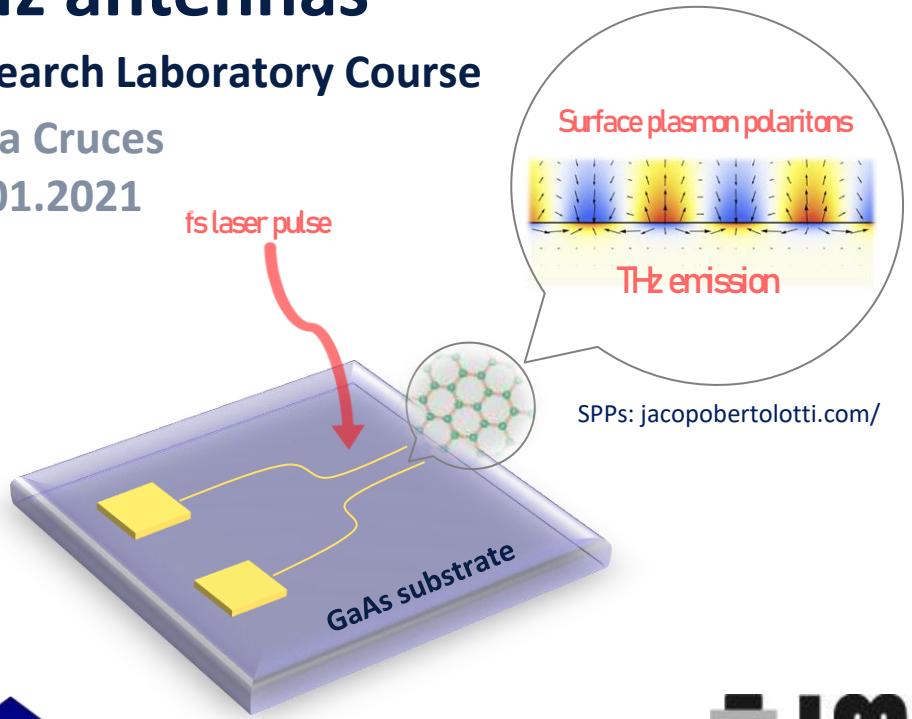
Deterministic transfer of h-BN/ graphene heterostructures for THz antennas

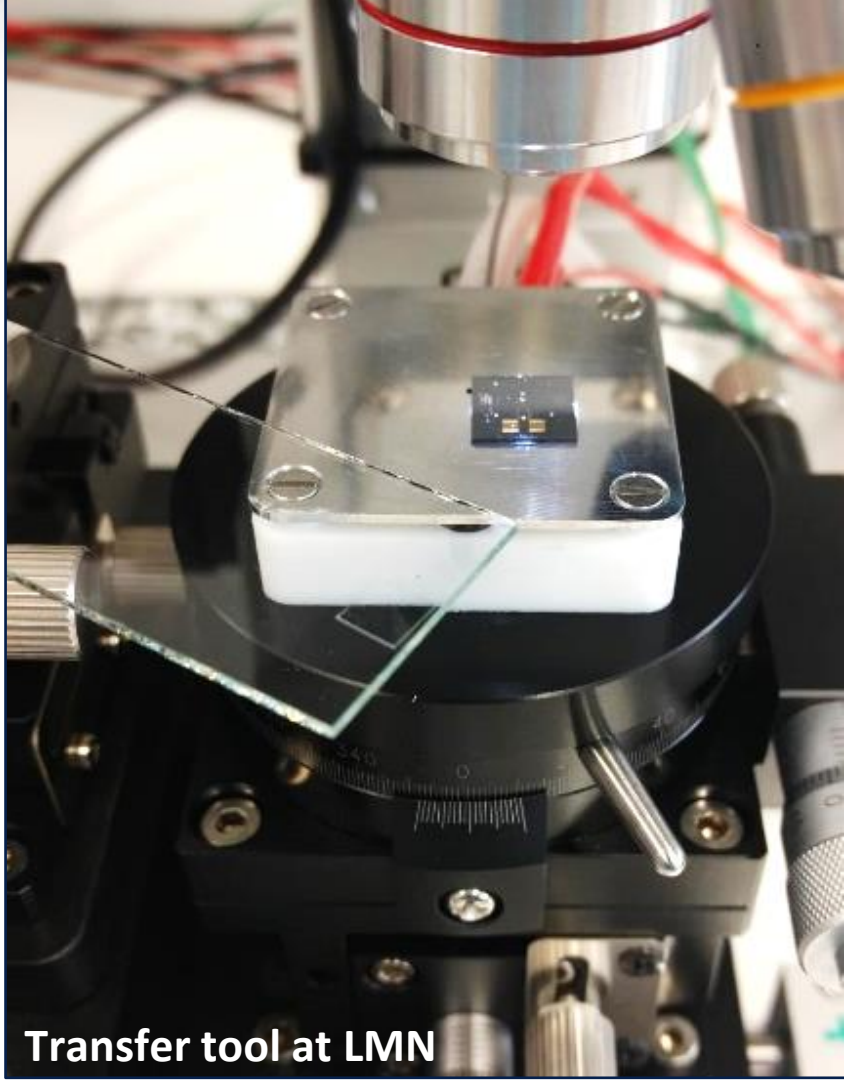
Research Laboratory Course

Sofía Cruces

27.01.2021



SPPs: jacopobertolotti.com/



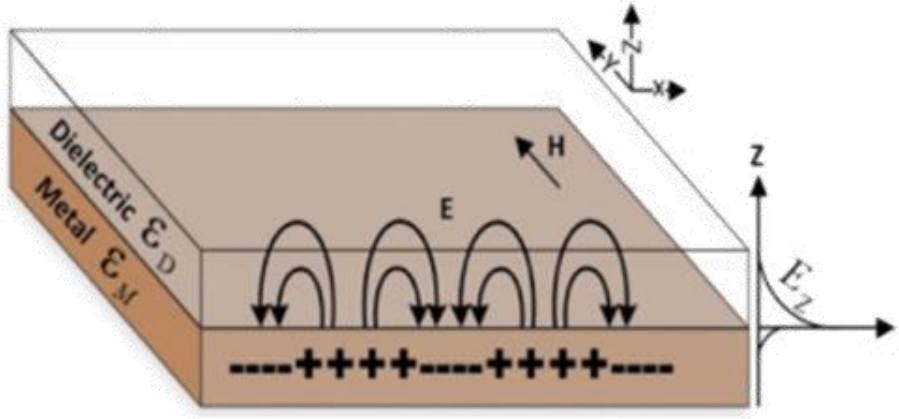
Transfer tool at LMN

UNIVERSITÄT SIEGEN

LMN SIEGEN

Graphene and its conductivity

- Resonance condition: $L = \frac{\lambda_{SPP}}{2} = \frac{\pi}{k_{SPP}}$
- Plasmon dispersion relation: $\frac{1}{\sqrt{{k_{SPP}}^2 - \frac{\omega^2}{c^2}}} + \frac{\varepsilon}{\sqrt{{k_{SPP}}^2 - \varepsilon\frac{\omega^2}{c^2}}} = -i\,\frac{\sigma(\omega\mu_c\tau)}{\omega\varepsilon_0}$



