



Nanotechnology and Graphene Nanoribbon-based devices

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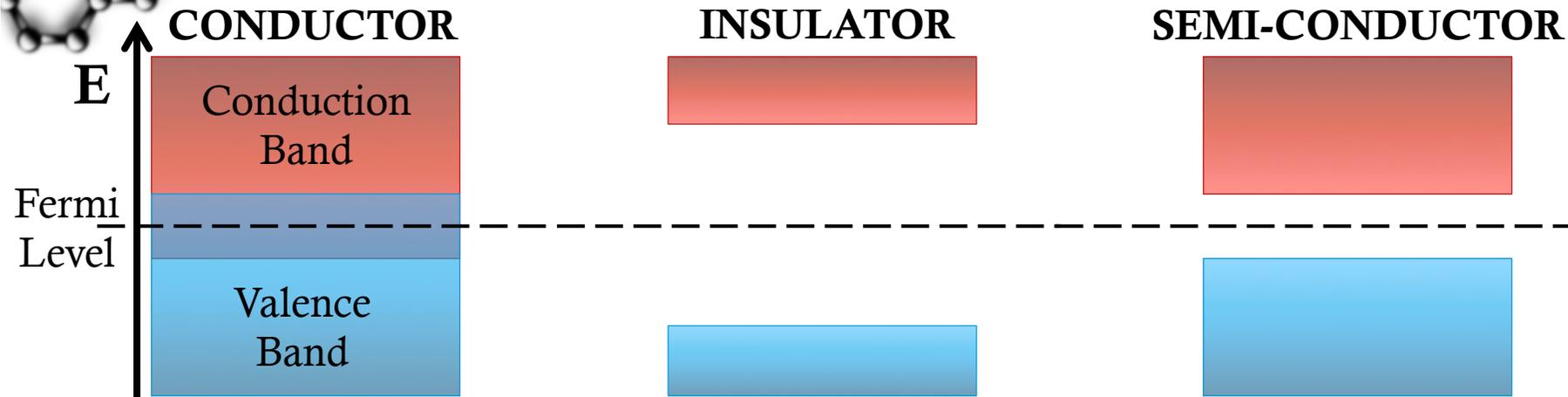
Directeur de thèse: Erik DUJARDIN



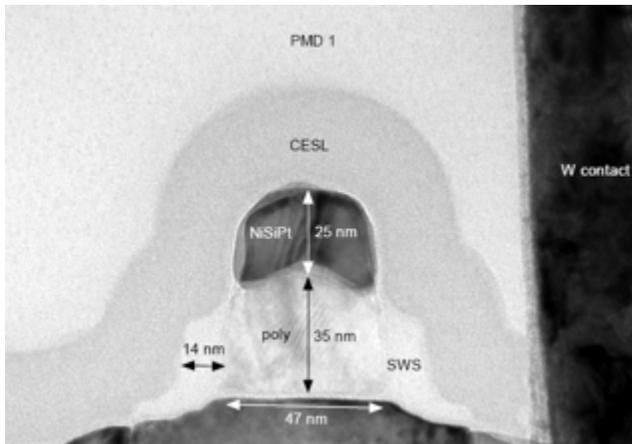
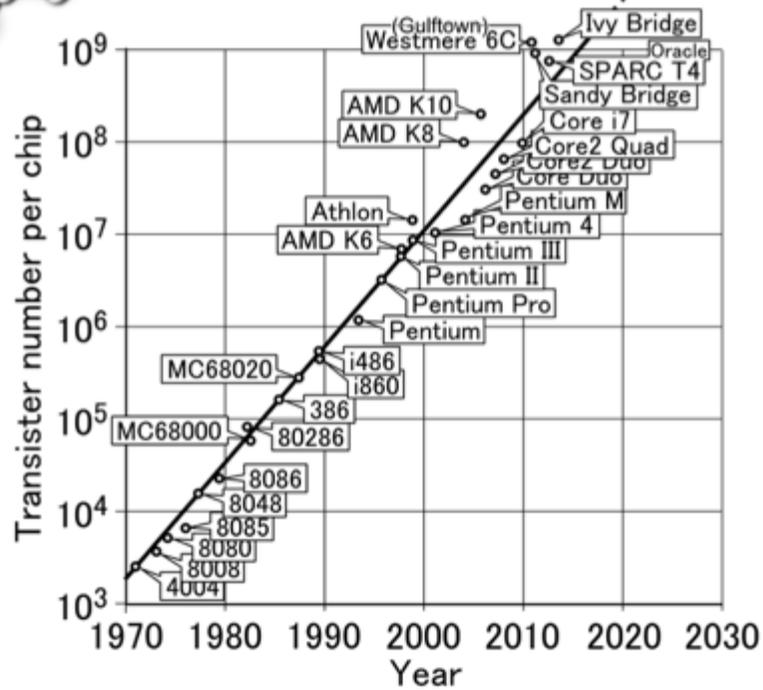
Debats de Recerca – Andorra la Vella
5-6 Novembre 2014



What's / Why Nano-Technology ?



