Superconducting Devices in Magic-Angle Twisted Bilayer Graphene

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In situ electrostatic control of two-dimensional superconductivity1 is commonly limited due to large charge carrier densities, and gate-defined Josephson junctions are therefore rare. Magic-angle twisted bilayer graphene (MATBG) has recently emerged as a versatile platform that combines metallic, superconducting, magnetic and insulating phases in a single crystal. Although MATBG appears to be an ideal two-dimensional platform for gate-tunable superconductivity, progress towards practical implementations has been hindered by the need for well-defined gated regions. Here we use multilayer gate technology to create devices based on two distinct phases in adjustable regions of MATBG [1,2]. We electrostatically define the superconducting and insulating regions of a Josephson junction and observe tunable d.c. and a.c. Josephson effects. The ability to tune the superconducting state within a single material circumvents interface and fabrication challenges, which are common in multimaterial nanostructures. This work is an initial step towards devices where gate-defined correlated states are connected in single-crystal nanostructures. We envision applications in superconducting electronics and quantum information technology.

References

[1] de Vries, F.K., Portolés, E., Zheng, G. et al. Gate-defined Josephson junctions in magic-angle twisted bilayer graphene. Nat. Nanotechnol. (2021)
[2] Rodan-Legrain, D., Cao, Y., Park, J.M. et al. Highly tunable junctions and non-local Josephson effect in magic-angle graphene tunnelling devices. Nat. Nanotechnol. (2021)

Figures

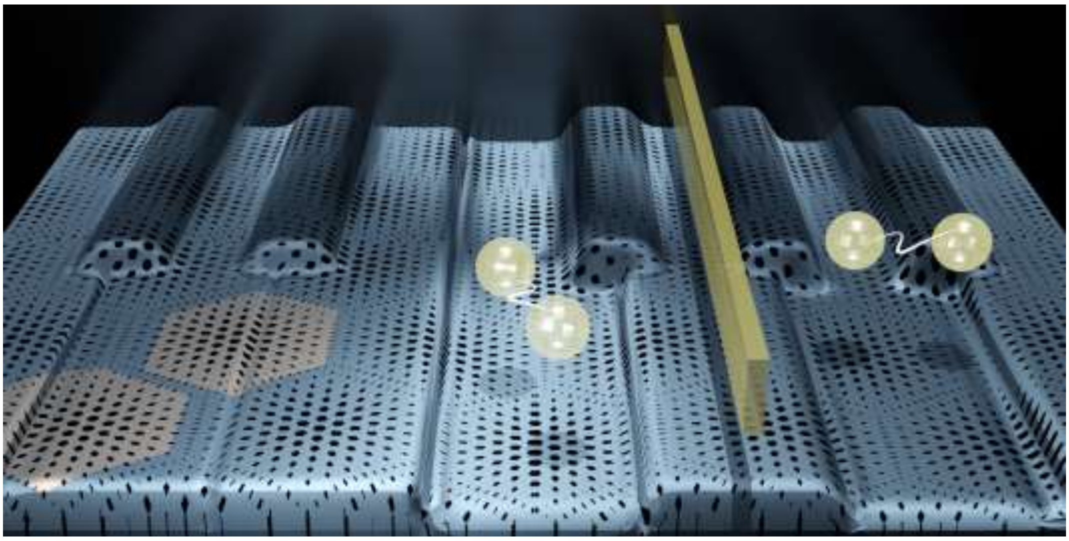

Figure 1: Artist impression of the material keyboard in twisted graphene, hosting superconducting and insulating states in a single device.