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UCL Université catholique de Louvain

Epitaxial Cu film: an ideal platform for the graphene growth, transfer and device fabrication

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[3] *Electrical Engineering department (ELEN), Université catholique de Louvain (UCL), Belgium*
[4] Department of Materials Science and Engineering, The Pennsylvania State University, PA 16802, USA

Monday July 29, 17:15-17:30

ICCGE-19
2019 OMVPE-19
Keystone, Colorado, USA

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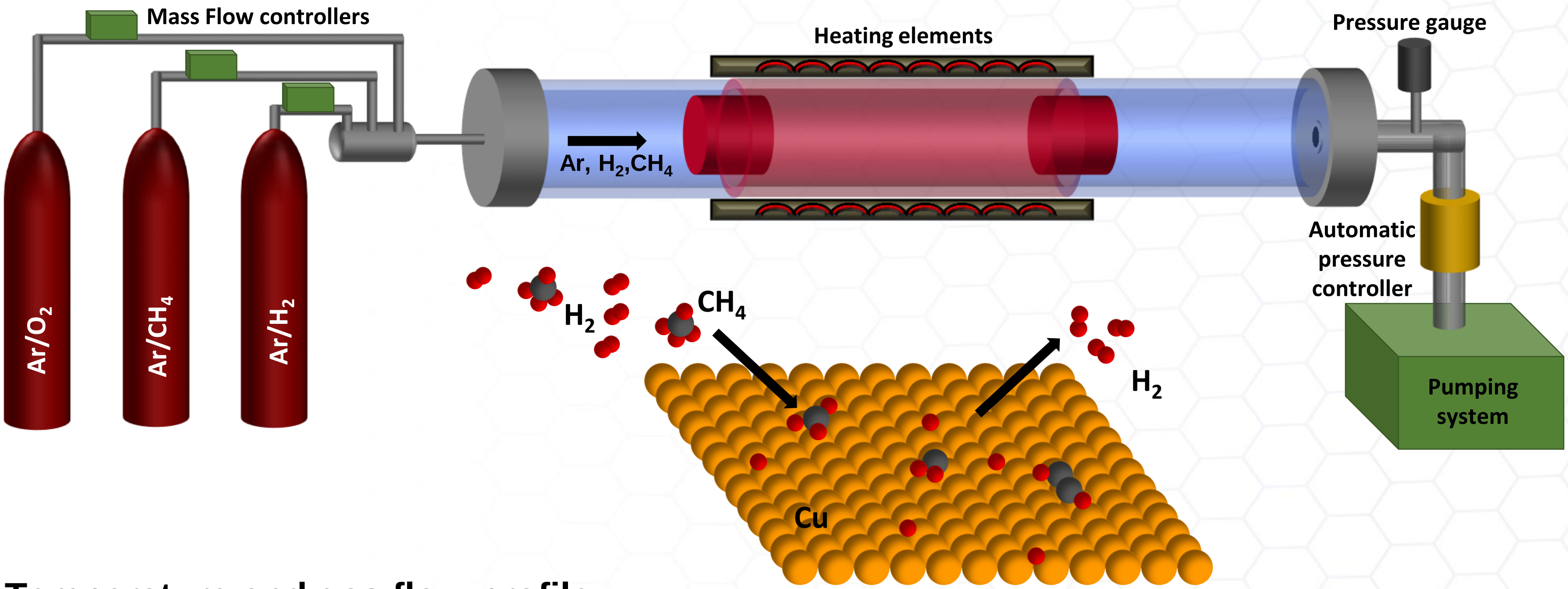
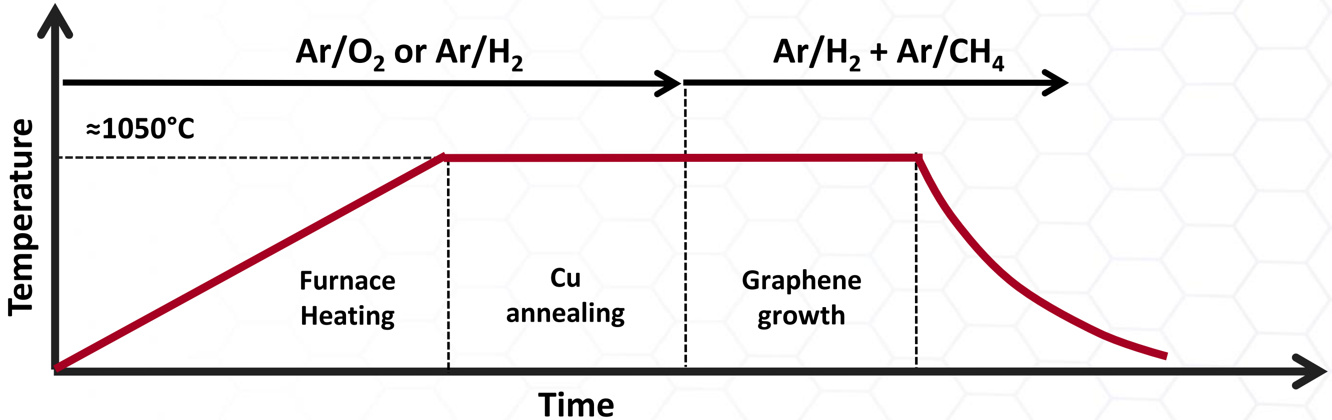
Outline

1. **Introduction**
2. Cu substrate roughness & graphene planarity
3. As-grown graphene physical integrity
4. Control over the thickness
5. Transfer of graphene
6. Direct characterization and device fabrication
7. Conclusions

Synthesis process



Temperature and gas flow profile



Millimeter-size graphene domains

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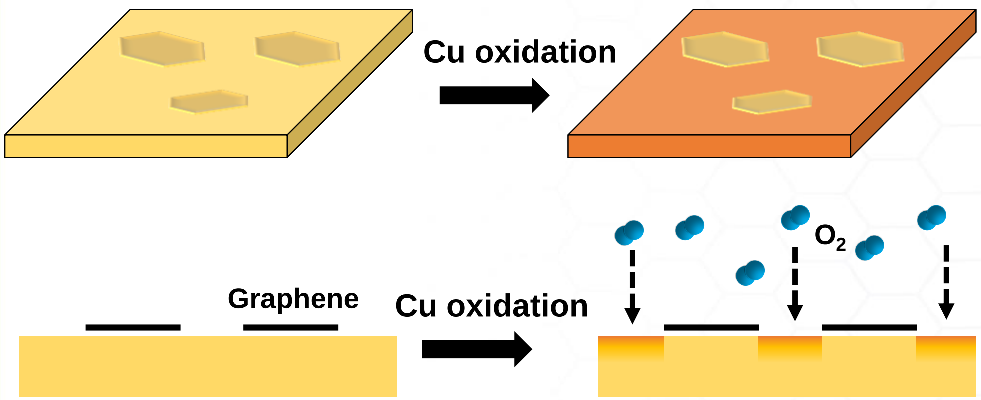
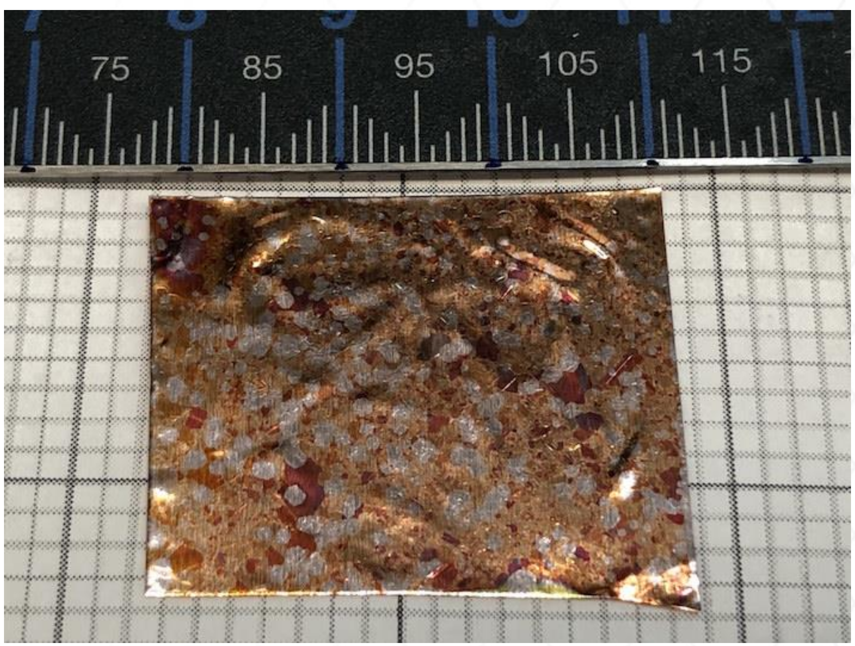
Direct optical visualization of graphene





