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Lithographic band structure engineering of graphene

By miniaturisation and careful shaping, any material can be pushed into a (quantum) regime, where the dimensions and shape become essential for the overall behaviour, and the electronic band structure is significantly altered. Materials with a low intrinsic dimensionality, such as the two-dimensional material graphene, allow direct access to the entirety of atoms constituting the crystal, making engineering of the band structure particularly attractive. While high-density nanostructuring has been predicted to provide customisation of the properties of graphene, there has been limited progress in realising this in practice; even high-end top-down fabrication procedures introduce enough edge-disorder and contamination to obscure the predicted behaviours. Here we demonstrate band structure engineering by direct, ultra-dense lithographic patterning of graphene. We fabricate a 35 nm-period superlattice of etched holes separated by as little as 12-15 nm in a graphene sheet encapsulated in hexagonal boron nitride. We observe a distinct magnetotransport regime, with nonlinear Landau levels, and a band gap of 156 meV, which can be tuned with an external magnetic field. The transport measurements are in excellent agreement with both tight-binding simulations and an analytical model. A moiré superlattice from the underlying substrate is observed both before and after nanostructuring, and we see transport features unique to our engineered band structure both at the main and moiré charge neutrality points, indicating that the engineered band structure is cloned by the moiré superlattice. Band structure design in two-dimensional materials by top-down patterning enables the realisation of a number of exciting predictions and opportunities such as spin qubits [1], valleytronics [2] and waveguides [3].

References

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[2] M. R. Thomsen *et al.*, *Phys. Rev. B*, 95 (2017) 235427
[3] J. G. Pedersen *et al.*, *Phys. Rev. B*, (2012) 245410

Figures

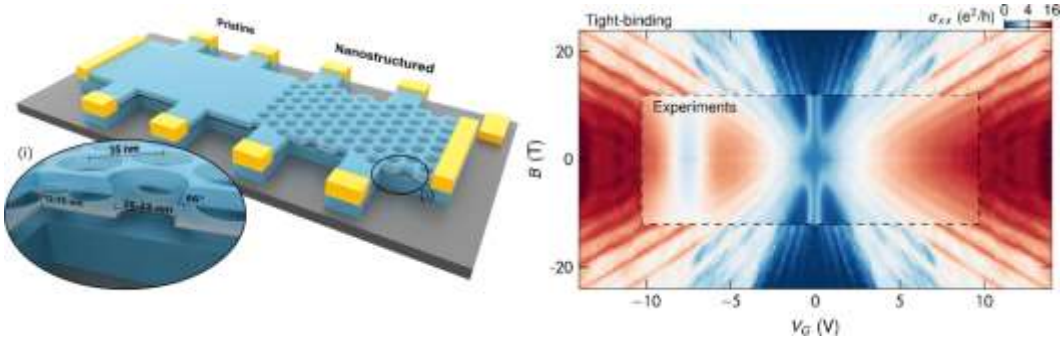

Figure 1: (left) Schematic of a measured device with high-quality nanostructured graphene, leading to an engineered bandstructure. (right) Magnetotransport measurements, directly overlaid on tight-binding simulations of the system.