Update on Charge Transfer Properties Through Graphene Layers in Gas Detectors

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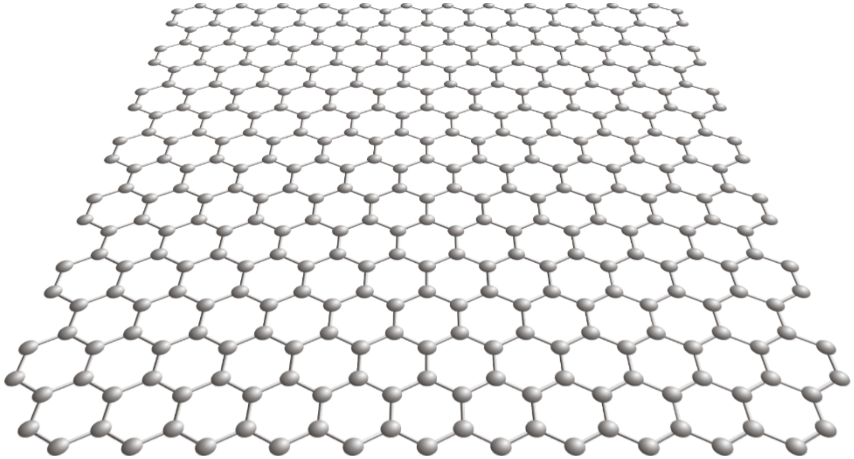
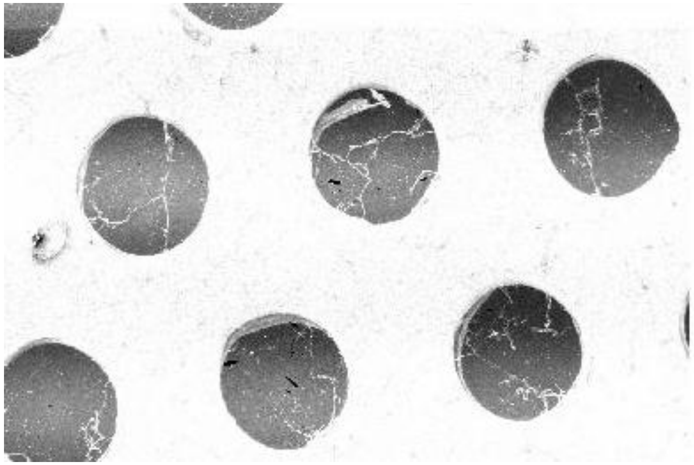
Graphene Layers in Gas Detectors

- Goal: create a device fully transparent to electrons and fully opaque to ions
- Graphene is narrowest and thinnest possible conductive mesh with pore size < 1 Å
- Study of charge transfer through graphene layer suspended on Cu meshes





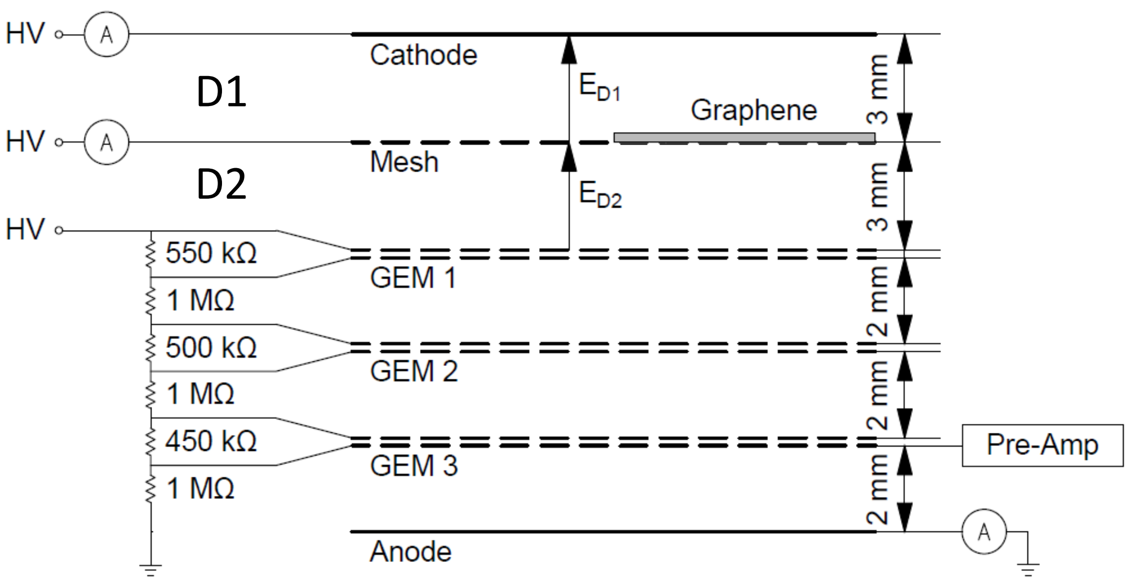
Motivation

- Best case scenario: create a membrane which is fully transparent to electrons and fully opaque to ions
- More realistic: create a membrane which is mostly transparent to electrons and fully opaque to ions

Methods

Setup

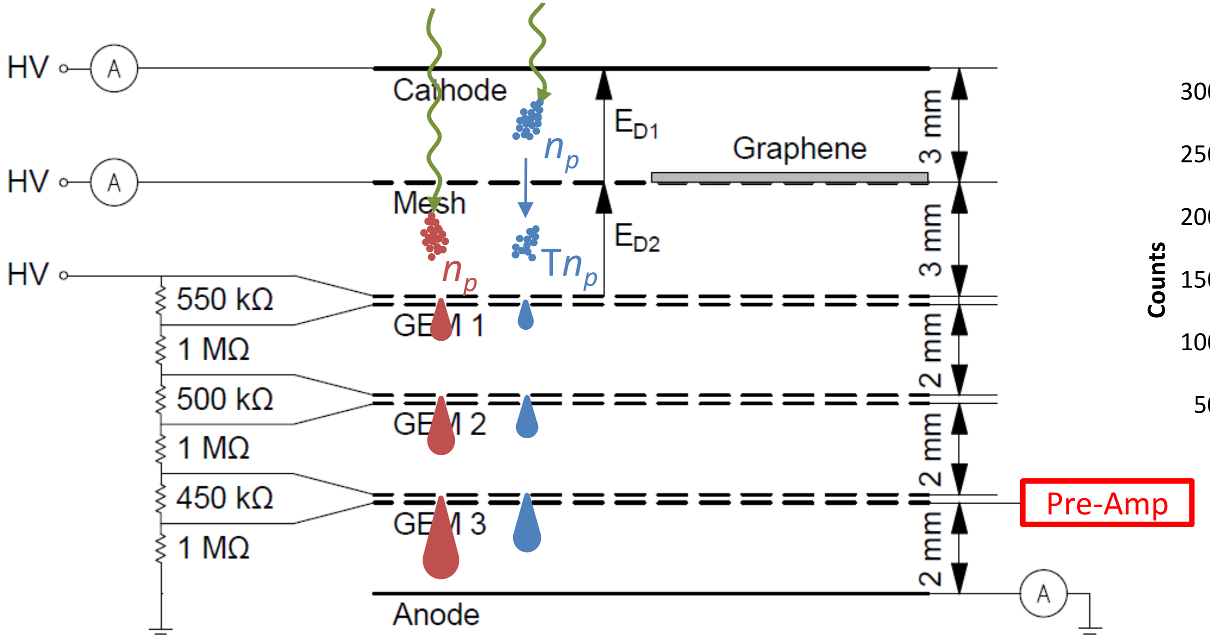
- Standard GEM setup with additional conversion volume on top
- Mesh partly covered with graphene layer between conversion volumes
- GEM powered through resistor divider
- Cathode and Mesh powered individually