Moore's Law



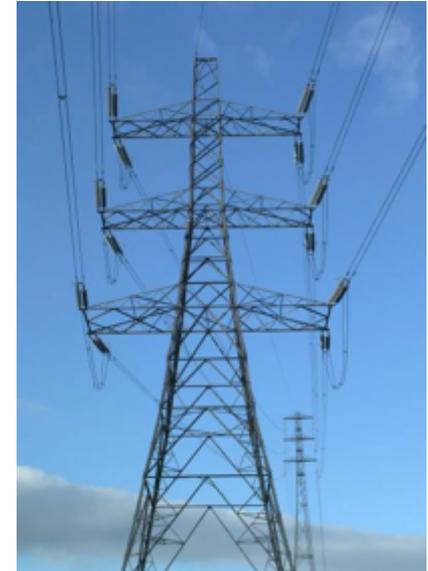
Joule Effect

$$Q \sim P = U \cdot I$$

$$U = R \cdot I$$



$$P_d = R \cdot I^2$$



What's / Why Nano-Technology ?

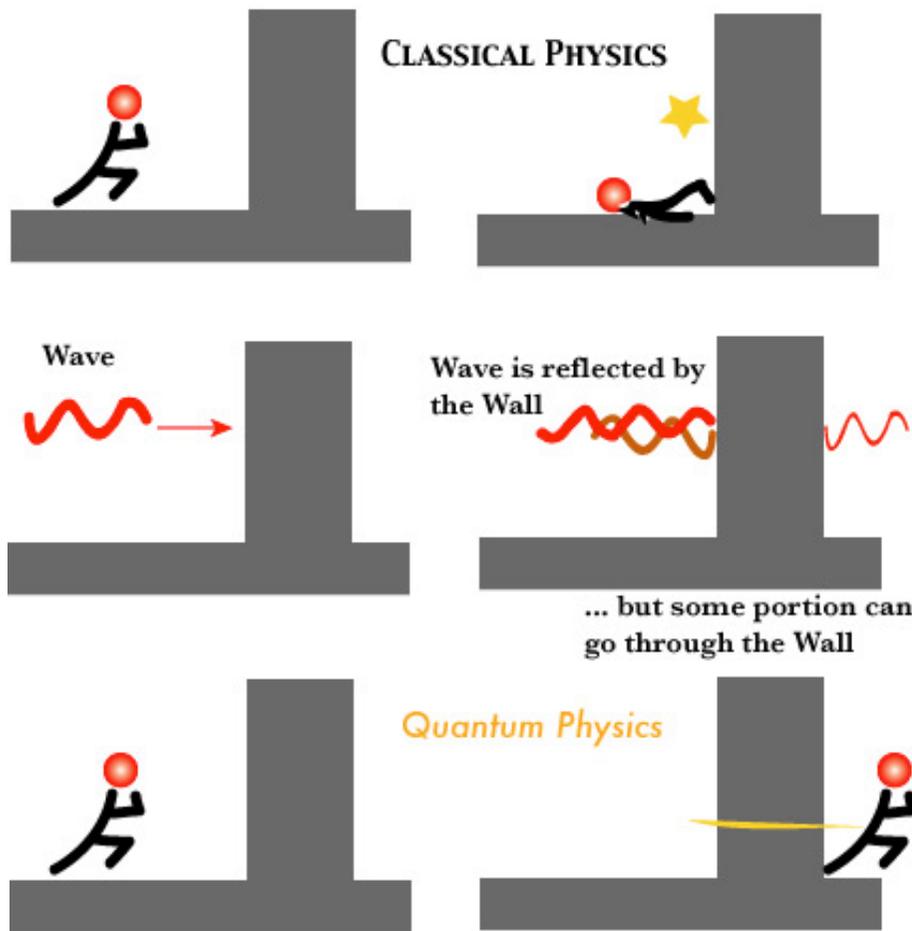


« Radical Abundance »

« There is plenty of room at the bottom. »

