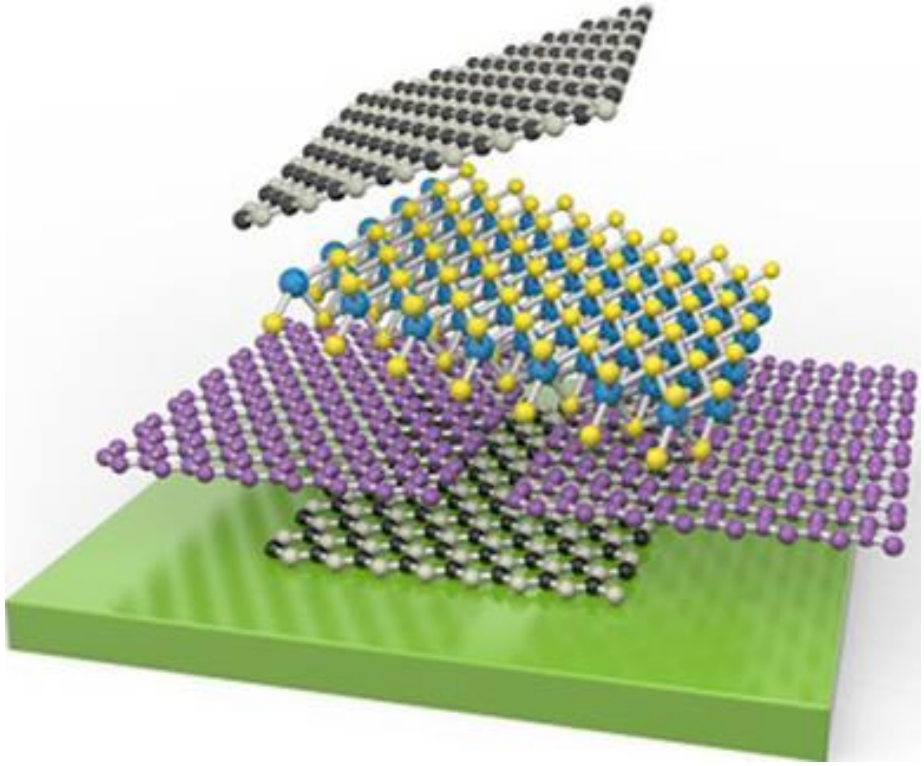
Annual report

2nd year of PhD in Nanosciences



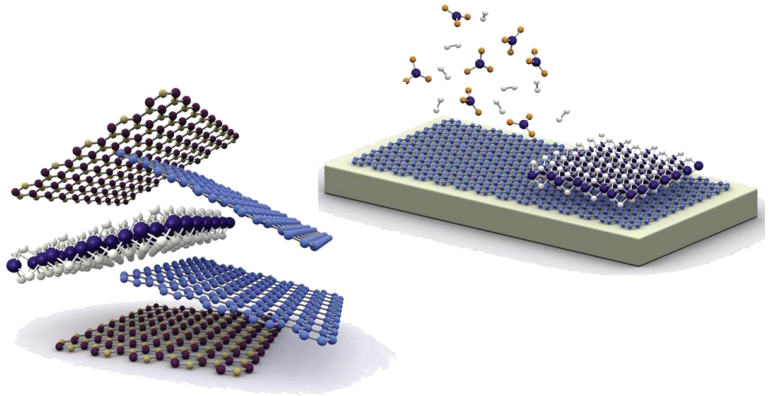
PhD Student: *Giulia Piccinini*

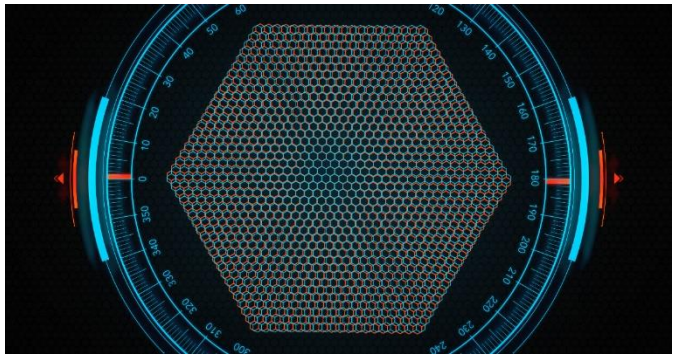
Internal Supervisor: *Luigi Rolandi*

External Supervisor: *Camilla Coletti*

2D materials van der Waals heterostructures

Materials by design by mixing and matching 2D crystals with different properties in one vertical stack → combinations with new functionalities

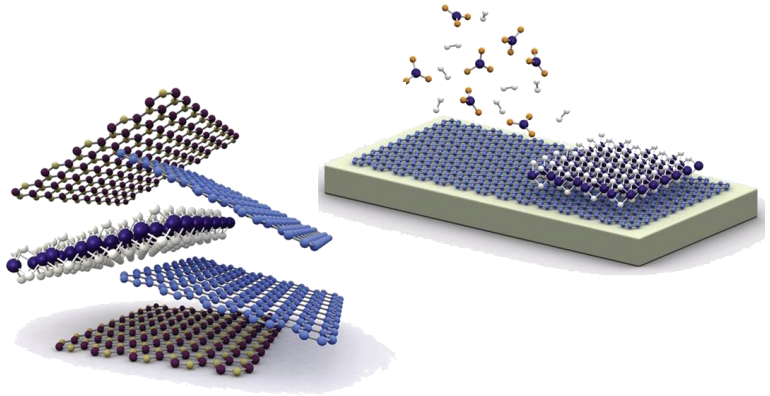


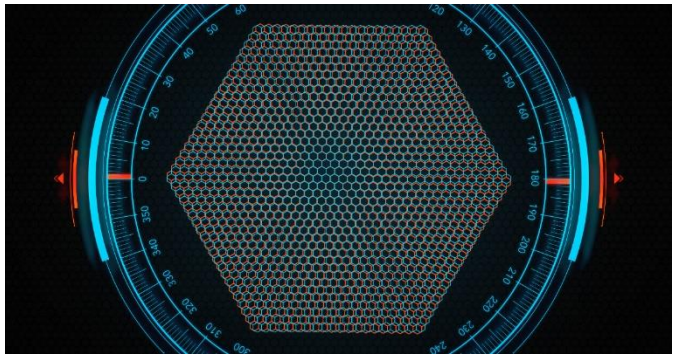


The **relative angle** between the individual elements changes the physics

2D materials van der Waals heterostructures

Materials by design by mixing and matching 2D crystals with different properties in one vertical stack → combinations with new functionalities

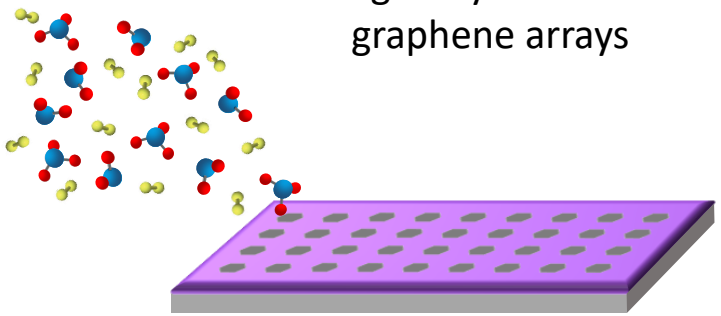


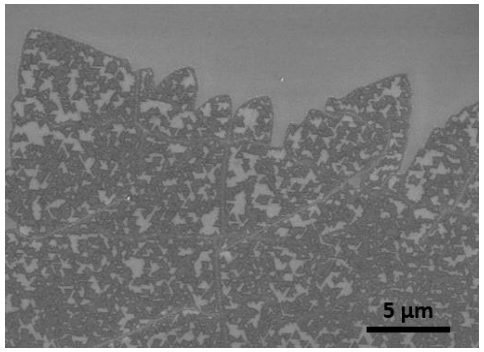


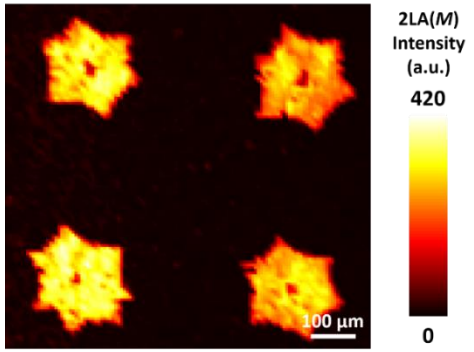
The **relative angle** between the individual elements changes the physics

WS_2/graphene heterostructure

Direct **synthesis** of monolayer WS_2 on single-crystal CVD graphene arrays







Structural and electrical **characterization** (doping, strain, electron and hole transport)

Collaborations:

- aging of WS_2
- WS_2 optical dielectric function


2D Materials

PAPER

Optical dielectric function of two-dimensional WS_2 on epitaxial graphene

Michele Magnozzi, Marzia Ferrera, Giulia Piccinini, Simona Pace, Stiven Forti, Filippo Fabbri, Camilla Coletti, Francesco Bisio and Maurizio Canepa


THE JOURNAL OF PHYSICAL CHEMISTRY C

pubs.acs.org/JPCC Article

Edge Defects Promoted Oxidation of Monolayer WS_2 Synthesized on Epitaxial Graphene

