

Ballistic transport in electrostatic graphene superlattices

Rebecca Hoffmann¹

Giulia Piccinini¹, Julien Barrier¹, David Barcons Ruiz¹, Hanan Herzig Sheinfux¹, Kenji Watanabe², Takashi Taniguchi², Adrian Bachtold^{1,3}, Frank H.L. Koppens^{1,3}

¹-ICFO – The Institute of Photonic Sciences, Castelldefels (Barcelona), Spain

² - Research Center for Functional Materials, National Institute for Materials Science, Tsukuba, Japan

³ - ICREA-Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain

rebecca.hoffmann@icfo.eu

Electrostatic superlattices can be realized in two-dimensional materials through the application of spatially periodic electrostatic potentials via patterned gate electrodes or structured dielectrics, resulting in electronic band structure reconstruction with tunable characteristics [1,2]. This methodology provides precise control over superlattice geometry and periodicity. Although high carrier mobility has been demonstrated in such systems, unambiguous signatures of ballistic transport—including negative differential resistance in cross-junction geometries and transverse magnetic focusing—have not yet been reported.

We present a nanofabrication approach that combines helium ion beam milling for mask definition with reactive ion etching of graphite gate structures [3], achieving superlattice periods below 20 nm (see Figure 1). Implementation of these gate arrays in van der Waals heterostructures based on graphene yields electrostatic superlattices while maintaining the intrinsic high mobility of the host material. We observe characteristic superlattice phenomena, including secondary Dirac points and the Hofstadter butterfly spectrum (see Figure 2). The exceptional electronic quality is evidenced by successful transverse magnetic focusing measurements and mean free paths limited by device dimensions rather than disorder.

References

- [1] C. Forsythe, et al., Nat. Nanotech. 13, 566-571 (2018)
- [2] R. Huber, et al., Nano Lett. 20, 8046-8052 (2020)
- [3] D. Barcons Ruiz, et al., Nat. Commun. 13, 6926 (2022)

Figures

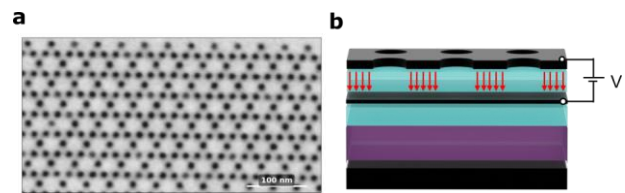


Figure 1: (a) STEM image of He ion milled Si etching mask with 16nm pitch. (b) Schematic of Heterostructure.

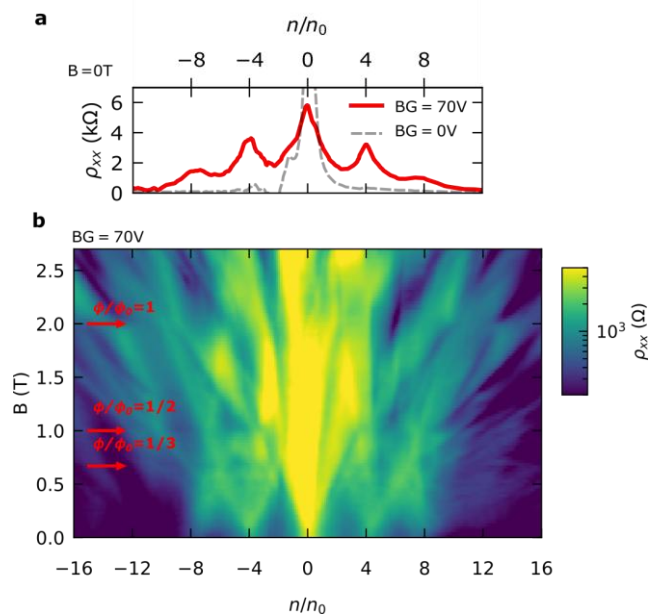


Figure 2: Transport measurements of a device with 47nm pitch square lattice geometry. (a) Longitudinal resistivity versus superlattice filling for the case of no superlattice potential applied (grey) and a high superlattice potential applied (red). Satellite peaks appear. (b) Longitudinal magneto-resistance measurements, showing Hofstadter butterfly.