Eric Drexler

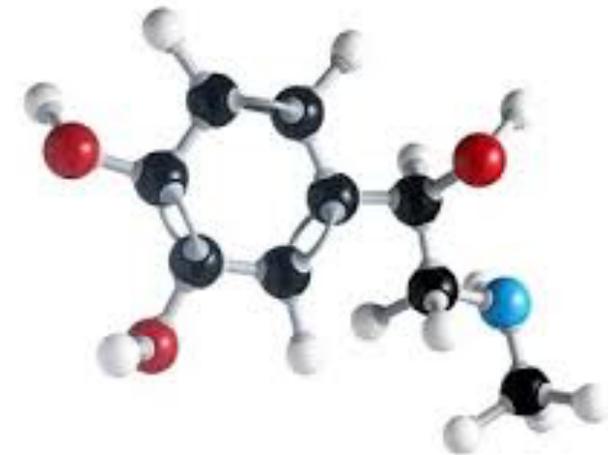
Richard Feynman

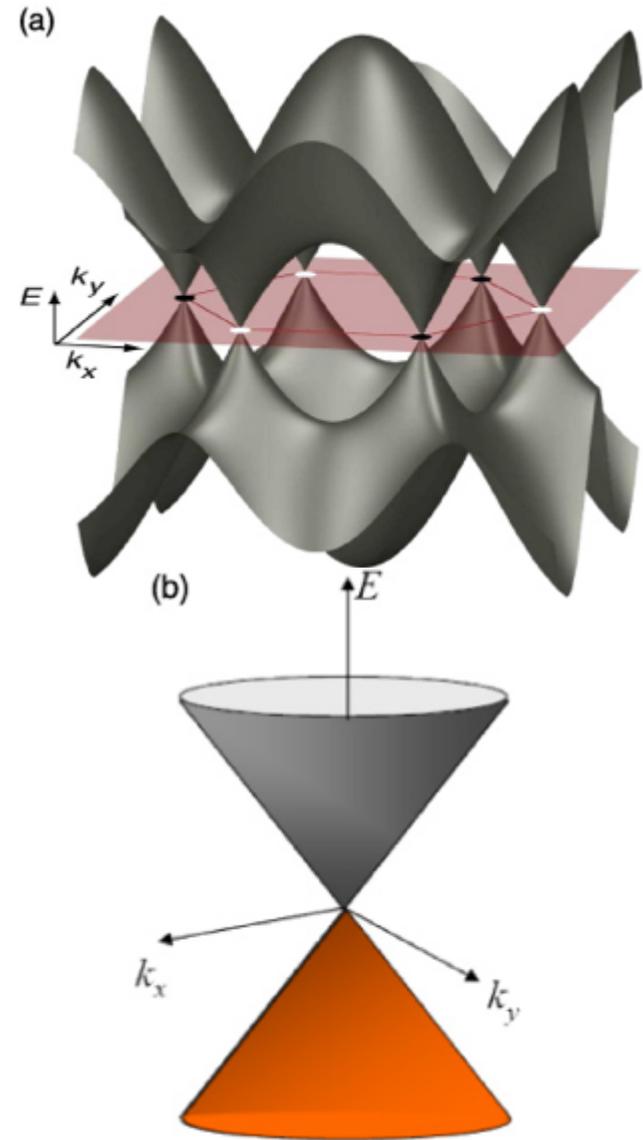
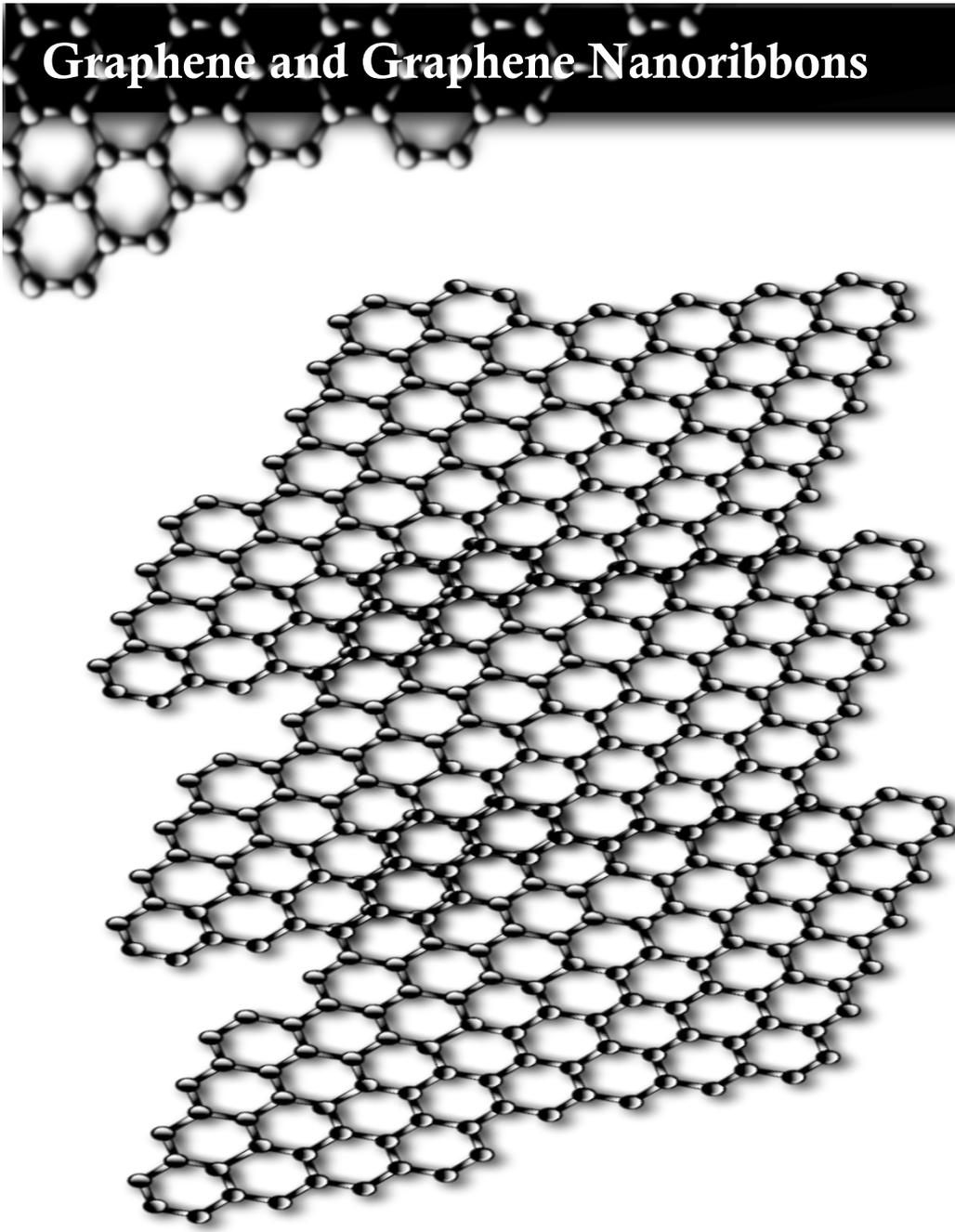