Chemical potential (μ_c)

- Tuned by bias voltage or doping
- Determines number of n & p in antenna

Relaxation time (τ)

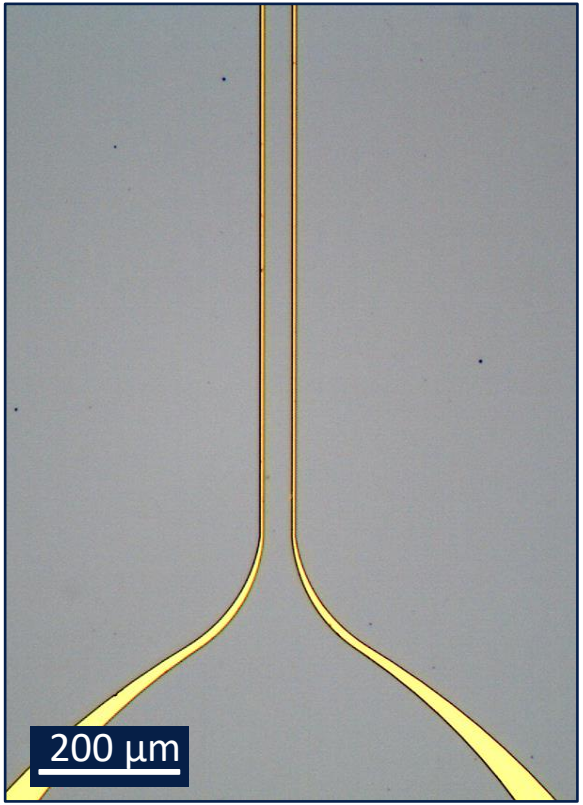
- Average life time of charges
- Determined by graphene quality

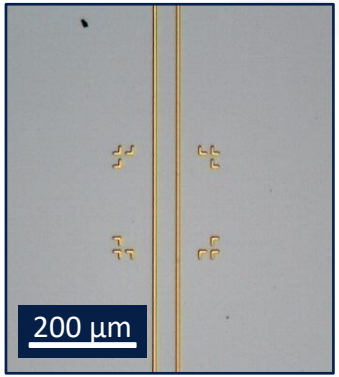
For functional antenna → large μ_c & τ

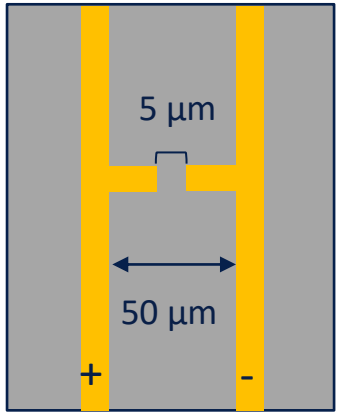
→Challenge: high-quality graphene!

Anwar, et al. Digital Communications and Networks, 2018. 4(4), 244-257.

Structure of THz Antenna







Dipole antenna

- GaAs substrate (E_g = 1.42 eV)
- Conduction lines & contact: Cr / Au
- Two graphene patches

- Supports SPPs in THz band (0.1 – 10 THz)
- Graphene SPP waves tuned by doping
- Design/shape of graphene antennas

Mechanical exfoliation

Advantages

- Monocrystalline Graphene
- Defect-free

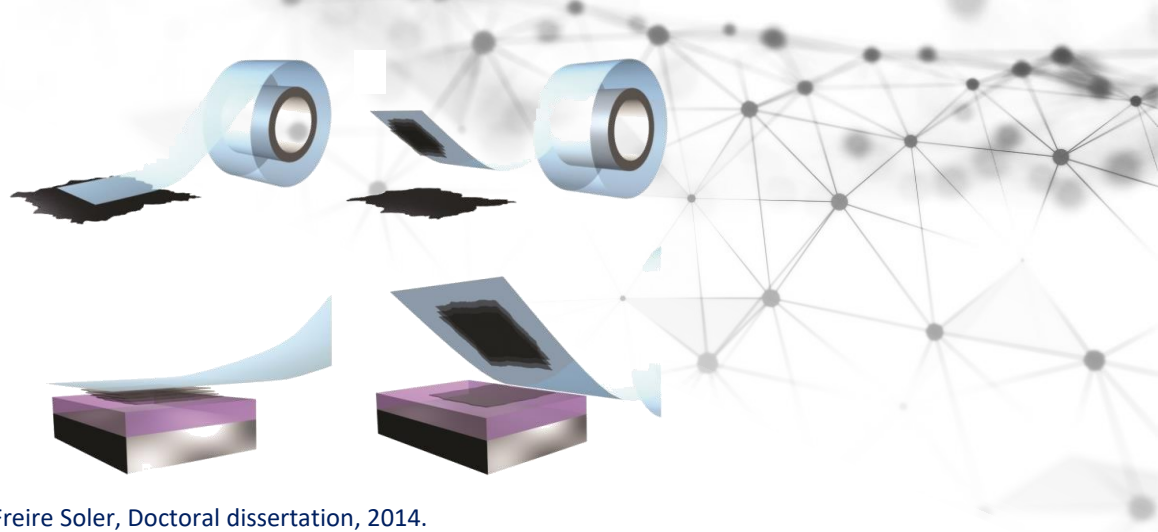
→ Cleanliness, high conductivity

Challenges

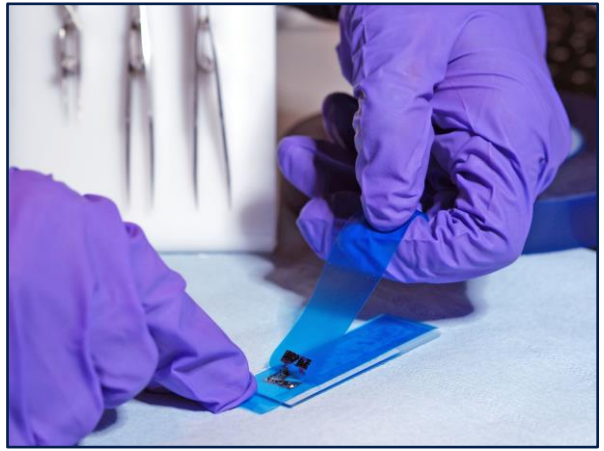
- Low yield
- Non-deterministic
- Small and irregular flakes

Parameters:

- Graphite source
- Tape (Nitto, Tesa)
- Force, speed, direction applied
- Number of subsequent exfoliations