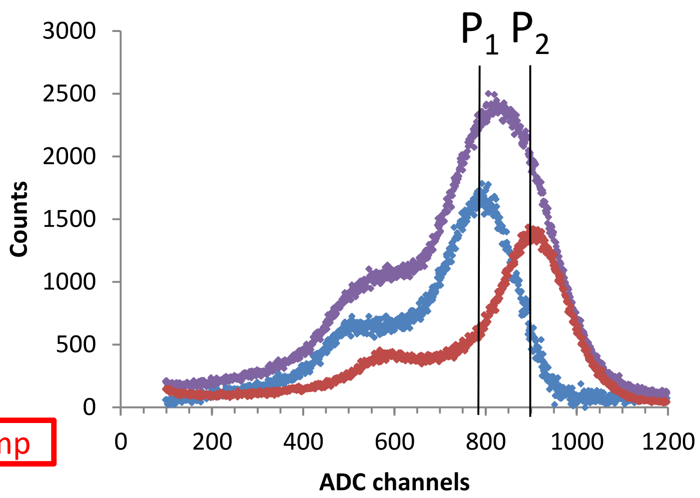


Electron Transparency

Ratio of peak positions from conversion below/above the mesh

$T_{electron} = P_1/P_2$





Electron Transparency

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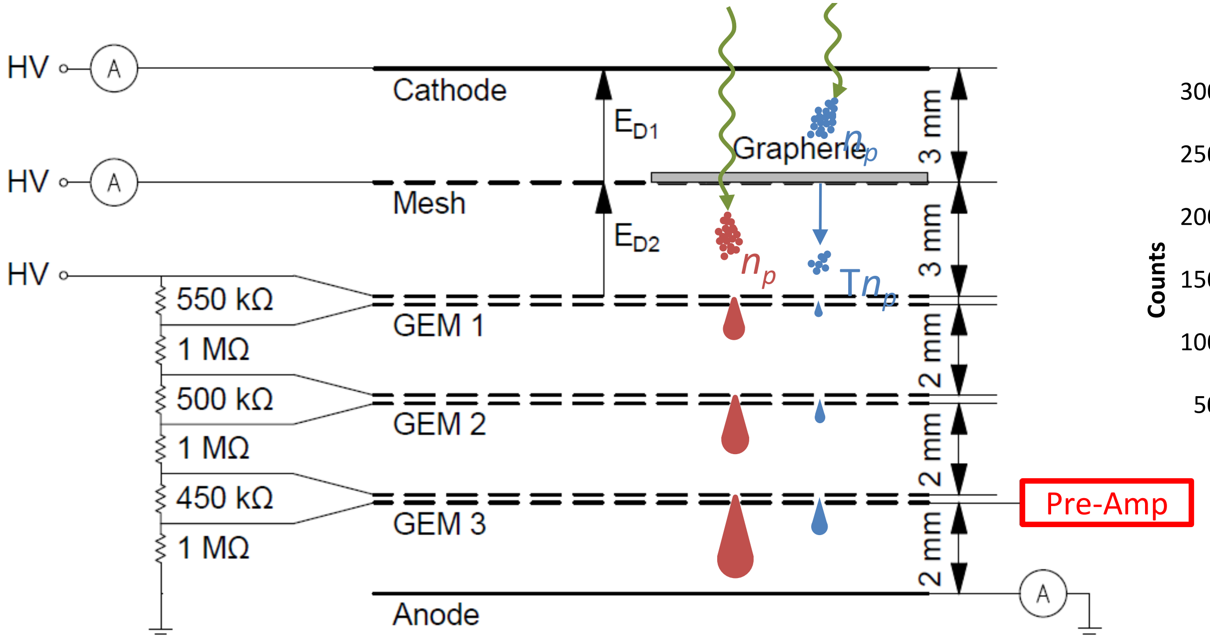
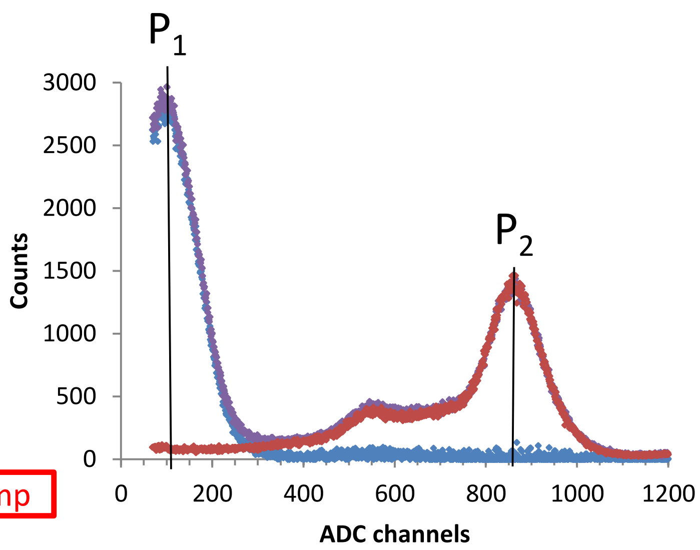
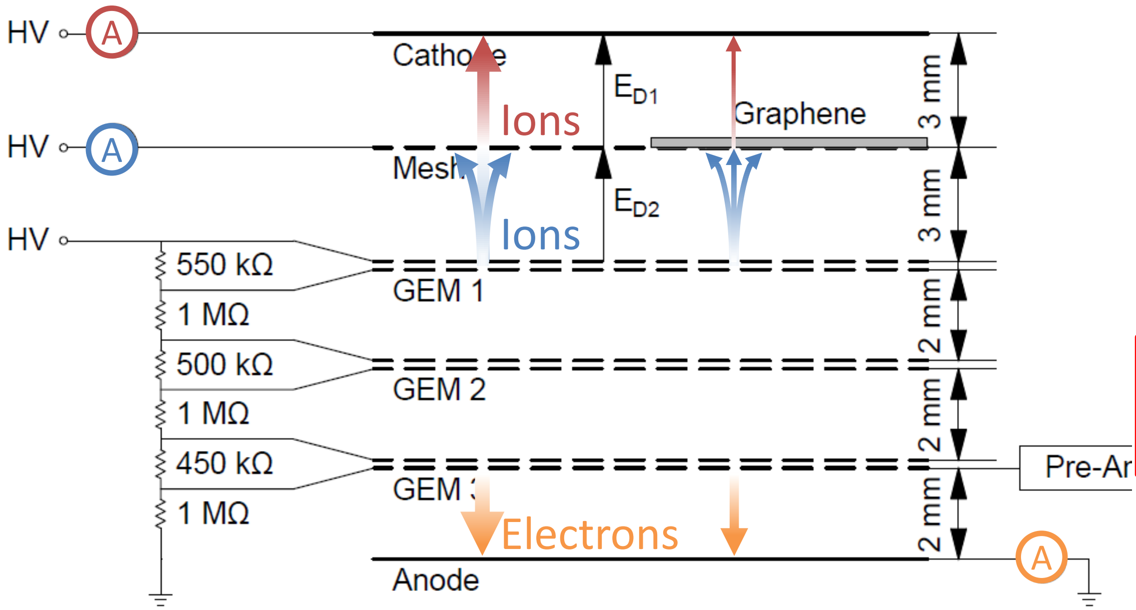




