TATOOS: TunAble Twistronics : local tuning and probing of TOpOlogical edge states and Superconductivity in bilayer graphene

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Abstract

Studying the interface between different correlated electronic systems represents one of the most fundamental and technological challenge for future applications in quantum technologies. In this respect, twisted bilayer graphene (tBLG) which can show superconductivity and topological edge states (among other electronic phases), at some precise twist angles between its layers, seems to be the ideal candidate. However, to achieve these very complex structures it is necessary first to understand their physical origin and how we can control them.

In this regard, the general objective of TATTOOS is to provide an experimental and theoretical understanding of the physical origin of both the superconducting state and the existence of topologically protected channels, with the prospect of building clean junctions involving different correlated electronic systems.

We propose to investigate first the dependence of these states on the twist angle between the layers, and how their transport properties, down to the nanometer scale, are modified by the twist angle. We plan to do so by using different scanning probe microscopy techniques. The first one allows an in situ mechanical modification of the twist angle between the graphene layers in an electrically-contacted device by applying a lateral force to the uppermost layer. The second one, scanning gate microscopy, will be used to map the electron transport down to ultralow temperature. Combining experimental data with numerical simulations of transport in realistic tBLG model devices, we aim to address fundamental questions such as the physical origin and nature of the superconducting and topologically-protected channel, their spatial homogeneity and robustness against local variations of electrostatic or magnetic environment, among others.

Second, we propose to build “all-tBLG” junctions between a superconductor and different other phases, including topologically-protected 1D edge channels. This will be realized through van der Waals stacking of two graphene layers grown by chemical vapor deposition (CVD). While one layer should have a single grain boundary, which is achieved by the merging of two crystals, the other layer should be single crystalline. By the appropriate selection of the alignment of both graphene crystals along the grain boundary, a twist angle of the upper layer should be achieved, which makes it possible, for example, to obtain a superconducting state on one side and topologically protected channels on the other side of the grain boundary.

Consortium

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