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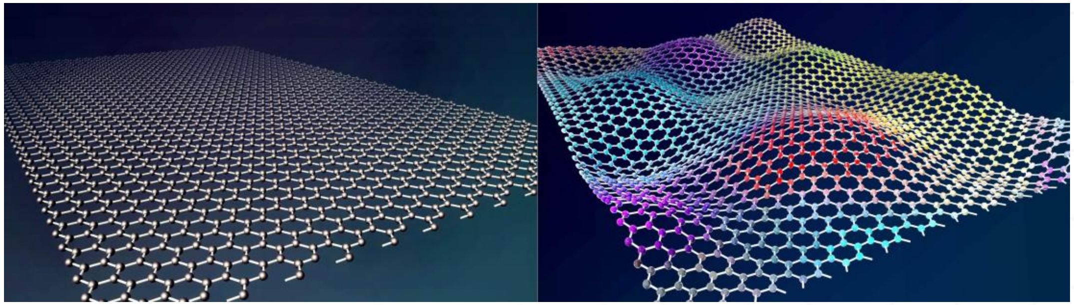
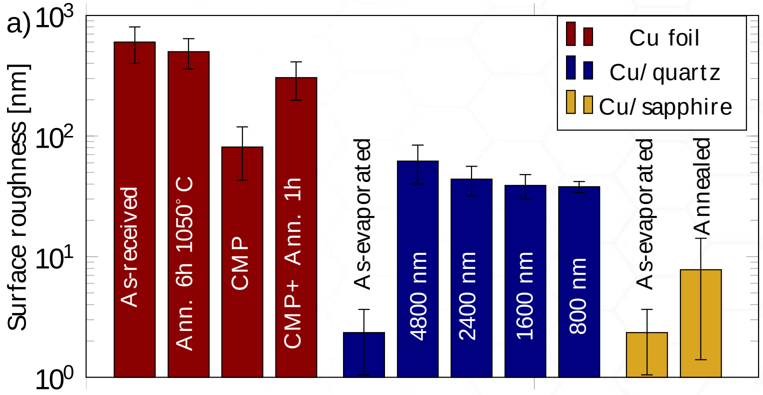
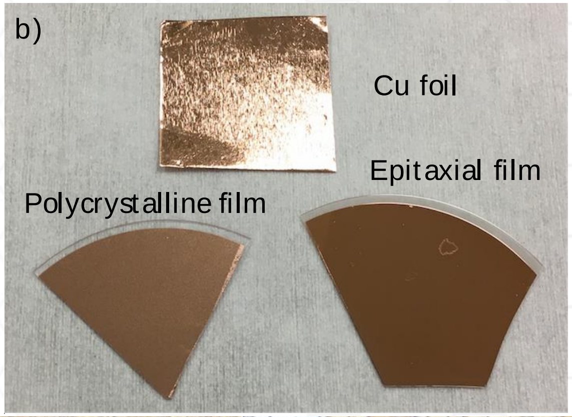
Surface planarity: foils vs. films

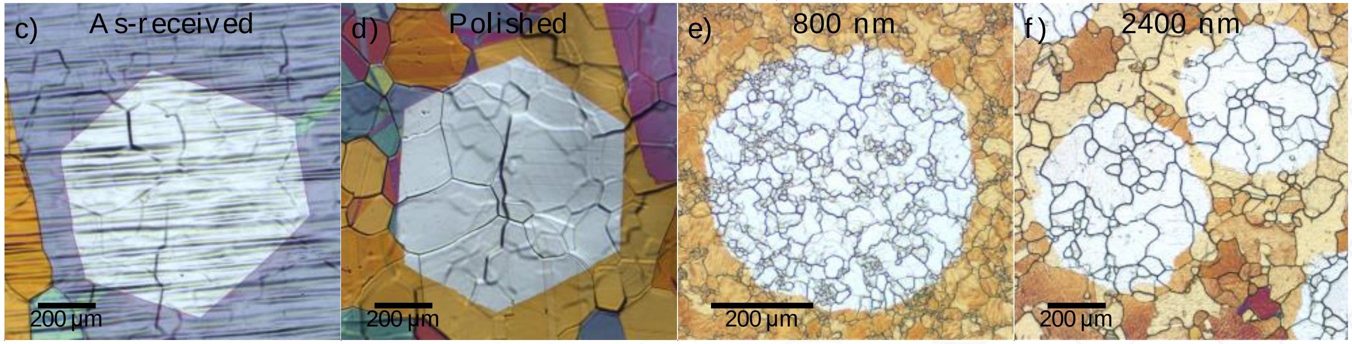


[Harvard University, 2011]

Graphene growth mimics Cu substrate surface morphology!







[B. Huet et al., Nanoscale (10) 21898, 2018]

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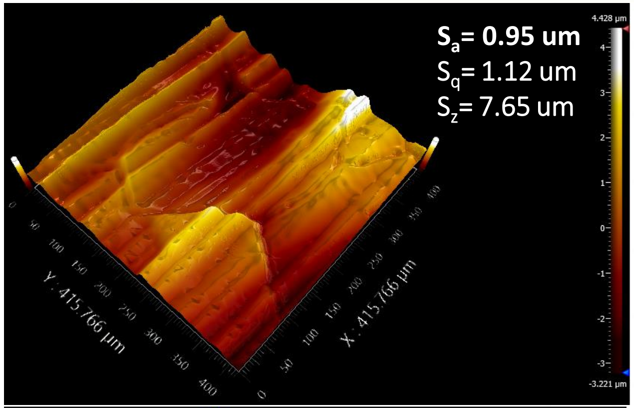
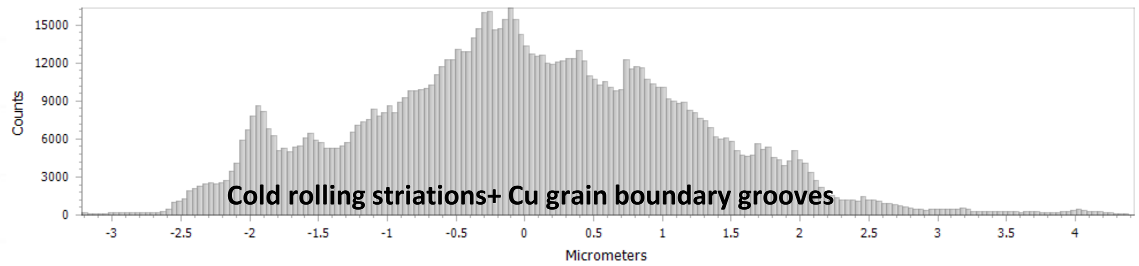
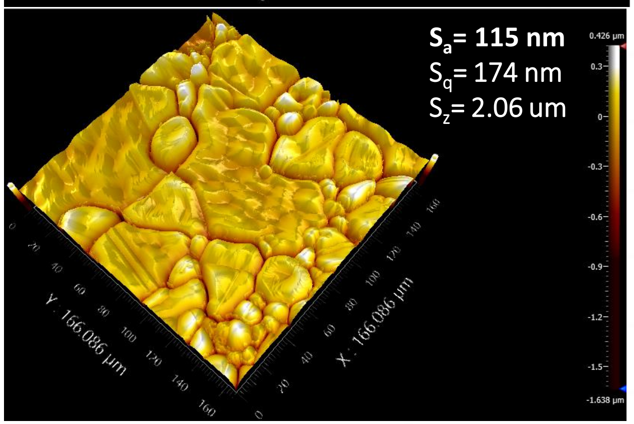
Cu surface benchmarking



