Transport effects of twist angle disorder in mesoscopic twisted bilayer graphene

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Magic angle twisted bilayer graphene is a tunable material with remarkably flat low-energy bands near the Fermi level, leading to fascinating transport properties and correlated states at low temperatures. However, grown pristine samples of this material, which are nominally free of impurities and defects, break up into landscapes of domains with slightly differing twist angle. These so-called twist angle domains strongly influence the physical properties of each individual sample. This poses a significant problem to the interpretation and comparison between measurements conducted on different samples. In this work we studied numerically the effects of twist angle disorder on quantum electron transport in mesoscopic samples of magic angle twisted bilayer graphene. For this, we used a novel approach which exploits the equivalence between small deviations of twist angle and interlayer hopping amplitude in regards to the coupling of the graphene sheets. This equivalence was shown in our previous work [1].

We find that the magnitude of the twist angle variation has a strong effect on the conductance, while the size of the twist angle domains is of much lesser significance. We further find a significant property of twist angle disorder in near-magic angle twisted bilayer graphene that distinguishes it from onsite energy disorder: it leads to an asymmetric broadening of the energy-resolved conductance. We establish a relationship between the asymmetric broadening of conductance and the asymmetric density of states of twisted bilayer graphene at angles smaller than the first magic angle $\theta \approx 1.05^{\circ}$. Our results show that the qualitative differences between the types of disorder in the energy-resolved conductance of twisted bilayer graphene samples can be used to characterize them at reasonably high temperatures, enabling systematic experimental studies of the effects of the different types of disorders also on the other properties such as the competition of the different types of correlated states appearing at lower temperatures.

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