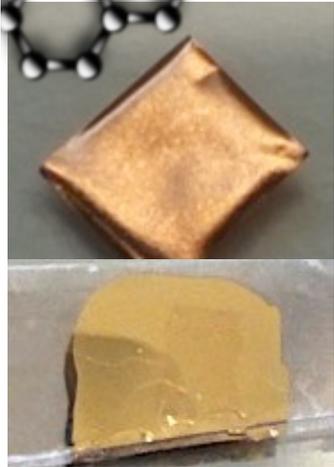
Classical Physics
Quantum Mechanics



- 1 cm = 0,01 m
- 1 mm = 0,001 m
- 1 μm = 0,000001 m
- 1 nm = 0,000000001 m



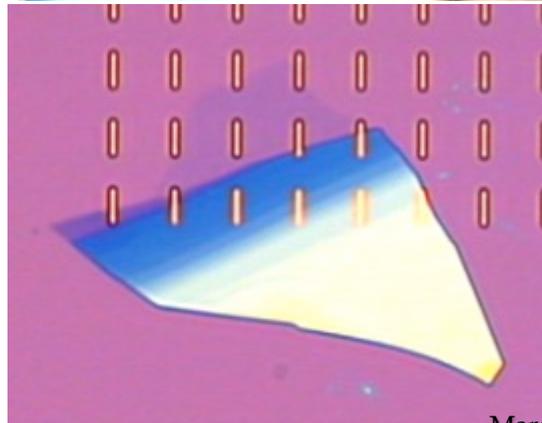
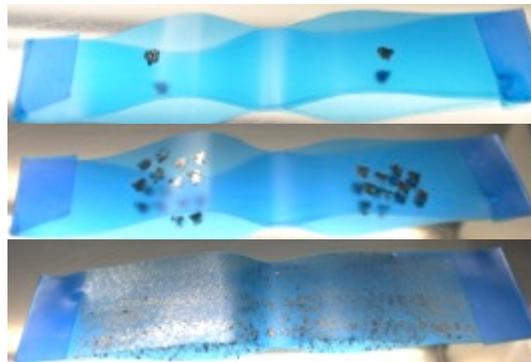




CVD Graphene/Cu

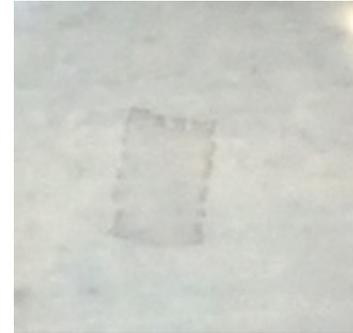
- Copper is removed by using ammonium persulfate.
- Transfer in DI water
- Sample deposition
- H₂O and IPA cleaning

Mechanical exfoliation

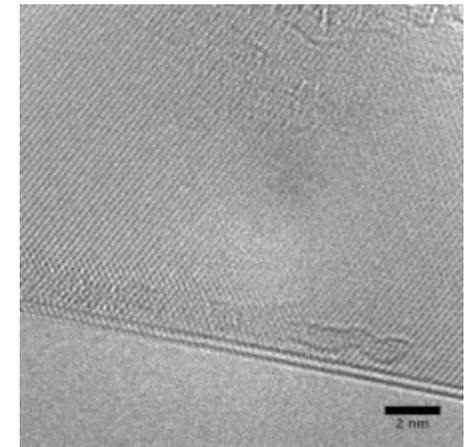


- Graphene is deposited on SiO₂/Si for optical identification of monolayers.

Graphene decontamination

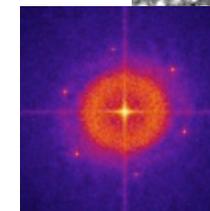
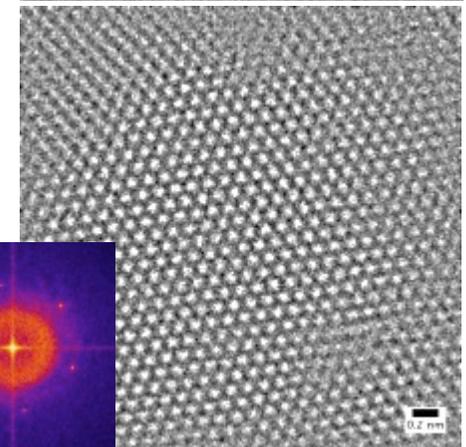


