

LabClass QuantHE

Master Nanosciences

NanoSaclay
Laboratoire d'Excellence
en Nanosciences et Nanotechnologies



PALM
Laboratoire d'Excellence
Physique : Atomes Lumière Matière

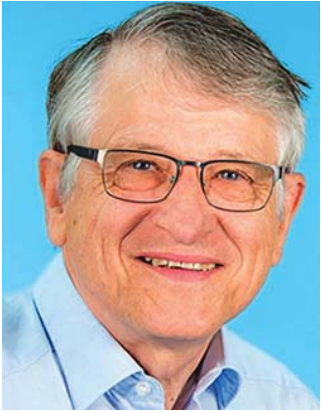
université
PARIS-SACLAY

Julien Basset

Laboratoire de Physique des Solides – NS² group

Quantum Hall effect in Graphene

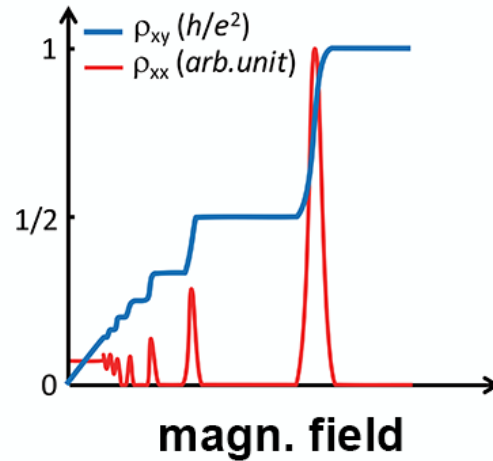
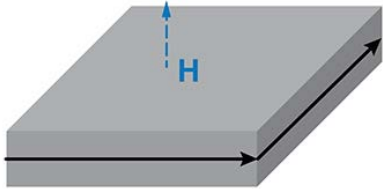
Klaus von Klitzing



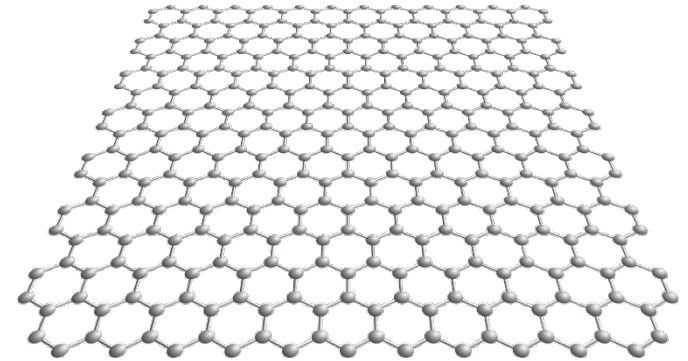
Andre Geim and Konstantin Novoselov



Integer quantum Hall effect (1985)



Graphene (2010)



This labclass: Mixing of QHE and Graphene

A Two-parts lab class

1. Part 1: Microfabrication of the Graphene Hall Bar

- CVD grown graphene
- Transfer of graphene on doped Silicon

- Lithography of the micron-sized Hall bar
 - ✓ Photon lithography
 - ✓ RIE etching
 - ✓ E-gun evaporation of metals

Institut Néel
Grenoble –
Vincent Bouchiat



Centre de
Nanosciences et de
Nanotechnologies
(C2N)



2. Part 2: Low temperature, high field measurement of the QHE

- Liquid Helium measurement stick
- Superconducting magnet
- Precision electronics

Laboratoire de
Physique des Solides



A Two-parts lab class

1. Part 1: Microfabrication of the Graphene Hall Bar

- CVD grown graphene
- Transfer of graphene on doped Silicon

Institut Néel
Grenoble –
Vincent Bouchiat



- Lithography of the micron-sized Hall bar
 - ✓ Photon lithography
 - ✓ RIE etching
 - ✓ E-gun evaporation of metals

Centre de
Nanosciences et de
Nanotechnologies
(C2N)