Ion Transparency

Current measurements on cathode and mesh

$$T_{ion} = \frac{I_{cath}}{I_{cath} + I_{mesh}}$$

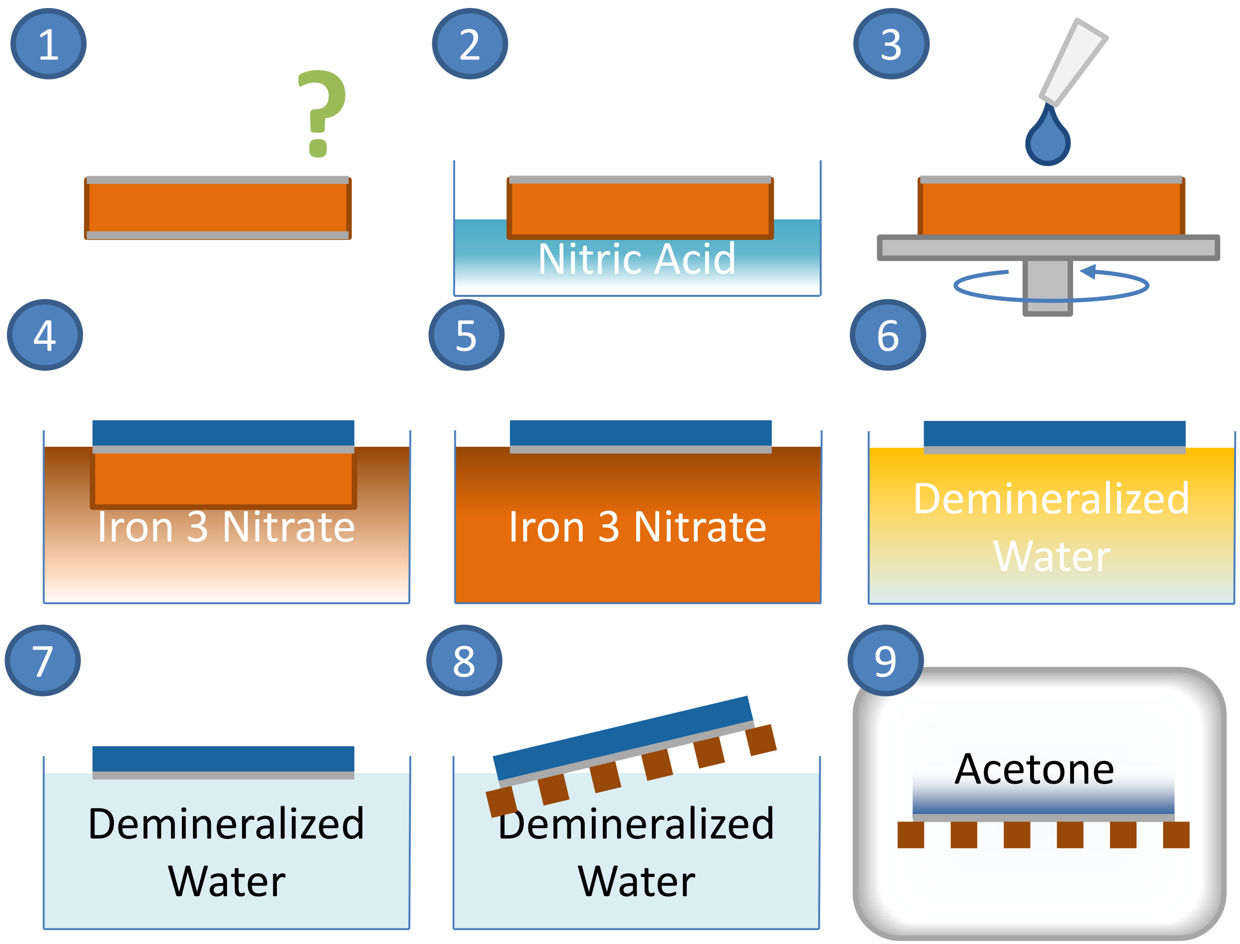


while maintaining const. ion back-flow into both conversion volumes for different field ratios

$$IBF = \frac{I_{cath} + I_{mesh}}{I_{anode}} = const.$$

Graphene Transfer

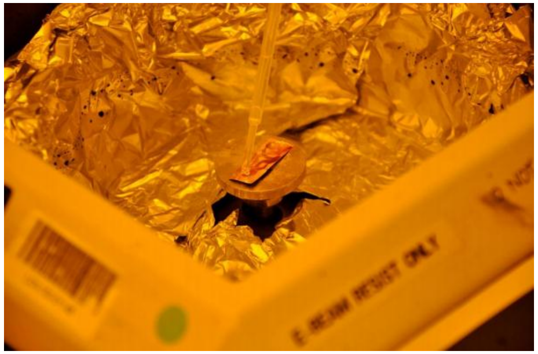
Graphene Transfer



1. Find “good” side of copper foil
2. Etch away “bad” layer in nitric acid
3. Spin-coat with PMMA
4. Etch away copper foil with Fe 3 nitrate
5. PMMA with graphene layer on bottom floating on Fe 3 nitrate
6. First step of cleaning with demineralized water
7. Second step of cleaning with demineralized water
8. PMMA with graphene on bottom scooped out with mesh/GEM
9. PMMA dissolved with acetone in Critical Point Dryer

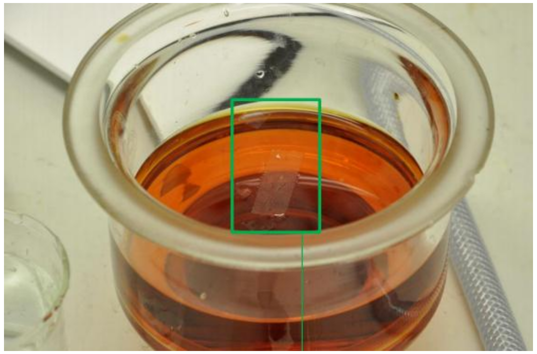
Graphene Transfer

CVD graphene on Cu foil

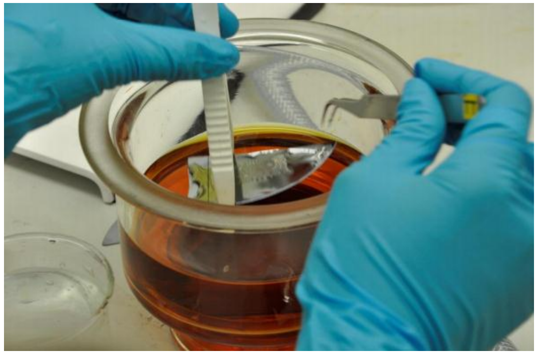


Small part of foil cut and spin-coated with PMMA

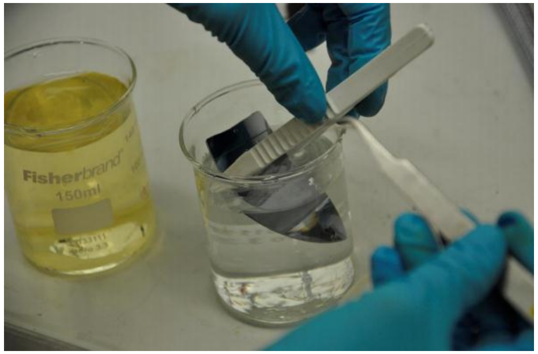
Put into etching liquid



PMMA floating on liquid with graphene attached

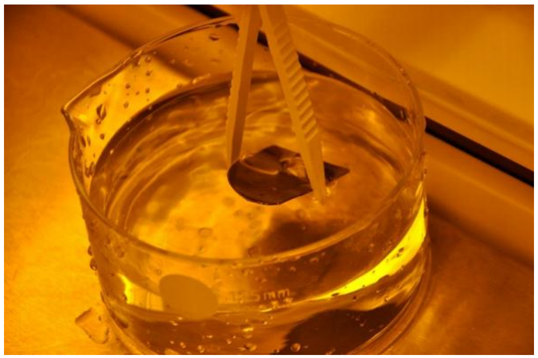


Sample scooped out with Si waver

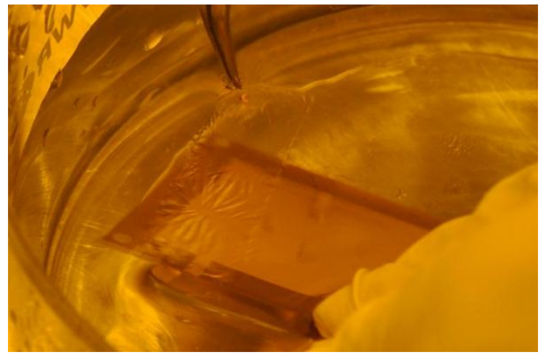


Two steps of cleaning with demineralized water

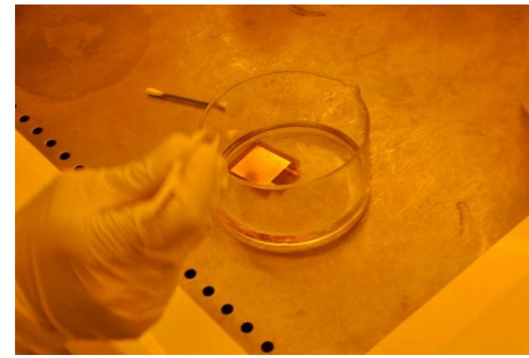
Graphene Transfer



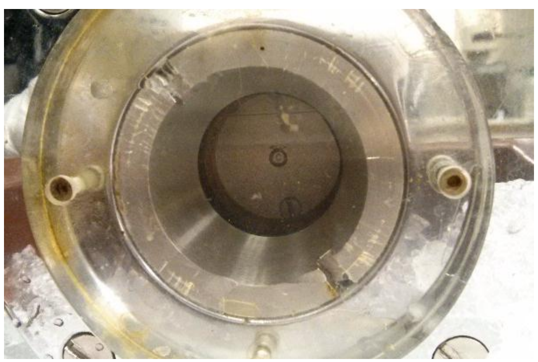
Moved to bigger beaker to enable transfer onto mesh