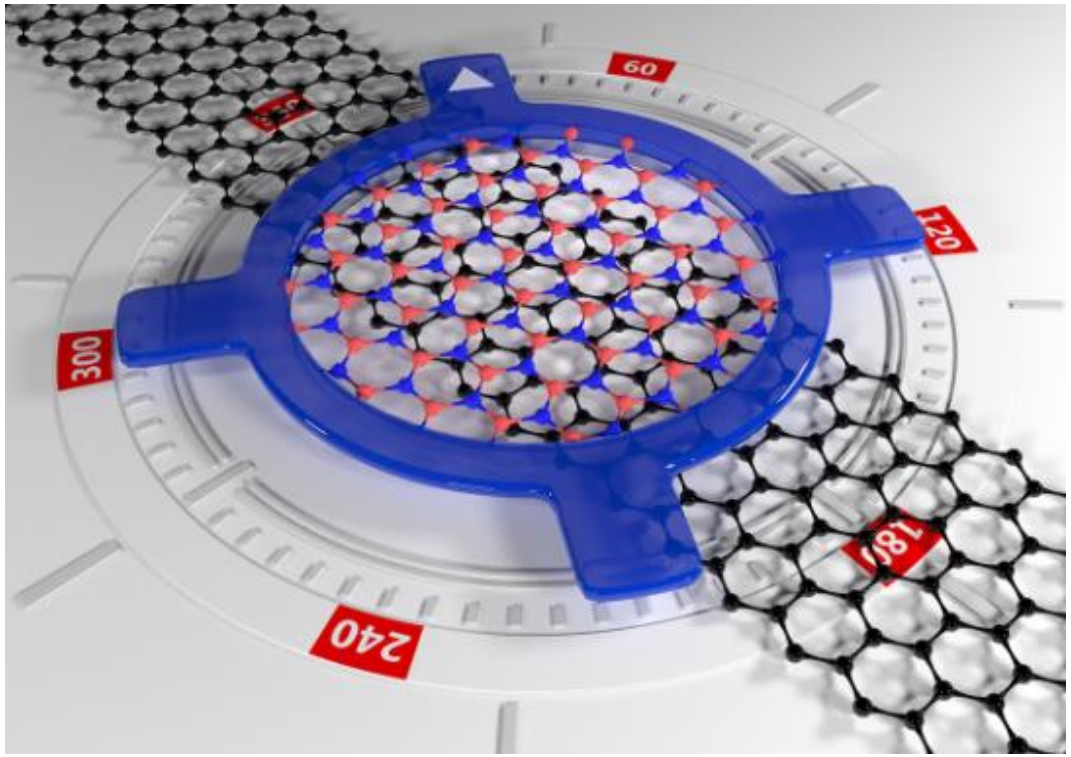
F Fabbri,* F. Dinelli, S. Forti, L. Sementa, S. Pace, G. Piccinini, A. Fortunelli, C. Coletti, and P. Pingue

Cite This: J. Phys. Chem. C 2020, 124, 9035−9044 Read Online

Piccinini *et al.*, *2D Mater.*, **7**, 014002 (2019)

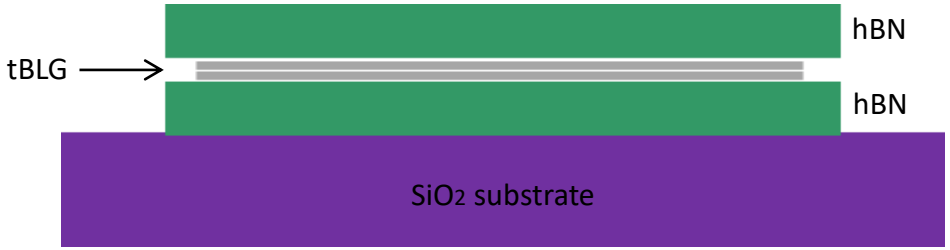
Talk "Deterministic direct growth of WS_2 on CVD graphene arrays" **@** Graphene Flagship's WP3 annual meeting

Twisted bilayer graphene (tBLG) encapsulated in hBN



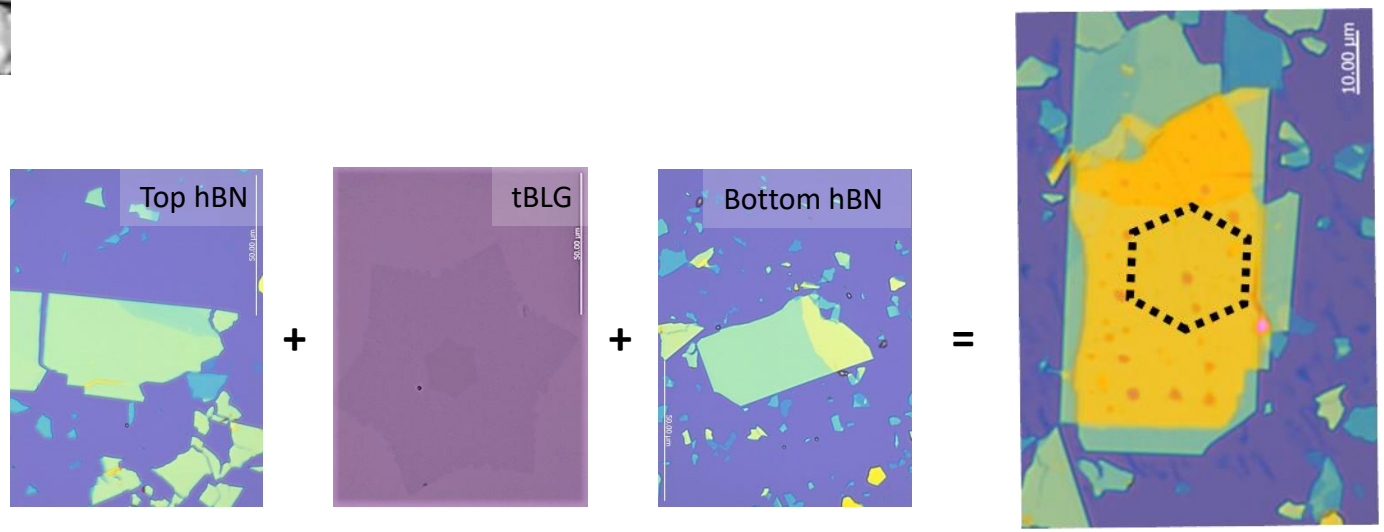
Twist angle → new degree of freedom induces several angle dependent properties in tBLG → vastly different electronic behavior that depends sensitively on the angle between the layers

tBLG encapsulated in hBN ← high mobility and fine gating

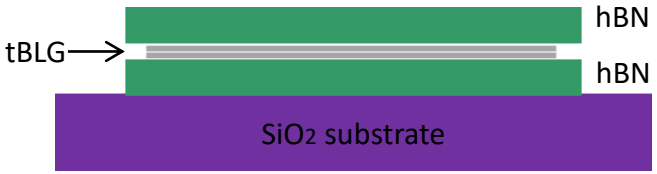


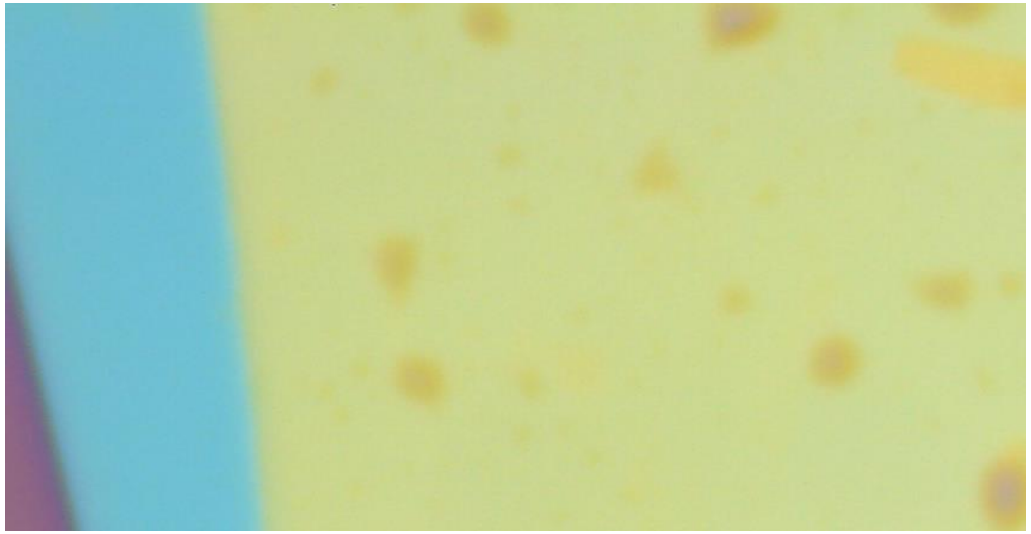
This year focus:

- ✓ Sample **characterization** and selection of the best possible area for device fabrication
- ✓ Development of skills in device **fabrication**
- ✓ Study of an **electrostatic model** to determine the charge density in the two graphene layers

