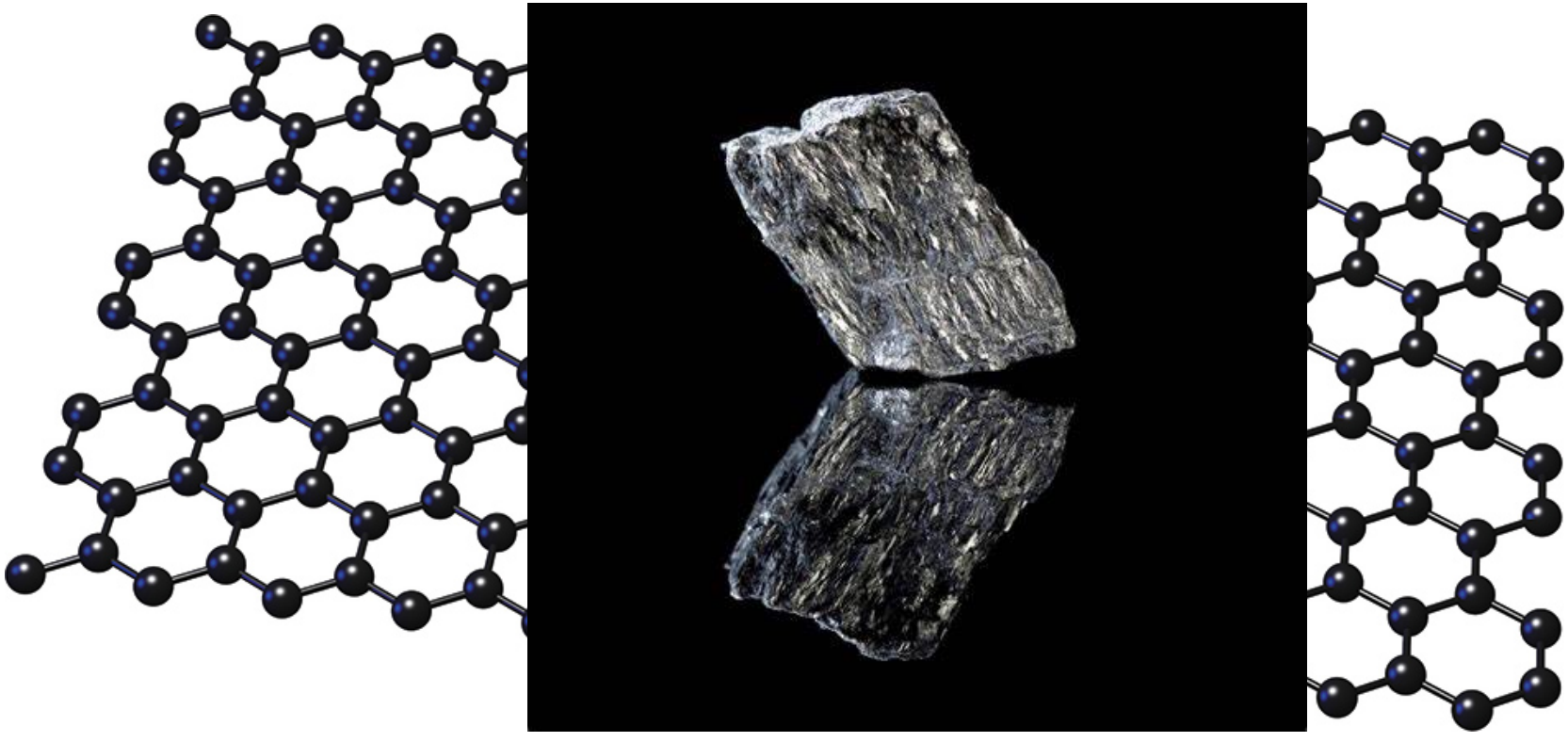
Graphene based nanoelectronic - a practical approach