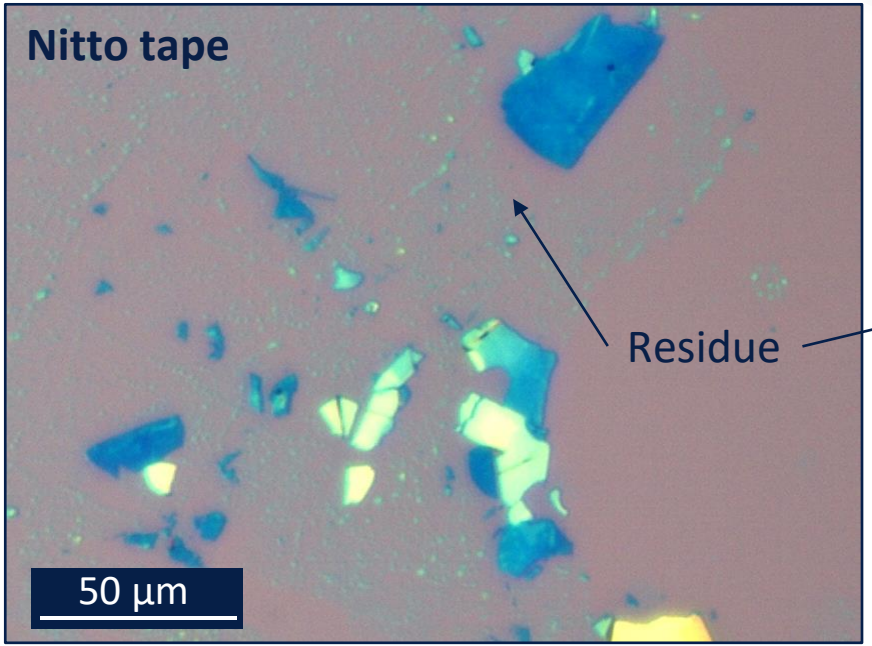


Freire Soler, Doctoral dissertation, 2014.

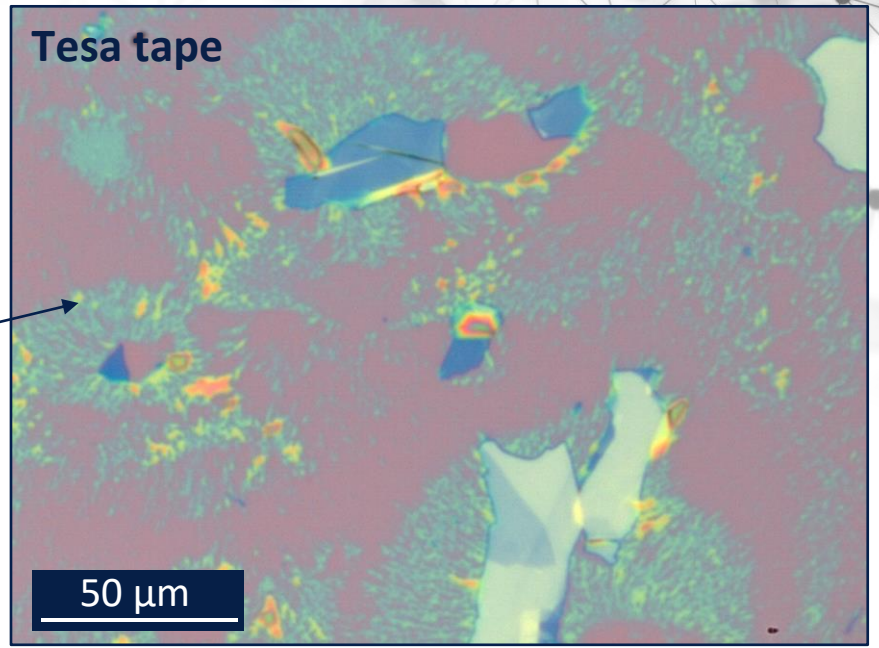


https://lmn.mb.uni-siegen.de/

Challenges of mechanical exfoliation



Residue

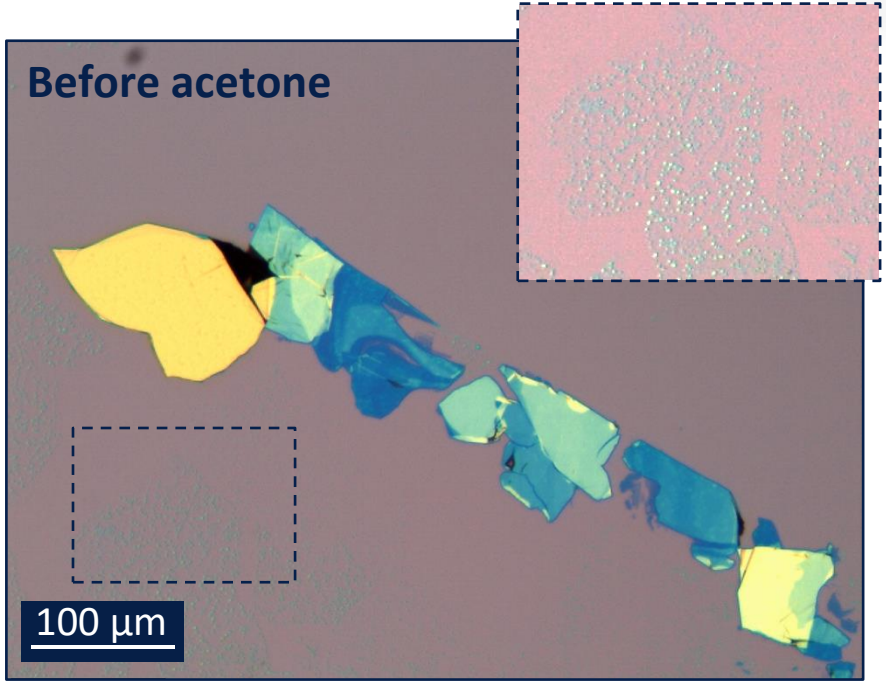


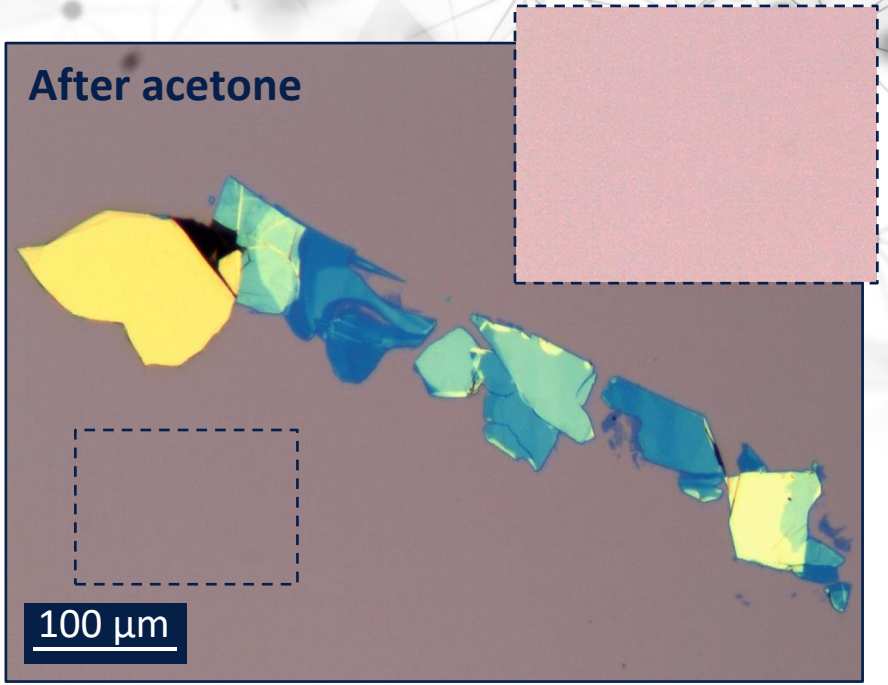
- Multiple subsequent exfoliations
- 100 °C for 1 min