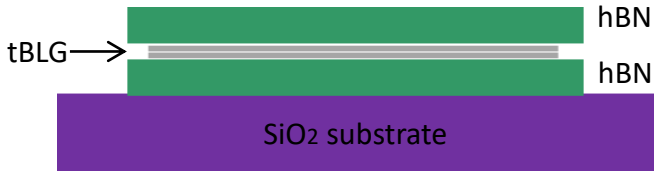


Sample characterization and device fabrication

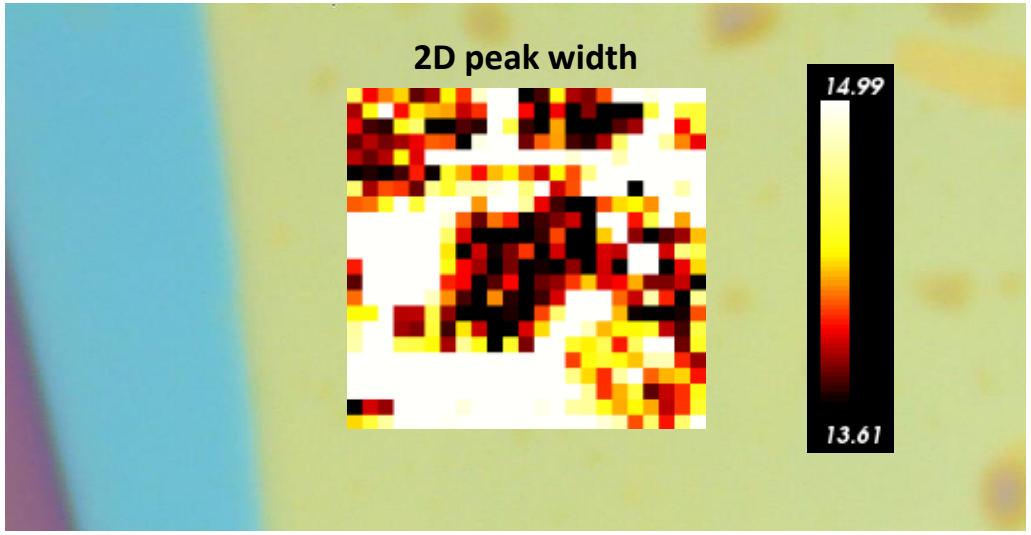


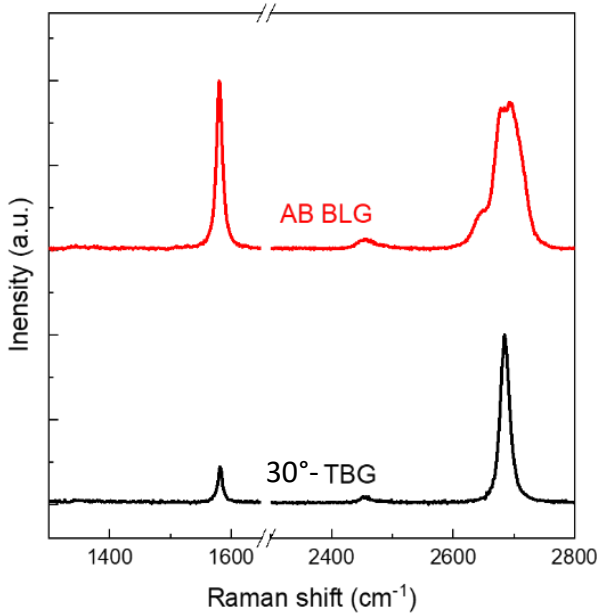


Sample characterization and device fabrication

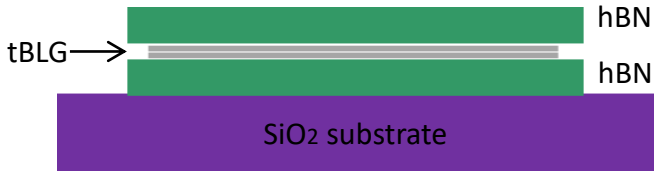


- Raman spectroscopy → check of the twist angle

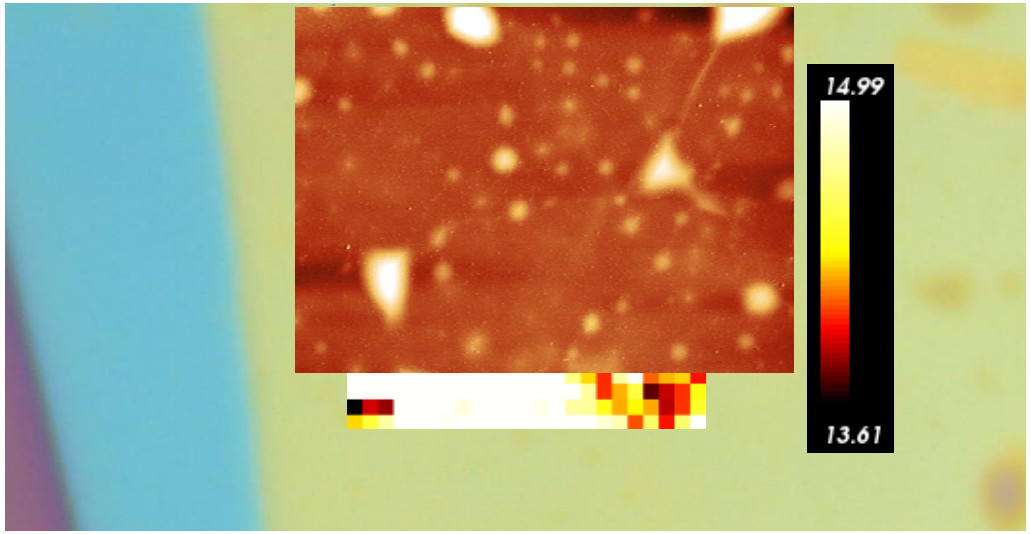


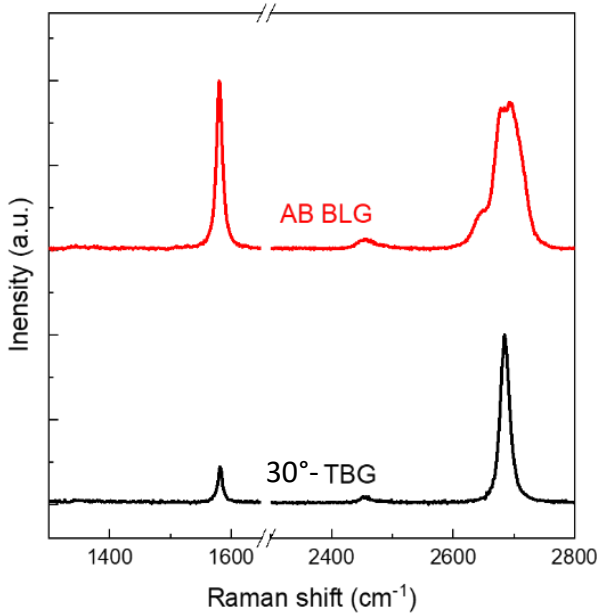


Sample characterization and device fabrication

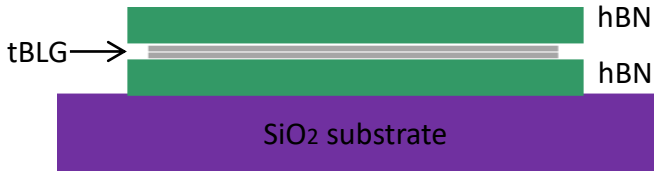


- Raman spectroscopy → check of the twist angle
- AFM → flat and clean area

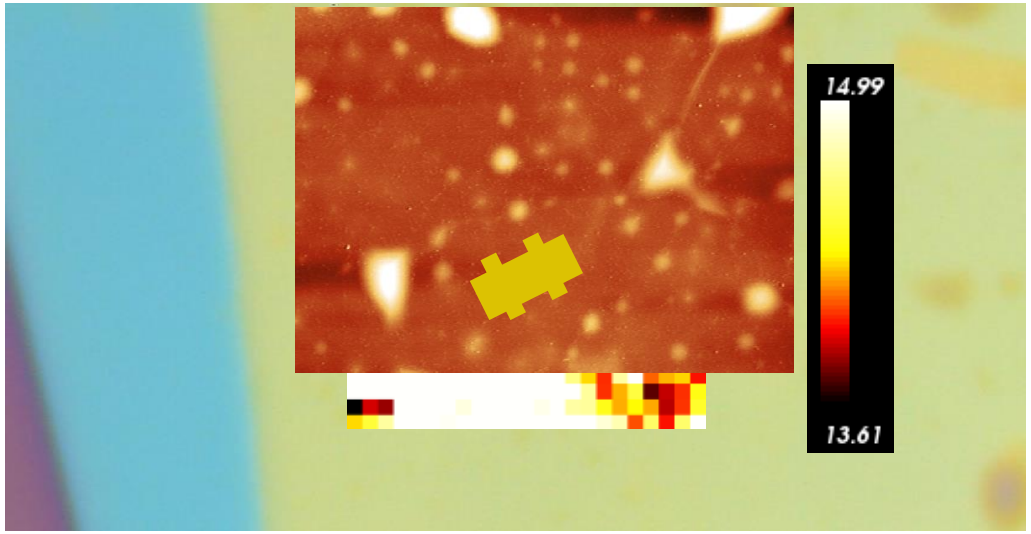


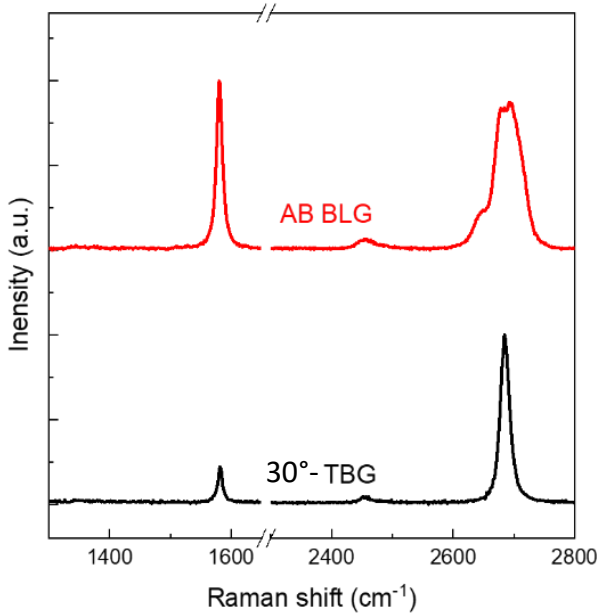


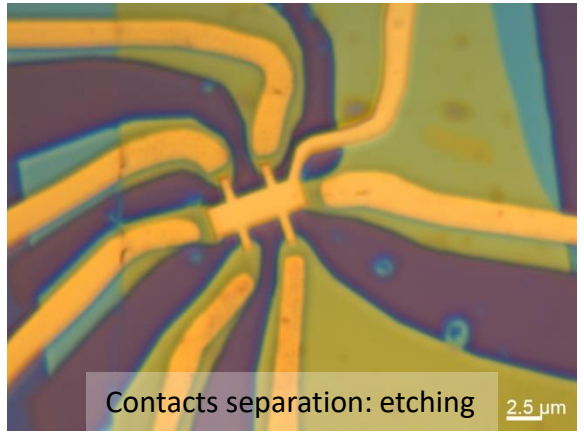