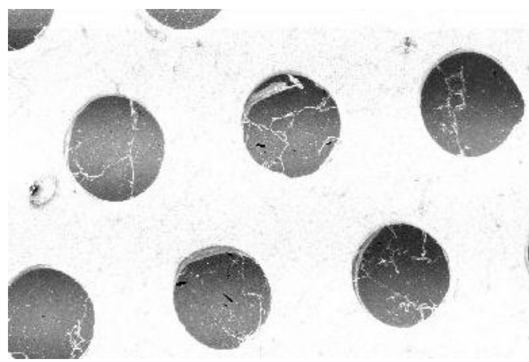
Sample scooped up with mesh

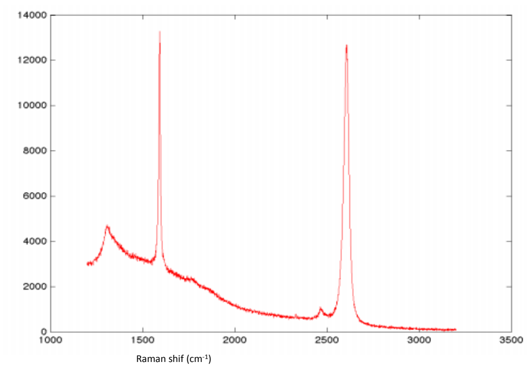


Sample put into aceton to dissolve PMMA



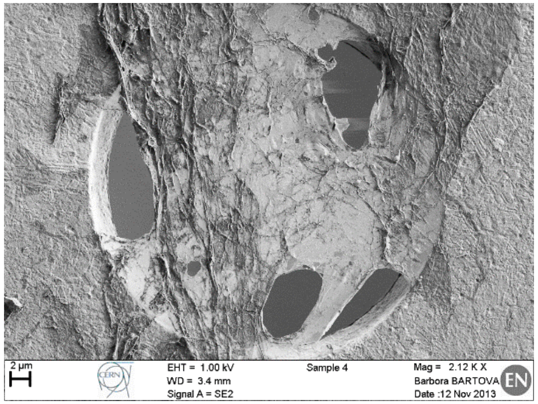
Sample dryed in Critical Point Dryer

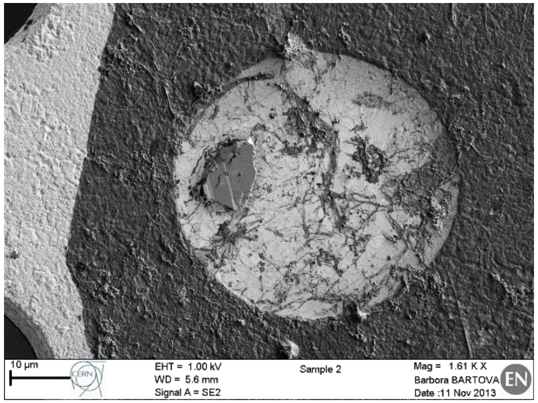


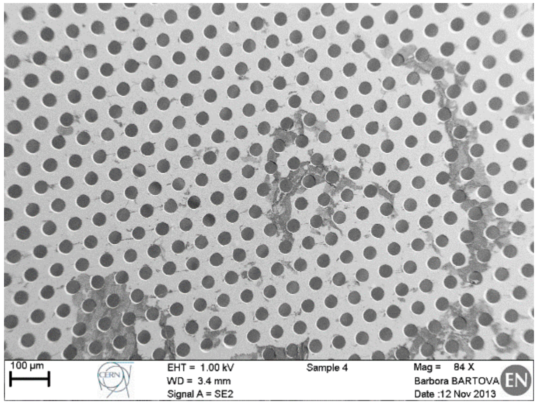


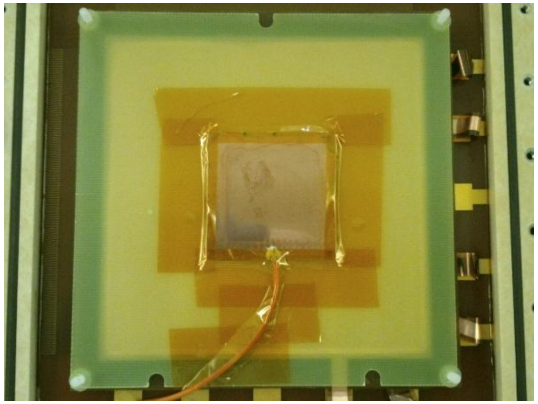
Sample checked with SEM to qualify coverage and with Raman Spectroscopy to check layer quality and PMMA contaminations

