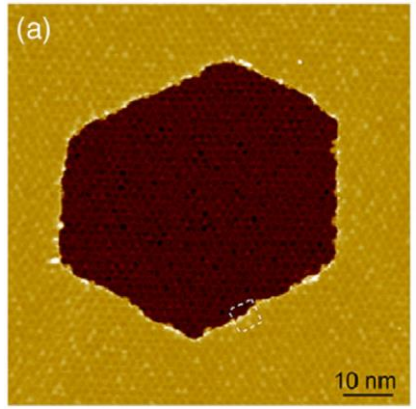
Antiferromagnetic
Ordering

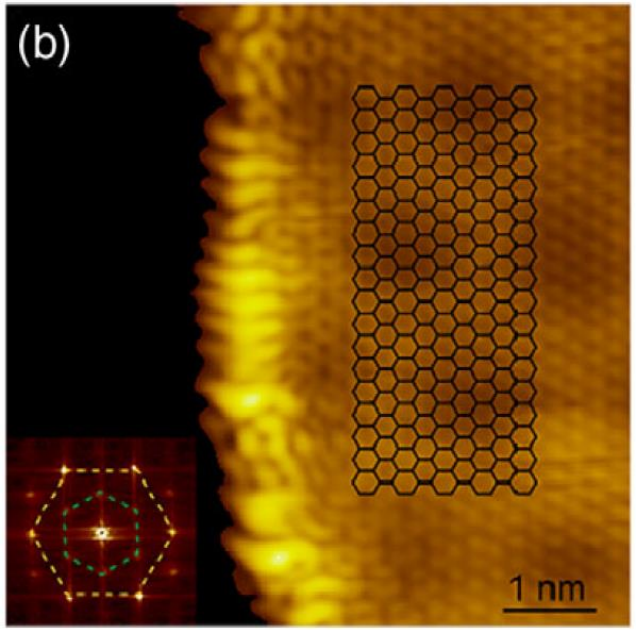
Edge disorder suppresses magnetic correlations !

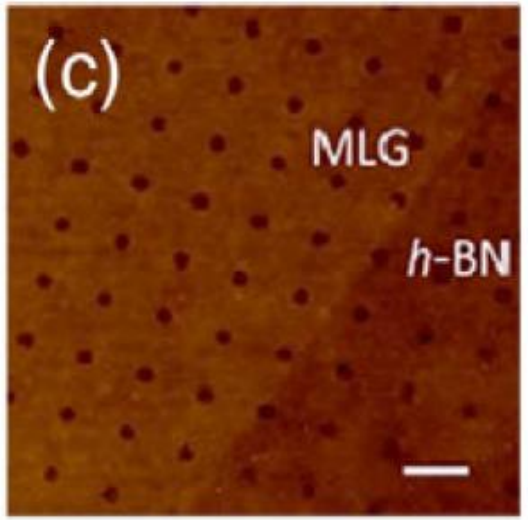
O. V. Yazyev, Rep. Prog. Phys. 73 056501 (2009)

