Moiré formed by heterogeneous structures composed of graphene and hBN under stress

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Introduction

This research explores moiré patterns in two-dimensional superlattices, such as those formed by stacking graphene and hexagonal boron nitride (hBN), which have the potential to the quantum phenomena like the Hofstadter Butterfly effect[1][2]. These patterns significantly influence the electronic properties of materials, but changing their characteristics is challenging due to the materials' rigidity. The proposed solution involves transferring these layers onto a flexible substrate, allowing for the adjustment of moiré patterns by bending.

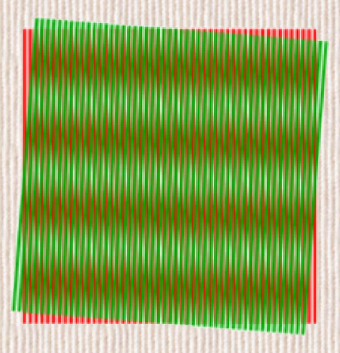

Figure.1 Moiré.

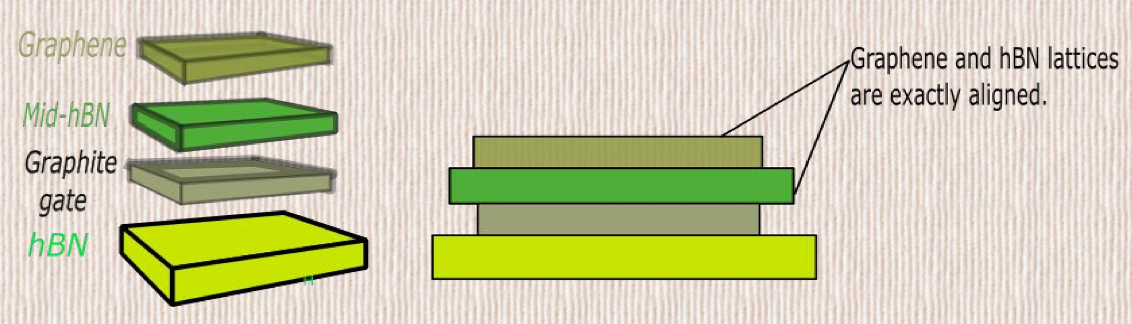

Figure. 2 Ideal Stacking Model.

Methodology

Using microscopy and Atomic Force Microscopy (AFM), we will select and characterize graphene and hexagonal boron nitride (hBN) flakes based on criteria like shape, size, and surface quality. This preparation enables the assembly of these materials into superlattices. Then, the stack is transferred onto a flexible plastic substrate with PMMA and mechanically deformed to apply tension to the graphene layer, modifying the moiré patterns to enhance the study of quantum effects. Electrodes will be designed and attached to the stack to measure electronic parameters through electric currents, allowing observation of the effects of tension-induced moiré pattern changes on the superlattice's electronic behavior, focusing on superconductivity and quantum phenomena. Measurements of electron transfer efficiency and other relevant data will be conducted in a low-temperature, high-magnetic-field environment.

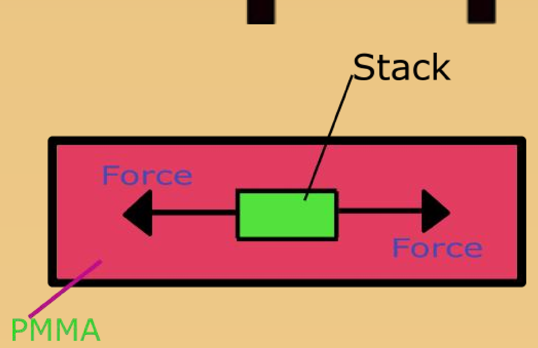

Figure. 3
Apply force to the stack using PMMA from overhead.

Results

We used atomic force microscopy (AFM) to find 42nm and 24nm thick hexagonal boron nitride(hBN) that could be used as the bottom hBN and Mid-hBN. Next, We have found some graphene that appears to have the same lattice orientation as Mid-hBN and the right shape under optical microscopy.