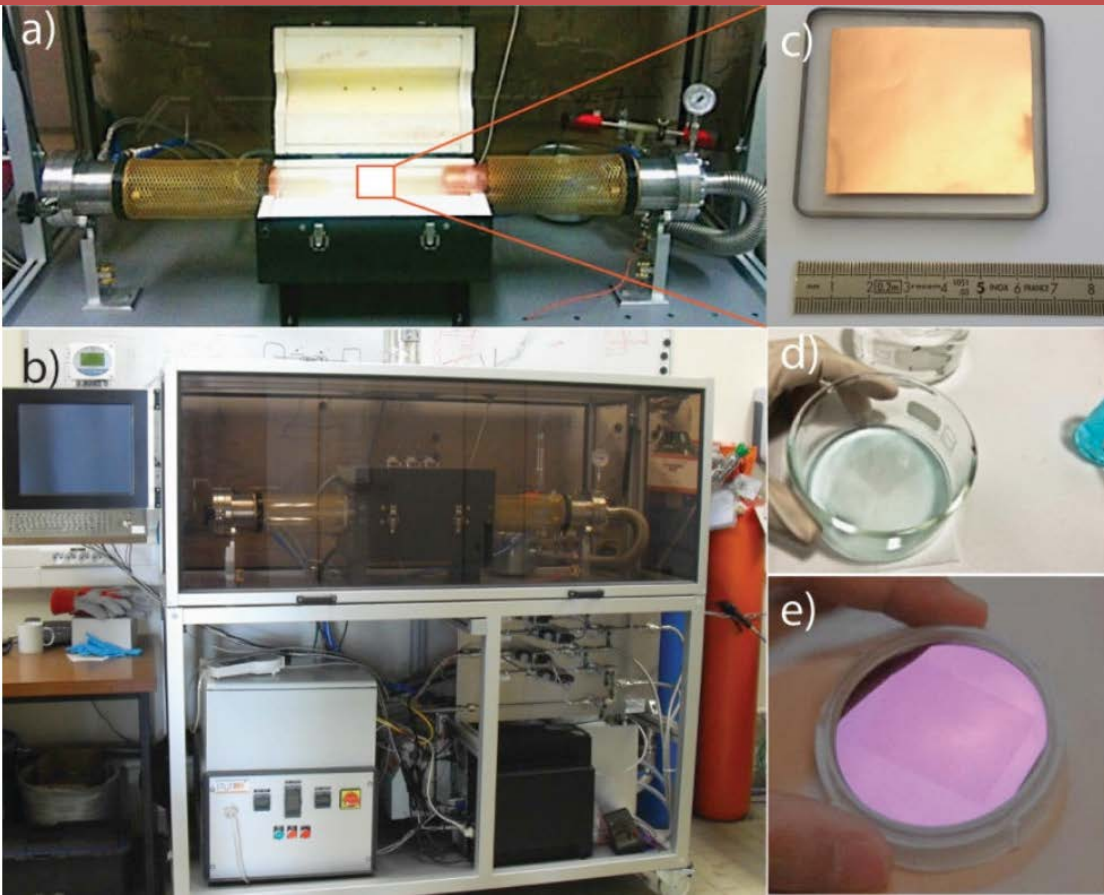
2. Part 2: Low temperature, high field measurement of the QHE

- Liquid Helium measurement stick
- Superconducting magnet
- Precision electronics

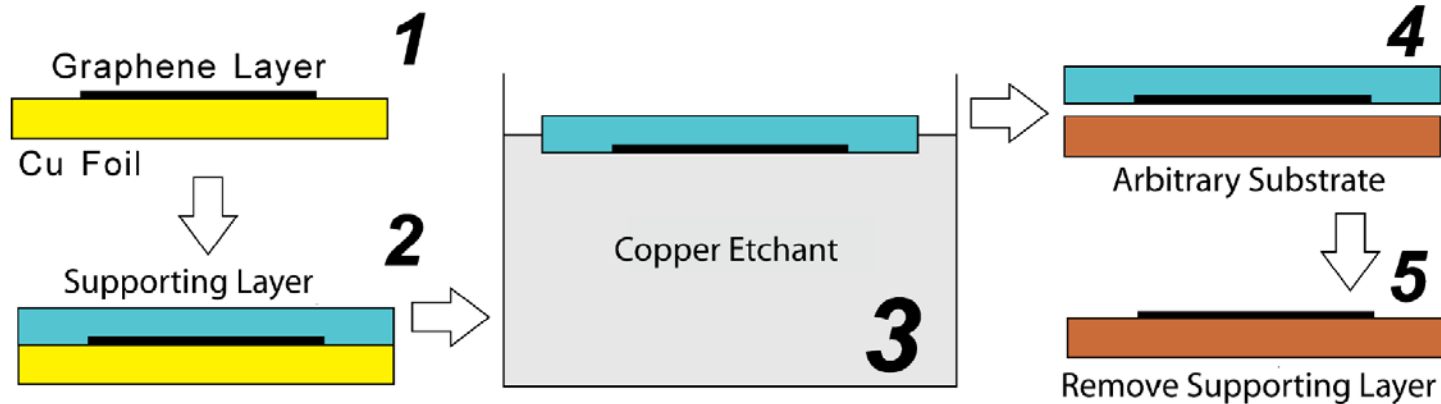
Laboratoire de
Physique des Solides



CVD grown graphene transferred on doped Silicon substrate



1. Thin commercial copper foil
2. Thermal annealing to increase size of Cu crystalline domains
3. CVD of graphene ($T=1000^{\circ}\text{C}$, $\text{CH}_4 + \text{H}_2 + \text{Ar}$)
4. Spin PMMA resist as supporting layer
5. Etch Copper in Copper etchant solution
6. Transfer by fishing the graphene and dry
7. Remove PMMA in acetone