→ Small, irregular & thick flakes

Challenge → Residue removal

Tape residue removal

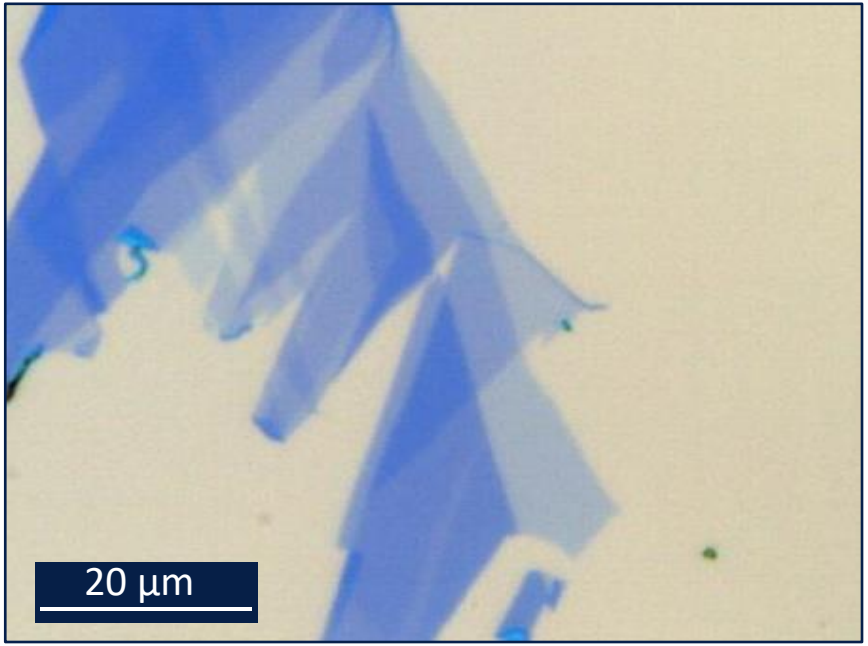


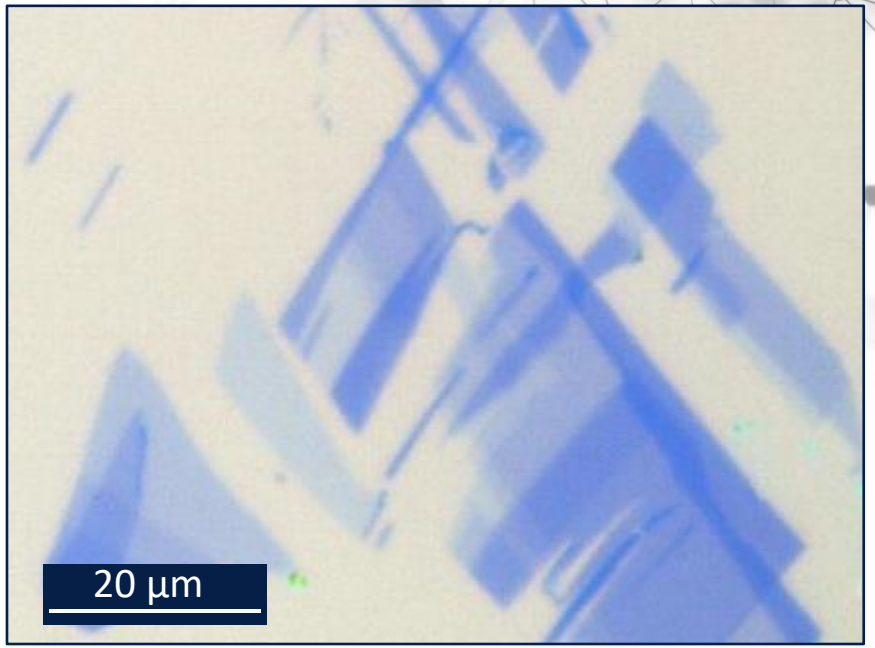


- 10 min in acetone
- Blow dried with N_2

→ Cleaner surface & flakes remain

Exfoliation of large area graphene flakes



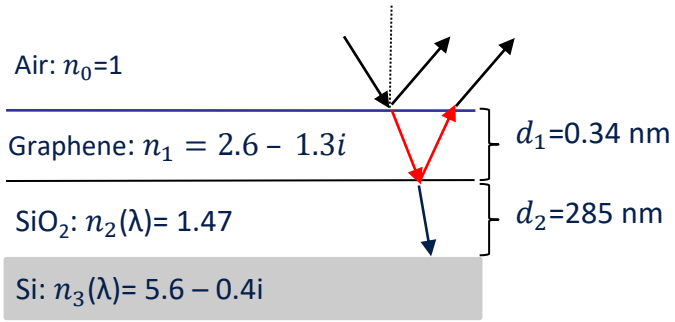


- Less number of subsequent exfoliations
- 75 °C for 3 min

→ Clean, thin & bigger flakes

Thickness determination using contrast spectra

- Model based on the Fresnel law
- White light source and no filter



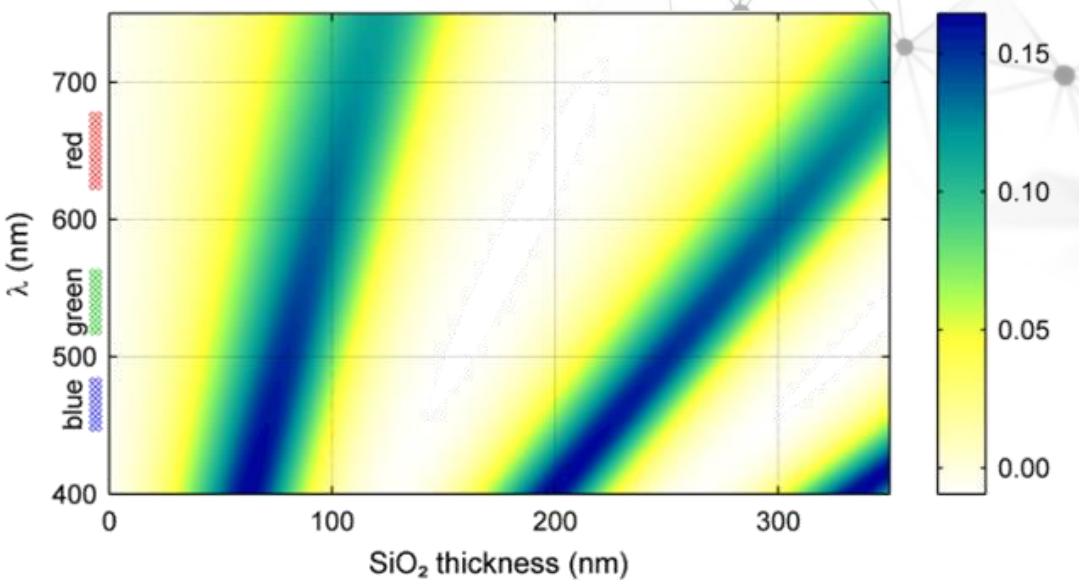
Contrast equation

$$C = \frac{I(n_1 = 1) - I(n_1)}{I(n_1 = 1)}$$

Graphene

Substrate

Contrast of graphene on SiO_2/Si



Novoselov, et al. Applied physics letters, 2007, 91(6), 063124.