After finding all suitable samples, we successfully stacked them together on a Si/Sio2 substrate. Afterwards, in order to apply stress to change the shape of the moire, we successfully transferred it to a plastic substrate and successfully applied stress through PMMA.

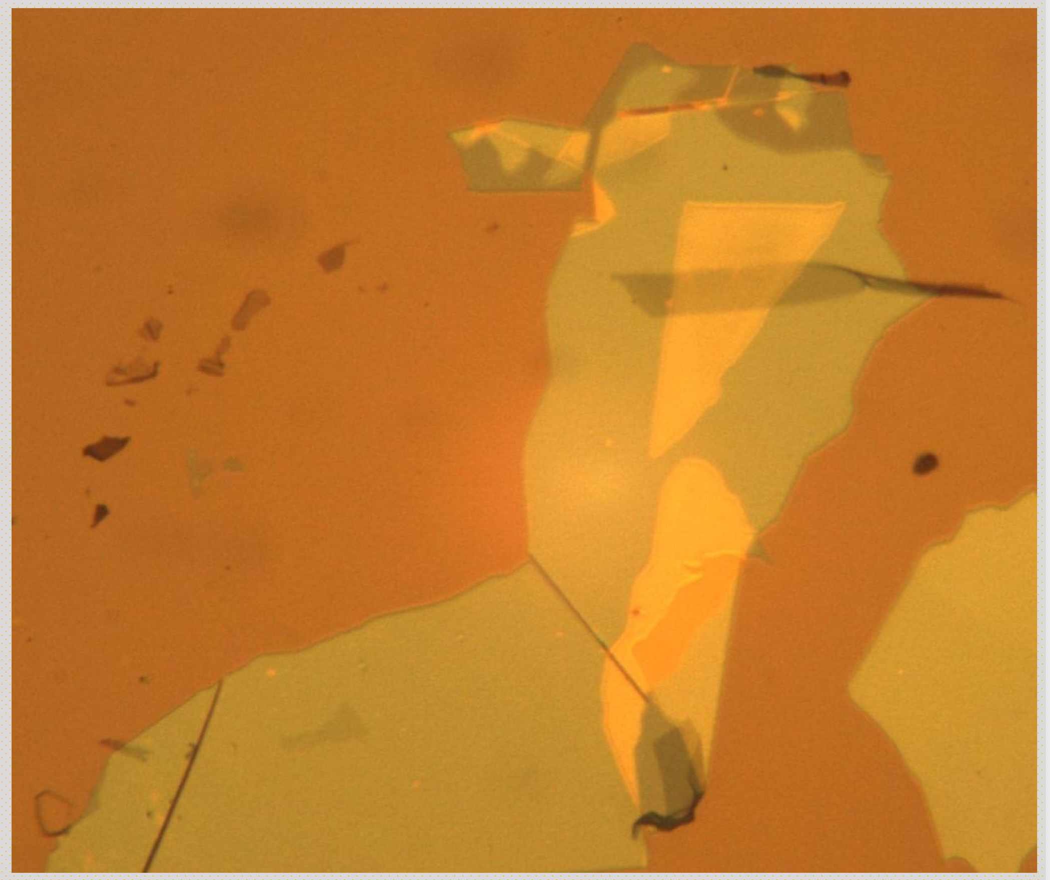

Figure. 3 Samples placed on Si/Sio2 substrate successfully stacked.

