Correlation of nanoscale electromechanical and mechanical properties of twisted double bi-layer graphene via UFM, PFM, and E-HFM

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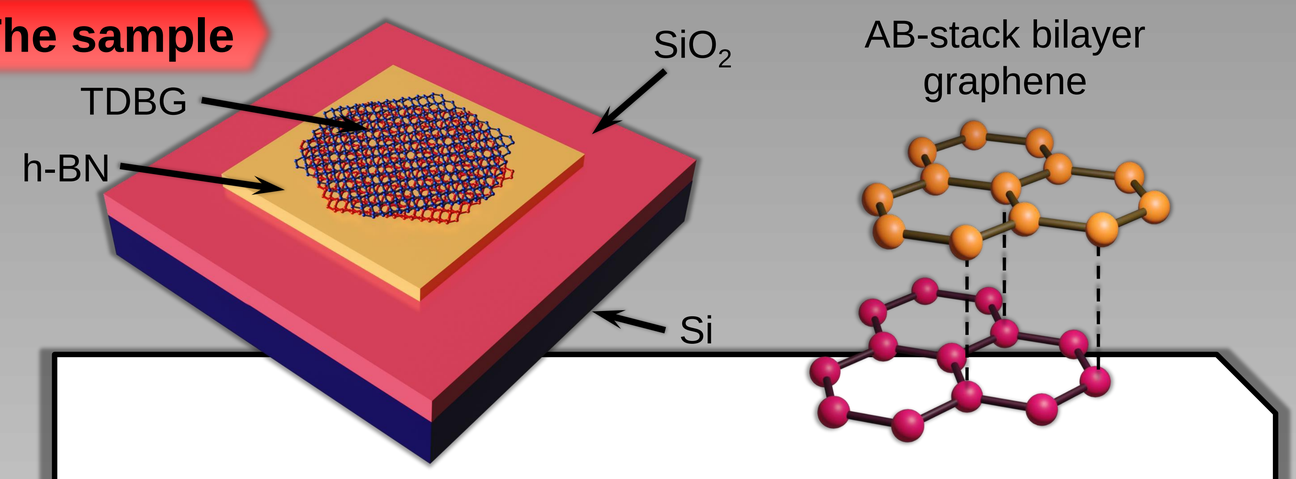
Introduction

- The 2D stack *interlayer twist angle* changes the lattice periodicity, creating a *Moiré pattern*.[1]
- This causes atomic reconstruction[2] → affecting the system's *electronic band structure* and its physical properties.

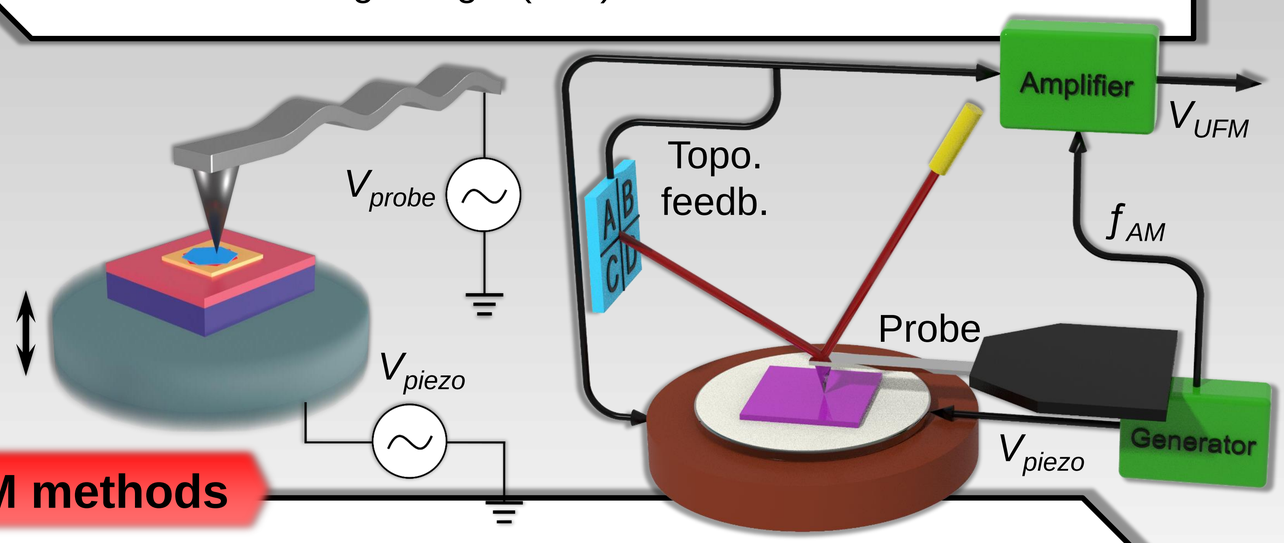
- Moiré pattern detection via Force Microscopy.
- Local changes of mechanical properties → analysis of Young's modulus.
- Picosecond-scale time-domain relaxation with nanoscale lateral resolution.

The sample



- Twisted double bilayer graphene (TDBG) on hexagonal boron nitride (h-BN).
- TDBG is composed by two AB-stacked bilayer graphene sheets rotated at the magic angle (1.1º).