Sample characterization and device fabrication



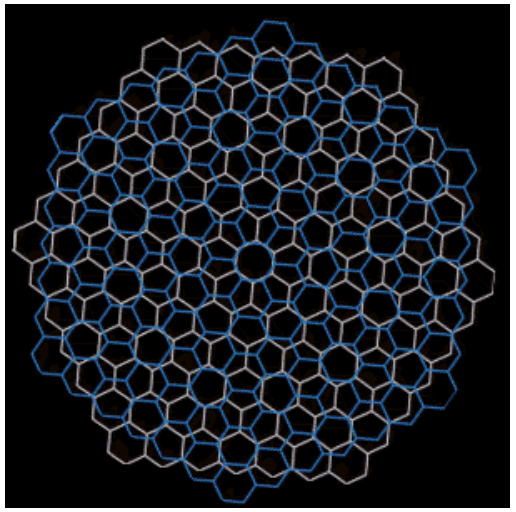
- Raman spectroscopy → check of the twist angle
- AFM → flat and clean area

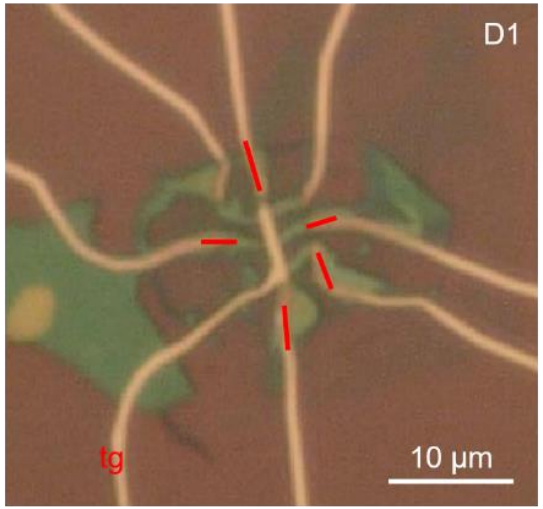






hBN/30°-tBLG/hBN



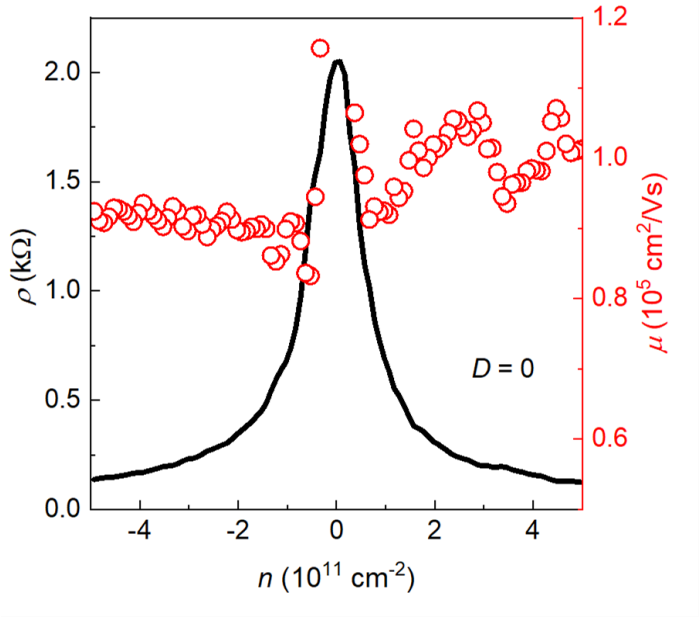


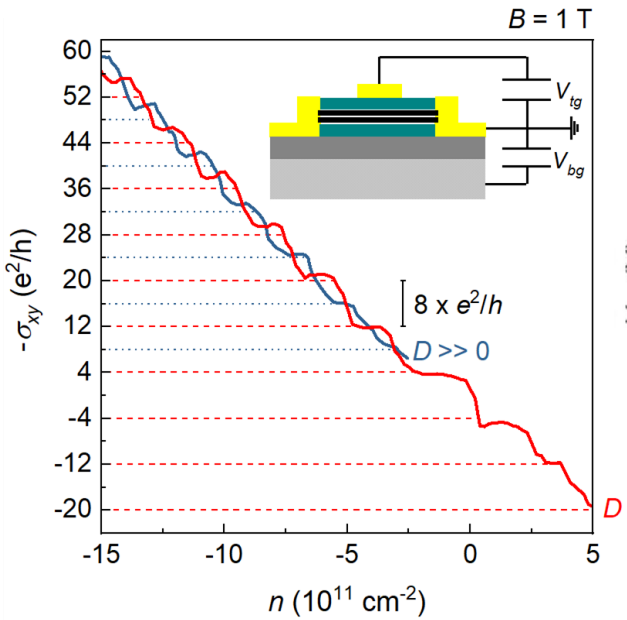
30°-twisted bilayer graphene from chemical vapor deposition (CVD):

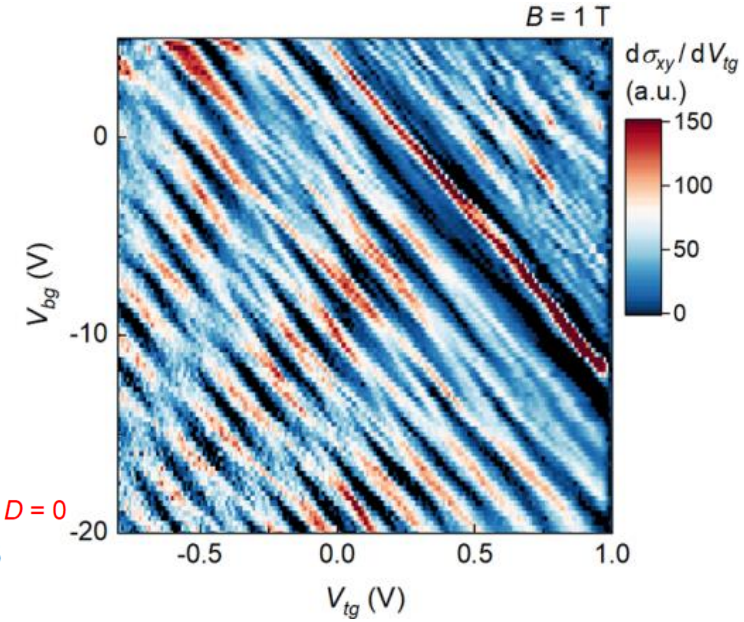
- No need of a manual stacking process
- **Interlayer decoupling** → possibility to tune the charge density of the two layers independently

Low-T magnetotransport measurements:

- **μ** up to **10^5 cm²/Vs**
- 30°-tBG behaves as **uncoupled graphene layers** ←8-fold degenerate quantum Hall states