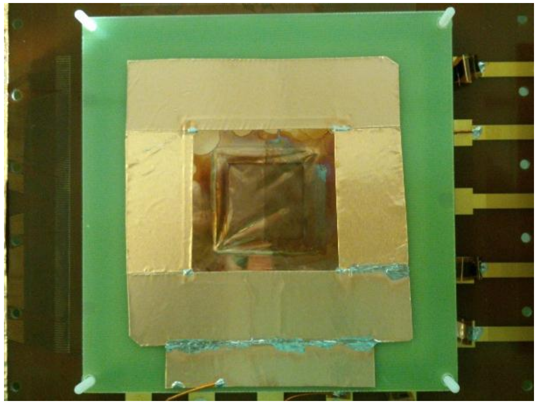
Graphene Transfer

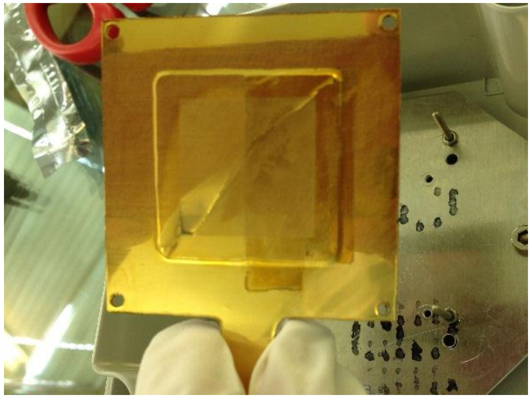




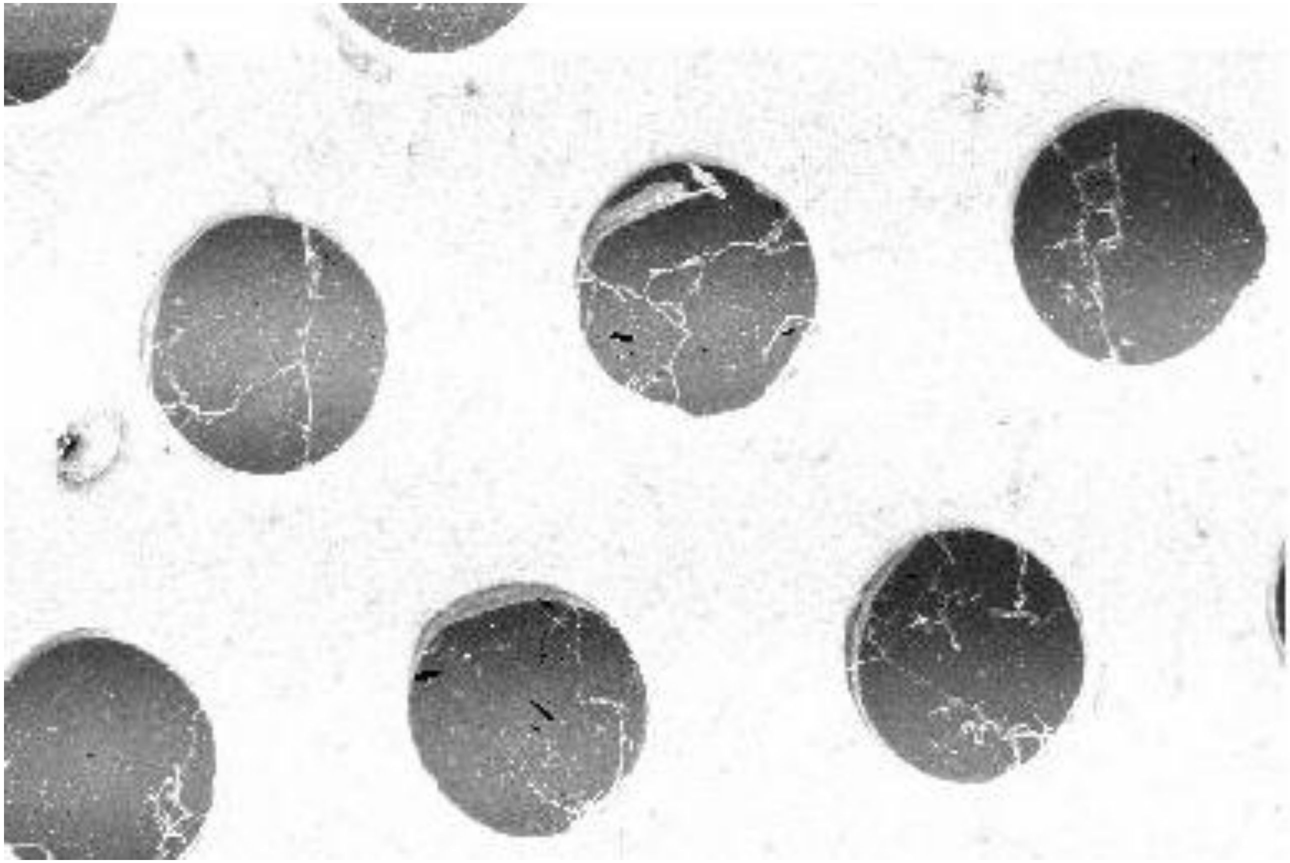








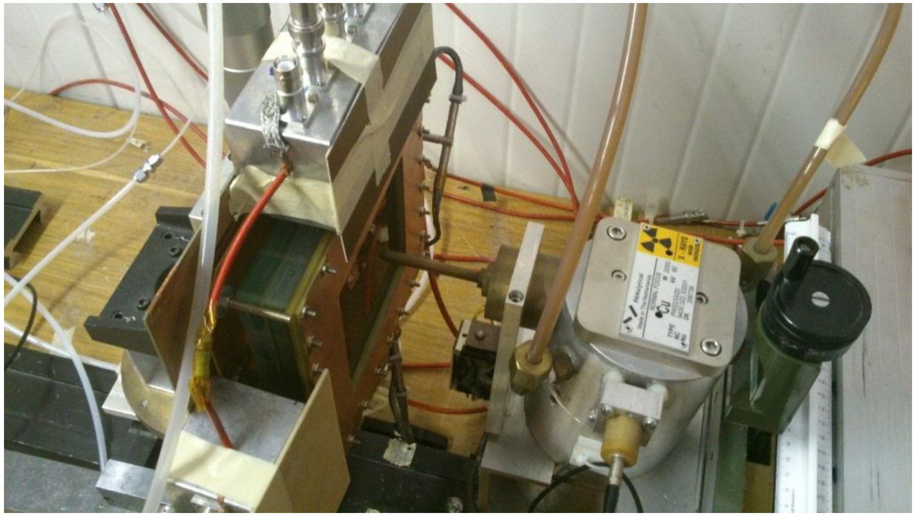
Graphene Transfer



Measurements

Setup

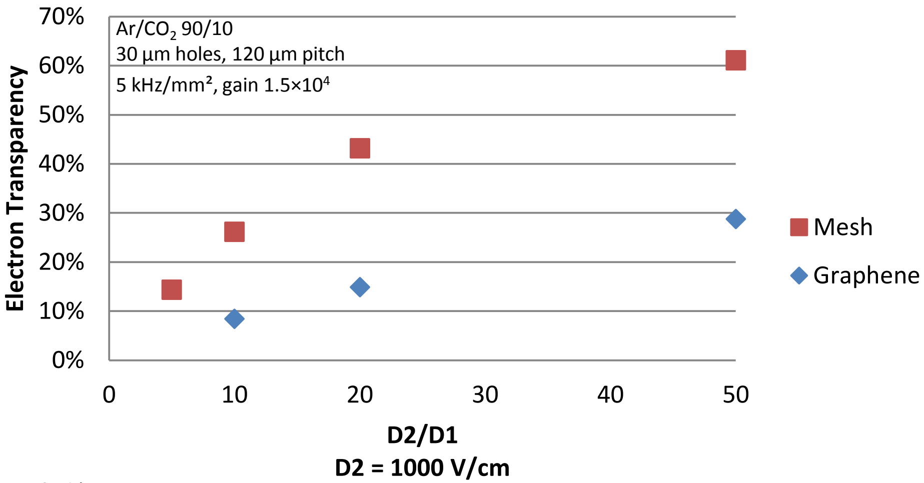
- Ar/CO_2 90/10
- Detector irradiated with Cu x-ray gun
- Collimated beam ~1 mm^2 beam size
- Electron transparency 5 kHz, Gain 1.5×10^4
- Ion transparency 2×10^5 Hz, Gain 1.5×10^4

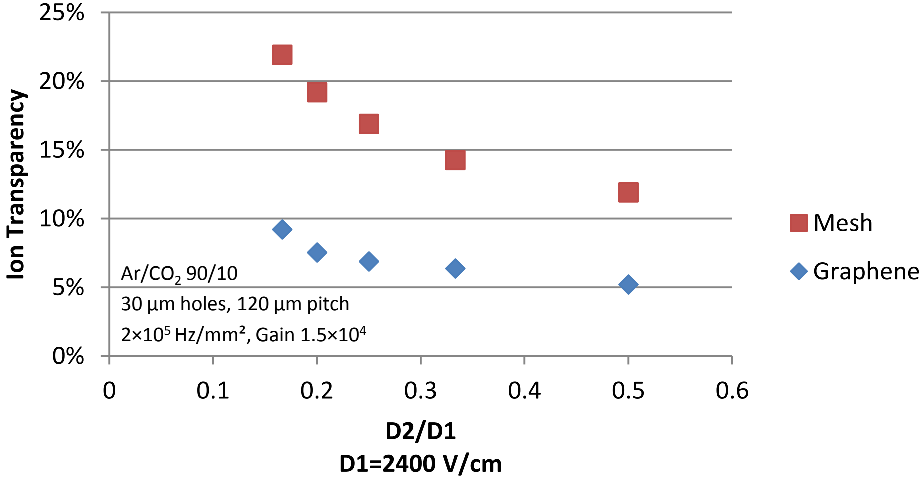


- Copper mesh with 30 µm holes and 120 µm pitch

First Results

- Lower transparency both for electrons and ions on the covered side
- Layer not opaque for electrons or for ions!



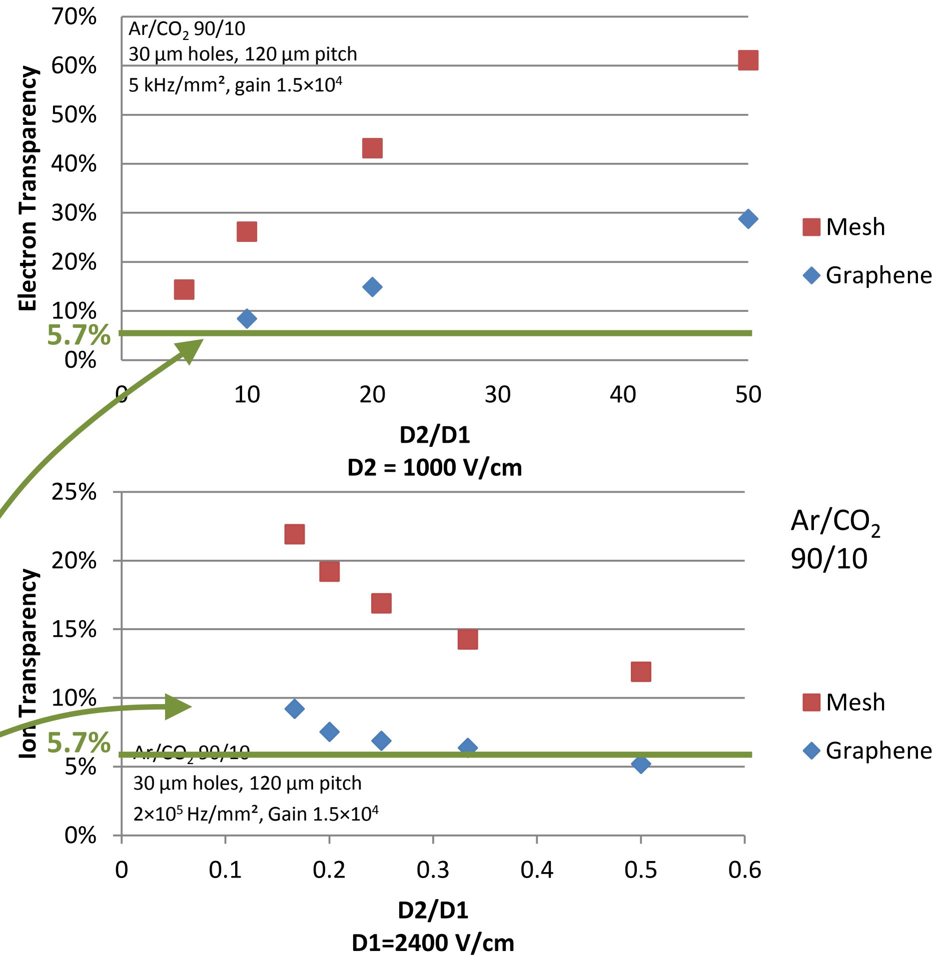


First Results

- We conclude that charge transfer is with high probability due to defects in graphene layer
  - Layer should be opaque to both electrons and ions in the field configurations and gas mixtures used
  - Transparencies increase with higher field ratios: comparable to mesh with smaller hole diameter
  - Transparency higher than optical transparency

First Results

- Lower transparency both for electrons and ions on the covered side
- Layer not opaque for electrons or for ions!