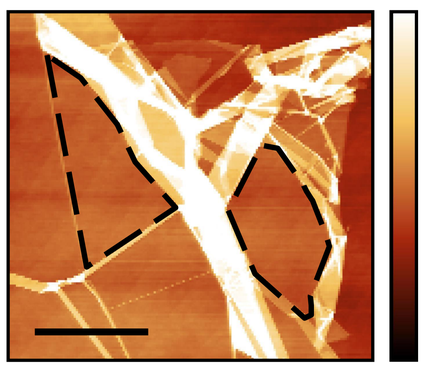
SPM methods



- Ultrasonic force microscopy (UFM) applies ultrasonic vibrations to the sample stage, which interacts with the tip to reveal nanoscale variations in mechanical properties.[3]
- Piezoresponse force microscopy (PFM) applies an AC voltage to the probe, inducing sample piezo-deformation, and detecting the electromechanical signals.[4]
- Electrical heterodyne force microscopy (E-HFM) monitors the tip-sample separation at a specific frequency while applying an AC voltage to the tip. The resulting electrostatic force variations are demodulated and detected.[5]

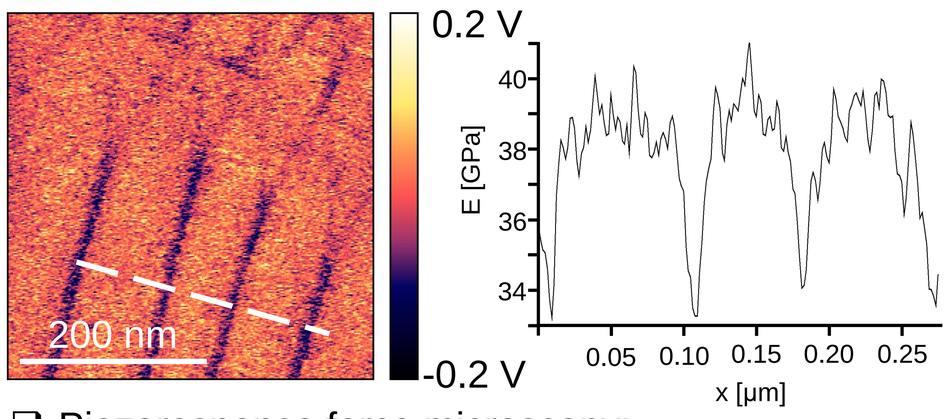
Results

- Topography:

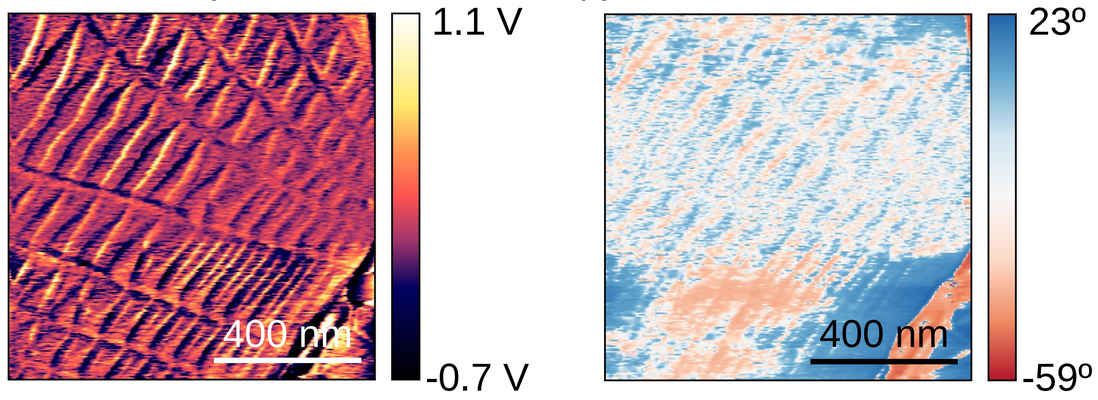


Black highlighted areas are twisted at 1.1º. Scalebar: 2 µm.

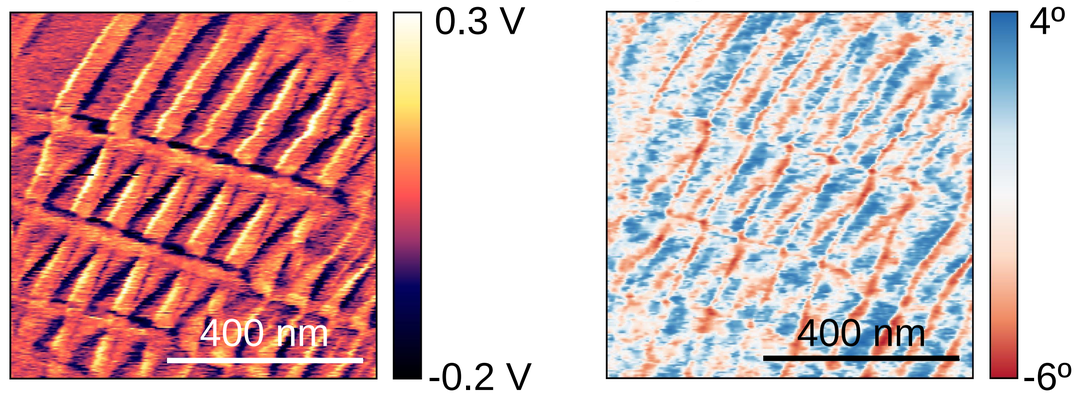
- Ultrasonic force microscopy:



- Piezoresponse force microscopy:



- Electric heterodyne force microscopy:



Conclusions

- ✓ PFM, UFM and E-HFM allow to image in a detailed way the Moiré pattern of TDBG.
- ✓ Elongated triangular domains pattern → presence of local non-uniform strain or pinning of stacking sites.
- ✓ Young's modulus is reduced by approximately 5 GPa along the domain walls with respect to the stacking domains.

References

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