or How to fabricate a G-FET

Laboratory of Organic Matter Physics
University of Nova Gorica

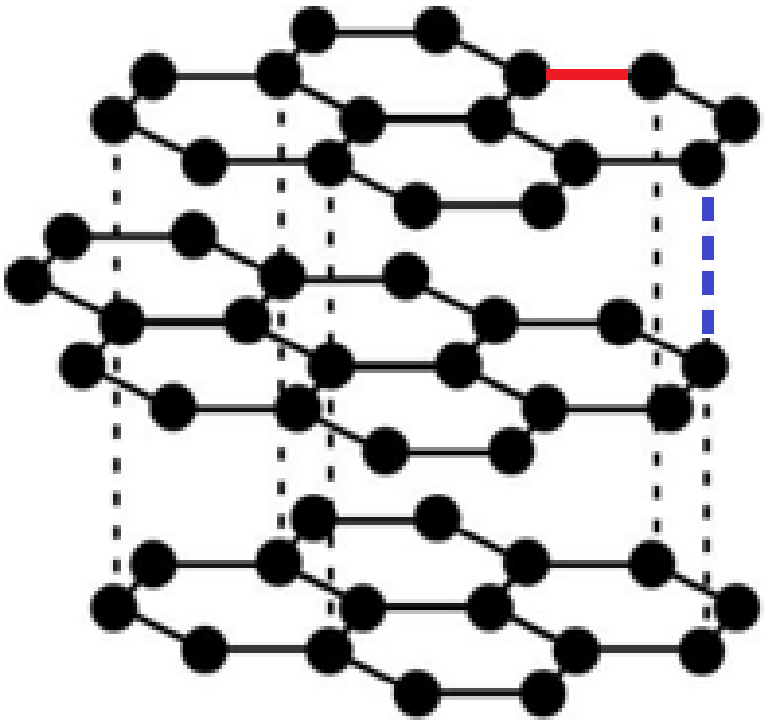
July 7, 2023

Graphene



thermofisher.com
B. Terrés, L. Chizhova, F. Libisch, et al. Size quantization of Dirac fermions in graphene constrictions Nat Com. (2016)

Graphene structure



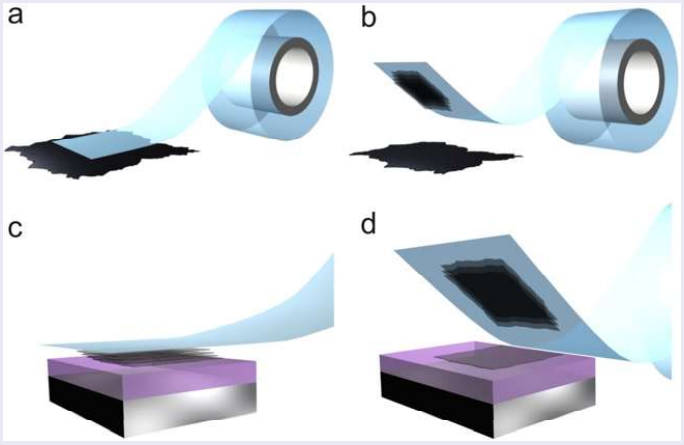
The atomic structure of graphite

- in-plane covalent bond:
  bond length$= 0.142nm$
  bond strength$\simeq 3.6eV$
- intra-plane van der Waals bond:
  bond length$= 0.335nm$
  bond strength$= 0.04eV$

Geim, Novoselov (2010): "The rise of graphene." Nanoscience and Technology: A Collection of Reviews from Nature Journals,11-19

Fabrication Techniques for Graphene

Micromechanical cleavage (Scotch Tape Method)



Whitener, Sheehan (2014): "Graphene synthesis.", Diamond and related materials 46, 25.
Novoselov, Castro Neto (2012): "Two-dimensional crystals-based heterostructures: materials with tailored properties." Physica Scripta, 014006.