Thickness determination using contrast spectra

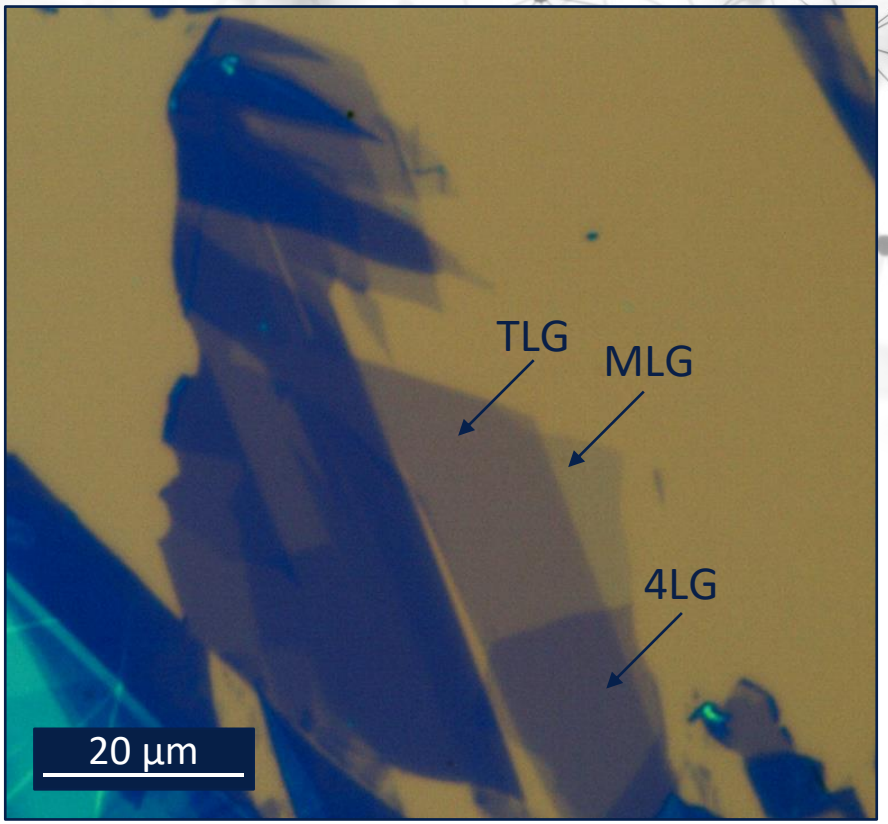
- Intensities with ImageJ

Contrast equation

$$C = \frac{I(n_1 = 1) - I(n_1)}{I(n_1 = 1)}$$

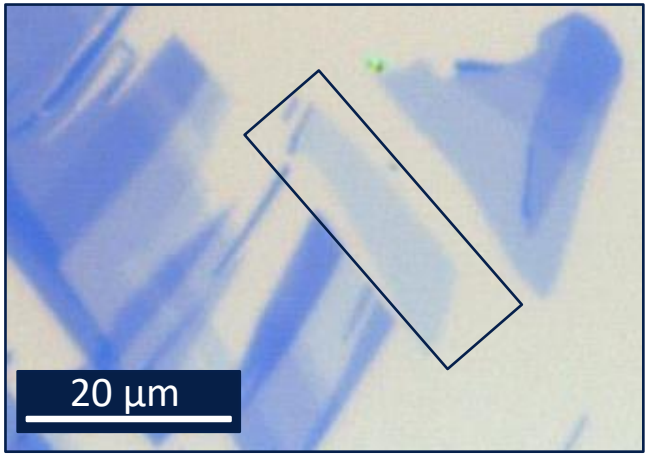
Number of layers

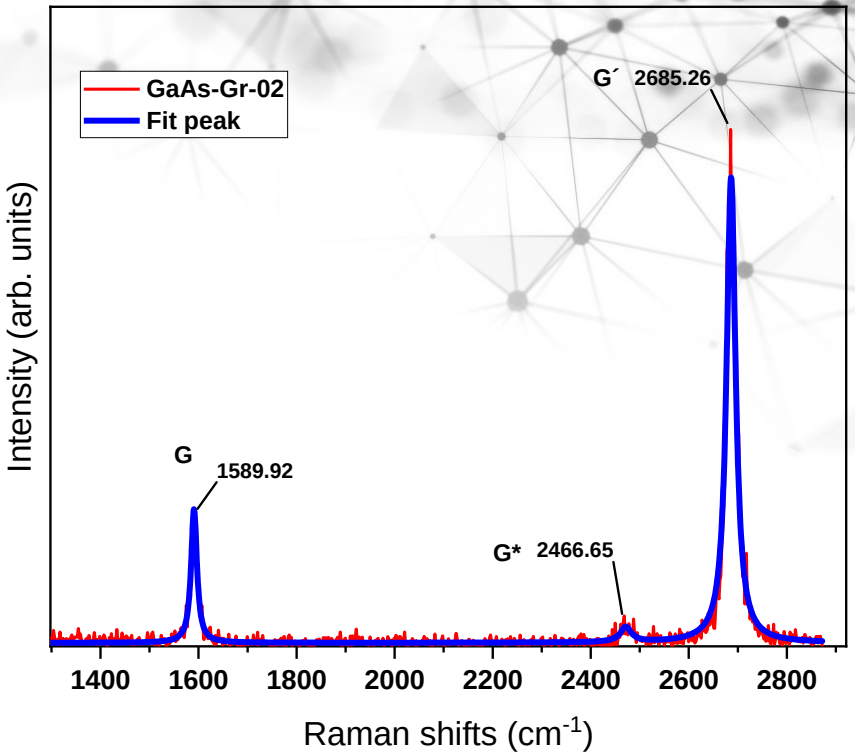
$$\mathrm{C} = 0.0046 + 0.0925\mathrm{N} - 0.00255N^2$$



Ni, et al. Nano letters, 2007, 7(9), 2758-2763.