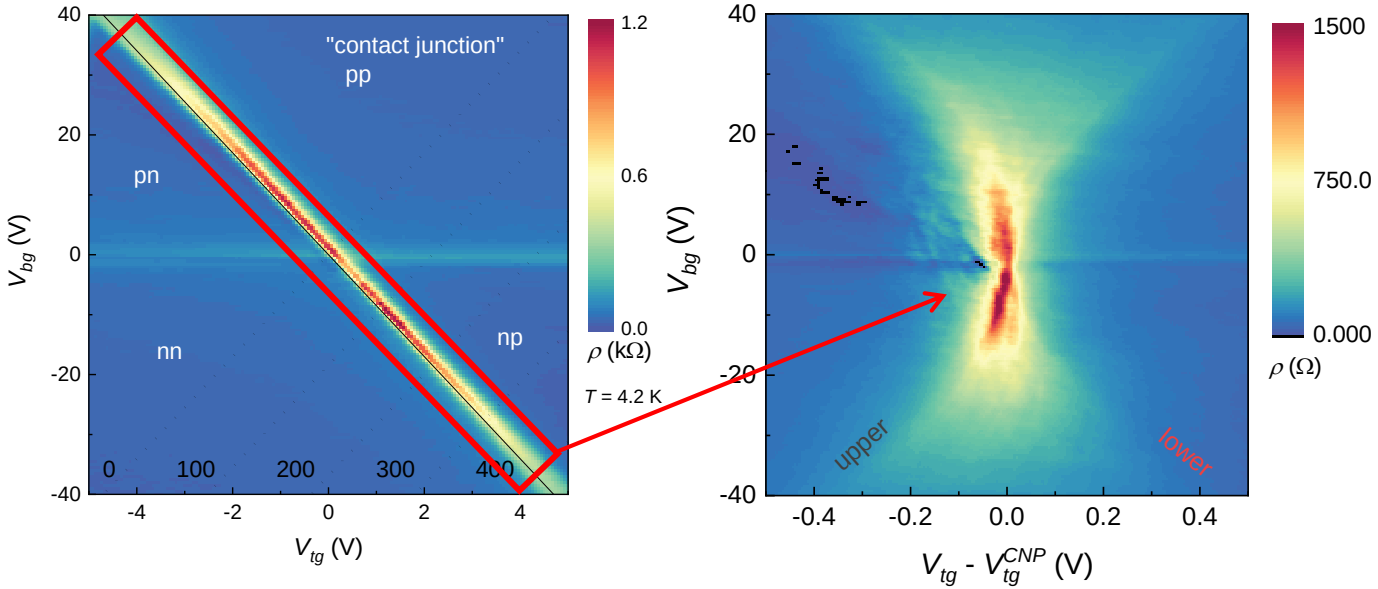




S. Pezzini *et al.*, Nano Lett., **5**, 3313–3319 (2020)

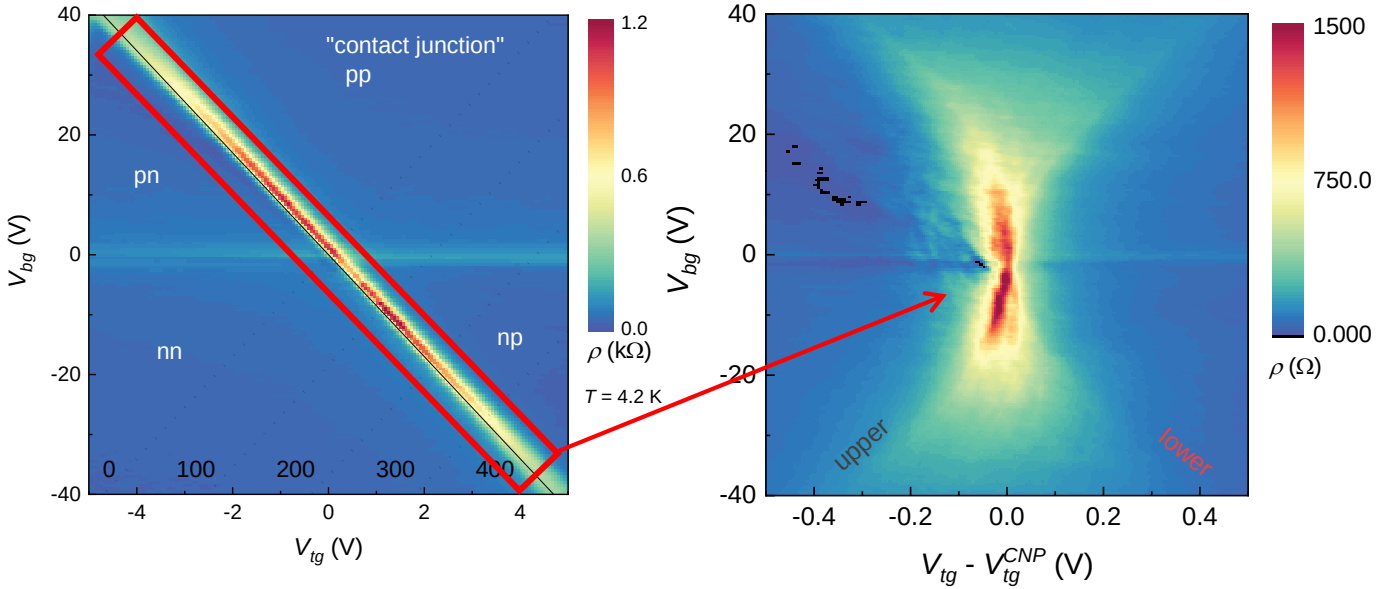
hBN/30°-tBLG/hBN

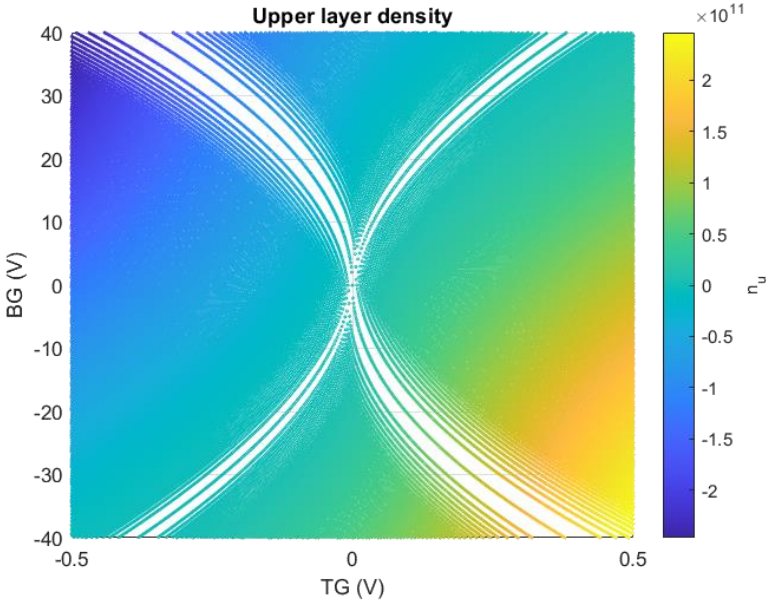
Possibility to control the **splitting** of the charge neutrality point