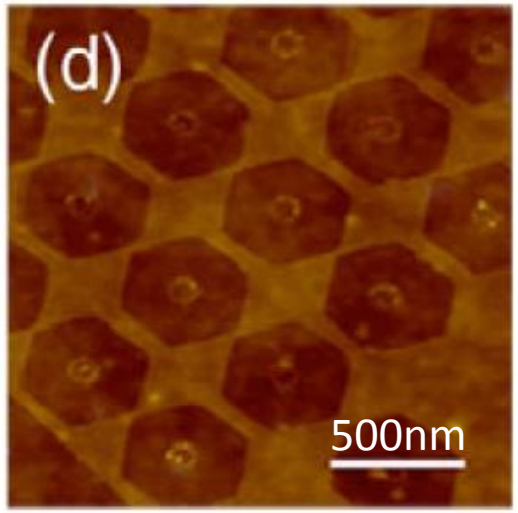
H-Plasma Etching

STM on Epitaxial Graphene on 6H-SiC

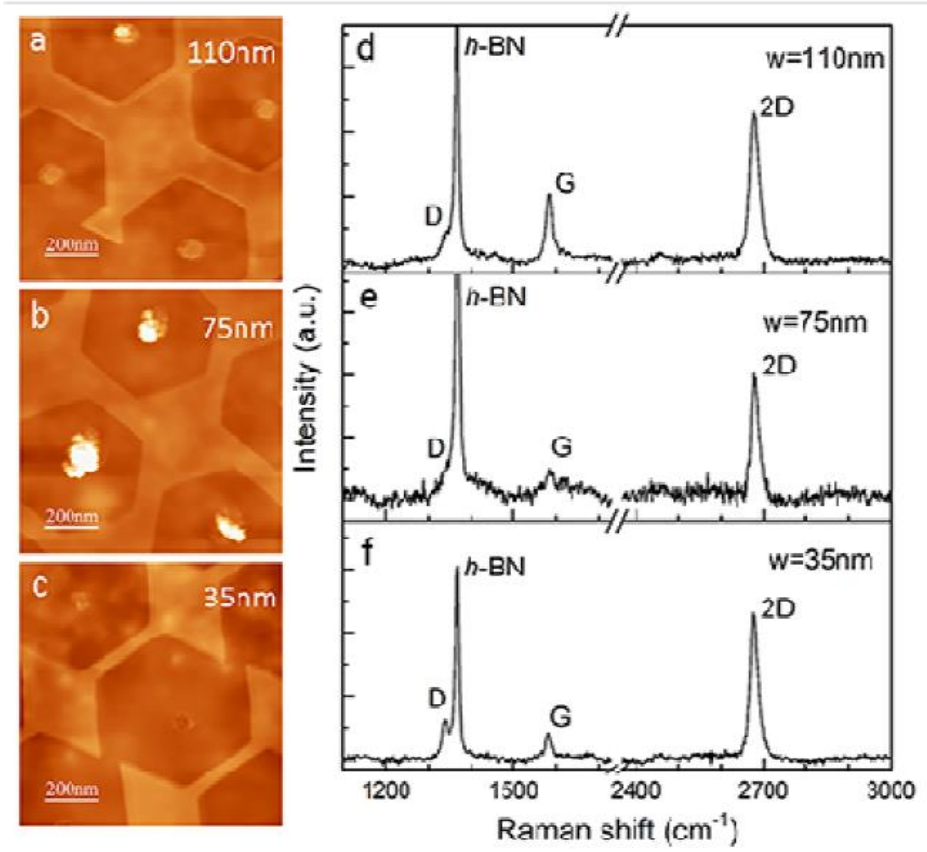




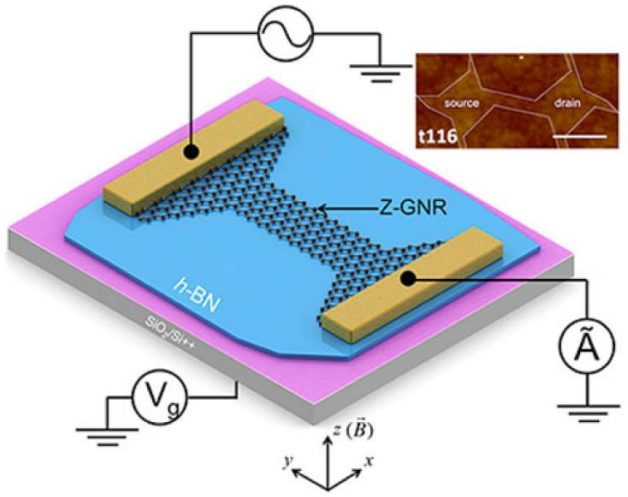


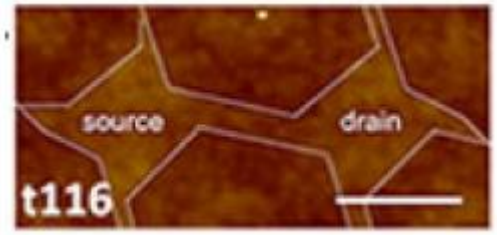


Single Layer Graphene on hBN