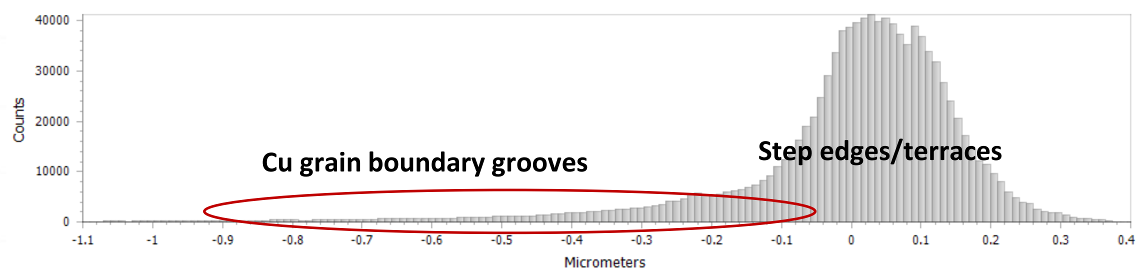
Histograms

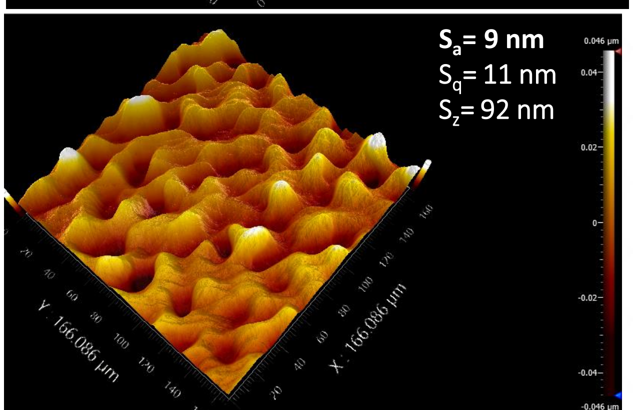
50 µm-thick Cu foil



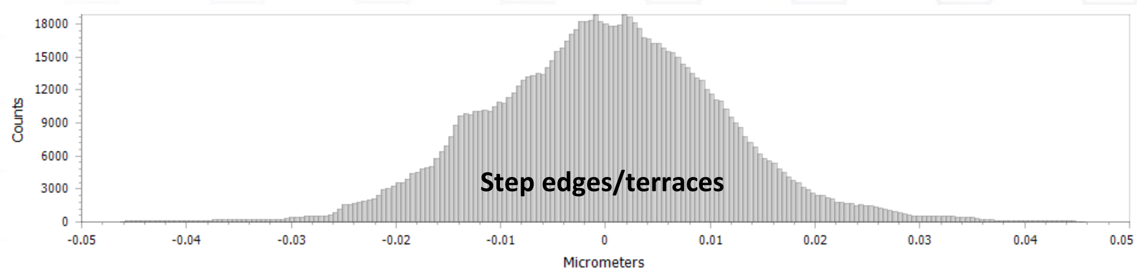


2400 nm-thick polycrystalline Cu film





1000 nm-thick epitaxial Cu film



Cu surface benchmarking

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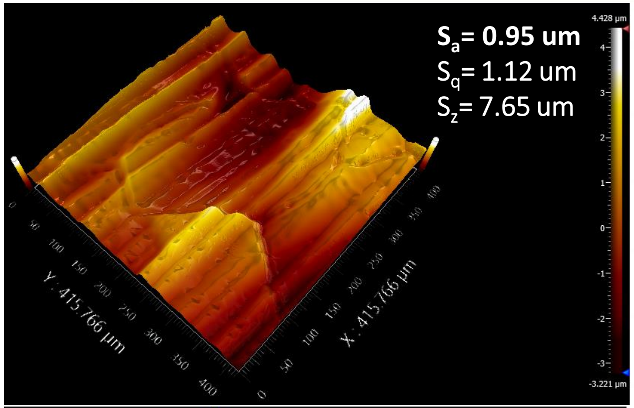
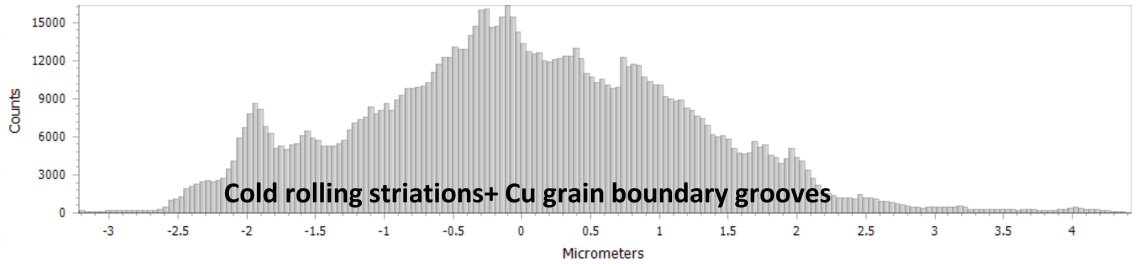
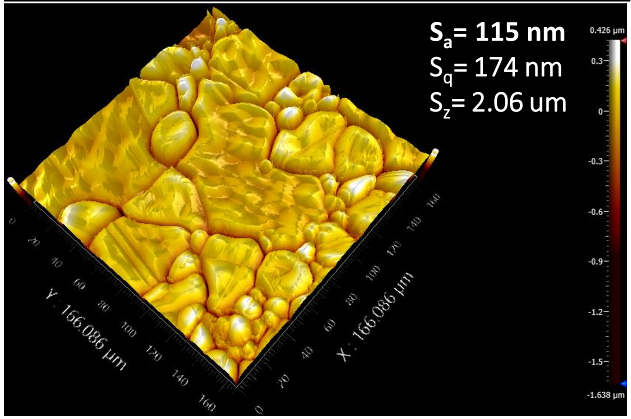
Histograms

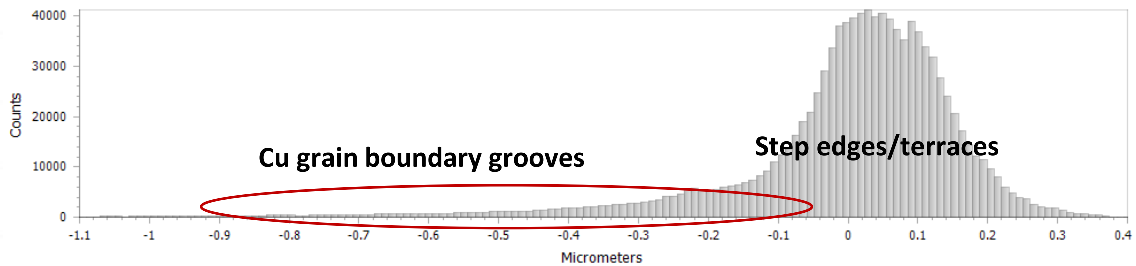


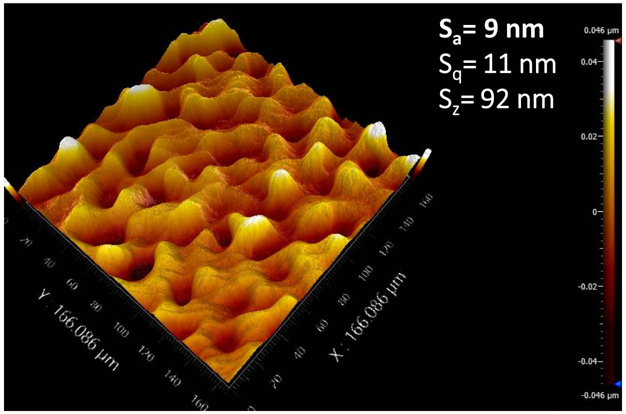
50 µm-thick Cu foil



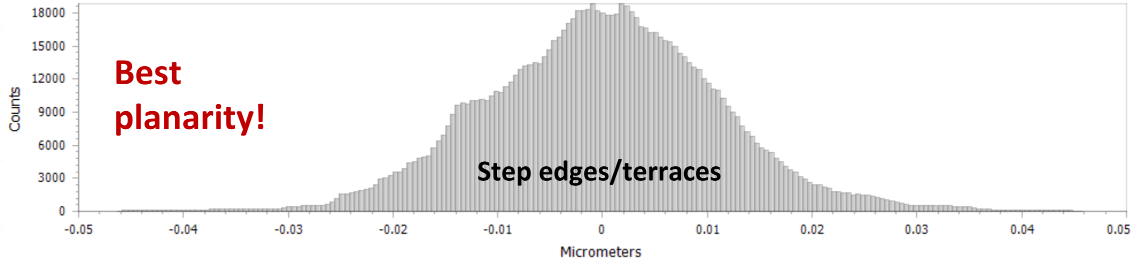


2400 nm-thick polycrystalline Cu film





1000 nm-thick epitaxial Cu film



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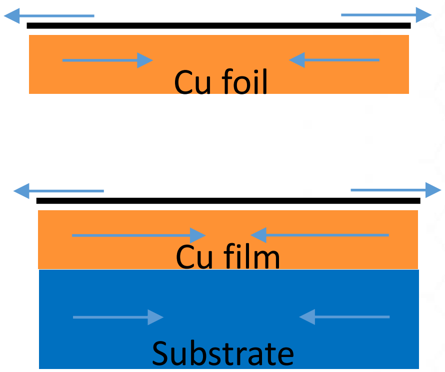
Cracks & wrinkles

In-plane compressive strain building up during cooling:

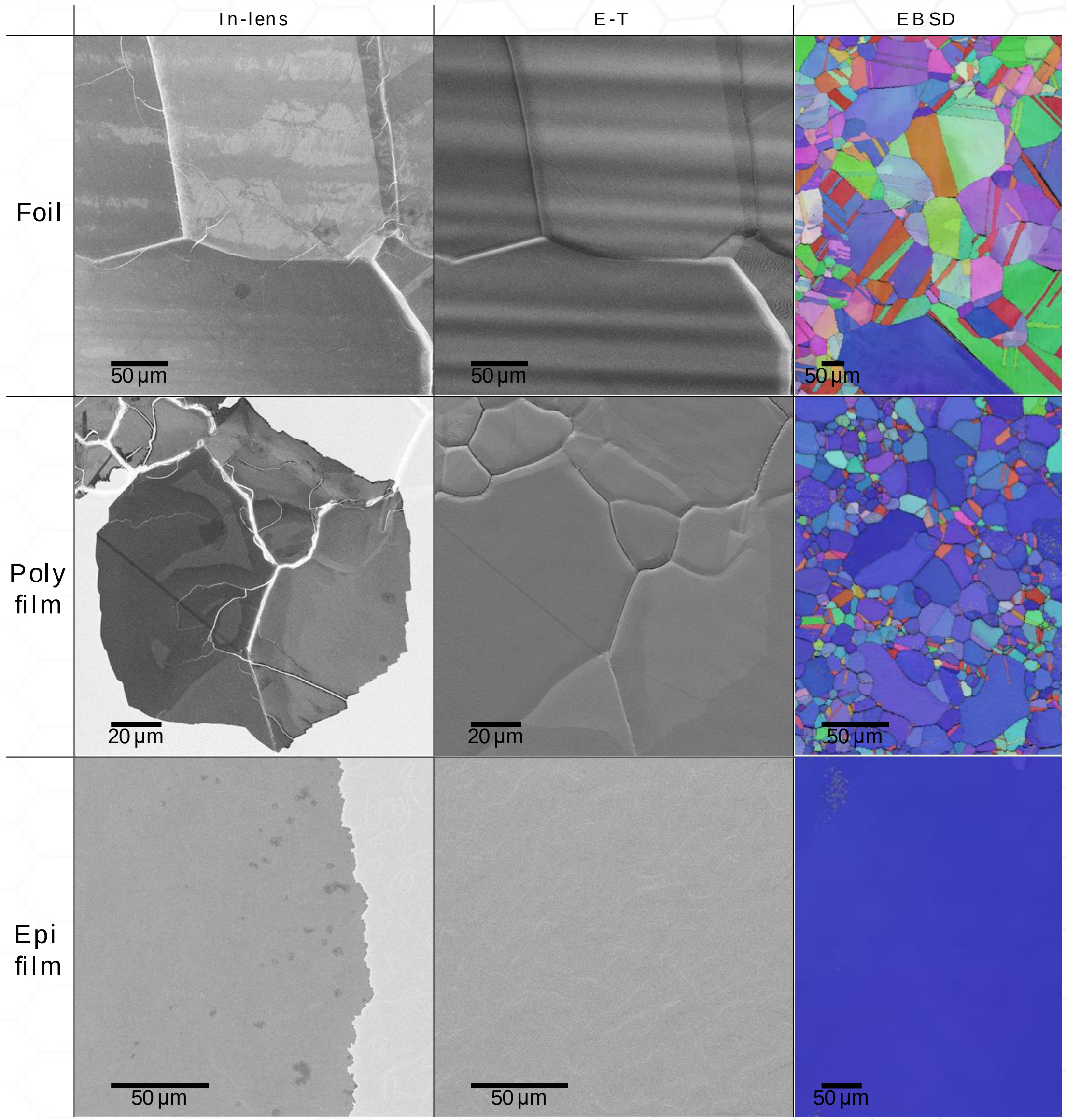
$\varepsilon \approx \Delta T\,(\alpha_{gr} - \alpha_{Substrate})$