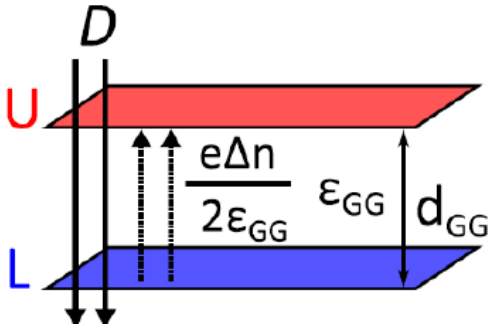
hBN/30°-tBLG/hBN

Possibility to control the **splitting** of the charge neutrality point





Electrostatic model

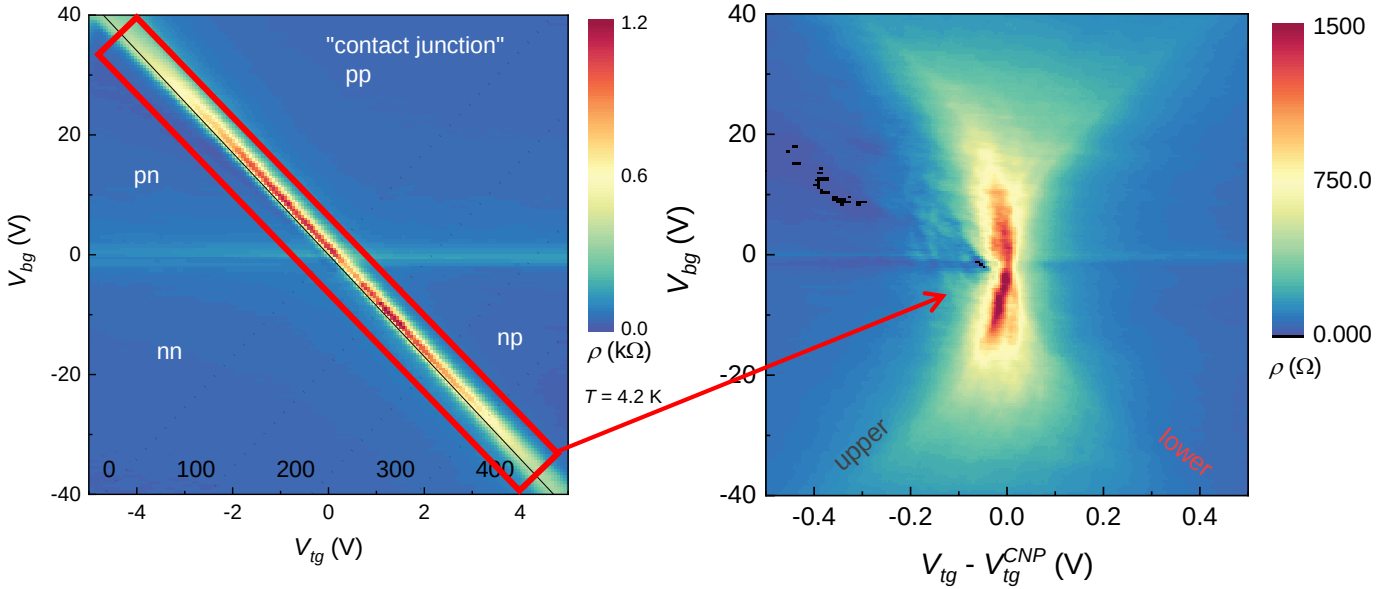


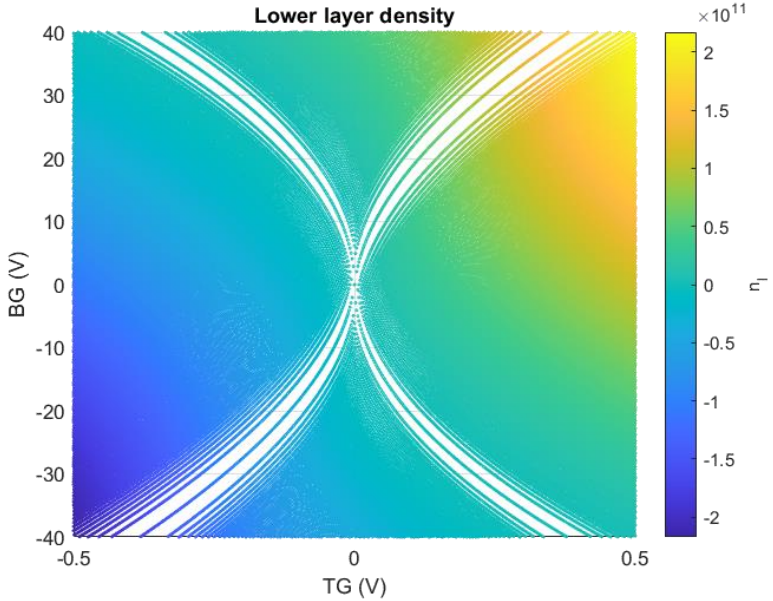
D screened by the layer density imbalance as well as the inter-layer dielectric environment

$$C_{GG}\frac{(\mu_U-\mu_L)}{e}=D-e\frac{(n_U-n_L)}{2}$$

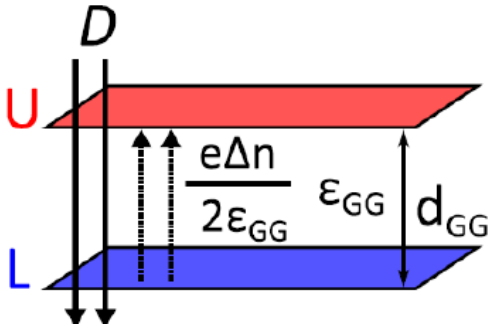
hBN/30°-tBLG/hBN

Possibility to control the **splitting** of the charge neutrality point





Electrostatic model

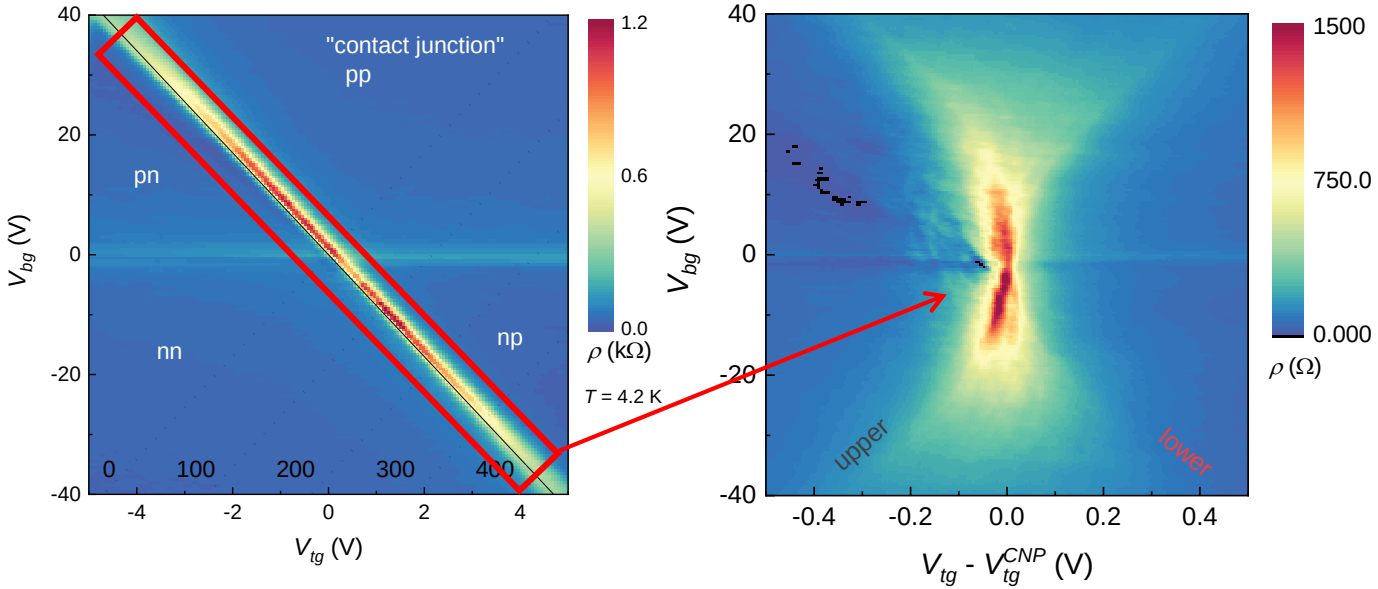


D screened by the layer density imbalance as well as the inter-layer dielectric environment

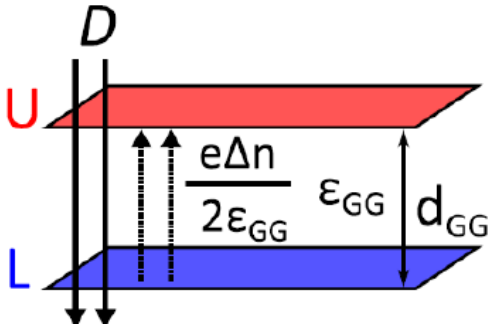
$$C_{GG}\frac{(\mu_U-\mu_L)}{e}=D-e\frac{(n_U-n_L)}{2}$$