Raman spectroscopy



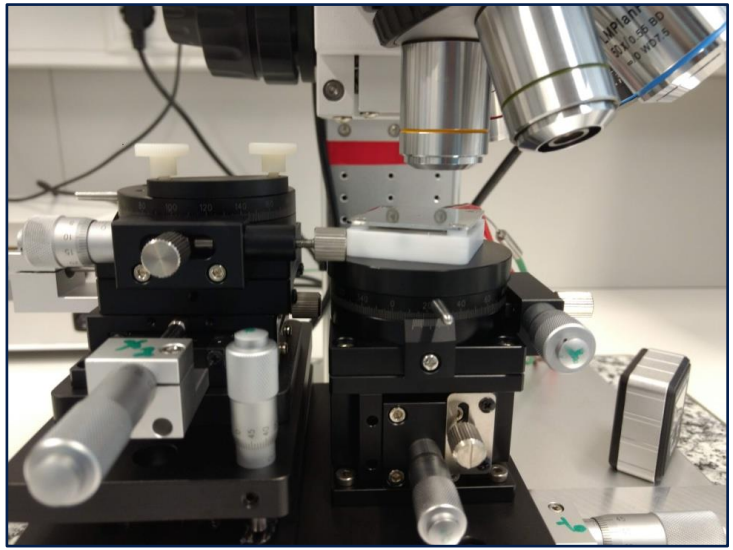


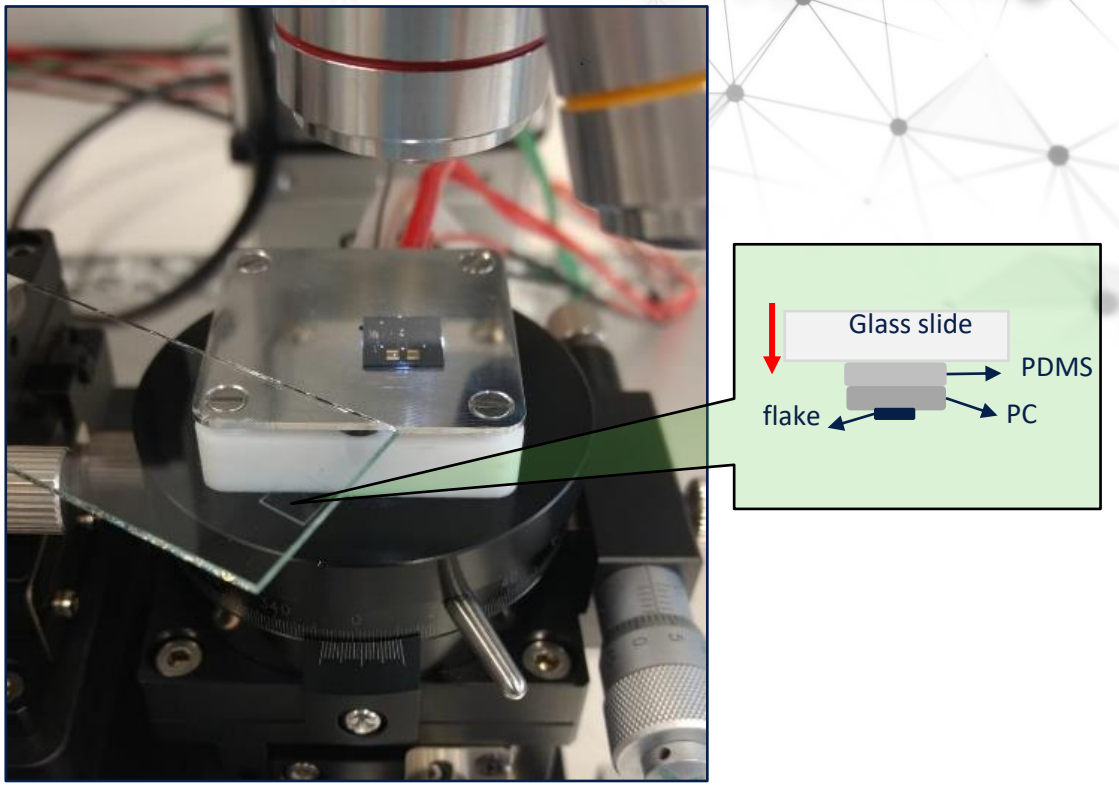
- No D – peak (1350 cm^{-1})
- *G´* band – single Lorentzian profile
- FWHM 22.3 cm^{-1}
- $I_G/I_{G'}$ (0.37)

→ Typical values for defect-free, ME graphene

- 532 nm laser
- 1200 l/mm grating
- 600 nm center wavelength

All-dry transfer method: Transfer tool





Stamping Scheme

1

Glass slide

2

Attachment/coating of PDMS/PC stamp

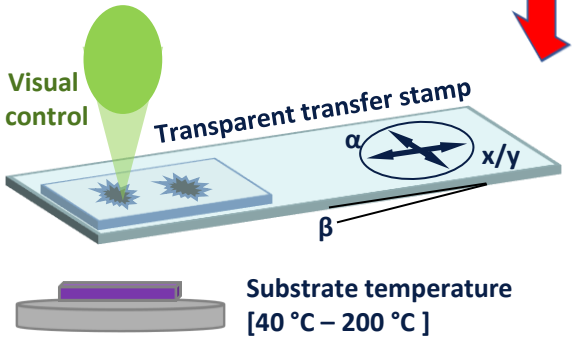
3

Preparation of graphene/hBN flakes

4

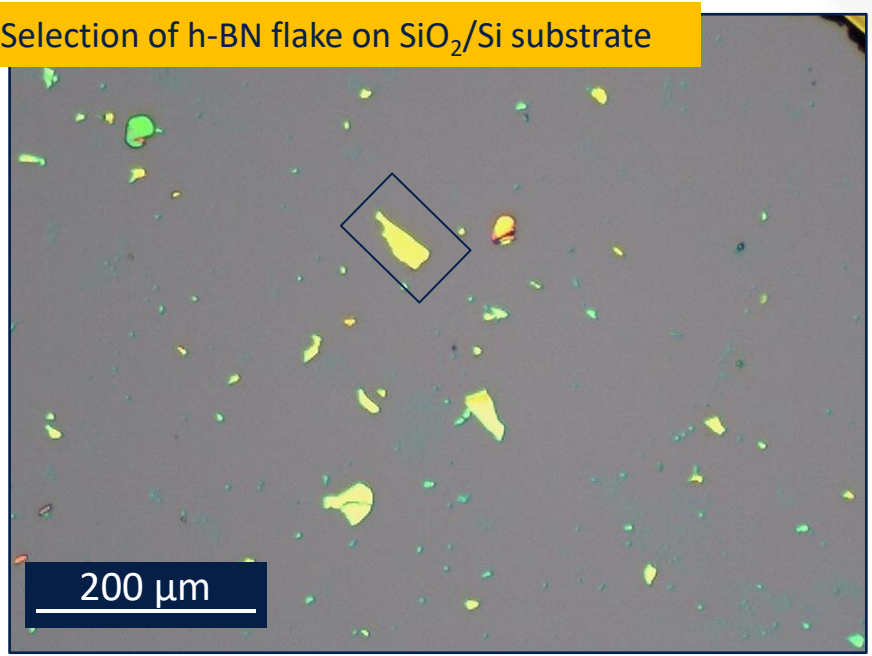
Quality control of flakes / flake search