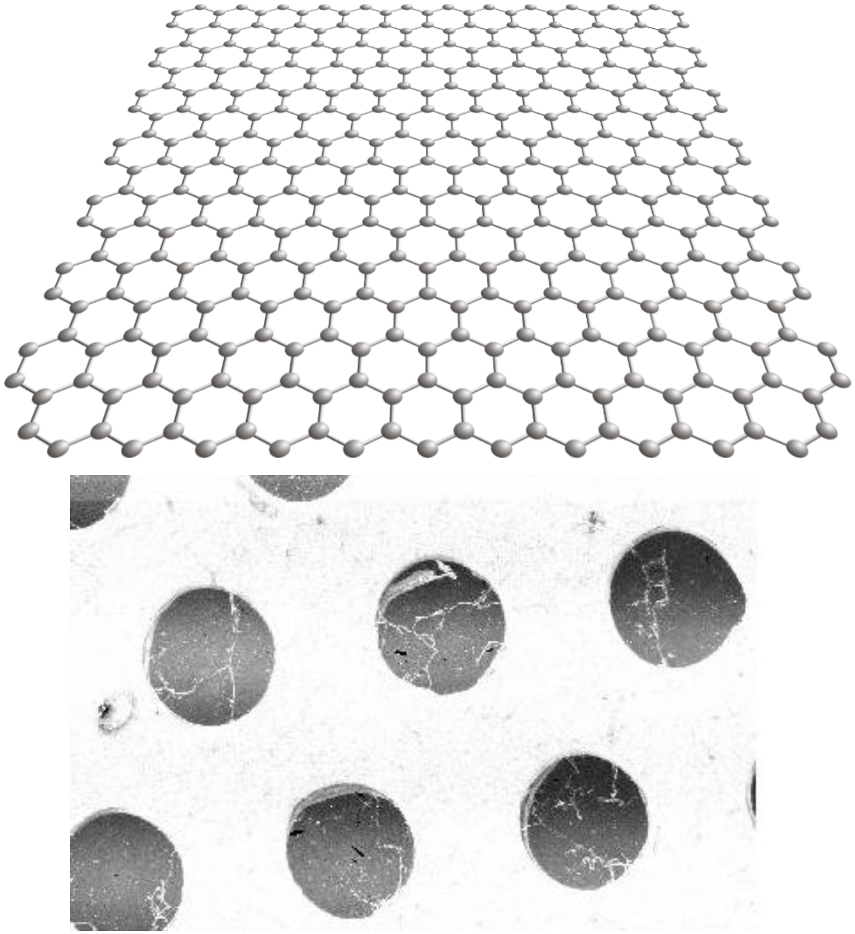


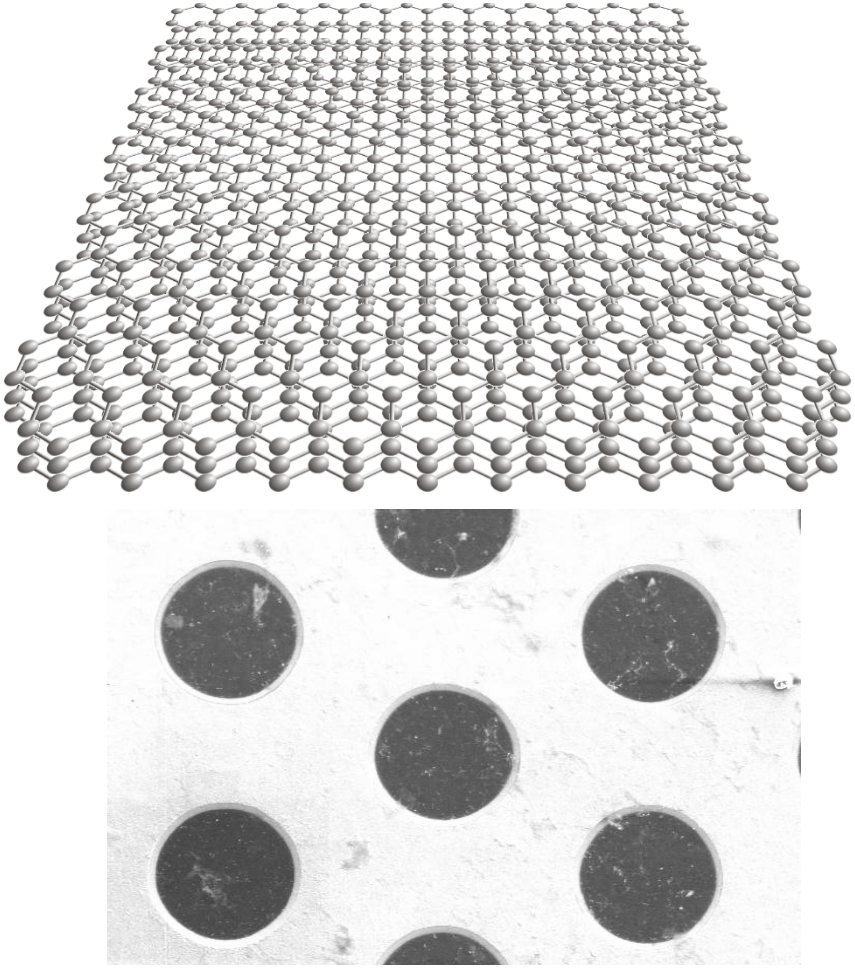
Transparencies of graphene layer exceeds optical transparency of mesh
→ Field focussing effect, defects in layer

Next Steps

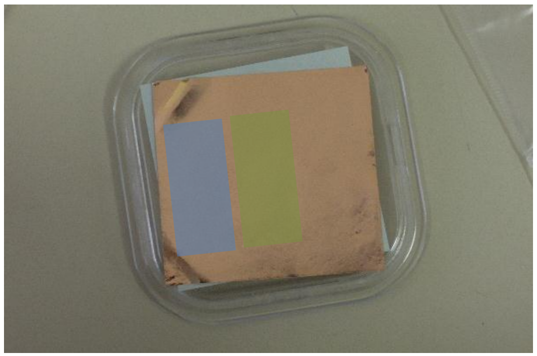
- Multilayer to verify if charge transfer is due to defects
- Improved transfer technique to achieve undamaged single-layers
- Graphene deposited on GEM to increase energy of electrons in front of layer

From Single Layer to Triple Layer Graphene

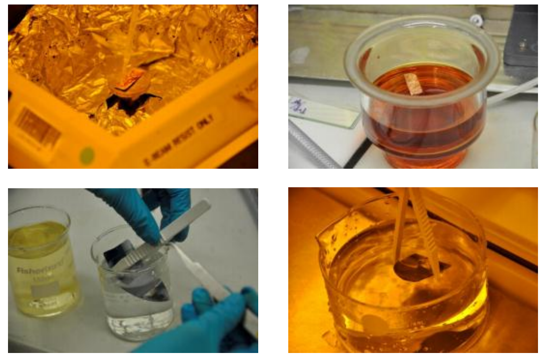




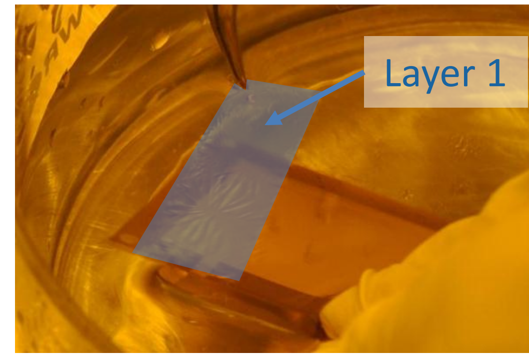
Graphene Transfer



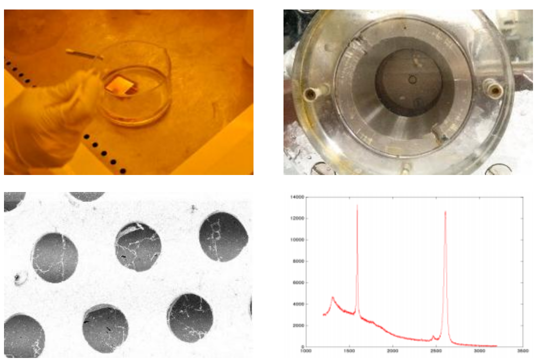
CVD graphene on Cu foil



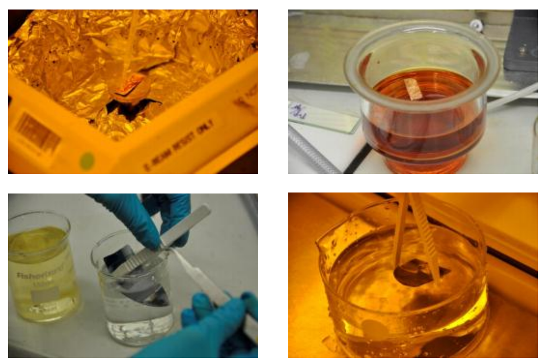
Spin-coat, etch, clean, prepare for transfer