hBN/30°-tBLG/hBN

Possibility to control the **splitting** of the charge neutrality point

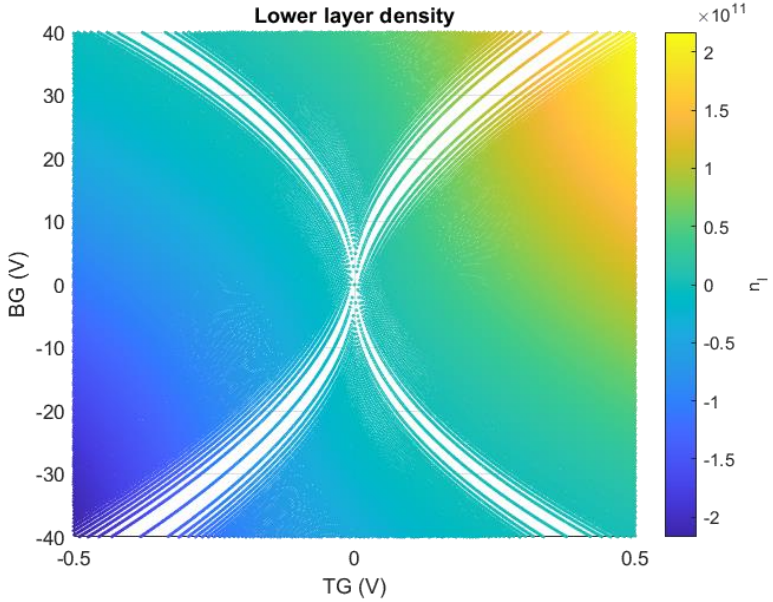


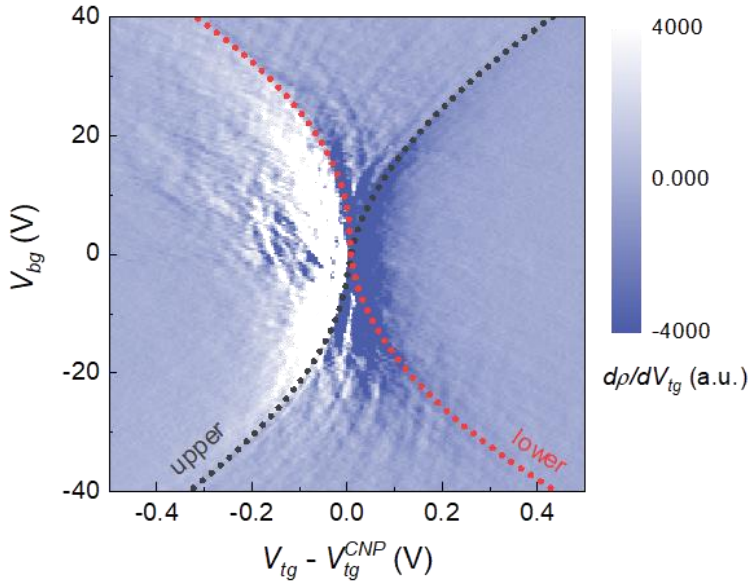
Electrostatic model

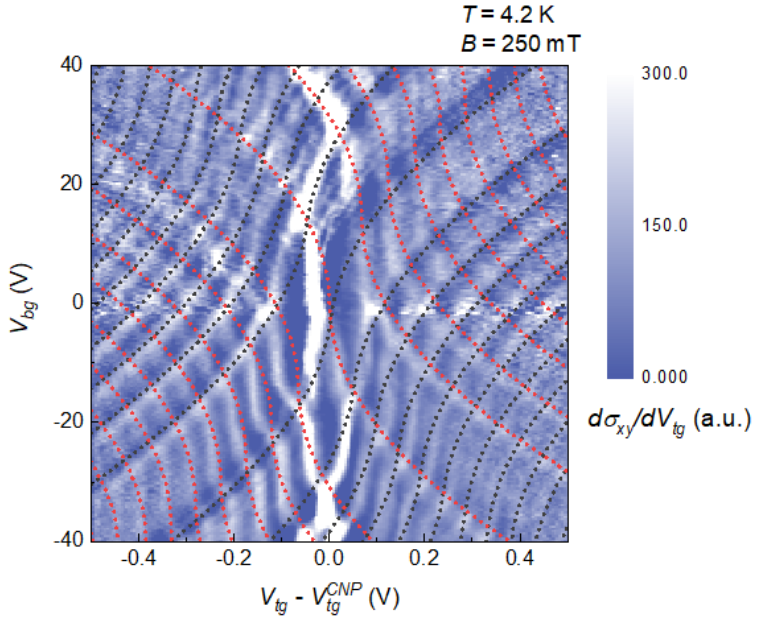


D screened by the layer density imbalance as well as the inter-layer dielectric environment

$$C_{GG}\frac{(\mu_U - \mu_L)}{e} = D - e\frac{(n_U - n_L)}{2}$$



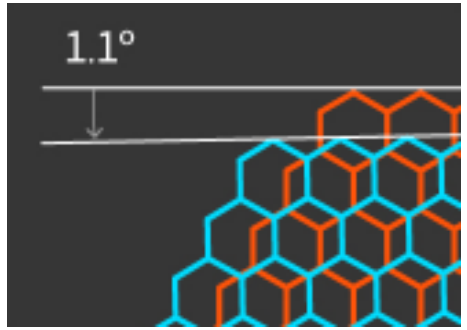


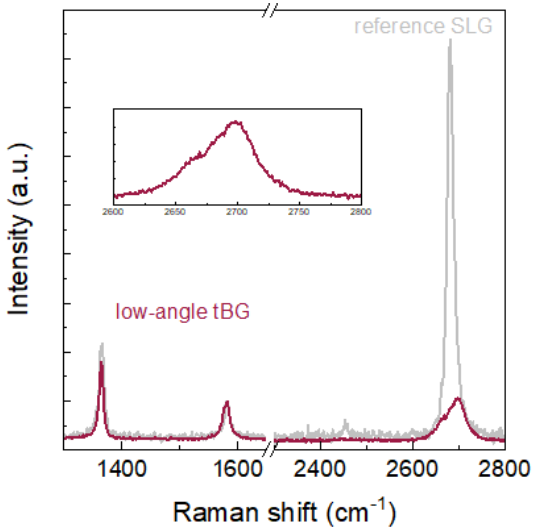


Next steps

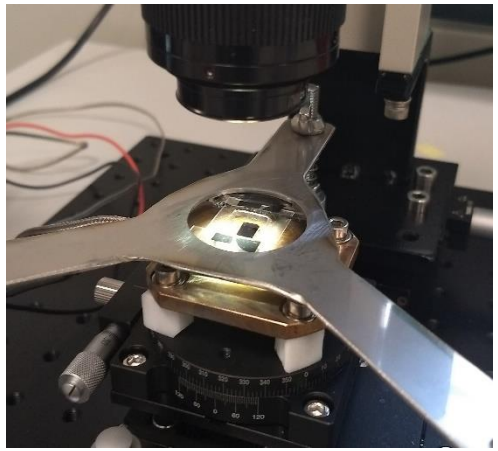
➢ hBN/1.1°-tBLG/hBN

1.1°-tBLG→ flat bands near zero Fermi energy, resulting in correlated insulating states at half-filling

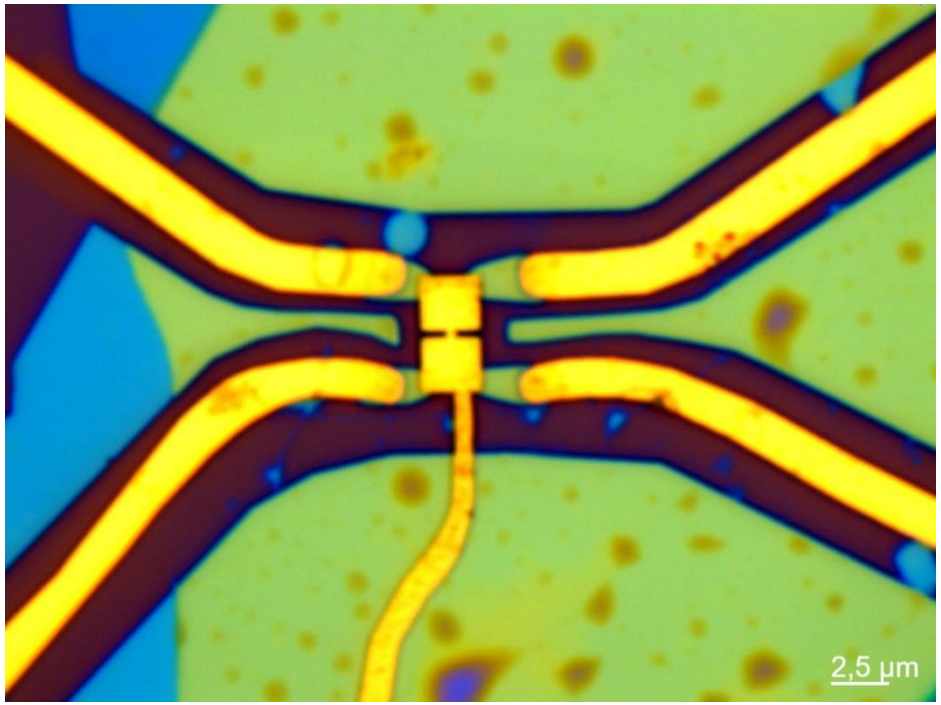




tBLG: manual assembly from CVD graphene



➢ Constriction in hBN/30°-tBLG/hBN

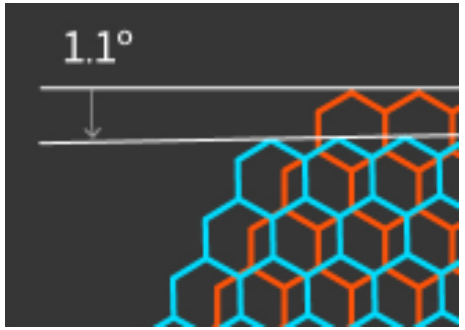


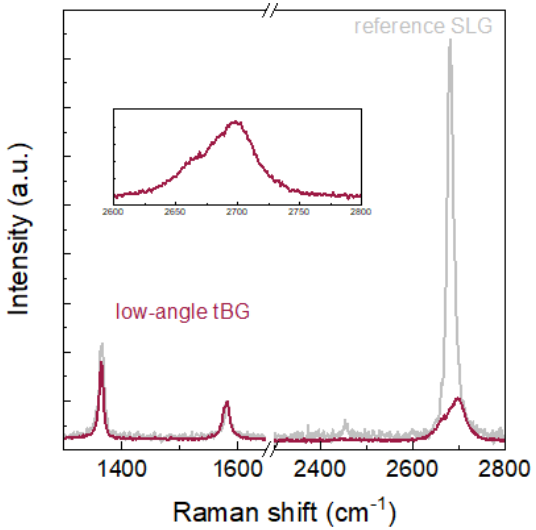
300 nm constriction in 30°-tBLG
→ ready to be measured in order to observe the conductance quantization

Next steps

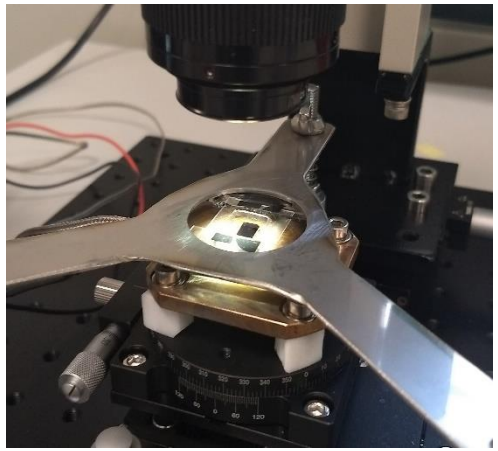
➢ hBN/1.1°-tBLG/hBN

1.1°-tBLG→ flat bands near zero Fermi energy, resulting in correlated insulating states at half-filling