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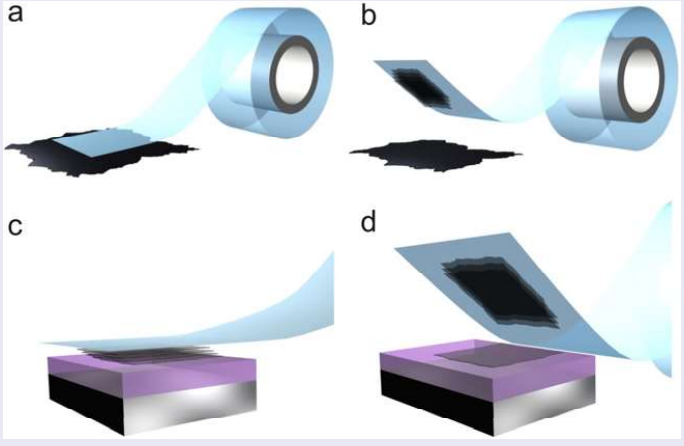
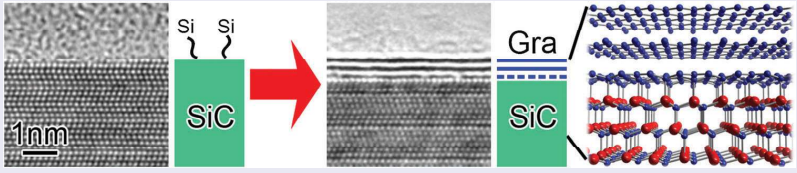


Epitaxial growth on SiC



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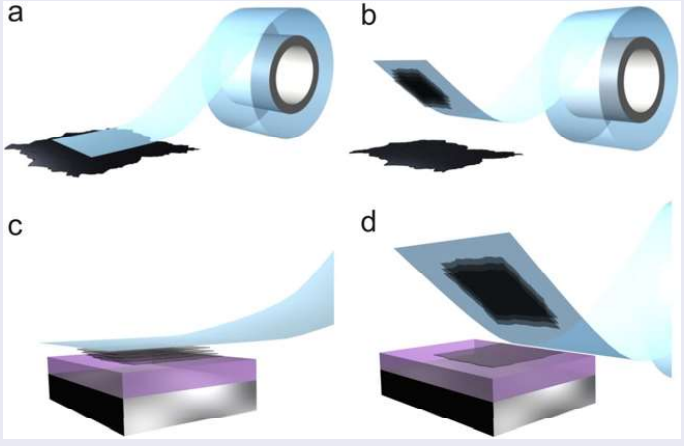

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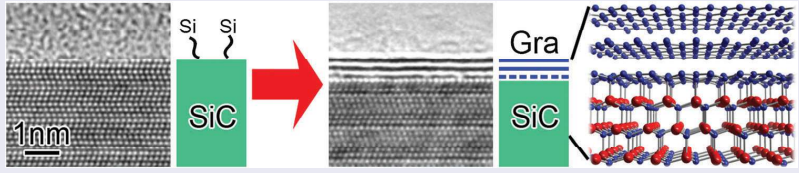
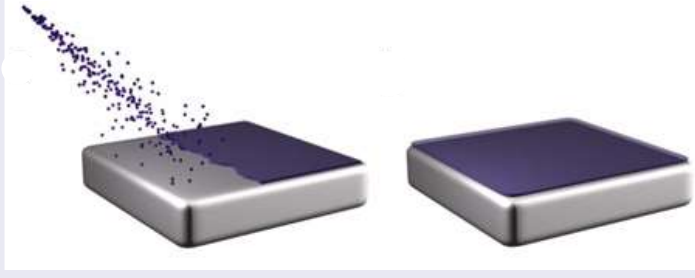


Chemical Vapor Deposition (CVD)



