

Magnetotransport properties of graphene devices contacted by resist-free stencil lithography

Ather Mahmood[†], Cheol-Soo Yang[§], Serin Park[§], Jean-François Dayen[†], Domink Metten[†], Stephane Berciaud[†], Jeong-O Lee[§] and Bernard Doudin^{†*}

[†]Institut de Physique et Chimie des Matériaux de Strasbourg (IPCMS) and Laboratory NIE, University of Strasbourg, UMR 7504 CNRS-UdS, 23 rue du Loess, 67034 Strasbourg, France. [§]Advanced Materials Division, Korea Research Institute of Chemical Technology (KRICT) Daejeon, 305-343, South Korea
bdoudin@ipcms.unistra.fr, ather.mahmood@ipcms.unistra.fr

Abstract We demonstrate large-scale fabrication of high-quality contaminant-free graphene devices, which is a key prerequisite for chemical functionalization applications. We investigate CVD graphene grown on Cu foil, subsequently transferred to Si/SiO₂ substrates. Patterning of graphene and metal evaporation for making contact wires and pads are performed through a multi-step mechanical stencils methodology. Micro- and nanolithography through stencil masks is already well known, but graphene device fabrication has seldom been achieved. In addition, the challenge remains to keep its outstanding electrical properties intact. In order to prove the robustness of the devices fabricated with this non-conventional lithography method, we have performed low-temperature magnetotransport measurements on cross-bar shaped devices. Our results show the existence of Shubnikov-de Hass oscillations and Quantum Hall (QH) Effect, the two hallmarks of good quality graphene. The corresponding Raman spectroscopy maps show a low D peak and a 2D/G peak ratio of ~3, a further evidence for a defect-free monolayer graphene device. Despite a certain degree of amorphization at the edges, the QH edge states remain robust so as to allow the circulation of charge carriers.

To further characterize the disorder in graphene devices we study quantum transport properties, sensitive to the nature of disorder in graphene. The presence of disorder (lattice defects, adsorbed species, folds, ripples) entails Inter- and Intra-valley scattering processes as a result of symmetry breaking at either A-B site or between adjacent valleys K , K' . Thus, depending on the intrinsic disorder, presence of external potentials due to trapped charges in the oxide or at the interface, conventional weak localization or weak (anti-) localization (WAL) can be observed in accordance with the recent WAL theory on graphene. We use this theory to fit the experimental magnetoconductance data and extract the values of scattering terms, validating the excellent intrinsic properties our samples. Finally, we show that this technique can be extended to more complex geometries and smaller device feature sizes.

References

- [1] Y. X. Zhou, A. T. Johnson, J. Hone, W. F. Smith, *Nano Lett.* **2003**, 3, 1371–1374. W. Bao, G. Liu, Z. Zhao, H. Zhang, D. Yan, A. Deshpande, B. LeRoy, C. N. Lau, *Nano Res.* **2010**, 3, 98–102.
- [2] E. McCann, K. Kechedzhi, V. I. Falko, H. Suzuura, T. Ando, and B. L. Altshuler. *Phys. Rev. Lett.* **97**, (2006) 146805.
- [3] V. I. Falko, K. Kechedzhi, E. McCann, and B. L. Altshuler H. Suzuura and T. Ando, *Solid State Comm* **143**, (2007) 33.
- [4] X. Wu, X. Li, Z. Song, C. Berger, W.A. de Heer *Phys. Rev. Lett.* **98**, 136801 (2007)
- [5] F. V. Tikhonenko, A. A. Kozikov, A. K. Savchenko, and R. V. Gorbachev, *Phys. Rev. Lett.* **103**, (2009) 226801.
- [6] A. Mahmood, C. Naud, C. Bouvier, F. Hiebel, P. Mallet, J.-Y. Veuillen, L. P. Lévy, D. Chaussende, T. Ouisse, *Journal of Applied Physics*, **113**, (2013) 083715.

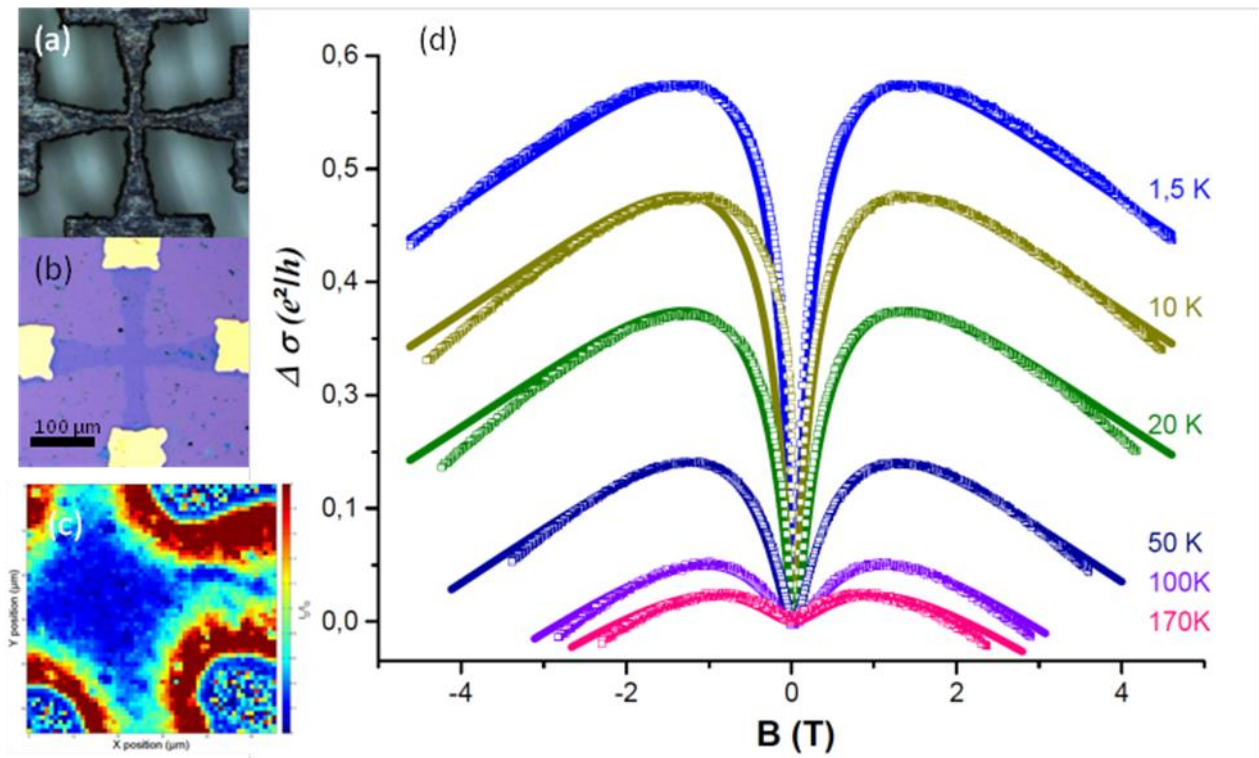


Figure: (a) Stencil mask pattern used to define the graphene device shape. (b) Optical image of the cross-bar shaped graphene device with width $30 \mu\text{m}$ and length $250 \mu\text{m}$. (c) 2D Raman map showing the I_{2D} / I_G peak ratio of the device central portion. (d) Magnetoconductance ($\Delta\sigma(B) - \Delta\sigma(0)$) curves of the device shown in (c) with at various temperatures. Dotted lines are the experimental data whereas solid lines are fit according to McCann's theory.