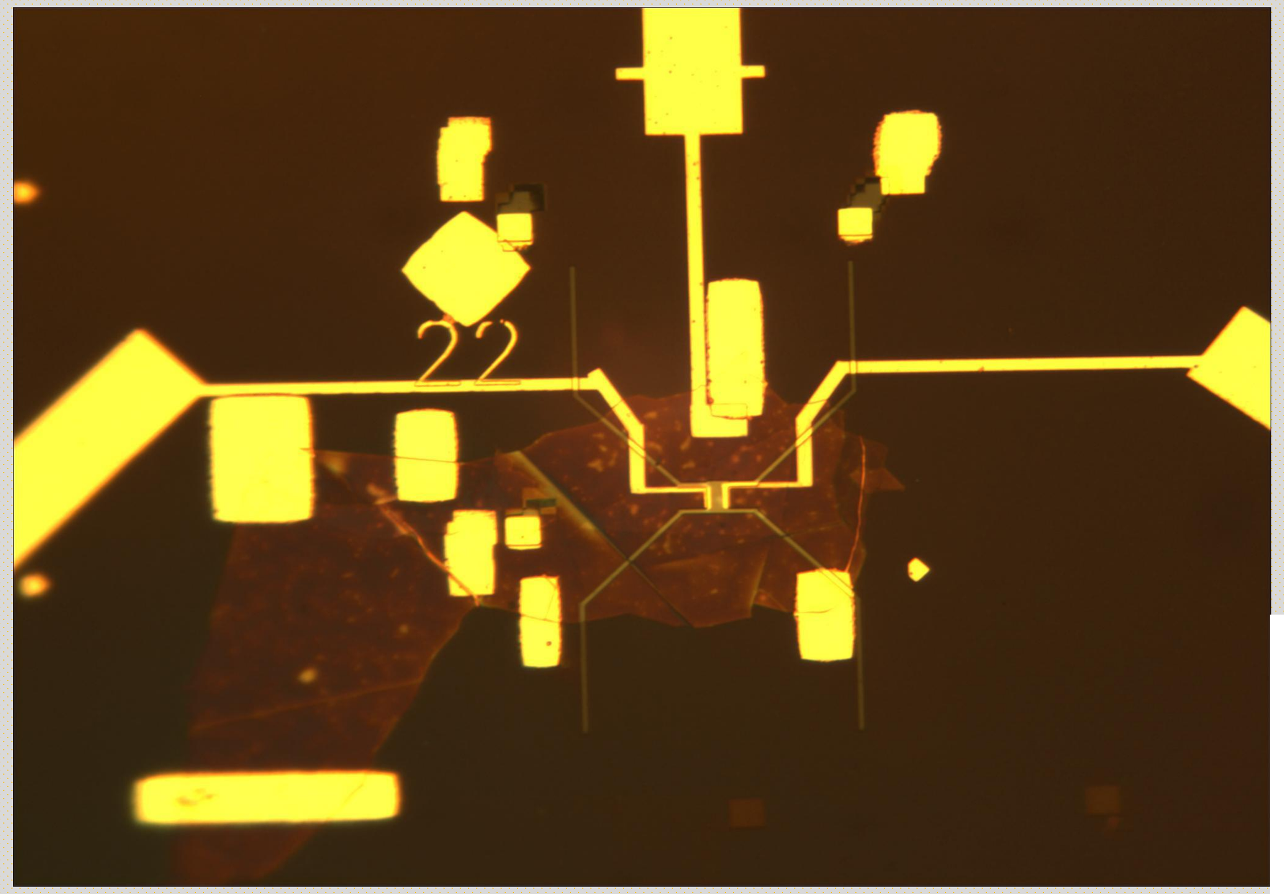

Figure. 4 Samples that have been top-down nanolithographed on a plastic substrate

The complete build of the electrodes has been carried out. After electrode building is done, the top-down Nanolithography was done through photolithography.

Upon conduction of the top-down nanolithography experiment in correspondence to the features of the substrate detection, it was detected that the current pathway is normal.

The change and distribution of resistance and current density under different magnetic field intensity were measured at 4K temperature. We can clearly see the split of the Landau level and the secondary Dirac points. That means we've managed to find and change the size and shape of moire.