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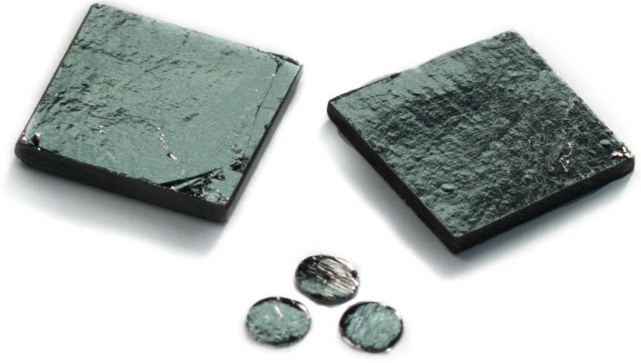
Selection of the parent material

Natural graphite:

Highly oriented pyrolytic graphite (HOPG) :



2spi.com/category/hopg-spi-supplies/

Selection of the parent material

Hexagonal Boron Nitride hBN:

- hexagonal lattice structure (similar to Gr): alternating boron (B) and nitrogen (N) atoms;
- dielectric material: $\Delta E_{bandgap}$=5.5 - 6 eV;
- weak interlayer bonding (but stronger compared to Gr);
- brittle nature: prone to fracture during exfolaition.

hqgraphene.com/h-BN.php

Selection of the parent material

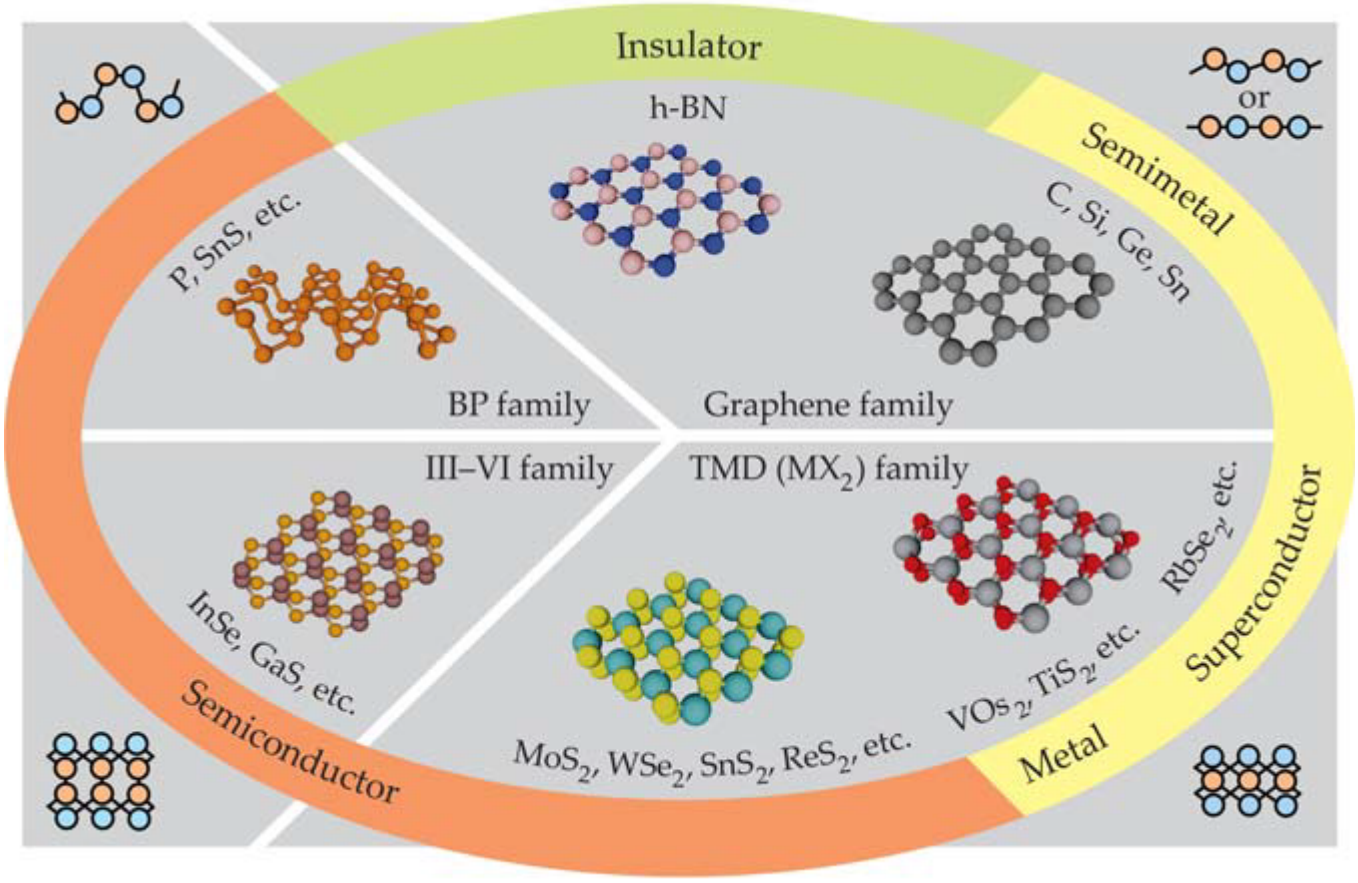
Molibdenum Disulfide MoS_2:

- hexagonal layered structure (similar to Gr);
- semiconductor: ΔE_g=1.8 eV;
- weak interlayer bonding (between Gr and hBN);

hqgraphene.com/h-BN.php

Selection of the parent material

Other two-dimensional materials



Ajayan, P., Kim, P., & Banerjee, K. (2016). van der Waals materials. Phys. Today, 69(9), 38.

The substrate

SiO_2/Si

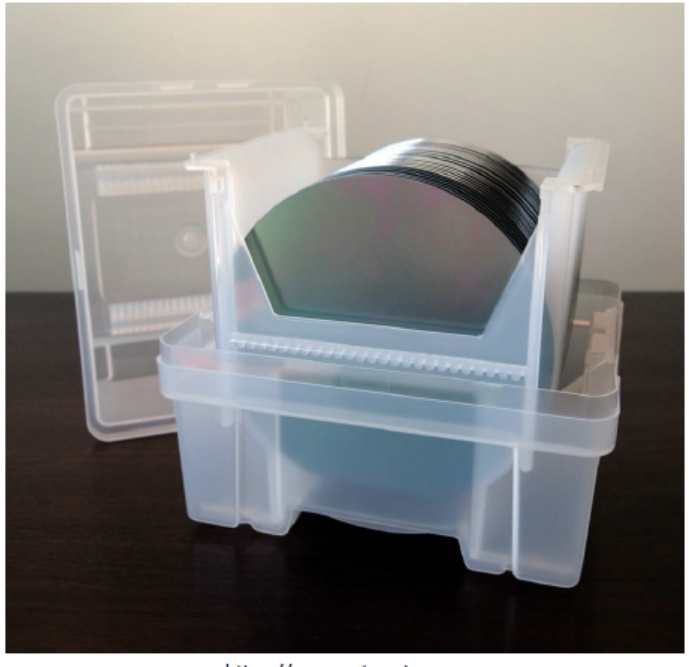
semiconductor

https://www.mindat.org/min-3659.html

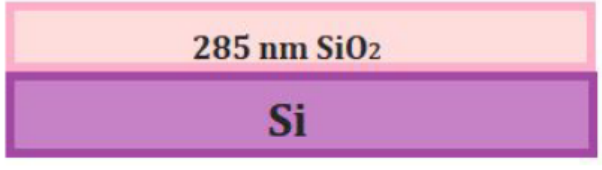
insulator

By Parent Géry via Wikimedia Commons

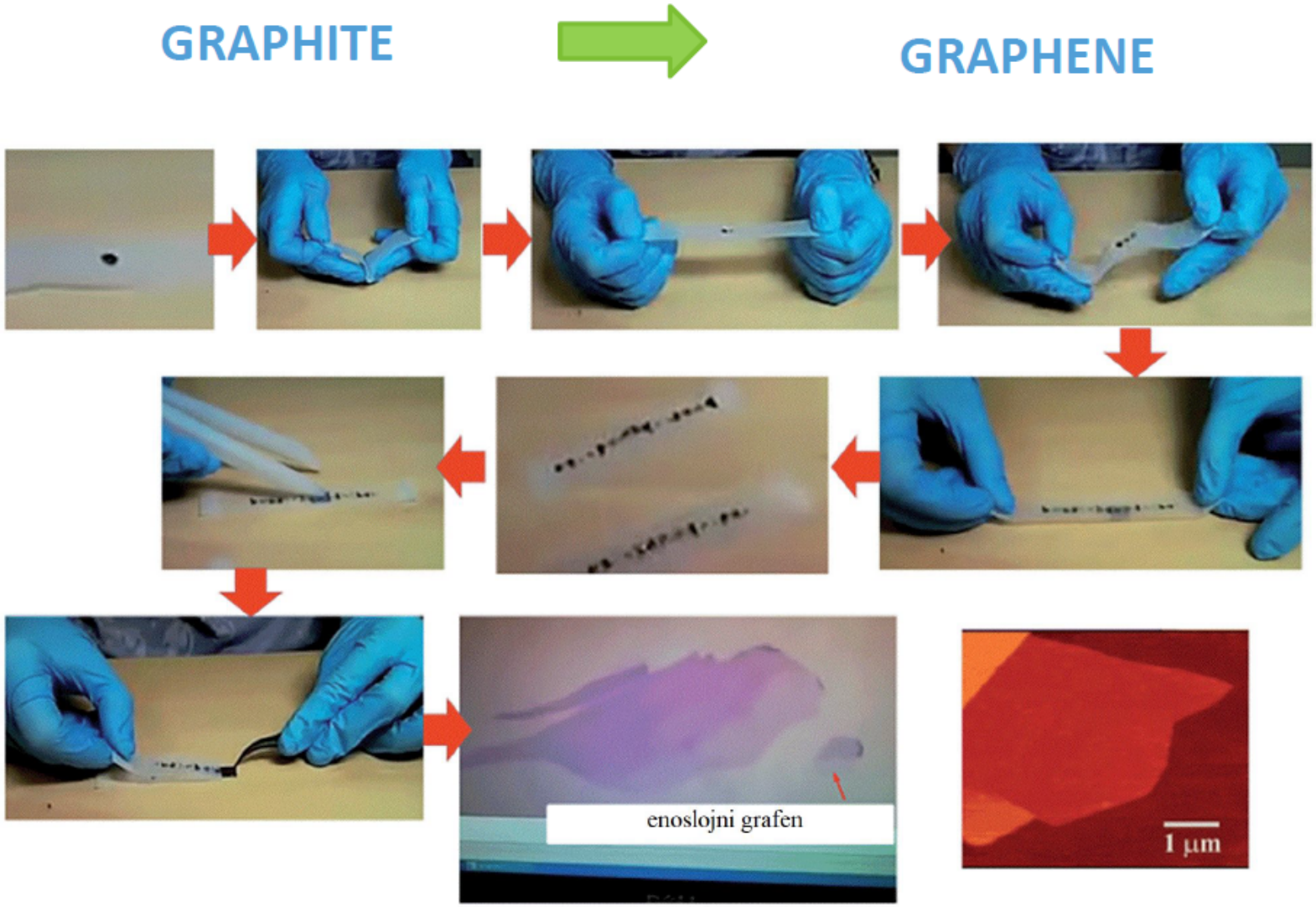
surface oxidation