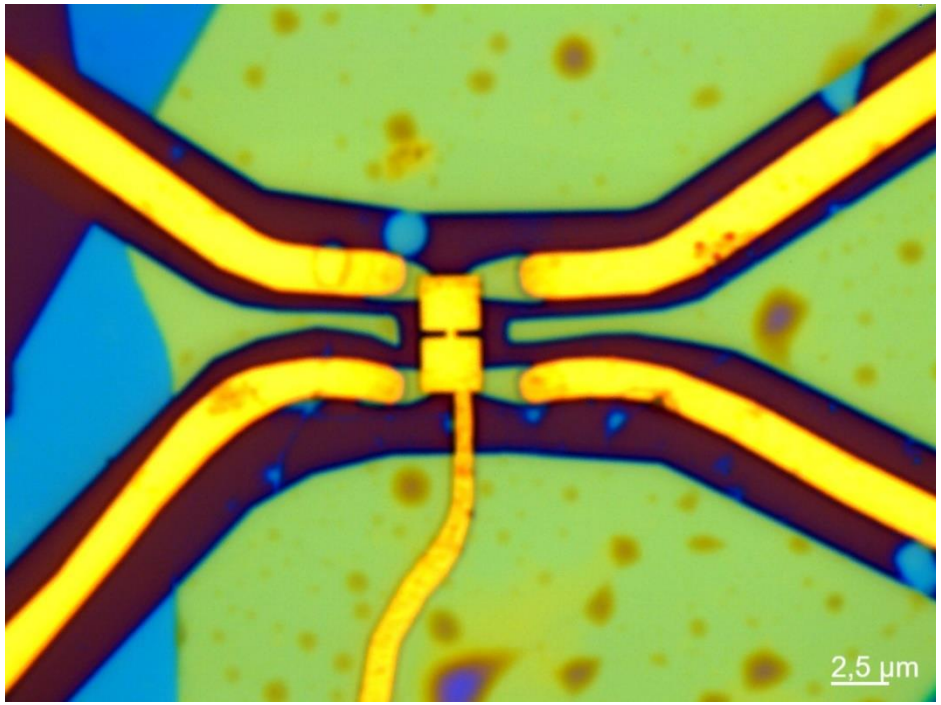




tBLG: manual assembly from CVD graphene



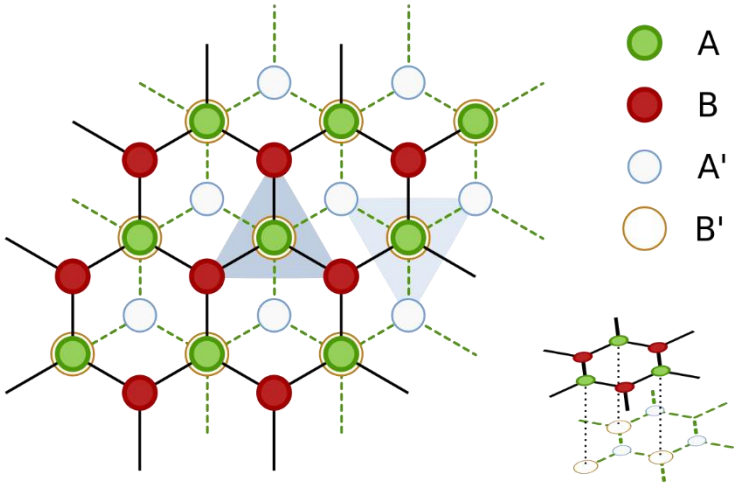
➢ Constriction in hBN/30°-tBLG/hBN



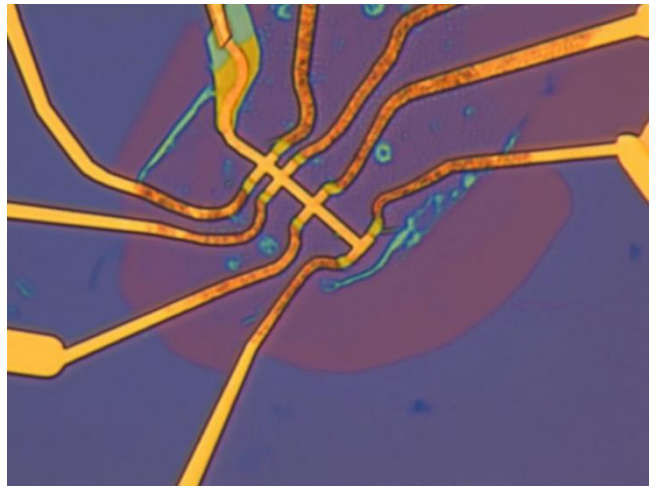
300 nm constriction in 30°-tBLG
→ ready to be measured in order to observe the conductance quantization

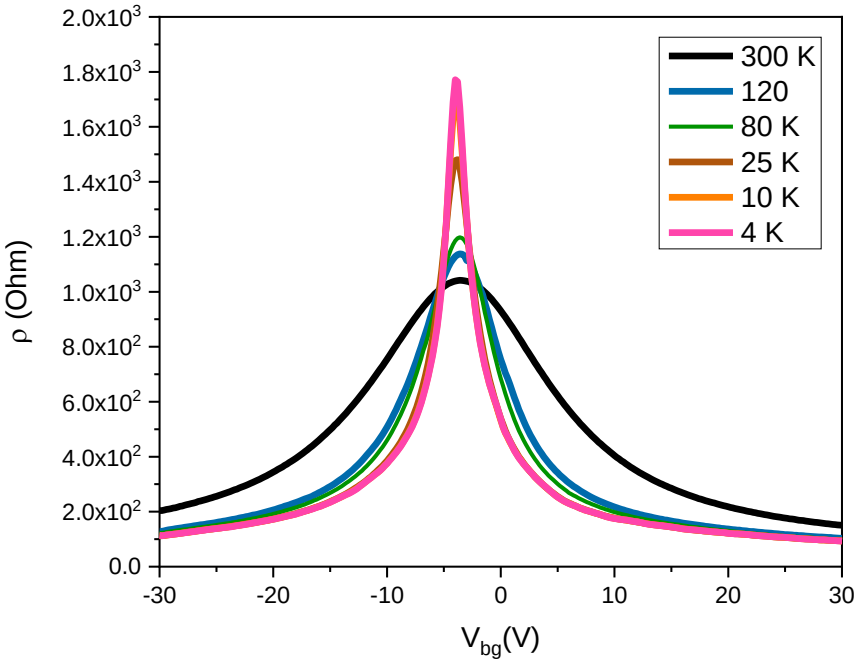
Training for magnetotransport measurements

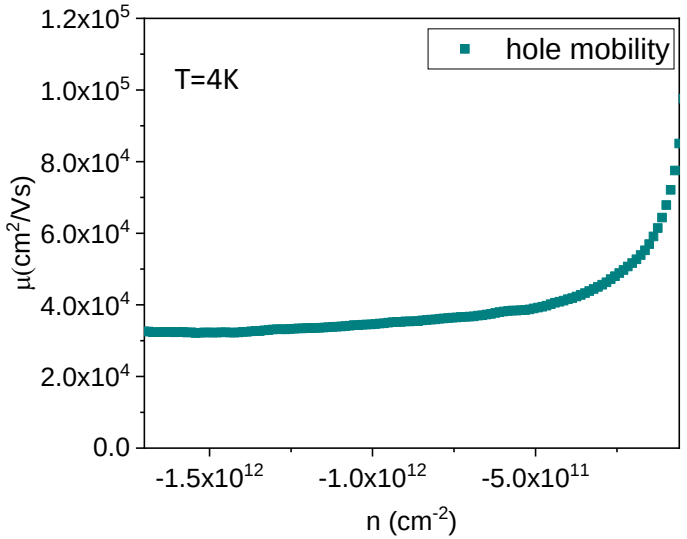
Electron transport measurements training on Bernal stacked BLG

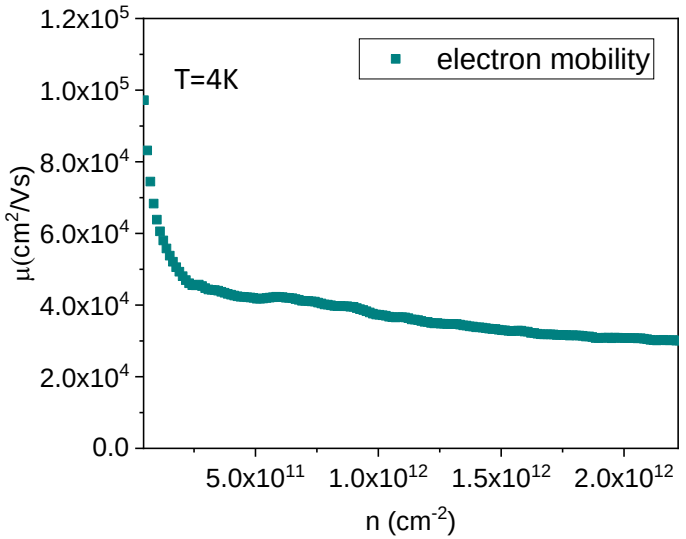


Standard electrical characterization on Bernal stacked BLG → resistivity curves as a function of the gate, mobility and charge density estimation









Training to be completed in the next few weeks!