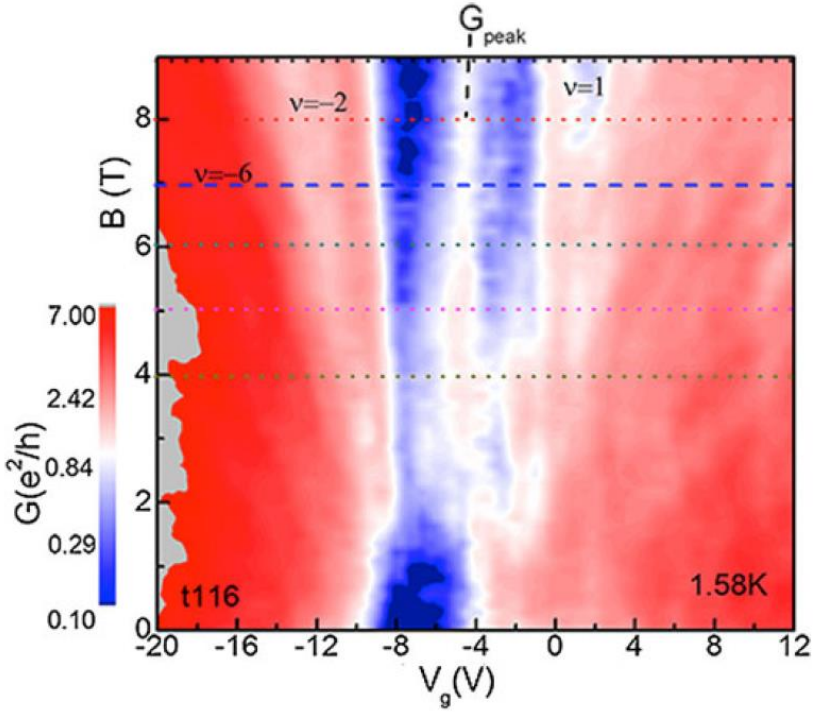


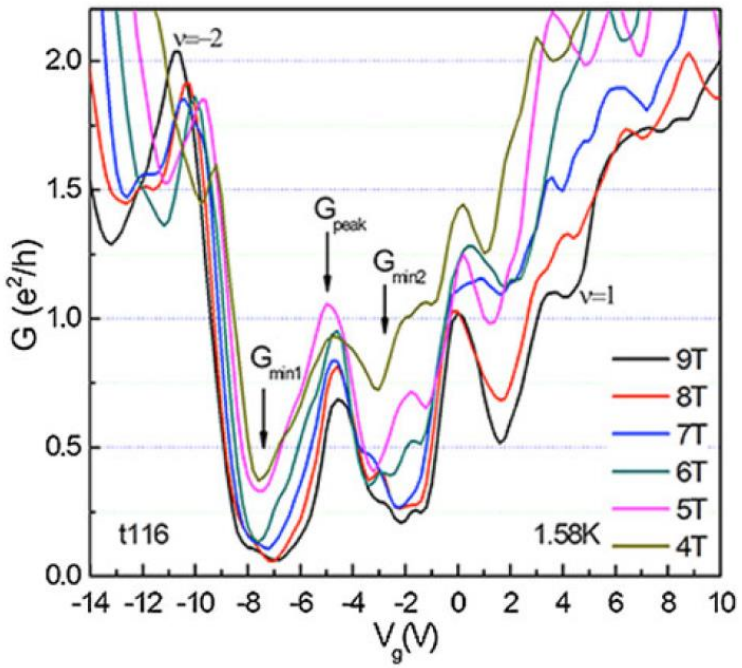
Magnetotransport of zzGNR



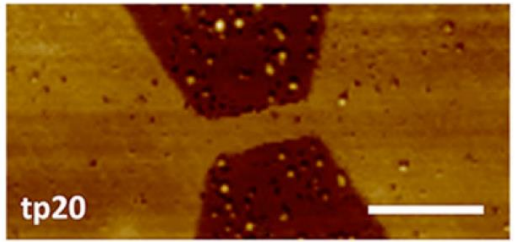


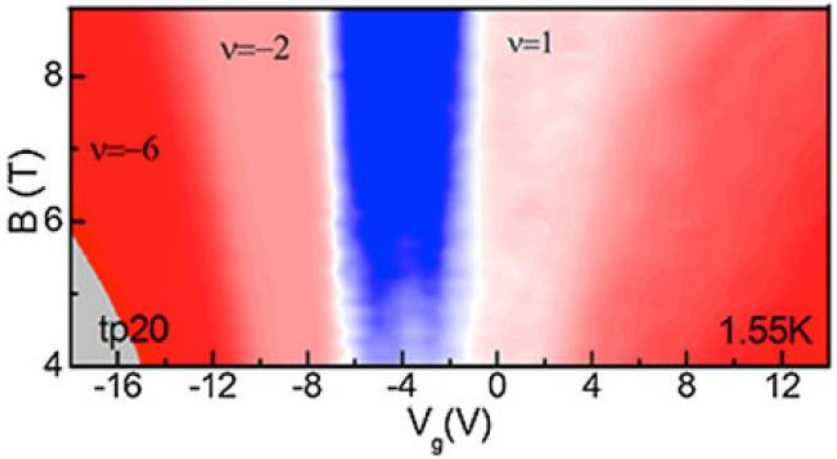
L = 260nm
W= 86nm





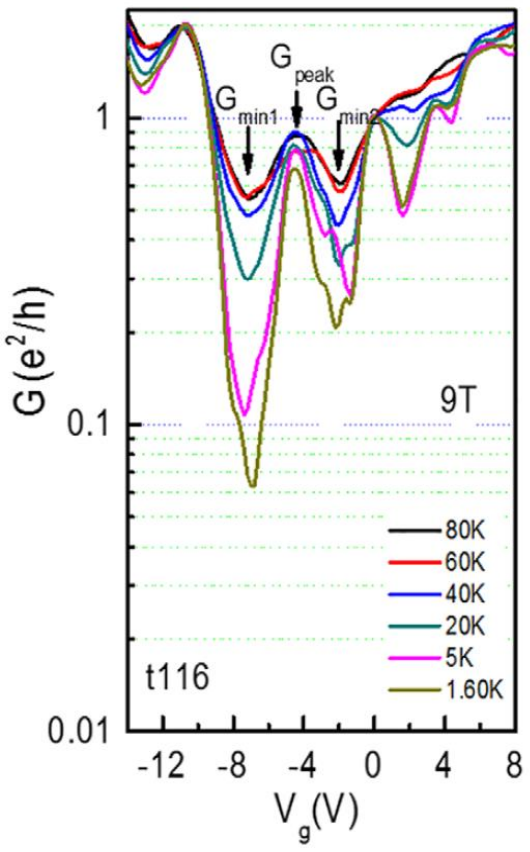