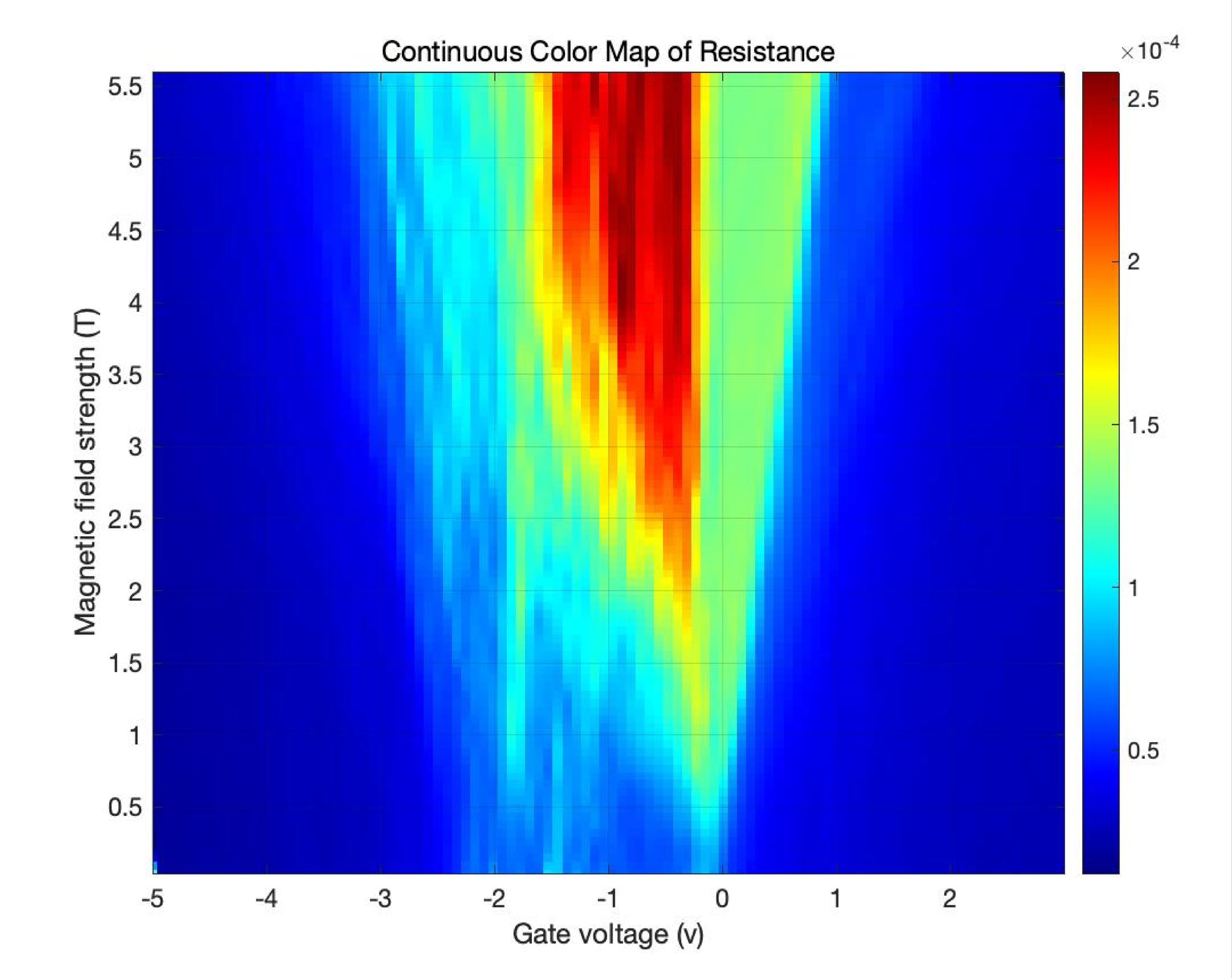

Figure. 4 Changes in resistance and current density measured under 4K, strong magnetic conditions.

Conclusions

At present, the shape and size of moire have been successfully changed by applying stress under the condition of 4K strong magnetic field, and the changes of its resistance and current density have been tested. It is proved that the scheme of changing the shape of moire by applying stress to PMMA is feasible.

What's Next?

1. Make and measure more same stacks to find more useful data.
2.Find some "interesting" appearances and physical changes in moire due to changes in shape and orientation.

Literature cited

[1] Du, Yongping, et al. "Moiré Effects in graphene-hBN Heterostructures." Physical Review Research, vol. 2, no. 4, Dec. 2020, doi:10.1103/physrevresearch.2.043427.

[2] Wang, Lujun, et al. "New Generation of Moiré Superlattices in Doubly Aligned hBN/Graphene/hBN Heterostructures." Nano Letters, vol. 19, no. 4, Feb. 2019, pp. 2371–76, doi:10.1021/acs.nanolett.8b05061.

Further information

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