https://www.spisemicon.com



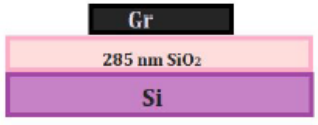
The micromechanical cleavage

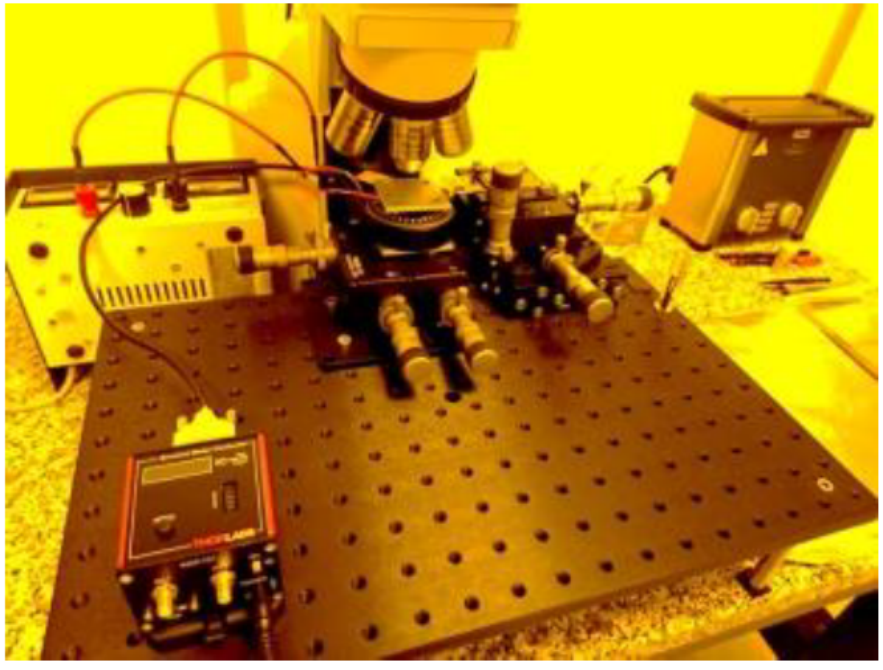


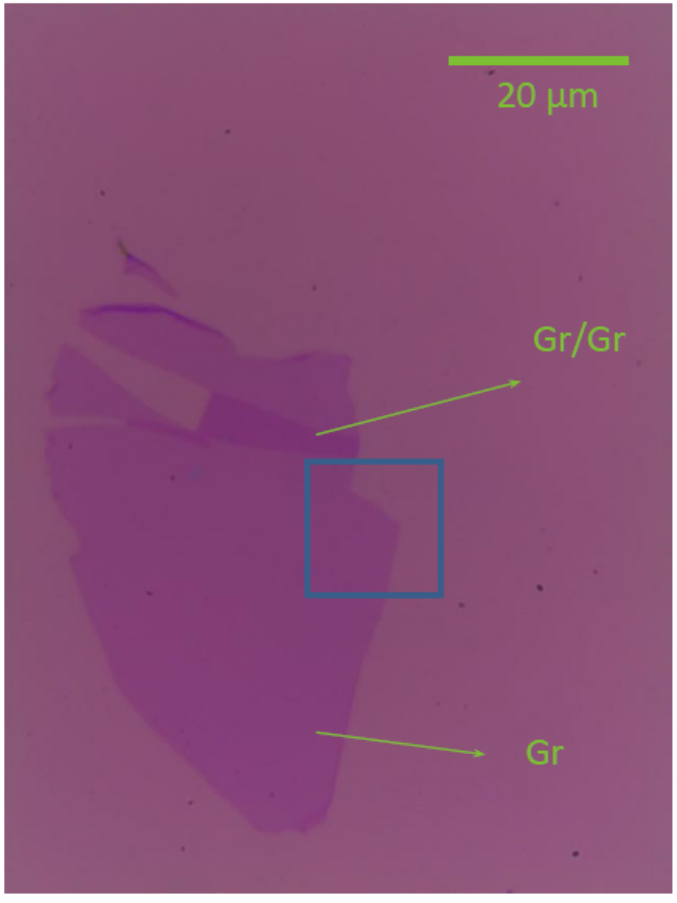
Wang etal. *Two-Dimensional Materials—Synthesis, Characterization and Potential Applications; Nayak* (2016)