Control Sample



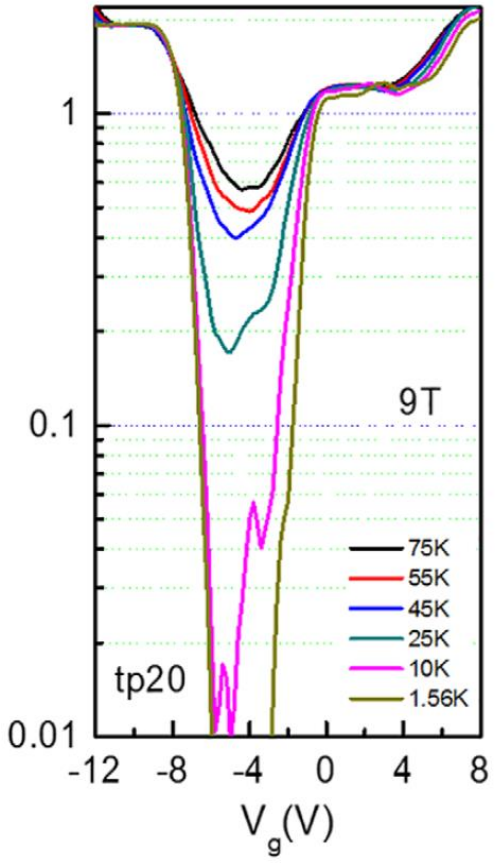


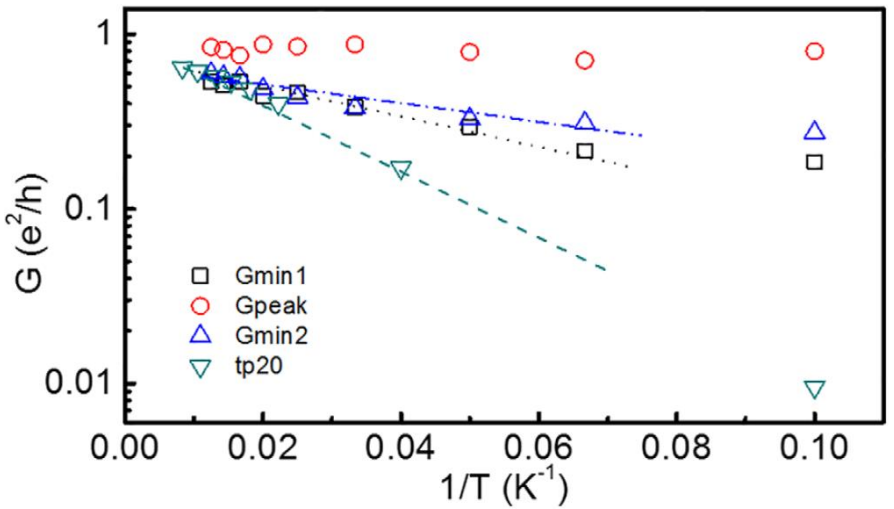
Temperature Dependence

zzGNR



Control Sample



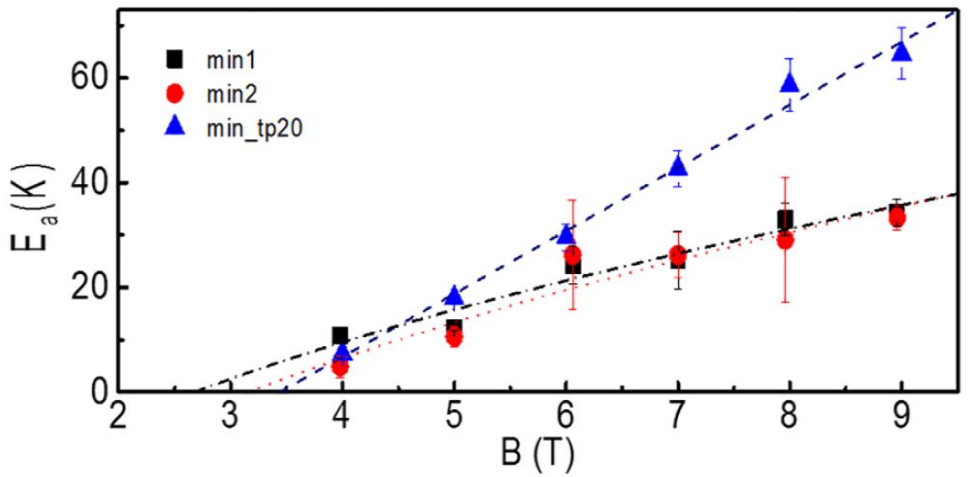


metallic

insulating

Electronic States at CNP