A Two-parts lab class

1. Part 1: Microfabrication of the Graphene Hall Bar

- CVD grown graphene
- Transfer of graphene on doped Silicon

Institut Néel
Grenoble –
Vincent Bouchiat



- Lithography of the micron-sized Hall bar
 - ✓ Photon lithography
 - ✓ RIE etching
 - ✓ E-gun evaporation of metals

Centre de
Nanosciences et de
Nanotechnologies
(C2N)



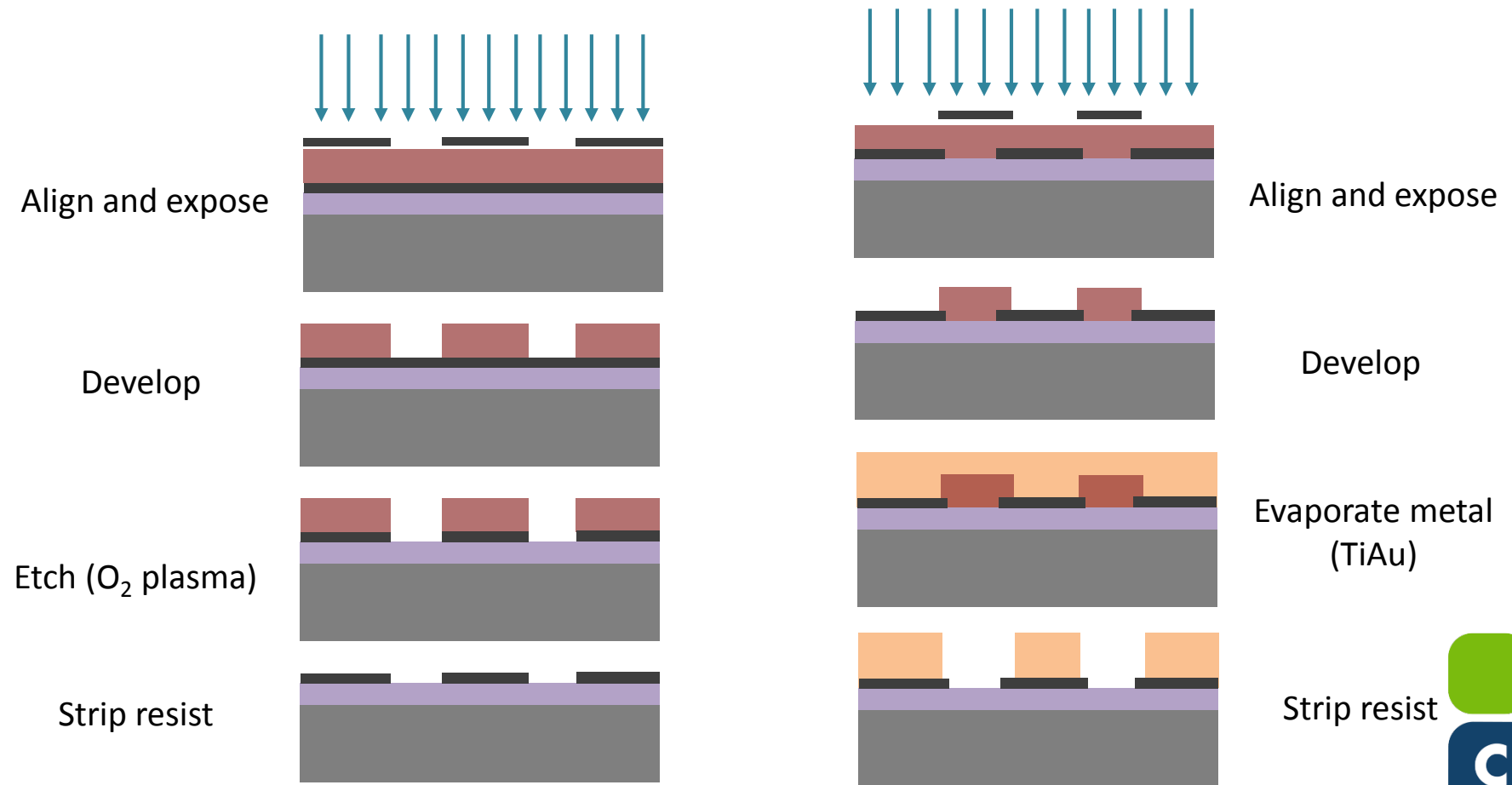
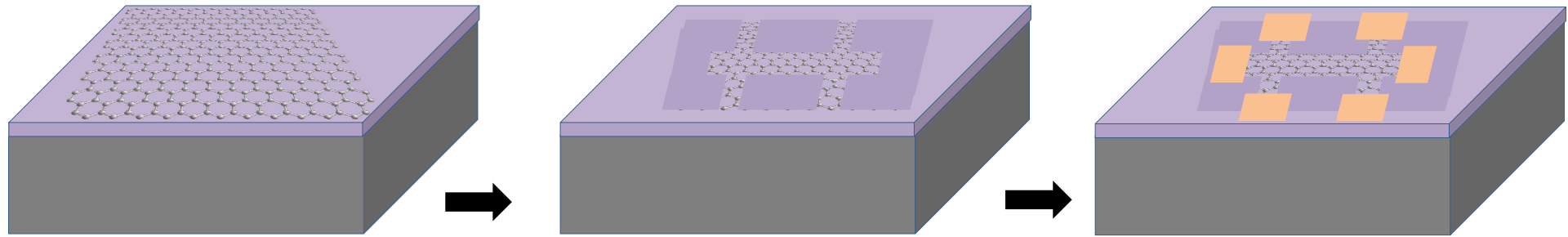
2. Part 2: Low temperature, high field measurement of the QHE