5

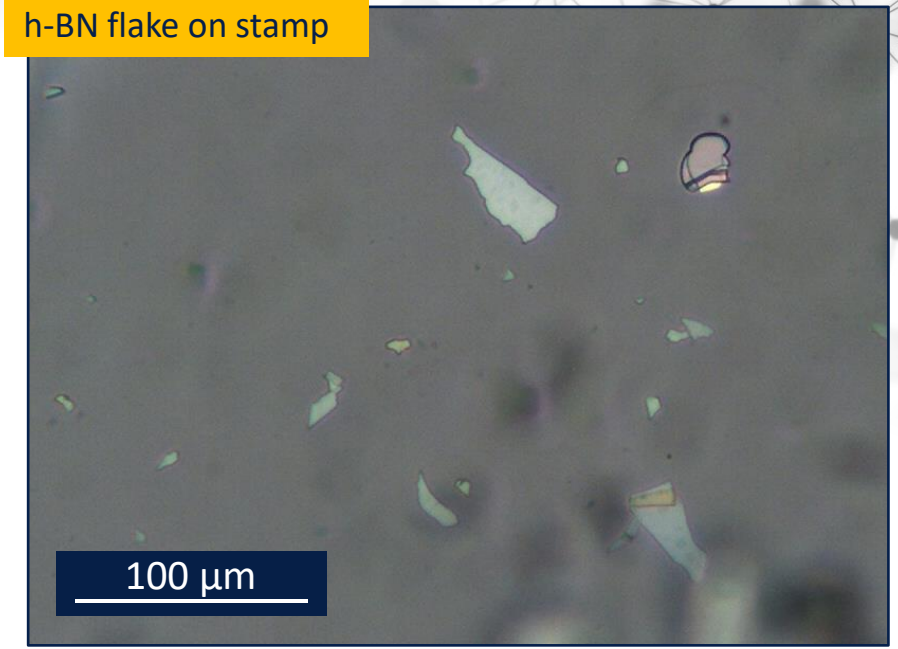


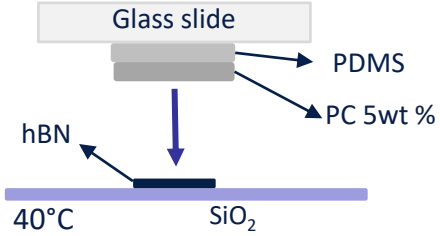
Pick up technique of flakes

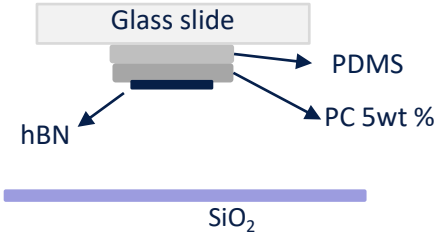
Selection of h-BN flake on SiO_2/Si substrate



h-BN flake on stamp

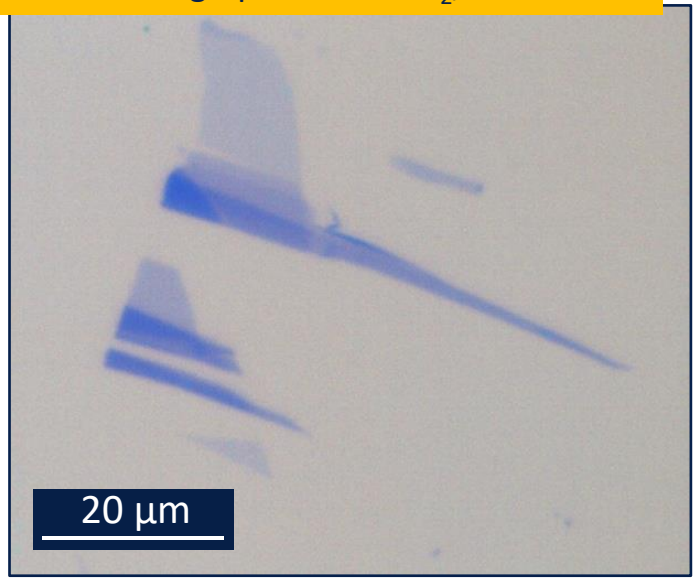






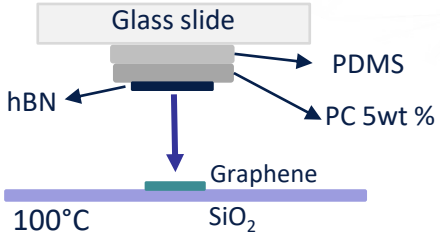
Pick up technique of flakes

Selection of graphene on SiO_2/Si substrate

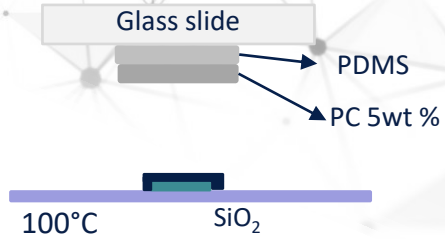


Drop-down

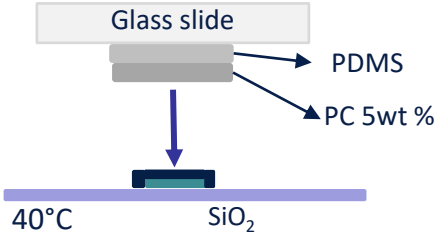
i.



ii.



iii. Pick-up



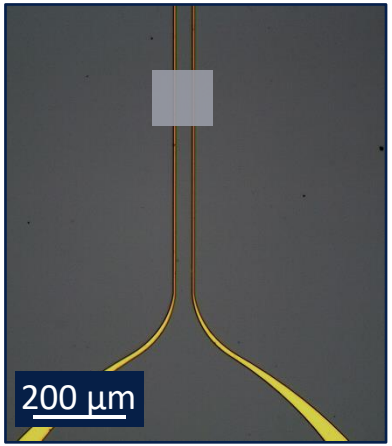
Challenges

- PC coating would break
- PDMS sticked to the substrate

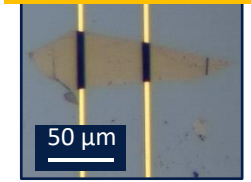
→Parameter optimization

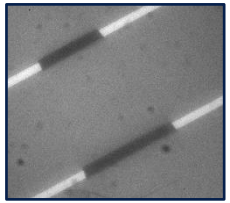
Pizzocchero, et al. Nature communications, 2016, 7(1), 1-10.