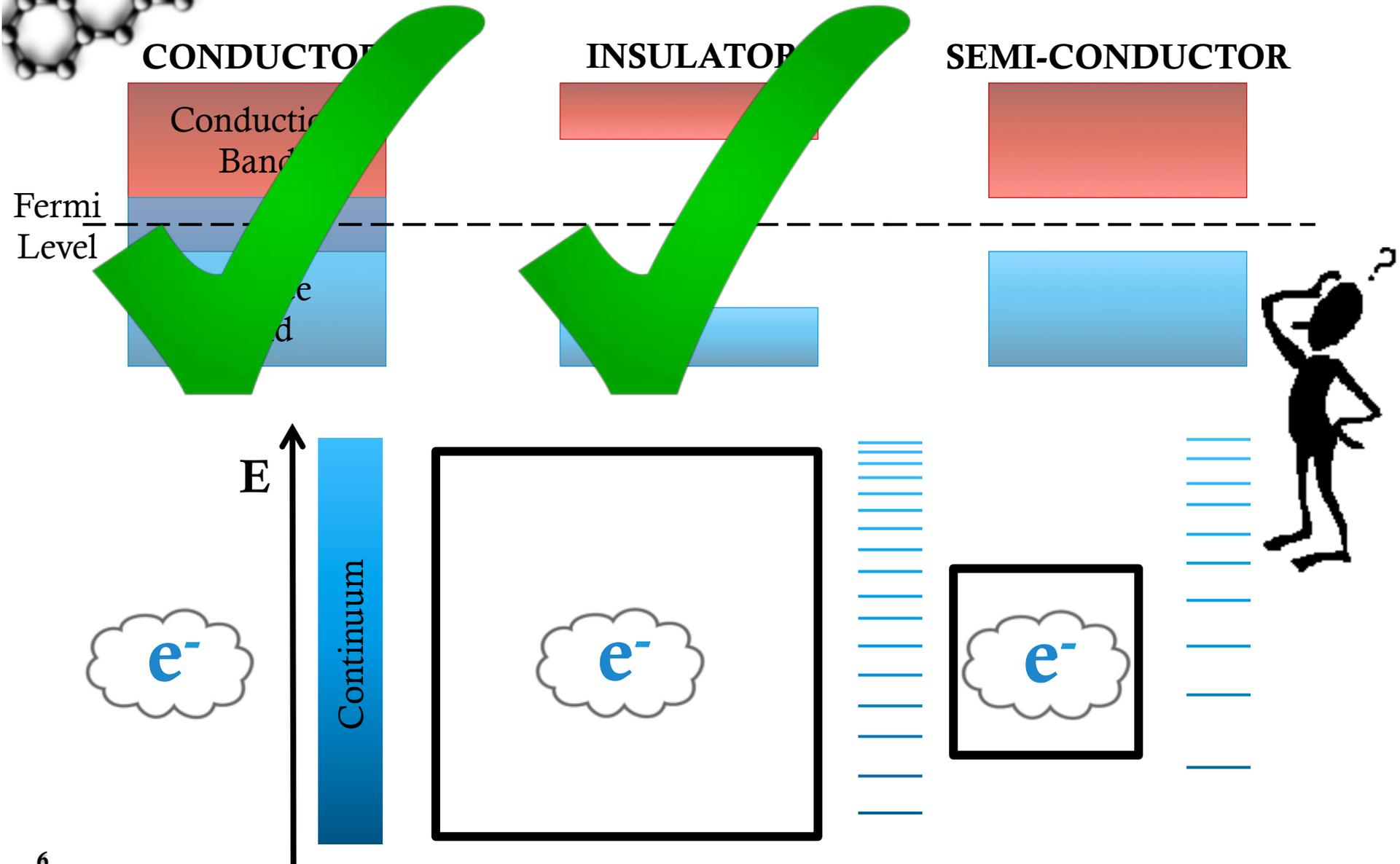
1. Resist-free transfer



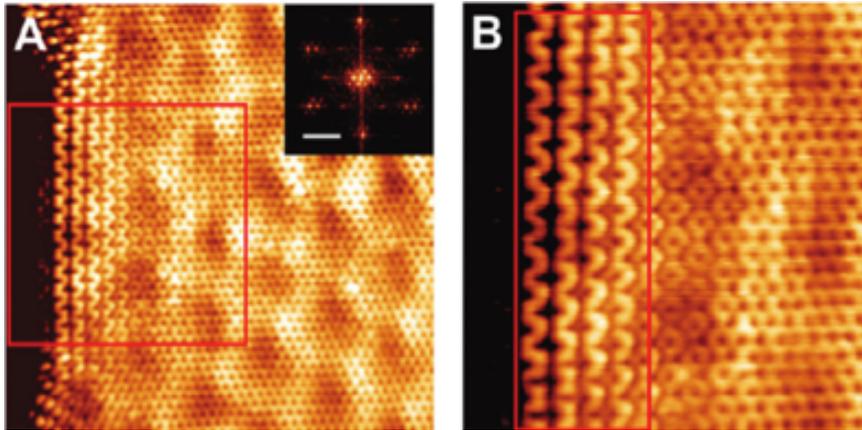
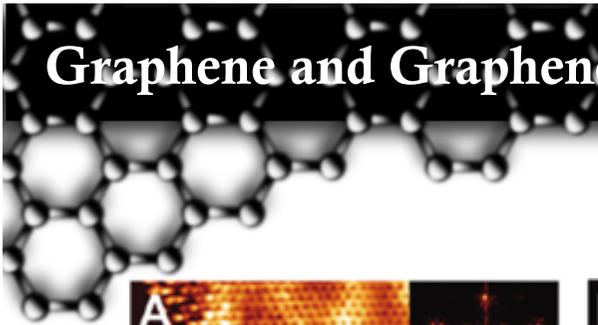
2. Thermal annealing:

- Up to 500°C
- Forming gas (Ar+H₂)
- 4 to 6 hours
- Repeated after every single step

