Charge Transfer Properties Through Graphene for Applications in Gaseous Detectors

S. Franchino\textsuperscript{1}, D. Gonzalez-Diaz\textsuperscript{1}, R. Hall-Wilton\textsuperscript{2}, R. Jackman\textsuperscript{3}, H. Muller\textsuperscript{1}, T. T. Nguyen\textsuperscript{3}, R. de Oliveira\textsuperscript{1}, E. Oliveri\textsuperscript{1}, D. Pfeiffer\textsuperscript{1,2}, F. Resnati\textsuperscript{1}, L. Ropelewski\textsuperscript{1}, J. Smith\textsuperscript{3}, C. Strelli\textsuperscript{4}, P. Thuiner\textsuperscript{1,4}, M. van Stenis\textsuperscript{1}, R. Veenhof\textsuperscript{1}

\textsuperscript{1}CERN, \textsuperscript{2}ESS, \textsuperscript{3}UCL, \textsuperscript{4}TUW

Overview

What is graphene
Why it is interesting
How we want to use it
What we did
What we still need to do
Graphene

Single layer of carbon atoms in an hexagonal lattice (~0.6 Å opening) with peculiar characteristics
Regarded as the thinnest and finest conductive mesh
The principle

Reported a strong asymmetry in electron and atom/ion transmissions through graphene

J. S. Bunch et al., Nano Letters 8, 2458
J. J. Lopez et al., J. Appl. Phys. 107, 104326
J. Longchamp et al., Appl. Phys. Lett. 101, 113117
S. Srisonphan et al., Sci. Rep. 4, 3764

Ideally a membrane opaque to ions and transparent to electrons
The idea

Build a **suspended graphene layer** without defects transparent to the drifting electrons and opaque to ions eliminating the ion back-flow in gaseous detectors

![Graphene Layer Diagram](https://via.placeholder.com/150)

It can also be used as **protective layer** (e.g. photocathodes) and to **enhance secondary electron emission** from materials.
The goal

Measure electron and ion transparencies of a graphene $O(\text{cm}^2)$ layer suspended on a metal mesh in gas as a function of electric field and gas mixture
Single layer transfer

Graphene is extraordinarily robust accounting for its thickness. It can be freely suspended over tens of μm.

CVD graphene, transfer, and quality checks done at UCL.
The measurement

\[ T = \frac{I_{\text{cath}}}{I_{\text{cath}} + I_{\text{mesh}}} \]

GEM as ion generator

Electrons

GEM as ion generator

Ions

Transparencies

Ar/CO₂ 90/10 mixture, 30μm Ø 120μm pitch mesh
1mm Ø collimated beam of 8keV Cu X-rays

Reduced the electron and ion transparencies

Same behaviour of very small optical transparency mesh
Measurement is dominated by defects on graphene

Multi-layer transfer

Triple layer

Single layer

Defects
Transparencies

Ar/CO$_2$ 70/30 mixture, 30μm ∅ 60μm pitch mesh
1mm ∅ collimated beam of 8keV Cu X-rays

Ion transparency reduced to the measurement sensitivity level
But electrons do not tunnel easily
Space or contaminants between the layers? Still defects?
Close to measure intrinsic properties of graphene

Increasing e\(^{-}\) transparency

Changing the electron energy by:
- changing the gas mixture (more argon, neon)
- increasing the electric field

Why not transfer a graphene layer on a GEM?

On the GEM

Electron Transparency

Graphene on top of a GEM
Ar/CO$_2$ 70/30
$E_{D1} = 50V/cm$, $E_{D2} = 1kV/cm$
X-ray beam (collimated and not)
**Tri-layer not transparent to electrons**
Graphene *shorted* the GEM electrodes

What do we still need

Real tri-layer grown as a whole thing
(quantum-mechanic object)

Direct measurement of the electron transmission as a function of the energy

Transfer the layer without damaging it
Maybe not transferring it at all?
Transmission in vacuum

No direct measurement for low energy electrons
Transmittance extrapolated from reflectance

Electron multiplier may be not needed if the light source is strong enough
**Tune** the electron **energy** at the eV scale
Transfer: changing approach

**Etch a mesh** from the substrate so that the **transfer is no longer needed**

Etch a mesh from the substrate so that the transfer is no longer needed.

Very promising preliminary results

Pure graphene (no contaminants), but damaged.

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Conclusions

Developed a technique to transfer graphene layers onto different substrates.

Charge transfer properties of graphene in gas are under studies.

Behaviour of the single layer, though of very good quality, dominated by defects.
Conclusions

Tri-layer graphene to minimise defects

Three atomic layers proved to stop ions

Electrons stopped because interspace or contaminants between the layers

Operated a GEM coated with graphene
Outlooks

Grow CVD tri-layer graphene
Continue testing graphene coated GEMs

Measure in vacuum the electron transparency as a function of the energy

Improve the etching techniques of the graphene substrate