$$G = e^{-\Delta/2k_BT}$$

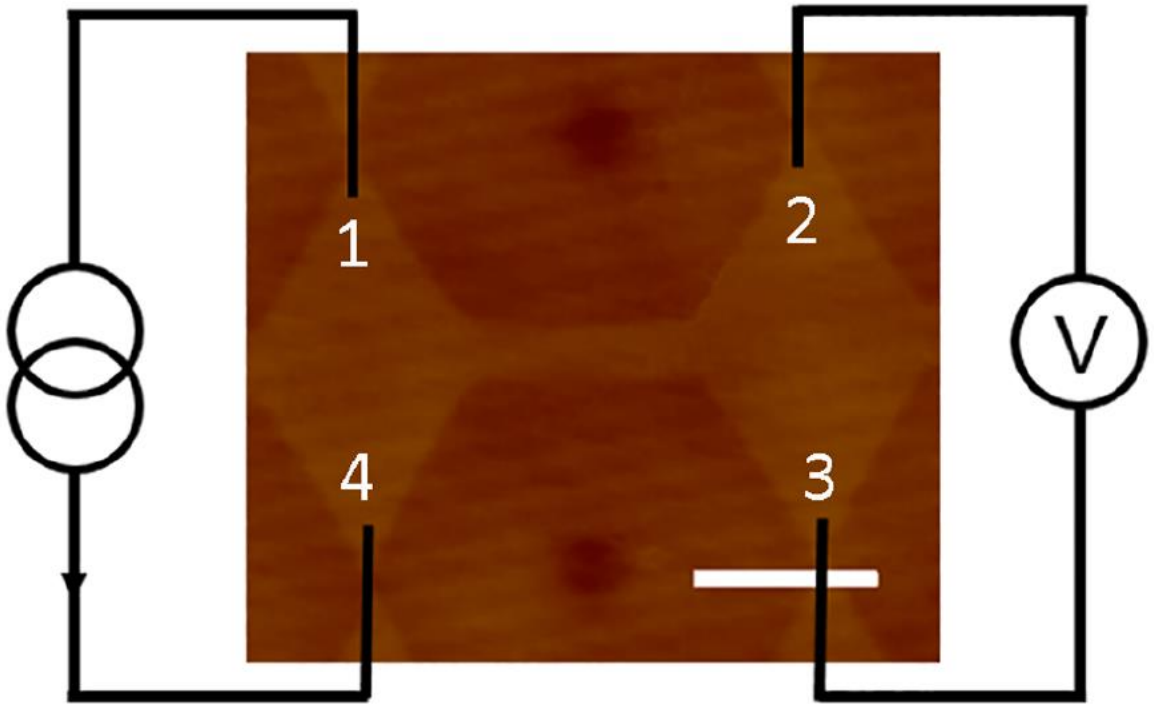


$$e^2/\varepsilon l_B \sim \sqrt{B}$$

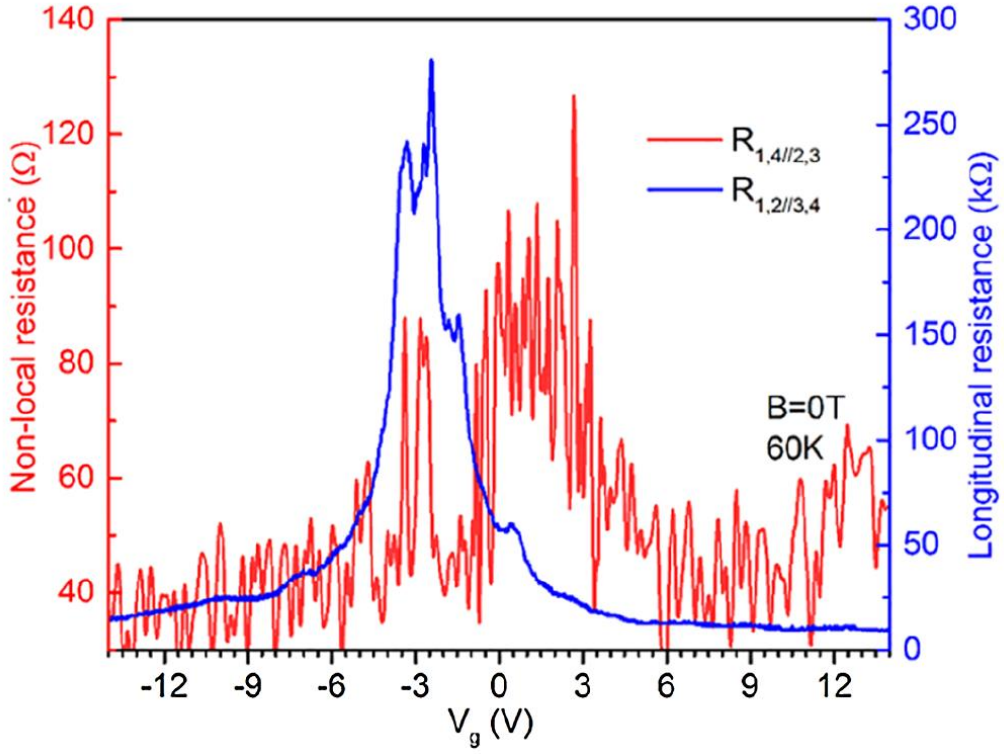
A.F. Young et. al. Nature Physics 8 550 (2012)

K. Yang, Solid State Commun. 143 27 (2007)

Nonlocal Measurement