ΔT = 1050°C - 20°C



Thermal expansion coefficient:

- **Graphene: -8.0 to -1.0 (x10^{-6}/K)**
- **Copper: +16.7 to +19.8 (x10^{-6}/K)**
- **Fused quartz: +4.0 to +6.0 (x10^{-6}/K)**
- **C-plane sapphire: +6.6 to +9.0 (x10^{-6}/K)**



[B. Huet & J.-P. Raskin, Nanoscale (10) 21898, 2018]

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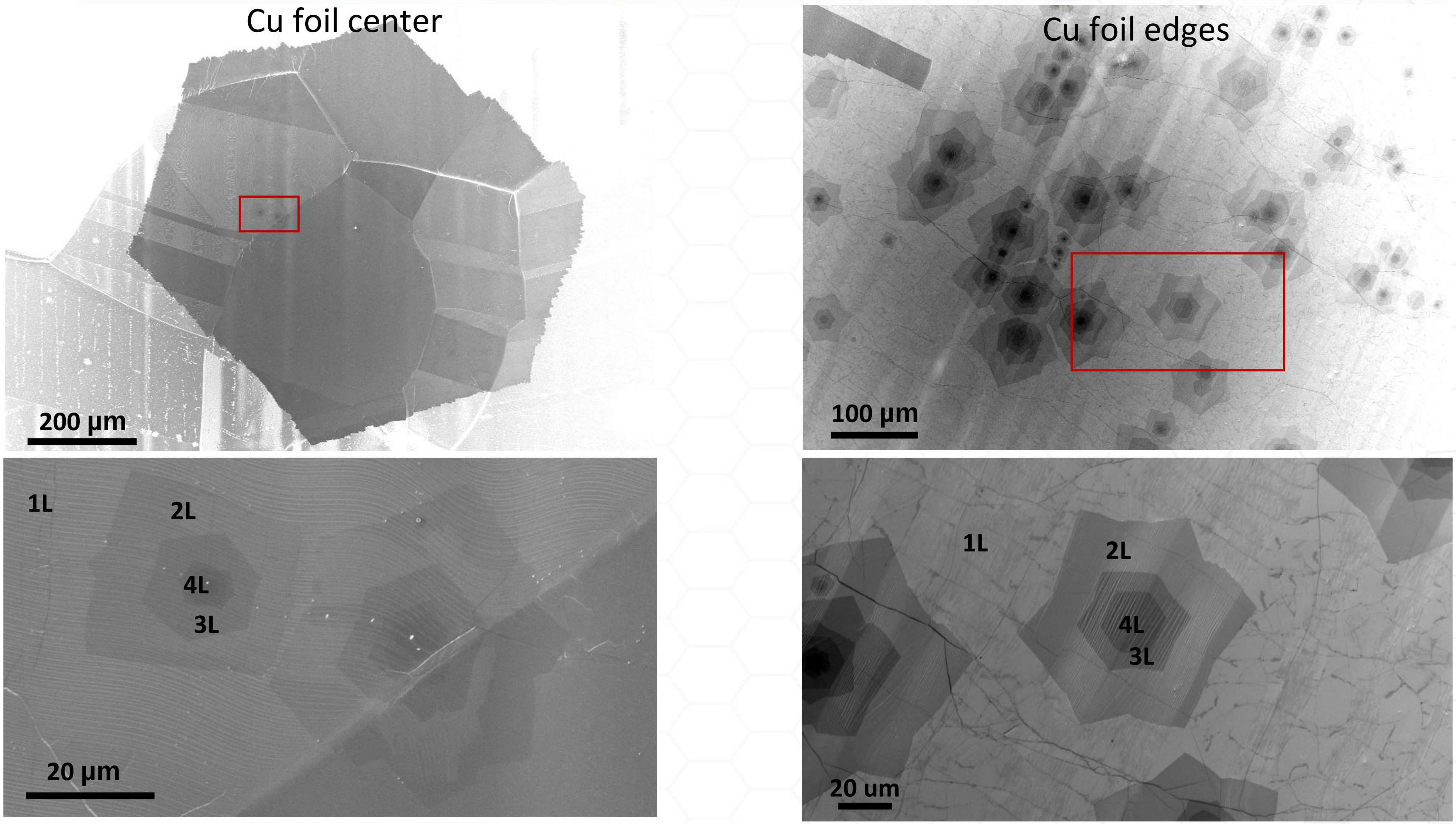
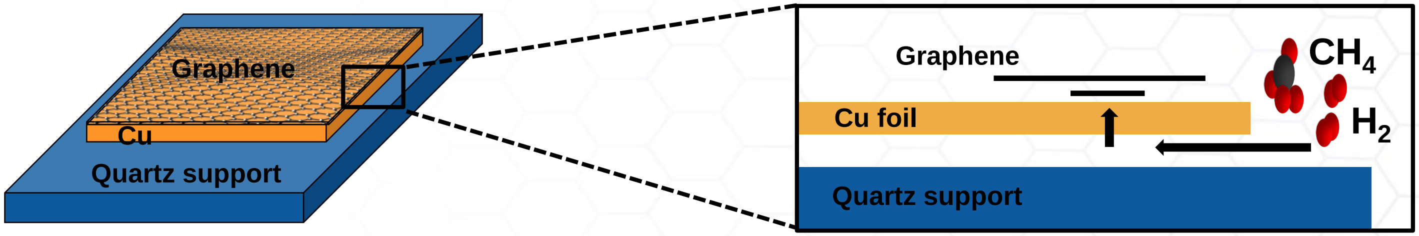
Control over the thickness





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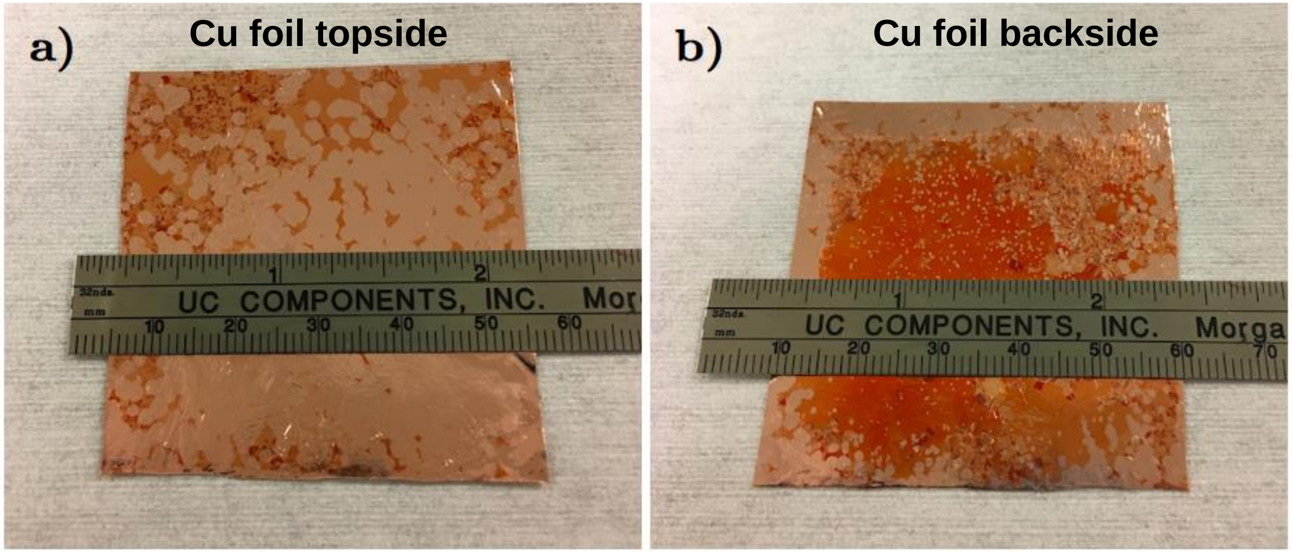
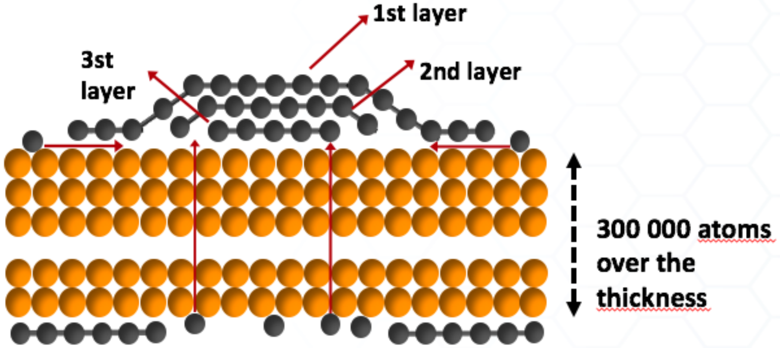
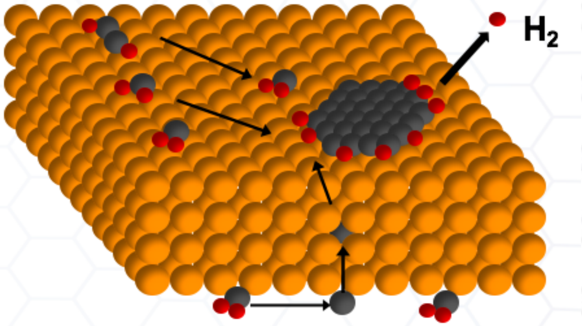
Control over the thickness

