Lithographic band structure engineering of graphene

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Two-dimensional materials such as graphene allow direct access to the entirety of atoms constituting the crystal. While this makes shaping by lithography particularly attractive as a tool for band structure engineering through quantum confinement effects, edge disorder and contamination have so far limited progress towards experimental realisation.

In this talk, we show work on a superlattice of holes (12-15 nm minimum feature sizes) etched in graphene encapsulated by hexagonal boron nitride, which results in profound effects on the band structure and the resulting quantum transport [1].
Through the high-quality lithographic patterning of the graphene, we achieve ballistic transport while opening a bandgap on the order of 0.15 eV. In magnetotransport measurements, we observe a regime that is distinctly different from the characteristic Landau fan of graphene, and further, observe that the bandgap can be continuously turned off by increasing the magnetic field strength. The measurements are accurately described by transport simulations and analytical calculations.

Finally, we observe strong indications that the lithographically engineered band structure at the main Dirac point is cloned to a satellite peak that appears due to moiré interactions between the graphene and the encapsulating material. Band structure design in two-dimensional materials by top-down patterning enables the realisation of many exciting predictions and opportunities such as spin qubits [2], valleytronics [3] and waveguides [4].

References

[1] B. S. Jessen, L. Gammelgaard *et al*. ***Nat. Nano***. (2019)
[2] T. G. Pedersen *et al*. ***Phys. Rev. Lett***.,473 (2008) 136804
[3] M. R. Thomsen *et al*., ***Phys. Rev. B***, 95 (2017) 235427
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Figures

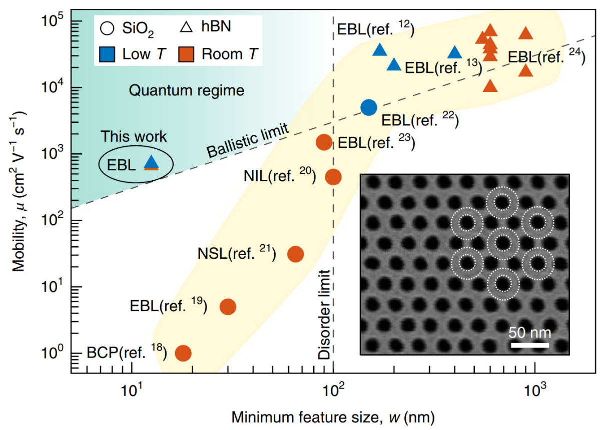

Figure 1: High-performance nanostructured graphene is possible due to hBN encapsulation and careful lithography and etching.

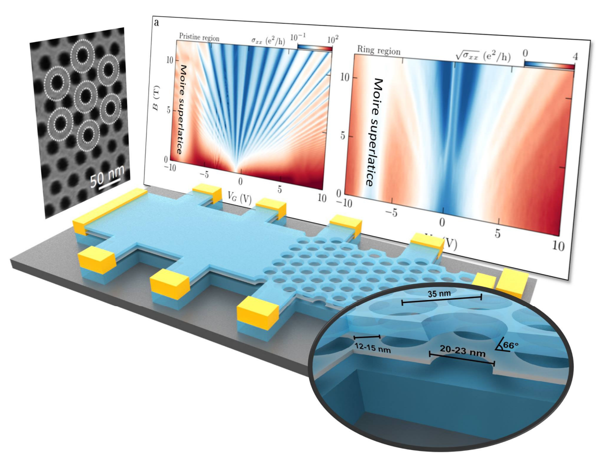

Figure 2: Nanostructuring of graphene leads to an engineered band structure, with associated magnetotransport.