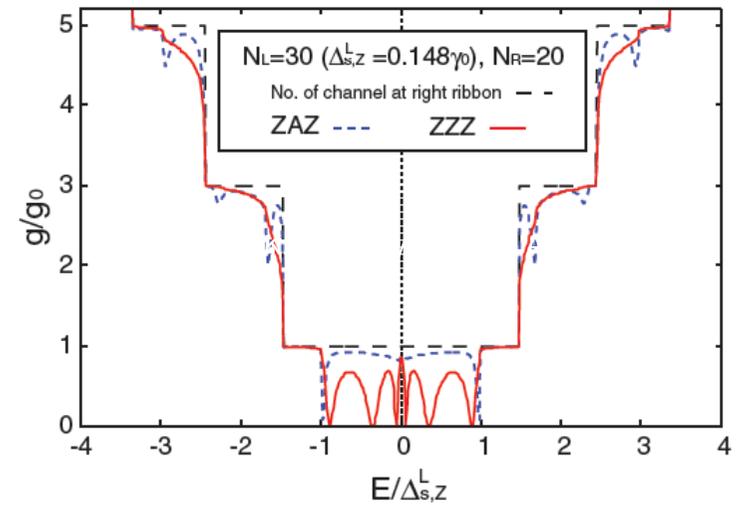
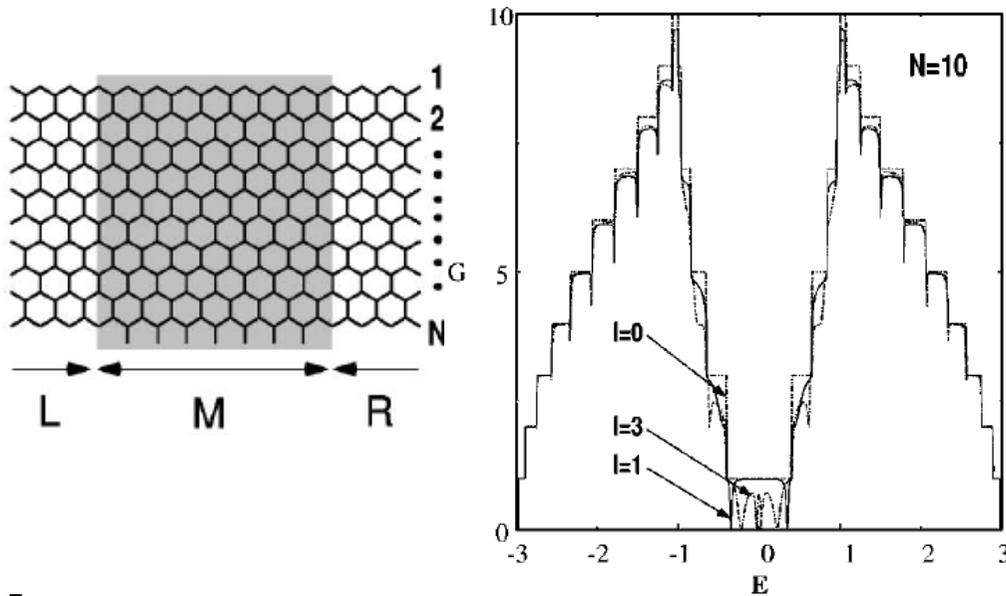
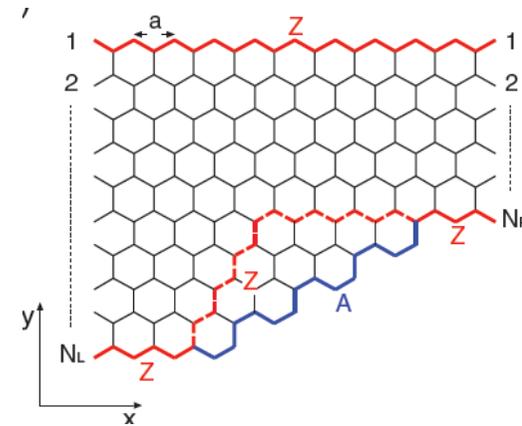




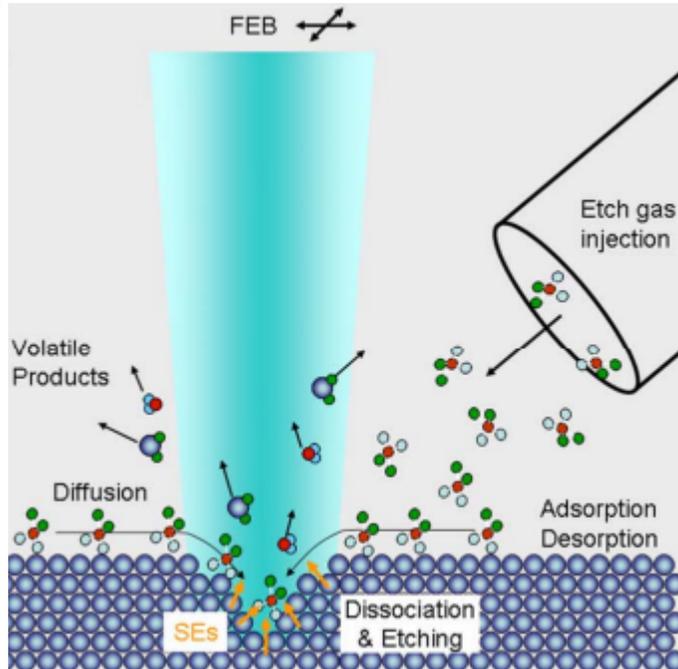
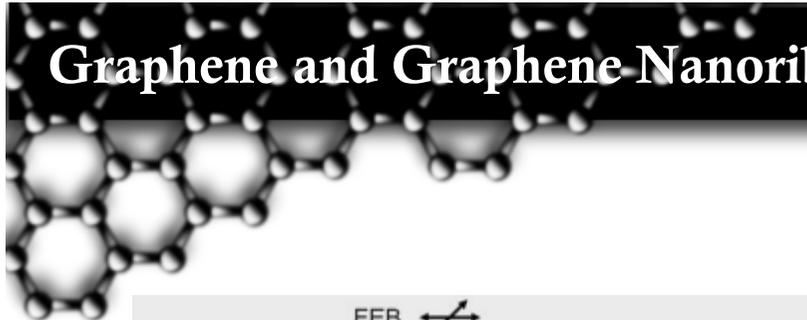
Graphene and Graphene Nanoribbons