Graphene growth: topside vs. backside

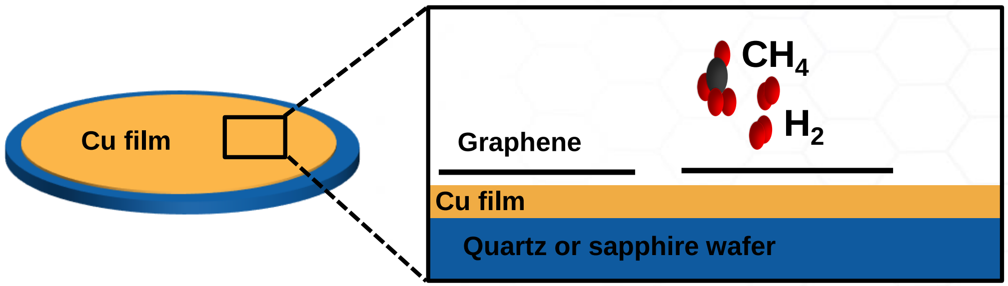


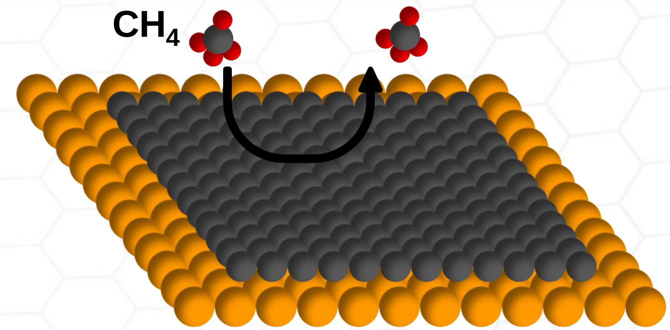
P_{gr} = 800 mbar
T_{gr} = 1050°C

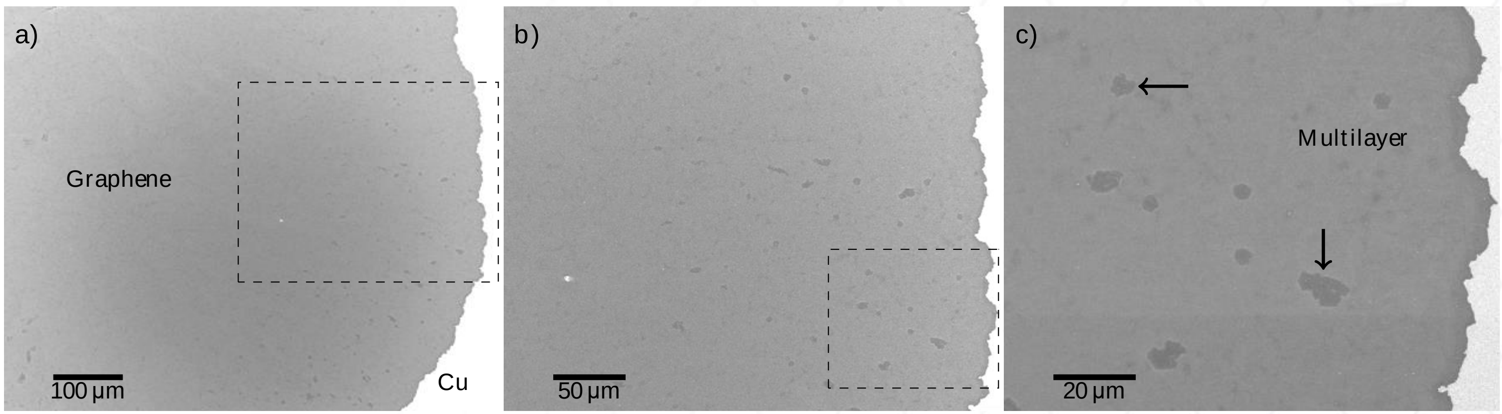




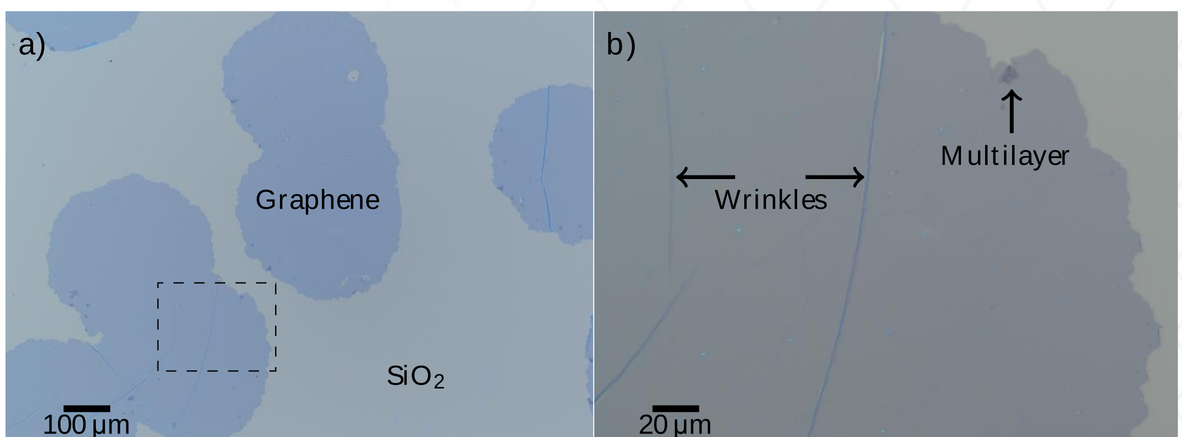
Multilayer graphene







Single layer >99.99%