L = 280nm
W= 62nm

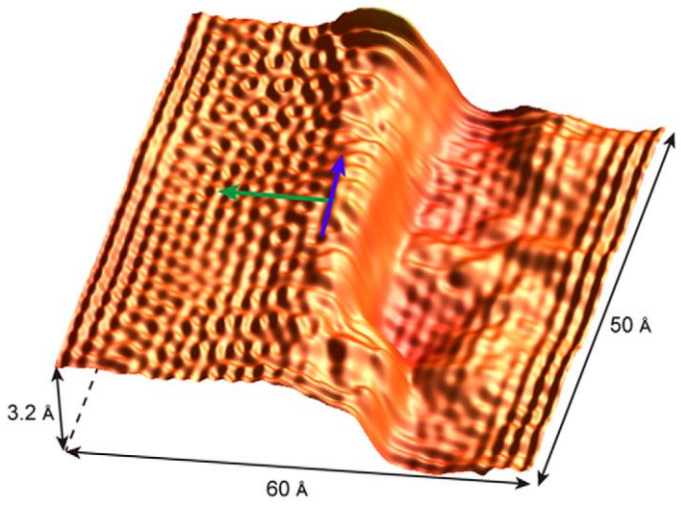


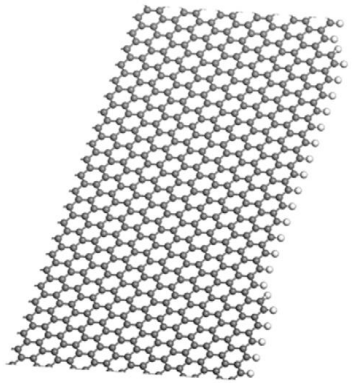
CNP = -3V
Nonlocal resistance = 1.2 V

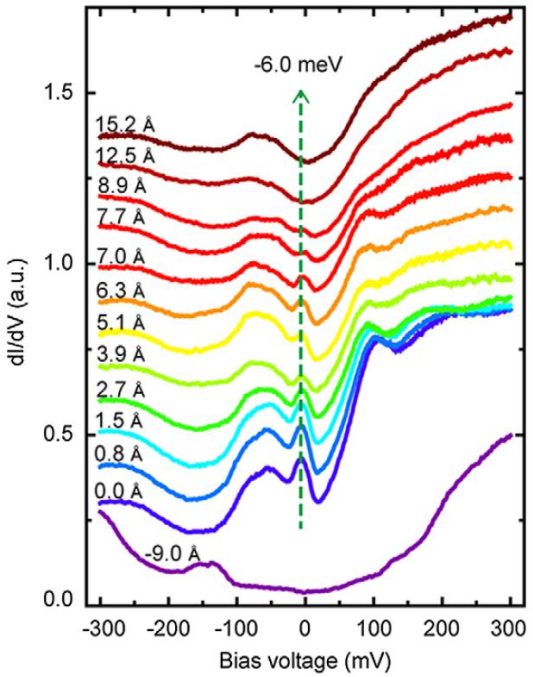
Location of V_{NL} ~ Location of G_{peak} ~ Edge Conduction