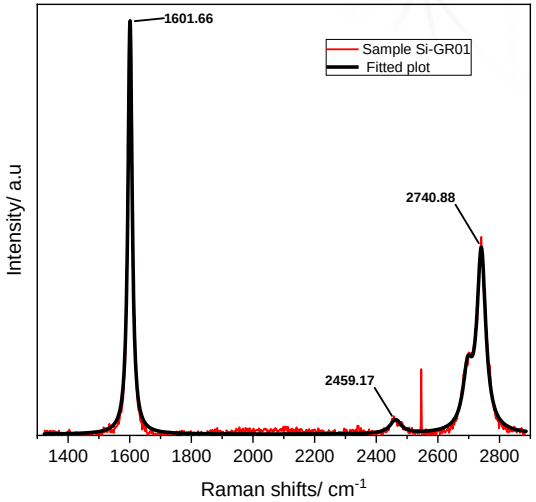
Visibility of graphene/graphite on GaAs substrate



Flake on antenna (Transfer OM)

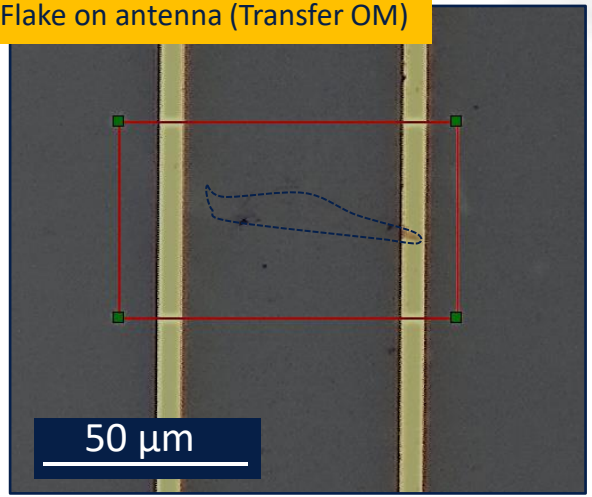




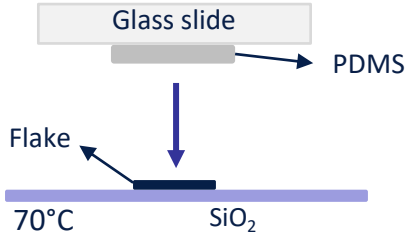


Thin flake on PDMS

Flake on antenna (Transfer OM)

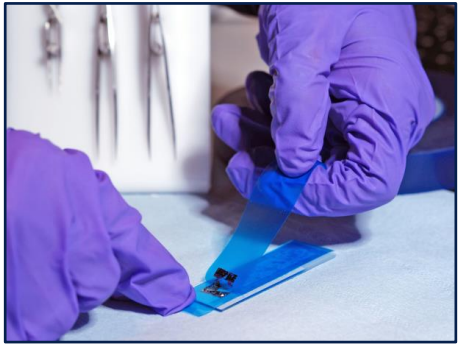


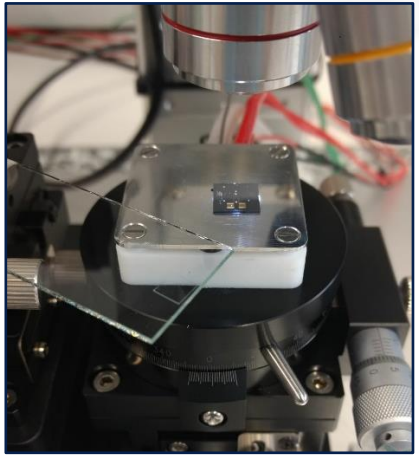
- High contrast at contact with Au



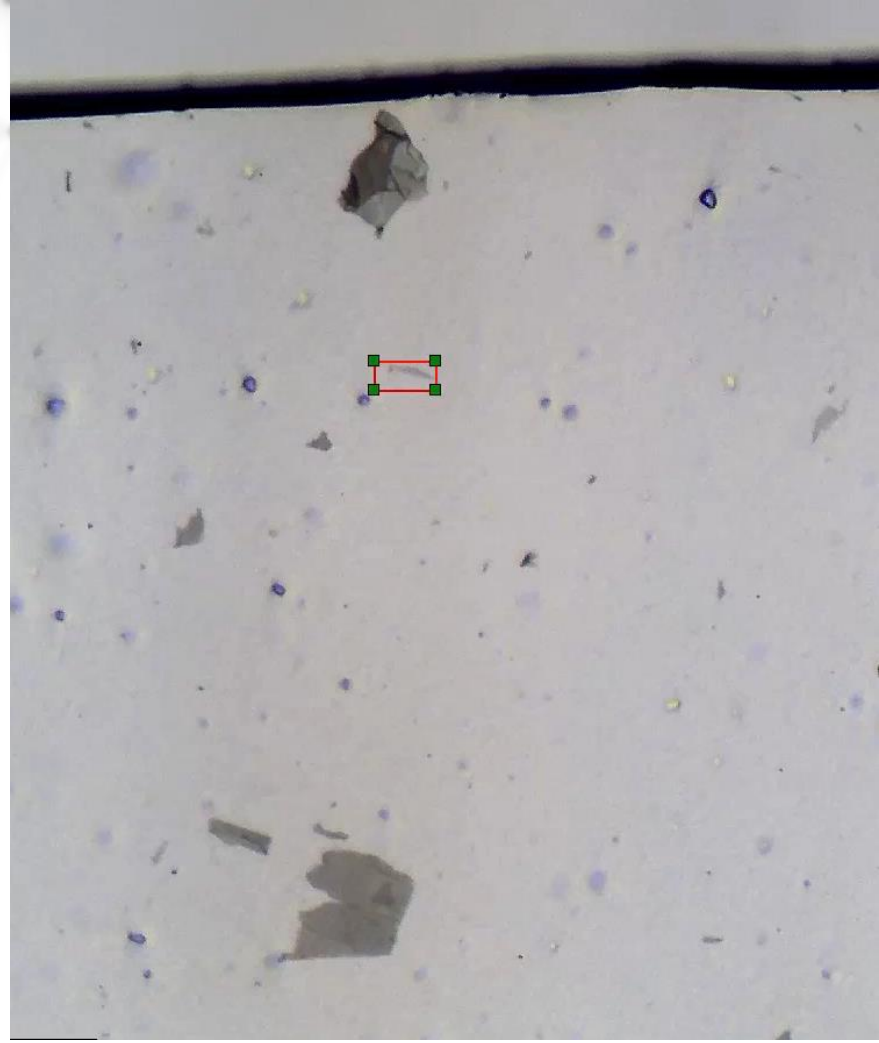
- Extremely low contrast on GaAs
- Raman measurements required

Outlook





- Raman spectroscopy mapping
- Rapid optical thickness using contrast
- Correlation of contrast and thickness on GaAs
- Complimentary techniques (AFM)
- Correlation of contrast and thickness on PDMS



Acknowledgements

Prof. Benjamin Butz
M.Sc. Charles Ogolla
LMN group members

Prof. Peter Haring Bolívar
Institute of High Frequency
and Quantum Electronics

Prof. Mario Agio
Laboratory of Nano-Optics