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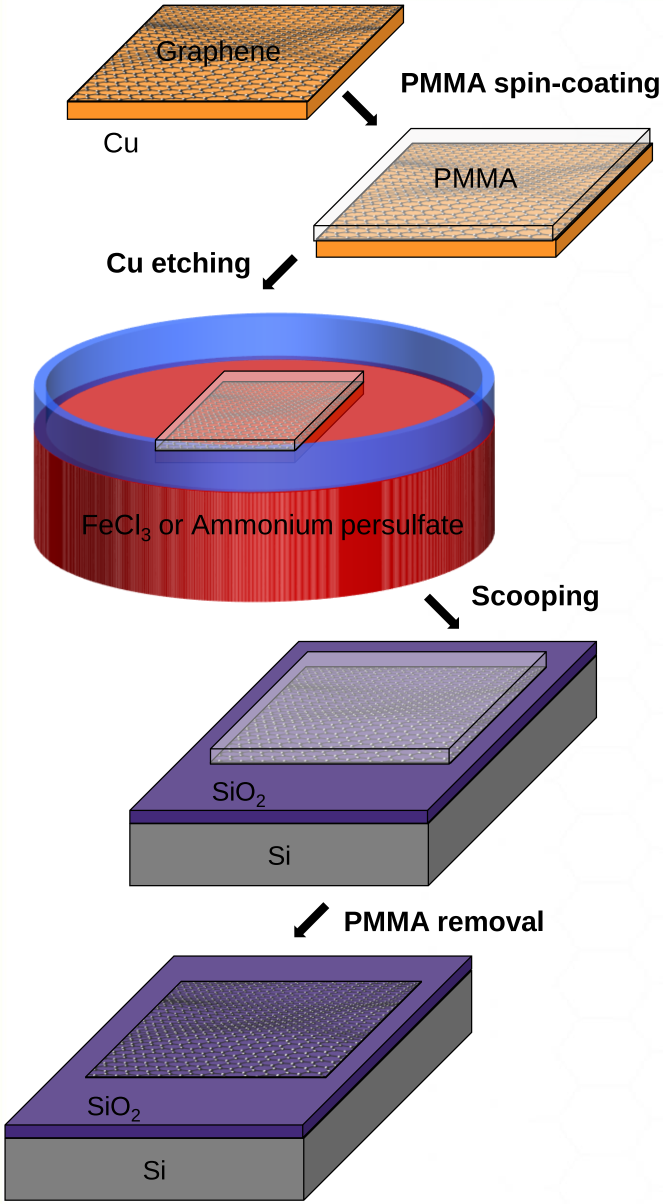
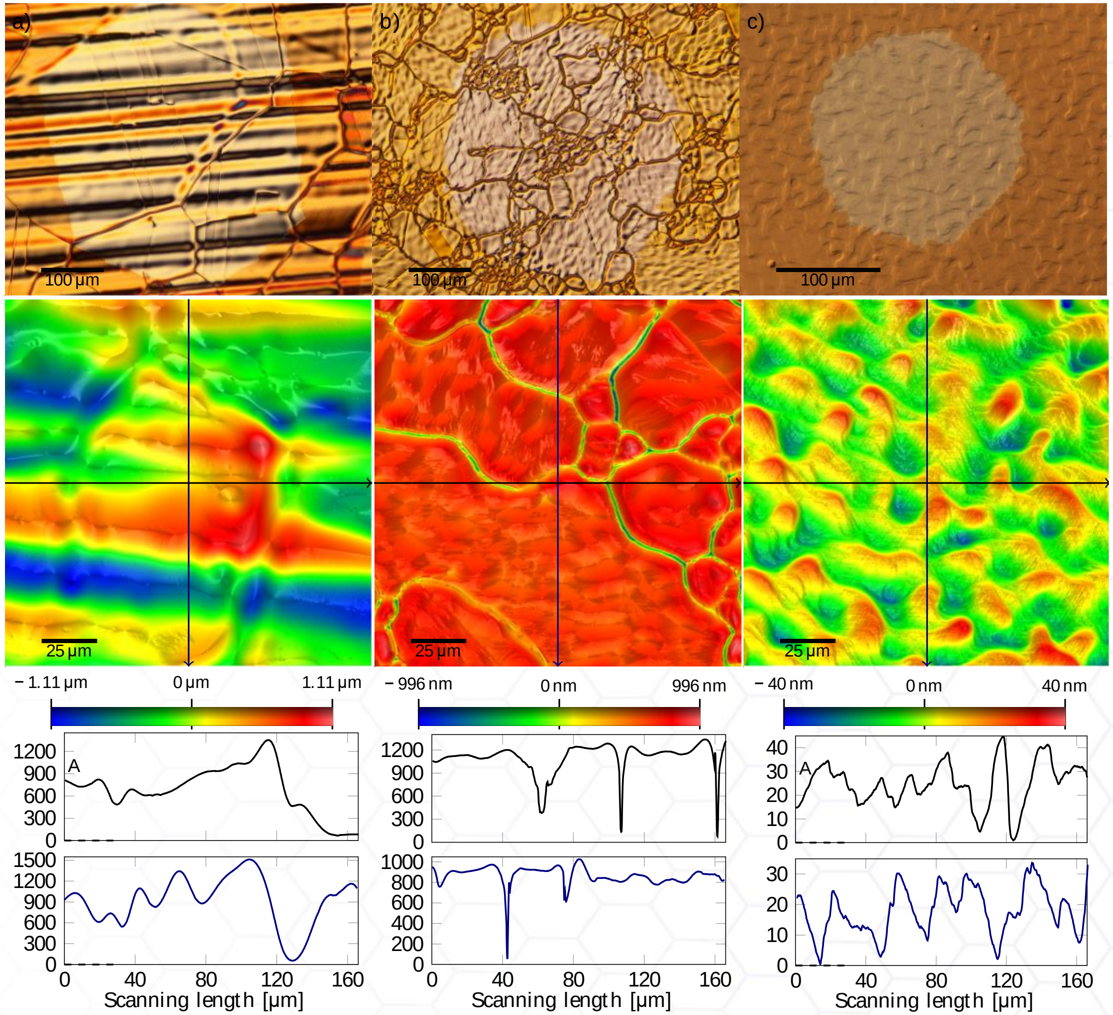
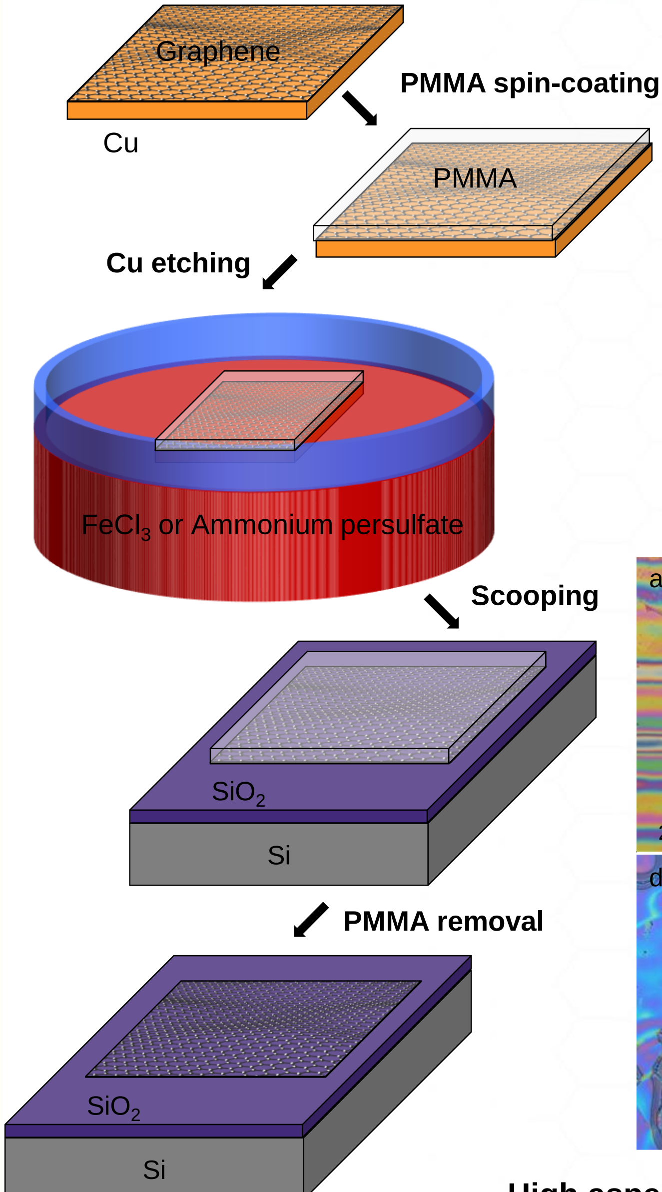
Graphene transfer

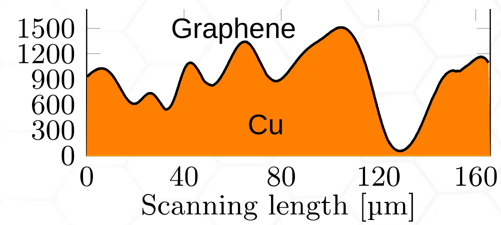


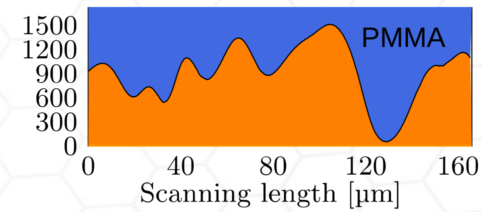


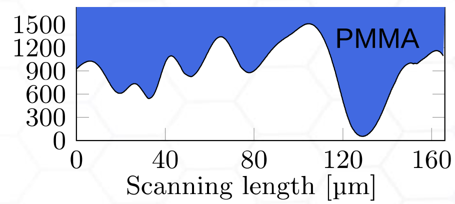
[B. Huet et al.,to be submitted]