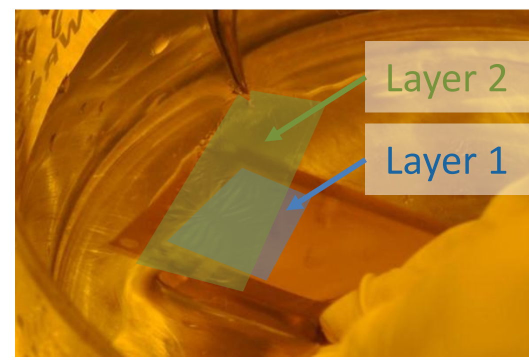
Sample scooped up with mesh



Clean, dry, qualify

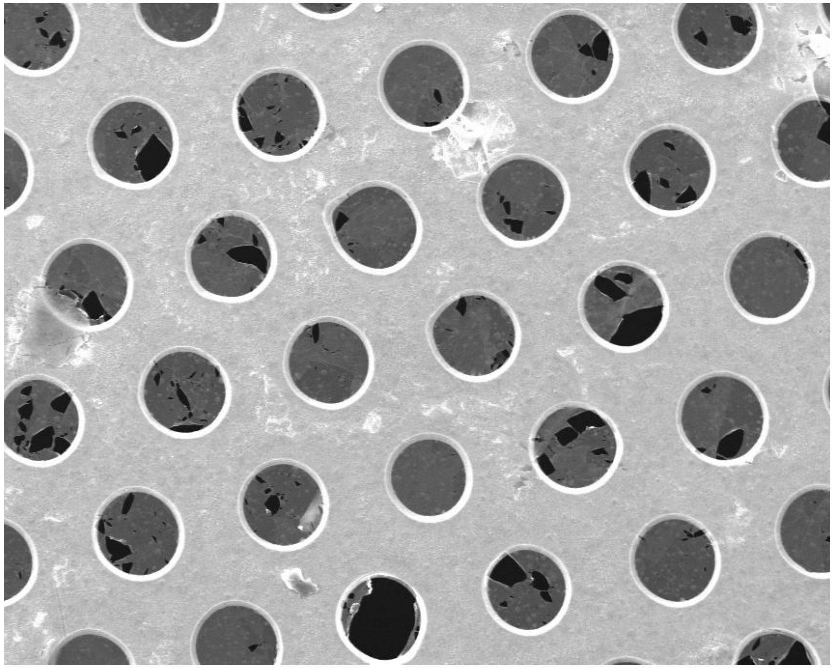


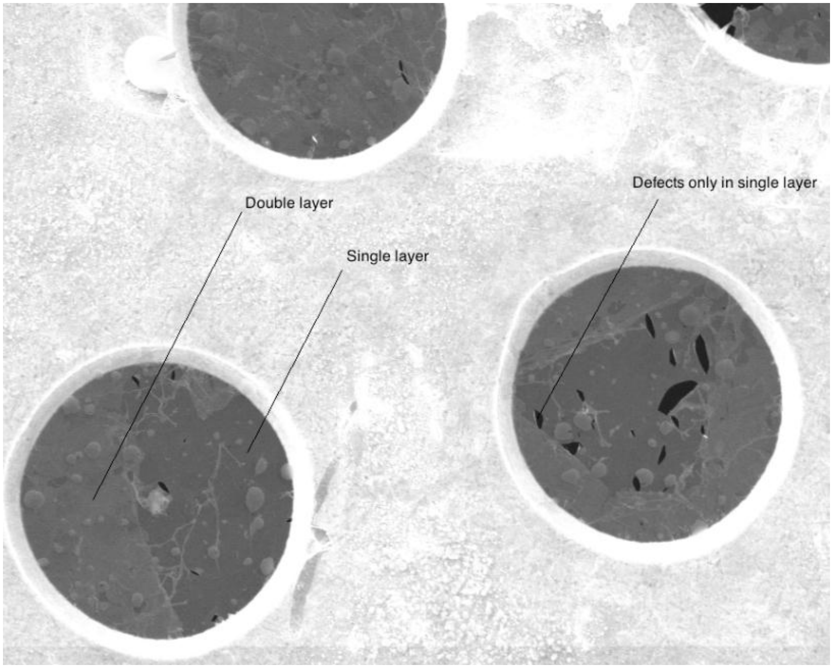
Spin-coat, etch, clean, prepare for transfer



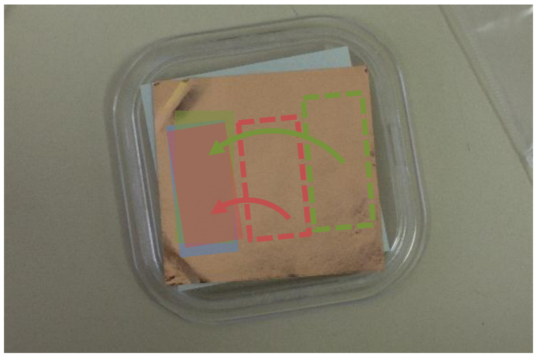
Sample scooped up with mesh and placed on layer

Graphene Transfer

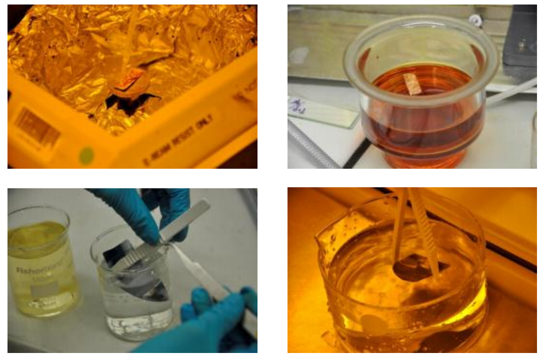




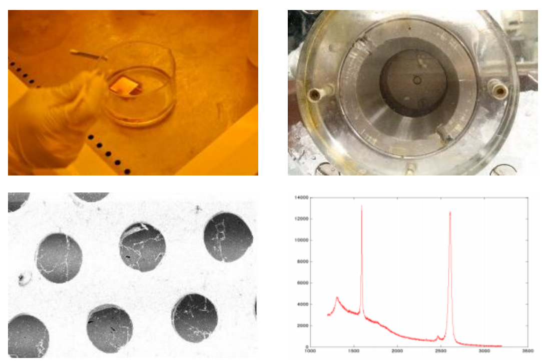
Graphene Transfer



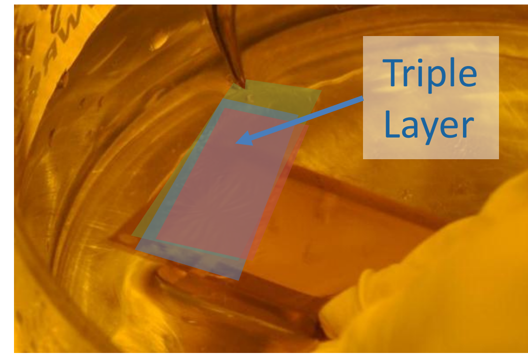
Transfer two additional layers of CVD graphene onto the single layer already on the copper foil