- Liquid Helium measurement stick
- Superconducting magnet
- Precision electronics

Laboratoire de
Physique des Solides



Optical lithography of the Graphene Hall Bar



A Two-parts lab class

1. Part 1: Microfabrication of the Graphene Hall Bar

- CVD grown graphene
- Transfer of graphene on doped Silicon

- Lithography of the micron-sized Hall bar
 - ✓ Photon lithography
 - ✓ RIE etching
 - ✓ E-gun evaporation of metals

Institut Néel
Grenoble –
Vincent Bouchiat



Centre de
Nanosciences et de
Nanotechnologies
(C2N)



2. Part 2: Low temperature, high field measurement of the QHE

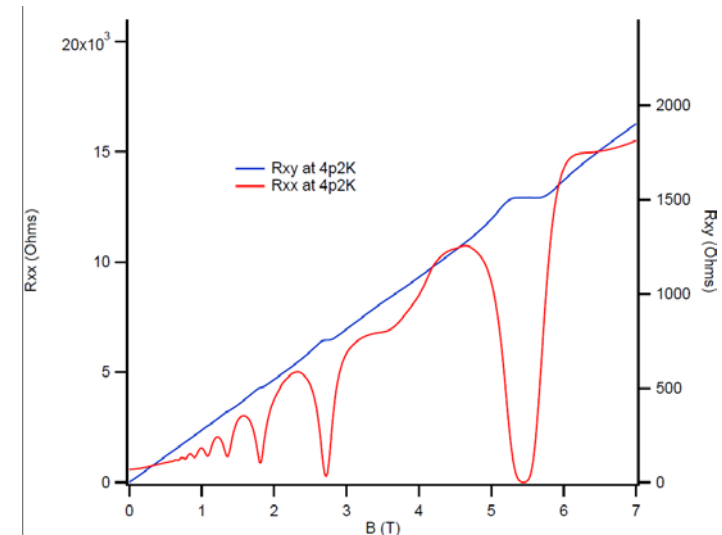
- Liquid Helium measurement stick
- Superconducting magnet
- Precision electronics

Laboratoire de
Physique des Solides



Quantum Hall effect measurement @ T=4.2K, B=5T

- $R_{xx}(T)$
- @ T=4.2K, $R_{xx}=f(B)$, $R_{xy}=f(B)$
- Density modulation
- Verification of SdH broadening with a dc current
- Verification of Landauer-Büttiker formalism on a plateau
- ...



Some work at home

- 2 weeks to give a report (2 people) containing:
 - Fabrication techniques at C2N
 - ✓ Used tools and techniques
 - ✓ Difficulties encountered
 - Low-T measurements at LPS
 - ✓ Theoretical aspect of the QHE
 - ✓ Technical aspects of the measurement (low-T, low noise, high field)
 - ✓ Low-B, mid-B and High-B data
 - ✓ Extraction of density, mobility in several ways
 - ✓ Verification of conductance quantization
 - ✓ DC-current influence on Shubnikov-deHaas oscillations
 - ✓ Landauer-Büttiker picture verification