True surface area

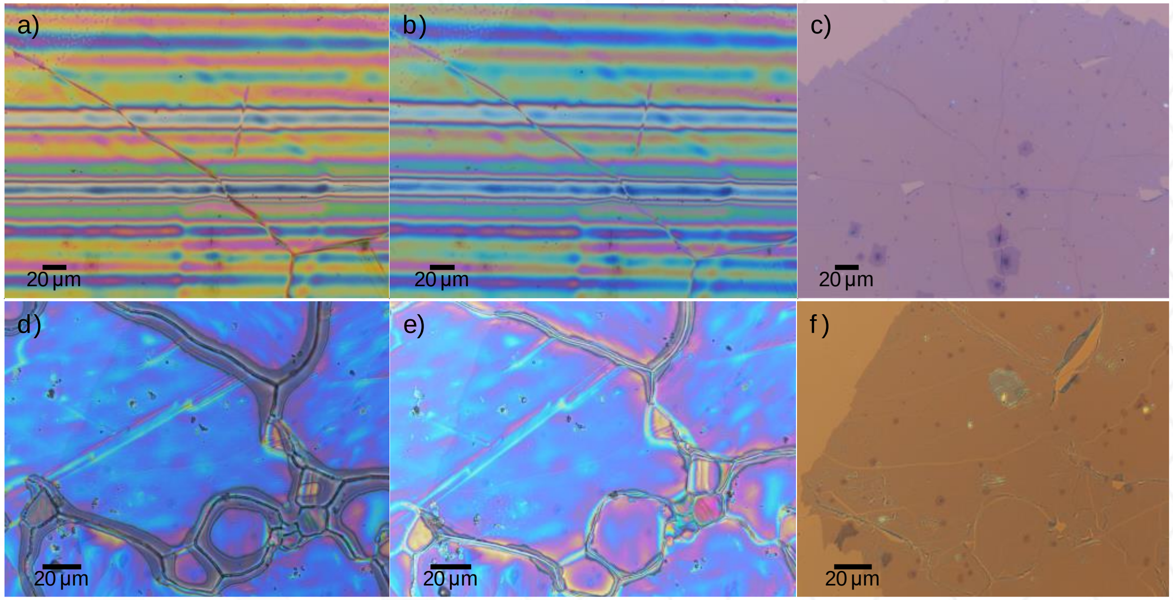






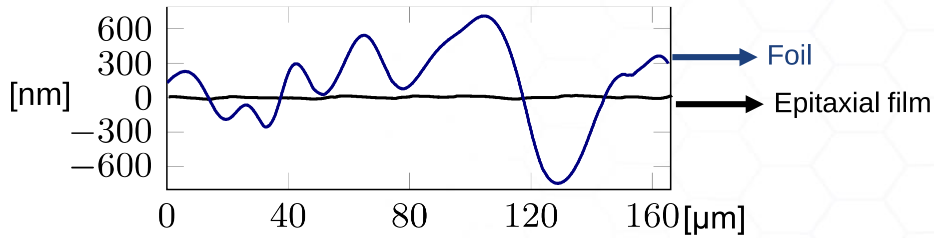


Corrugation/waviness can be partially relaxed!

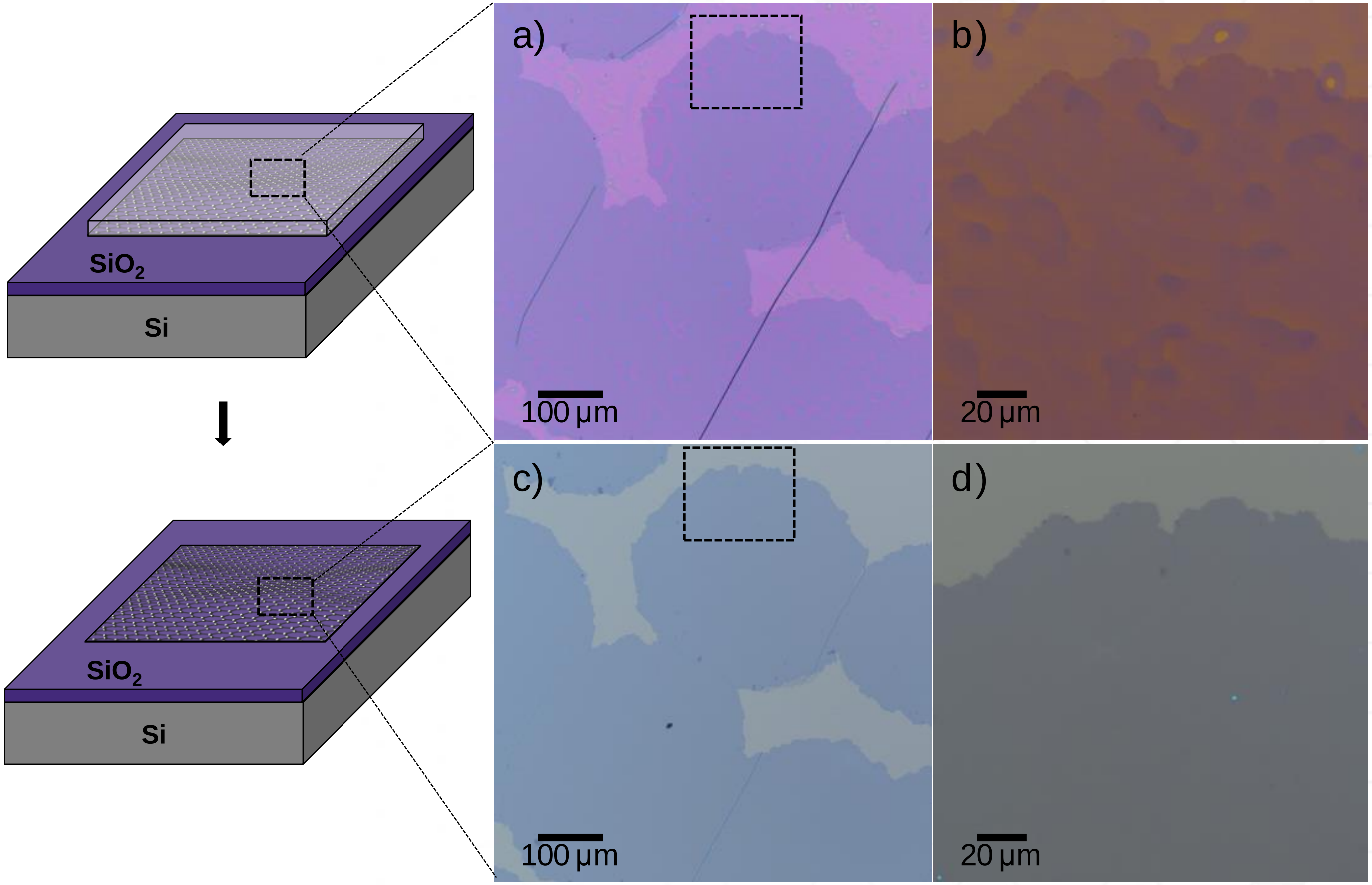


High aspect ratio Cu features prevent proper contact

True surface area



Substrate	Excess of surface area
Cu foils	0.60±0.45%
Polycrystalline Cu films	1.8±0.5%
Epitaxial Cu films	0.0105±0.0021%



[B. Huet, D. Snyder and J. Redwing ; To be submitted]

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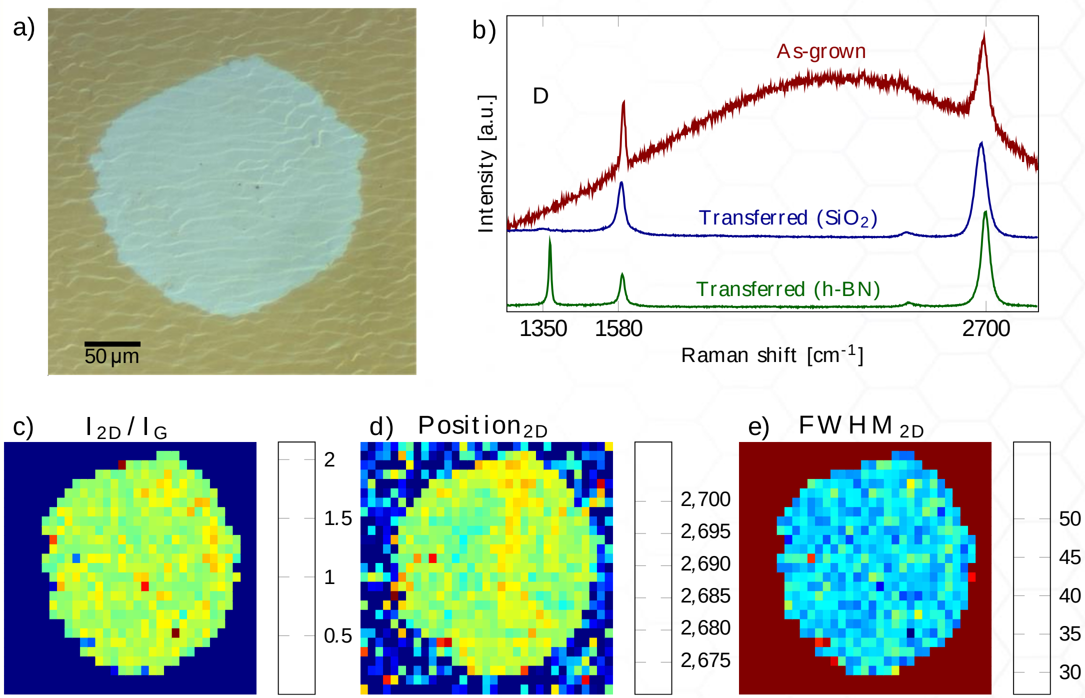
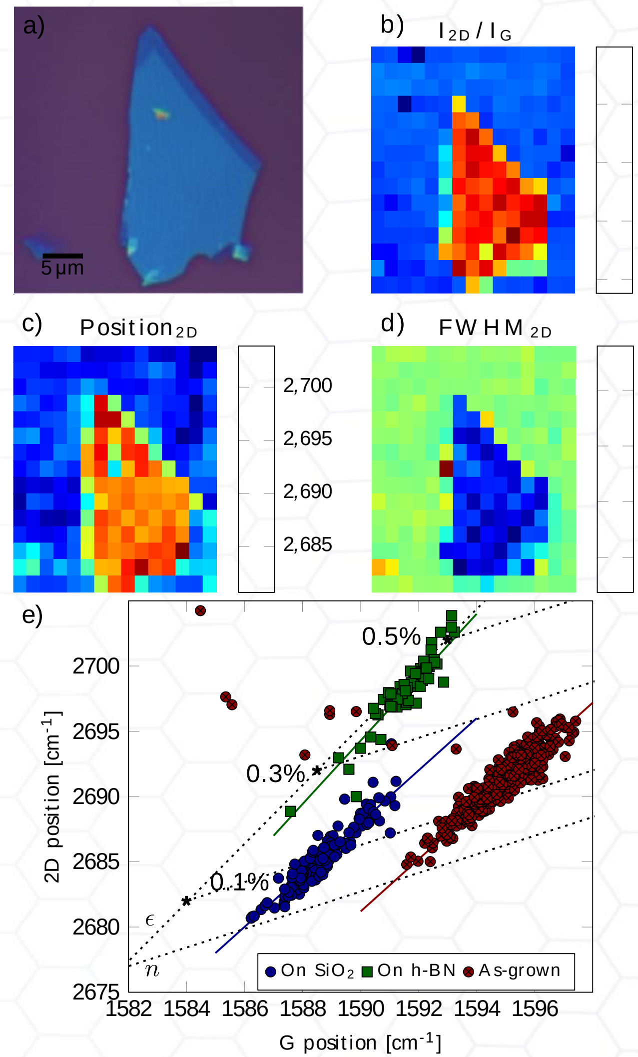
Raman mapping