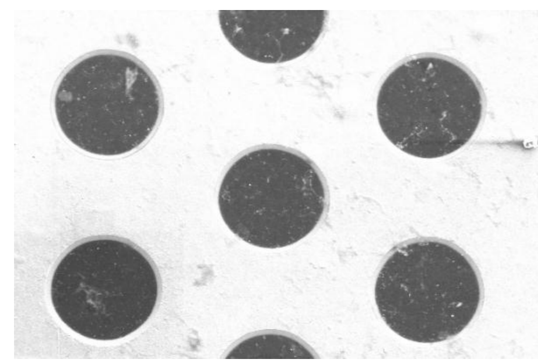
Spin-coat, etch, clean, prepare for transfer



Clean, dry, qualify



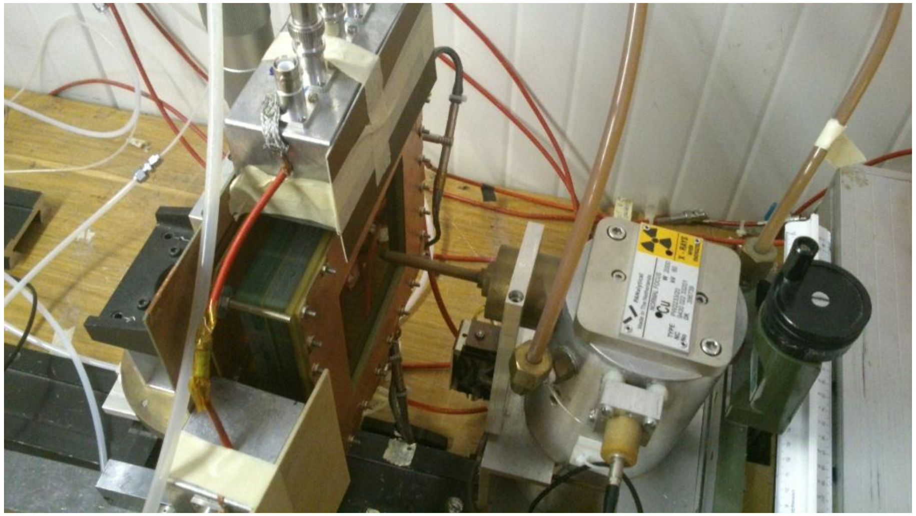
Triple layer under PMMA scooped up with mesh



Triple layer graphene on copper mesh

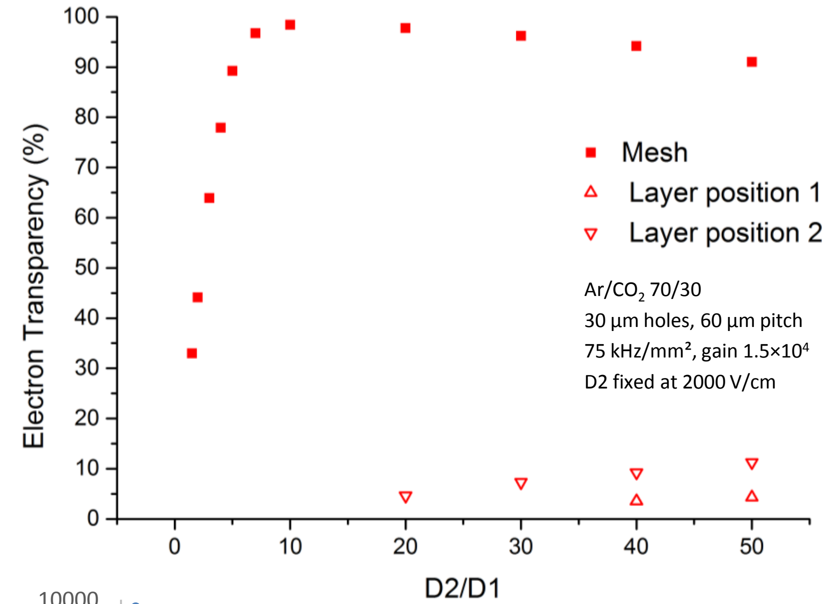
Setup

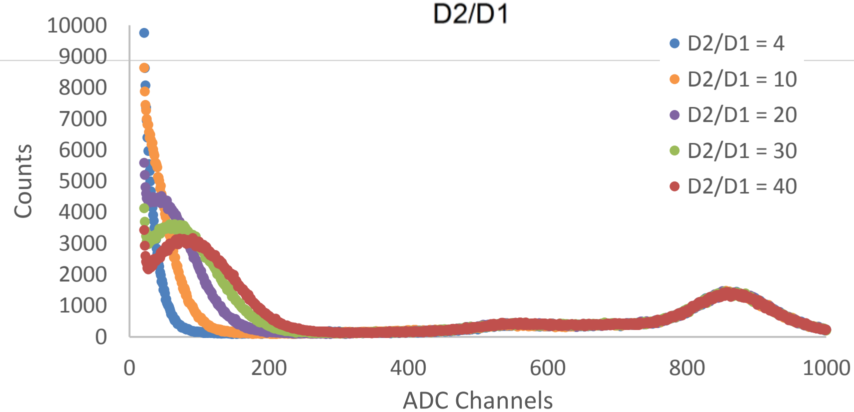
- Ar/CO_2 70/30
- Detector irradiated with Cu x-ray gun
- Collimated beam ~0.2 mm^2 beam size
- Electron transparency up to 30 kHz, Gain 1.5×10^4
- Ion transparency 80 kHz, Gain 1.5×10^4
- Copper mesh with 30 µm holes and 60 µm pitch



Results

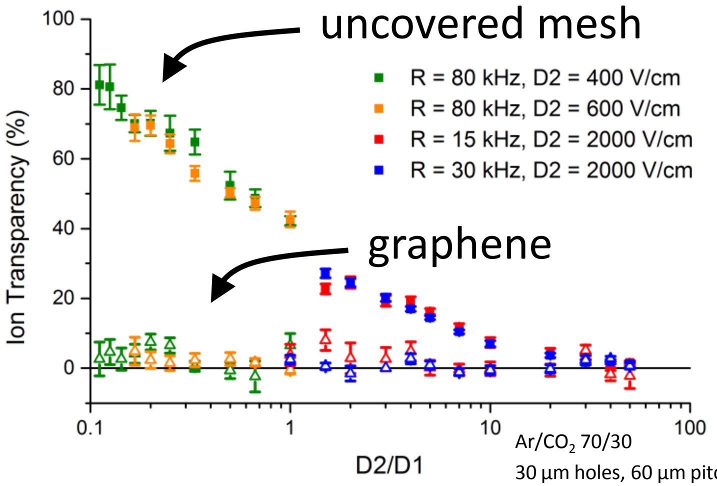
- Electron transparency by peak ratios
- Uncovered mesh
  - Transparency > 95%
  - Loss of primaries for low field D1
- Triple layer
  - Transparency > 10% for low field D1
  - For higher fields D1 peak still visible but peak-fit not possible

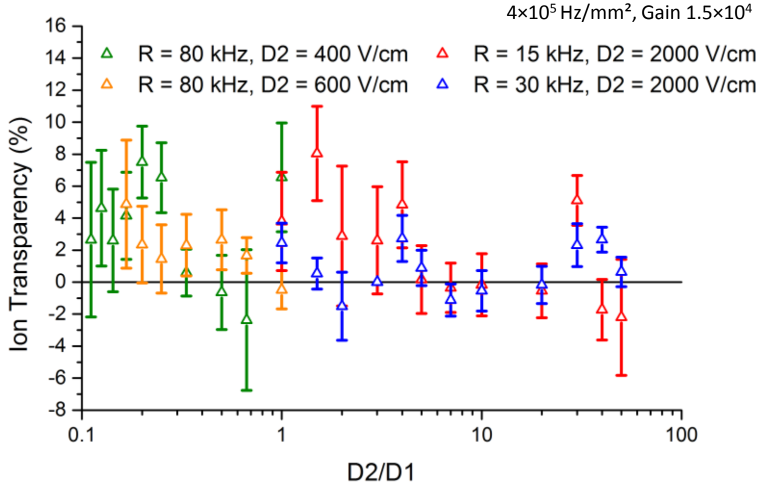




Results

- Ion transparency by cathode and mesh current measurements
- Uncovered mesh
  - Transparency > 80% for high field D1
- Triple layer
  - Transparency ~5% for high fields D1





Conclusions

- Triple layer not fully opaque to electrons and ions but effect less dominant than with single layer
- Change in transparency on different positions on layer suggests transfer through defects

Next steps

- Ongoing: study of transparency with double and triple layers to fully understand charge transfer
- Increasing Ar content of gas-mixture
- Changing to Ne gas-mixtures
- Graphene deposited on GEM to increase energy of electrons in front of layer

Appetizer