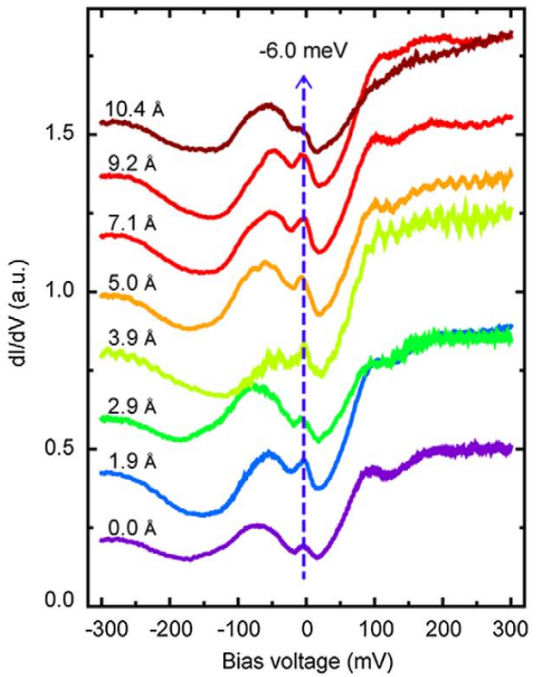
Scanning Tunneling Spectroscopy

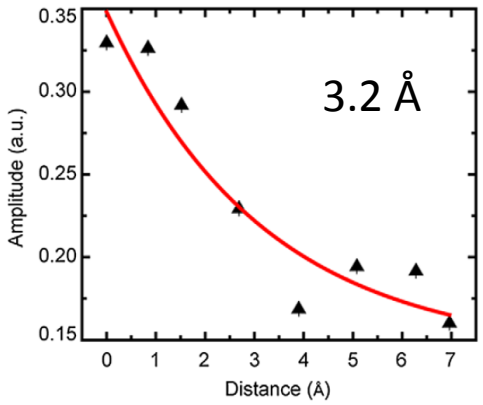
Epitaxial Graphene on 6H-SiC

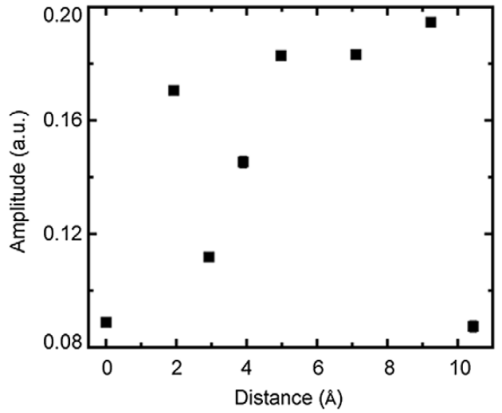












Epitaxial Graphene on 6H-SiC

Freestanding G
~
Supported G**

Epitaxial Graphene on hBN*

So is G/hBN samples

*B. Hwang et al., Sci. Rep. 6, 31160 (2016)

**H. Sadeghi, S. Sangtarash, and C. Lambert, Physica (Amsterdam) 82E, 12 (2016).

Conclusion

Wide ribbons → No band gap due to spin ordered antiferromagnetic states

→ Semi infinite Ribbons with zero energy states at zigzag edge

Electronic structure: Semi-infinite Ribbon ~ zzGNR

Theory : Zigzag Edge → Flat Bands → Localized Edge States

Practice : Quasi-Flat Bands → Delocalized edge states

→ Lower group velocity → limits the conduction at the edge

B field → Landau Regime

→ N=0 or ν=0 at CNP → nearly zero conductance with mixture of electrons and holes

Zigzag Ribbon → Flat bands at CNP inside N=0 or ν=0

→ Conductance !