Epitaxial Cu film



[B. Huet & J.-P. Raskin, Nanoscale (10) 21898, 2018]



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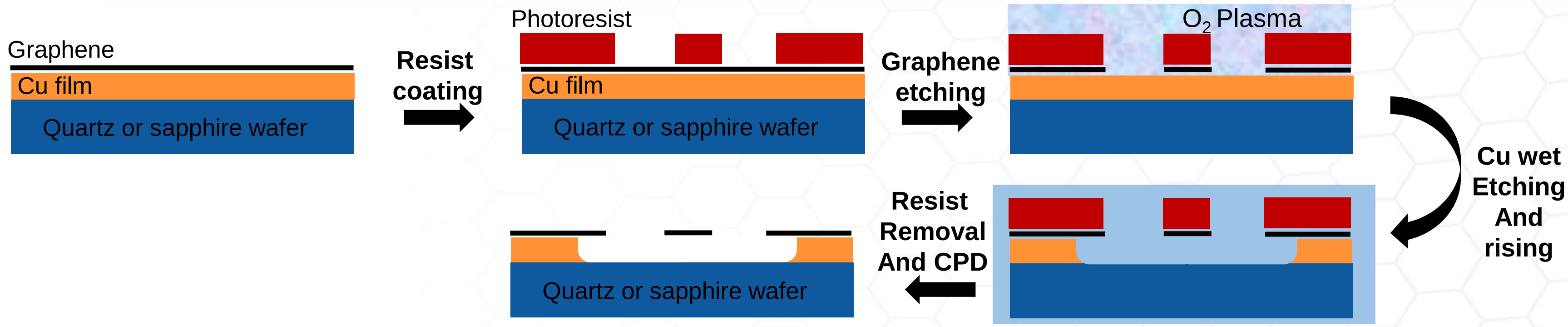
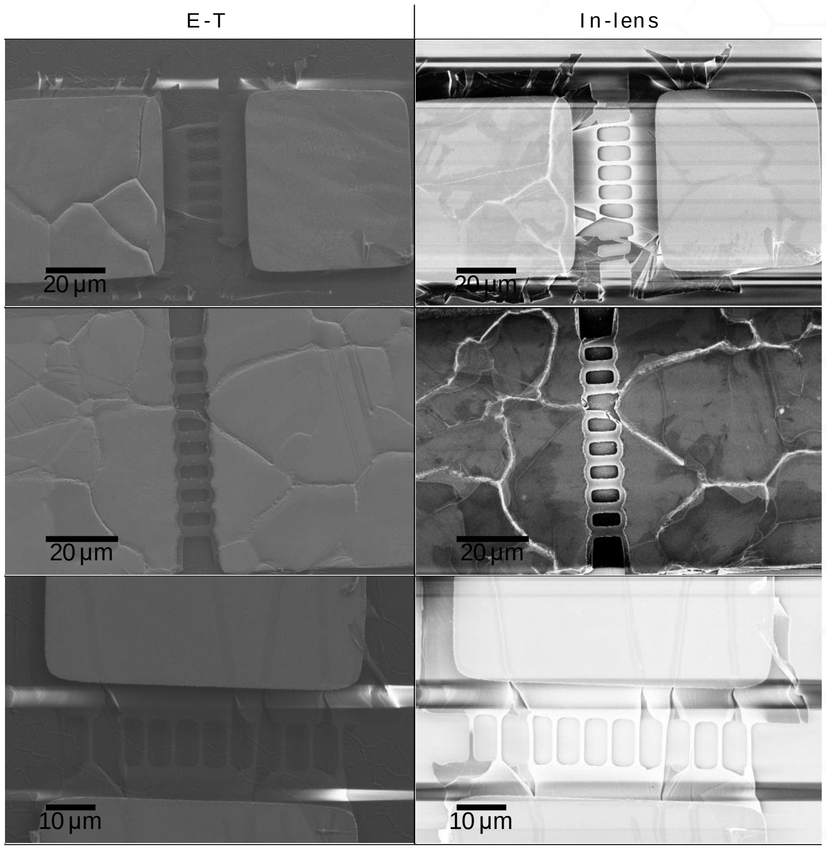
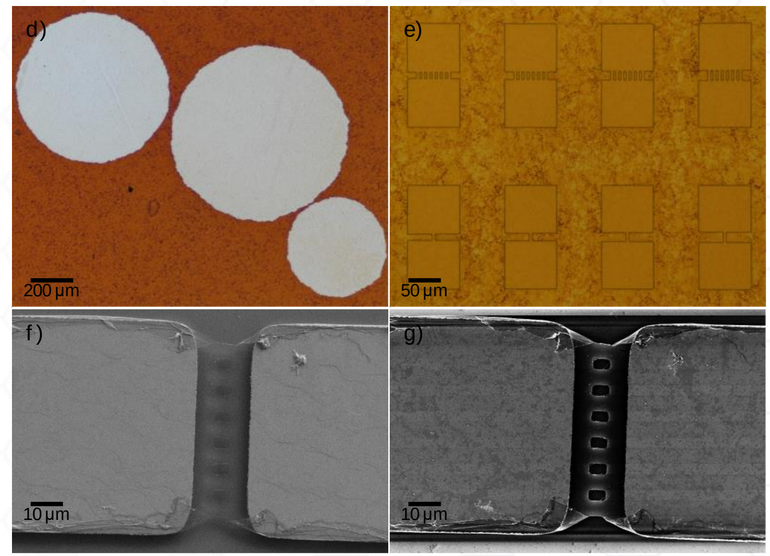
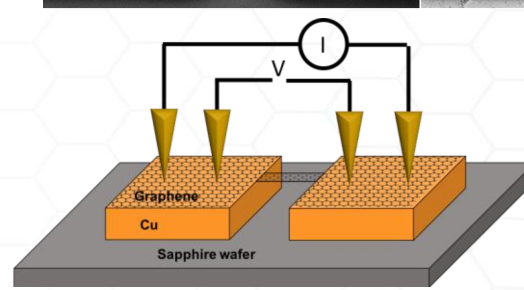
Direct processing of graphene









The sheet resistance :
759 ± 242 Ω/▢

Conclusions

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Epitaxial Cu films offer an ideal platform for graphene synthesis, transfer and device fabrication

- Superior surface roughness: about 2 orders of magnitude lower than foils
- Better control over number of layers: suppresses the major mechanism for ad-layer formation
- Improved physical integrity: minimal cracks & wrinkles
- Improved/more reliable transfer
- Direct device fabrication & characterization
- High throughput: batch of >25 wafers (3-in.)

More information:

- B. Huet et al., Role of Cu foil in-situ annealing in controlling the size and thickness of CVD graphene domains, Carbon, 2018.
- B. Huet et al., Role of the Cu substrate in the growth of ultra-flat crack-free highly-crystalline single-layer graphene, Nanoscale, 2018.
- B. Huet et al., Multi-wafer batch synthesis of graphene on Cu films by quasi-static flow chemical vapor deposition, 2D materials, 2019.
- B. Huet et al., Fundamental limitations for the transfer of graphene grown on Cu substrates, to be submitted.

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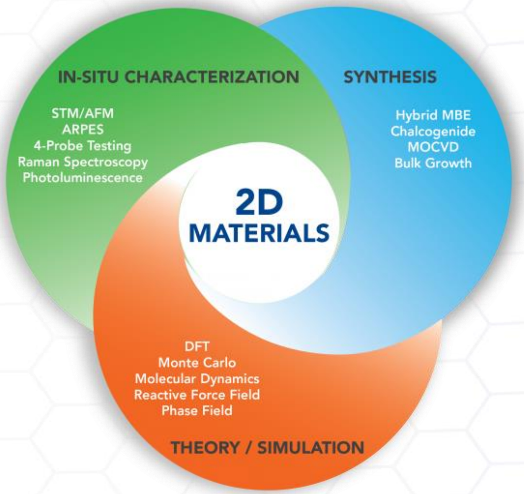

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- Partnership opportunities with PUI, MSI