A. Mayne Nano Lett 10(3), 943 (2010)

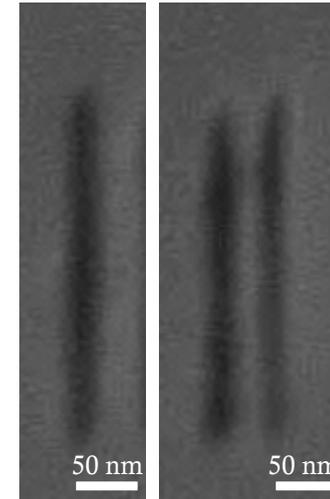


K. Wakabayashi et al. APL 95, 082109 2009

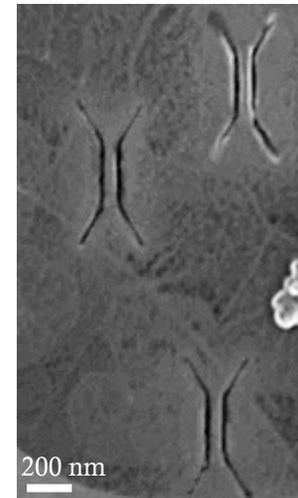


- E-beam induced chemical reaction
- H₂O or O₂
- 2 - 30kV
- Dose dependent (I, t, spot size)

- Arbitrary pattern



- Smooth edges

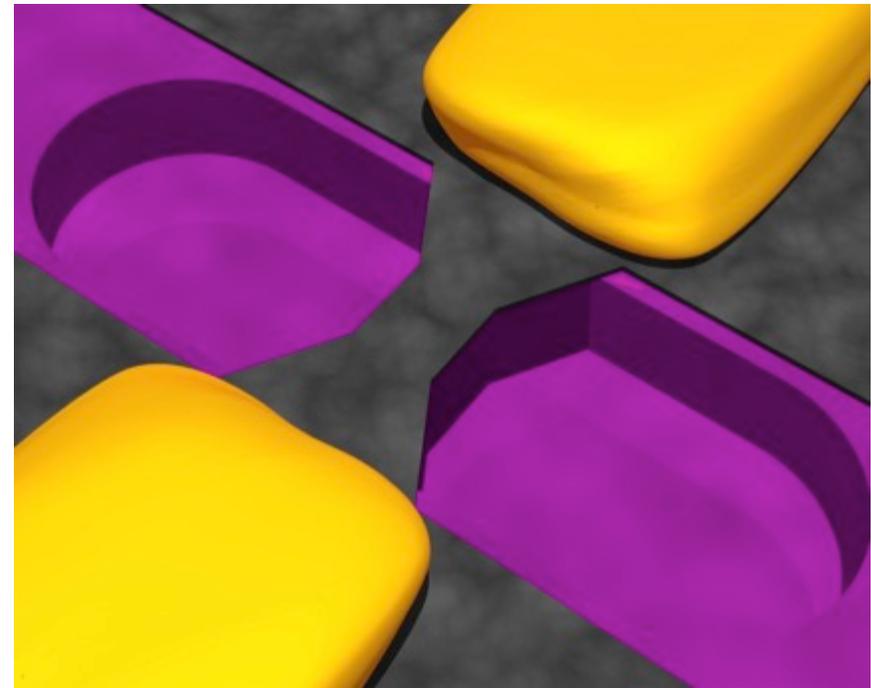
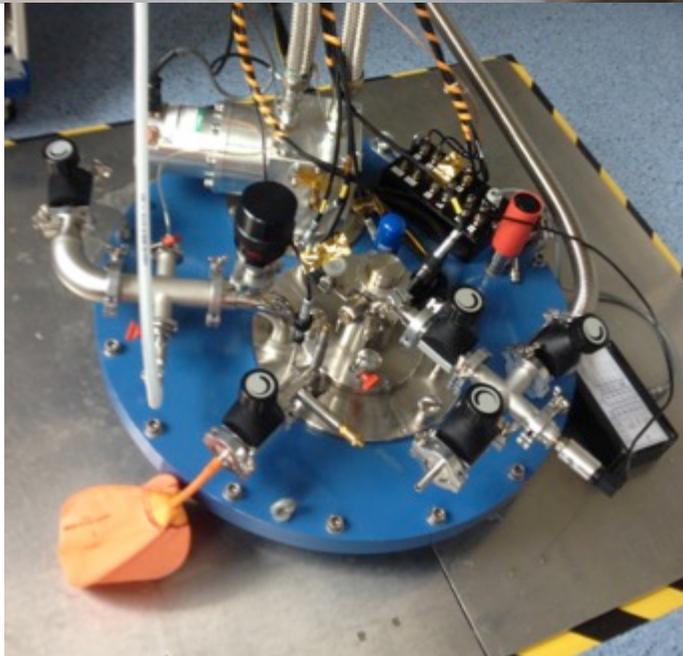