$\sqrt{B}$ → e-e interactions

ν=0 is inconclusive → Needs more theory/experiment

Thank you

Supplementary

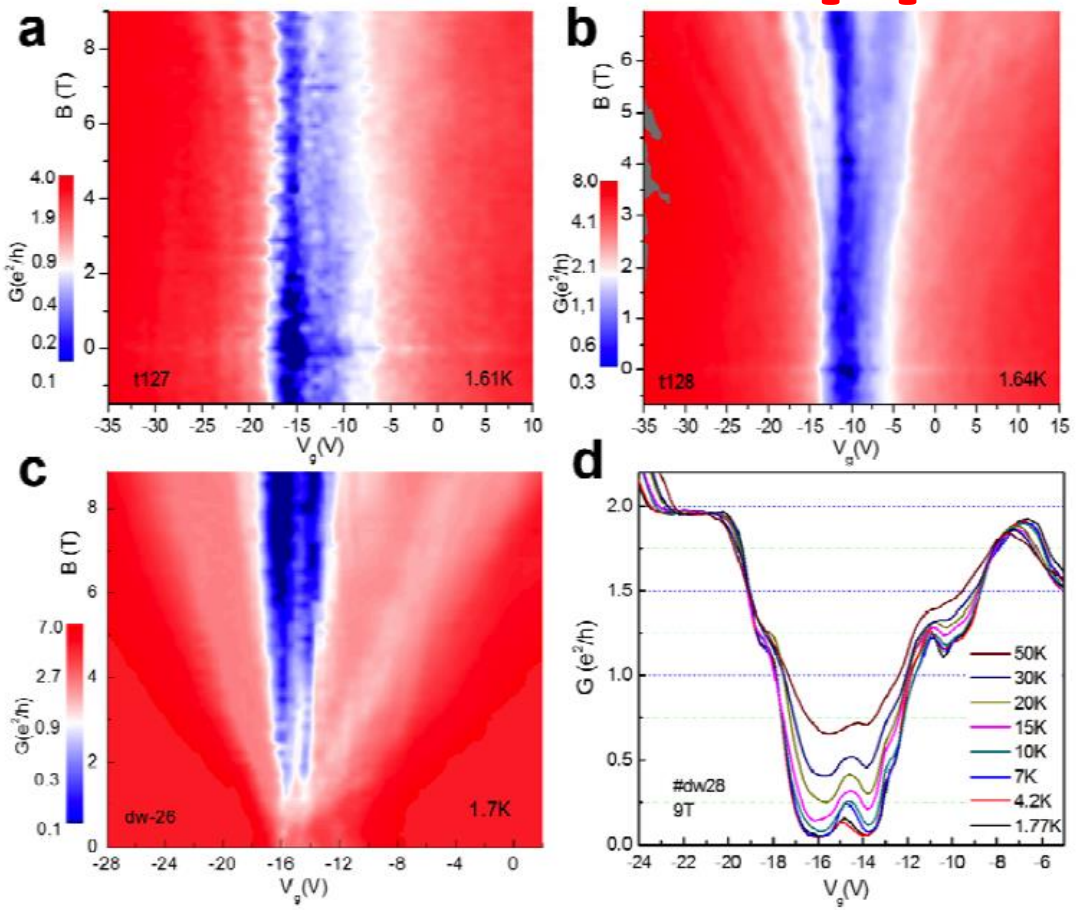


Figure S2| Magneto-transport measurements of other Z-GNR devices. a, sample# t127, *l* ~525 nm, *w* ~60 nm. **b,** sample#t128, *l* ~471 nm, *w*~101 nm. **c,** sample#dw-28, *l* ~500 nm, *w*~120 nm. **d,** Temperature-dependent magneto-transport measurement of sampel#dw-28 at B=9 T.

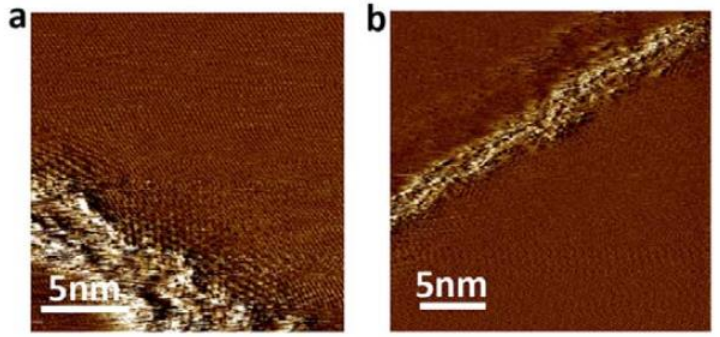


Figure S3| a, STM image of the mechanically cleavage edges of graphene; **b,** STM image of the oxygen-plasma etched edges of graphene.

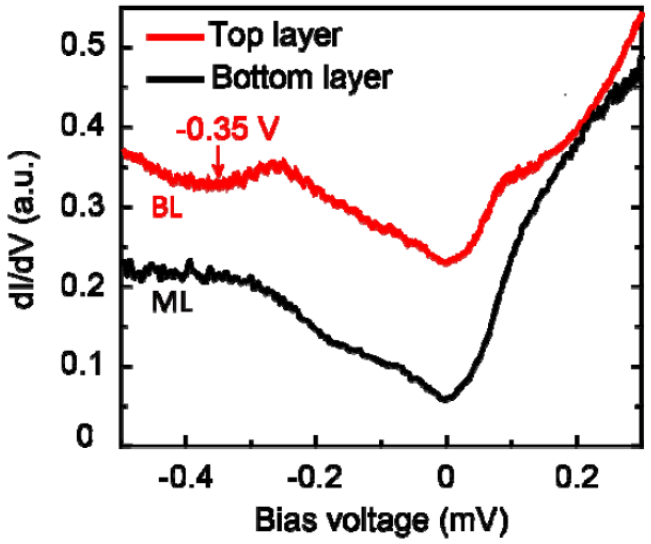


Figure S4| Layer-dependent tunneling spectra of as-grown epitaxial graphene