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Quantum transport in twisted bilayer graphene hydrid junction devices

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Abstract

In this work, we report the quantum transport of twisted bilayer graphene (tBLG) in two different device structures. First, we measured the quantum Hall transport in a CVD-grown monlayer-twisted bilayer graphene junction. The measurements of longitudinal cross-layer resistances shows quantized plateau at several back-gate voltages, which shows the scattering of edge states at the monolayer-bilayer interface. We also realize Josephson junctions based on the CVD-grown tBLG. Relatively large supercurrents are observed in our devices. The critical current oscillates with the magnetic field, which shows a Fraunhofer-like pattern. Multiple Andreev reflections (MAR) are also observed, indicating a phase-coherent transport.

1. Introduction

Twisted bilayer graphene (tBLG) is a non-AB stacked structure, in which one graphene rotates by a certain angle (θ) relative to the other. It is one of the simplest structures among the booming Van der Waals stacked 2D layered materials. From the start, Quantum Hall transport in tBLG has been investigated in homogeneous samples[1], but still less explored in hybrid devices. Recently, correlated insulating and superconducting phases are discovered in twisted bilayer graphene with magic twist angle, which inspires the investigation of this carbon-based two-dimensional superconductor and strongly correlated physics [2-3]. Meanwhile, inducing superconductivity into tBLG through the proximity effect is also worthy to explore. Till now, few research focuses on the hybrid tBLG-superconductor devices. In this work, we report the investigation of manipulating of the edge states in a tBLG-monolayer hybrid structure and transport measurements of tBLG Josephson junctions.

2. Experimental data

We first report on quantum Hall transport through a monolayer-bilayer junction device. The tBLG is grown on copper foil via chemical vapour deposition. After tBLG samples were transferred to heavily doped Si substrate with a 300-nm-thick layer of SiO_2 on top (Fig.1a), the graphene samples are etched into a multiple Hall bar geometry and the monolayer-bilayer interface stretches across the middle of Hall bar (Fig.1b). The measurements are performed in a PPMS system, with a base temperature of 1.9K.

At low temperatures, as shown in Fig.1c, Quantum Hall measurements of bilayer graphene show than the ν=12 platform develops earlier than the ν=8 with increasing magnetic field, a signature of twisted bilayer graphene [1]. Magnetoresistance measurements of R_{xx} across the junction (Fig.1d) exhibit quantized Hall plateaus for several ranges of gate voltage, which is a signal for edge states scattering at the interface of monolayer-tBLG junction. The observed resistance quantization can be explained by a Landauer-Buttiker formula over a wide range of filling factors [4-5].

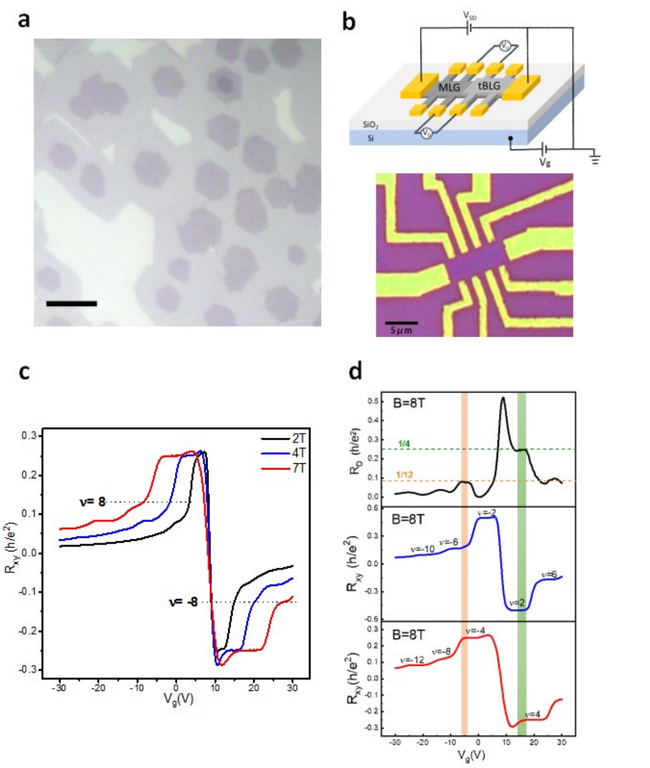

Fig. 1 a. Optical characteration of CVD-grown tBLG, the scale bar is 10μm. b. Sketch and Optical image of a cross-layer hallbar device. c. Quantum Hall resistances at different magnetic field as a function of back-gate voltage at T=1.9K. d. Top graph is the cross-layer resistance as a function of back-gate voltage at B=8T and T=1.9K, as

a companion, the middle and bottom graph is the Quantum Hall resistance of monolayer graphene and tBLG at B=8T and T=1.9K, respectively.