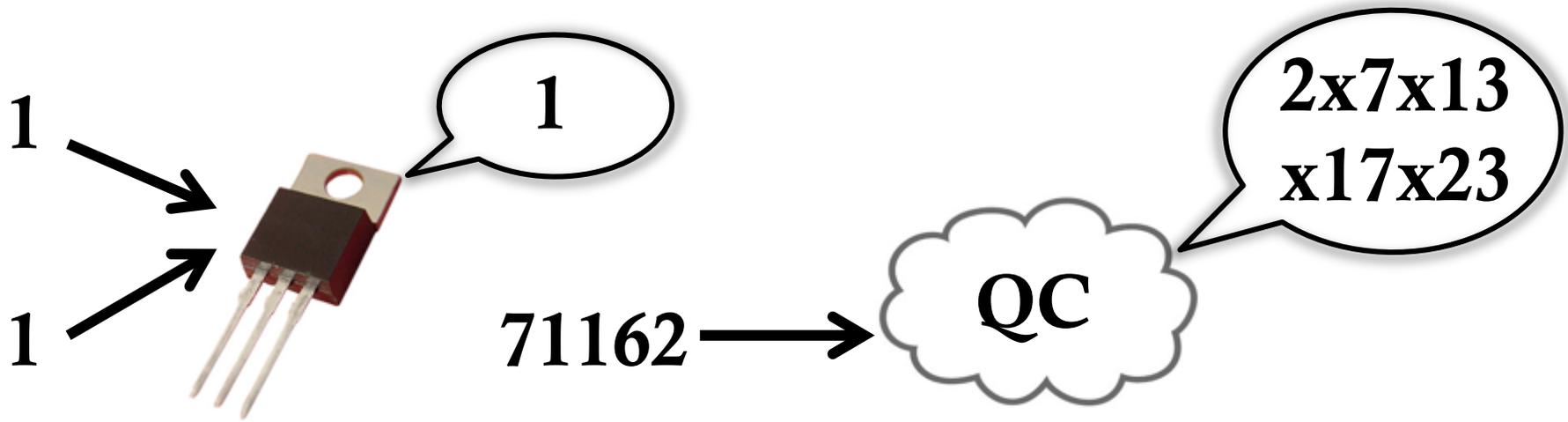
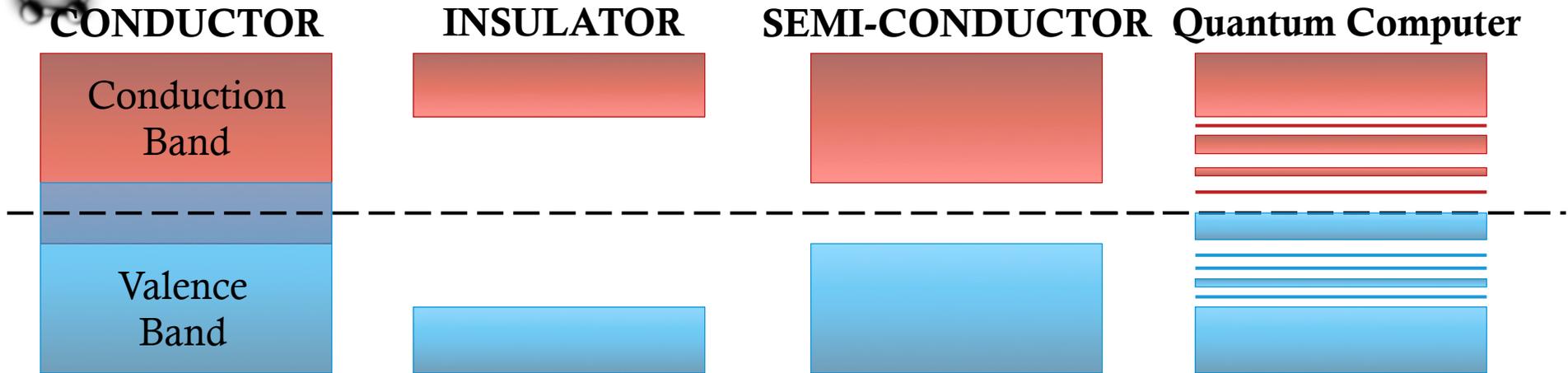
- Initial adsorbents
- Residual contaminants in SEM chamber
- EBIE re-deposition

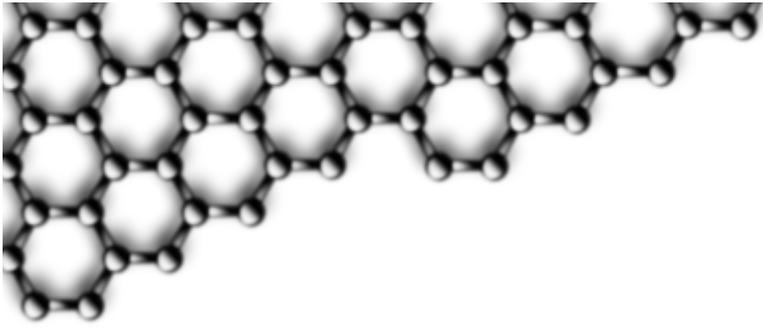
post-EBIE thermal annealing

M. Nuñez, E. Dujardin et al.
In preparation

Graphene and Graphene Nanoribbons







Thank you for your attention.