Furthermore, in our tBLG SNS junctions, the graphene bilayer is contacted with two adjacent superconducting electrodes, as seen in Fig.2b. After etching the graphene sheets and using electron beam lithography (EBL) to pattern a PMMA mask, Ti/Al electrodes were deposited by electron-beam evaporation, followed by lift-off processes. All the measurements are performed in a ^3He /^4He dilution refrigerator with a base temperature of 10 mK, in which the magnetic field is applied perpendicularly to the sample.

At temperatures below the critical temperature of superconducting electrodes, proximity-induced superconductivity in the tBLG leads to Josephson supercurrent. The dependence of critical supercurrent to the magnetic field exhibits a Fraunhofer-like pattern, as shown in Fig.2c. In addition, subharmonic conductance peaks in the measured dI/dV as a function of bias voltage V_b, can be observed below the superconducting critical temperature of aluminum electrodes, which are clear signatures of MAR. The evolutions of the corresponding subharmionic conductance peaks with temperature are shown in Fig.2d. The position of the conductance peaks shift closer to lower V_b with the increase of temperature. The observed MARs indicate a phase coherent transport in our tBLG junctions.

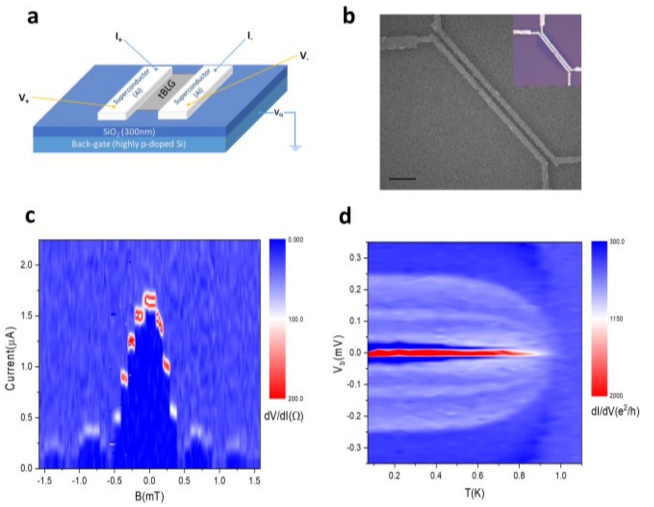

Fig. 2 a. Sketch of a tBLG Josephson junction device. b. SEM image of a tBLG Josephson junction device, the scale bar is 2μm. The inset is the corresponding optical image of the device. c. Color-scale plot of the differential resistance dV/dI as a function of magnetic field and current, taken at T=60 mK and V_g=30V. The critical current exhibits oscillations, showing a Fraunhofer-like pattern. d. Color-scale plot of the differential conductance dI/dV as a function of V_b and temperature, taken at T=60 mK, B=0T and V_g=15V.

3. Conclusions

We have investigated low temperature transport properties of graphene cross-layer hybrid junction devices and Josophson junction devices based on high quality CVD-grown tBLG. In the tBLG-monolayer junction, the new emerging filling factor ν=8 shows the broken degeneracy of the first excited Landau Level. The observed quantized cross-junction resistances indicate edge states scattering at the cross-layer interface. In the tBLG SNS junction, proximity-induced supercurrents are observed, and the oscillations of critical current with the magnetic field exhibit a Fraunhofer-like pattern. Signatures of multiple Andreev reflections indicates a phase-coherent transport in our Josephson junctions. This work paves a helpful way for the further development on hybrid tBLG-based devices.

Acknowledgements

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