The caracterization

OPTICAL MICROSCOPY

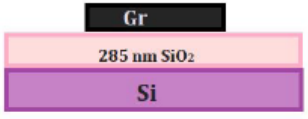


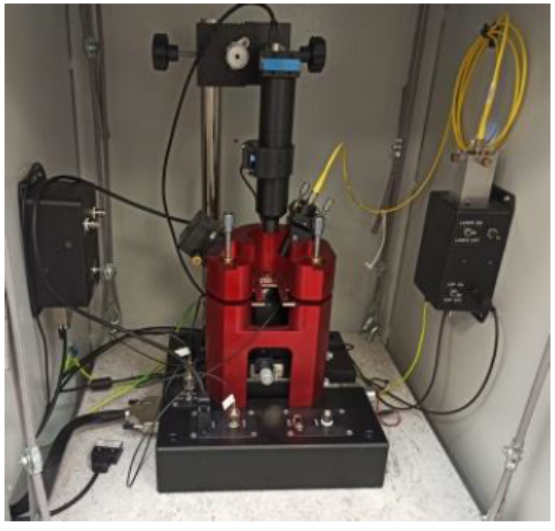


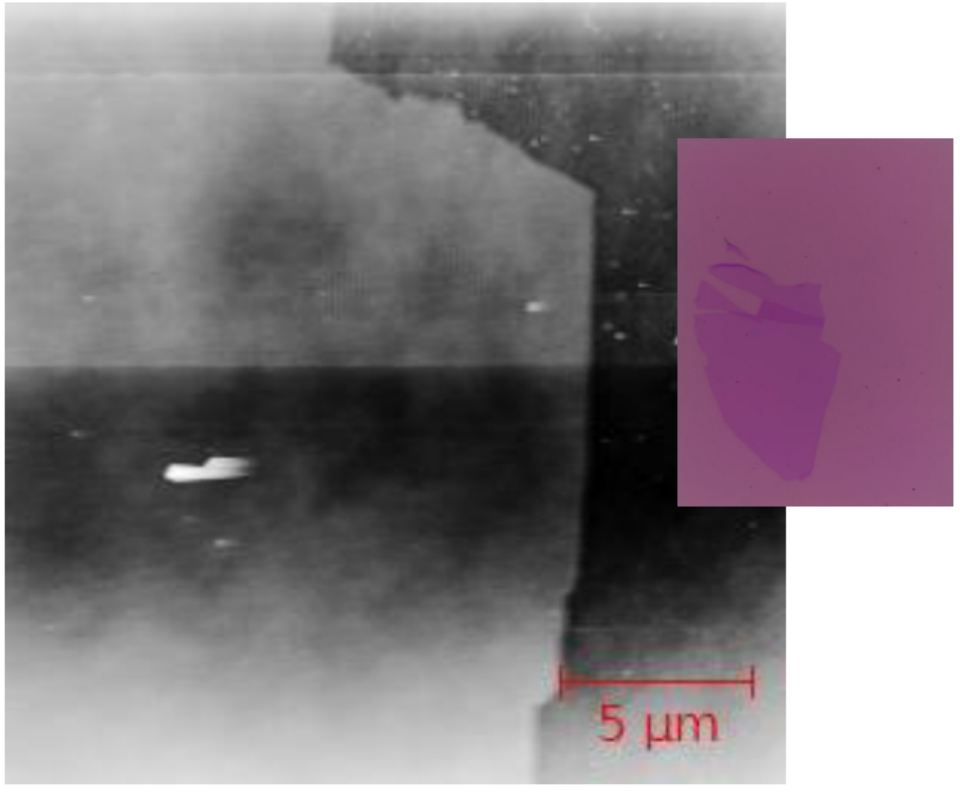


The caracterization

ATOMIC FORCE MICROSCOPY

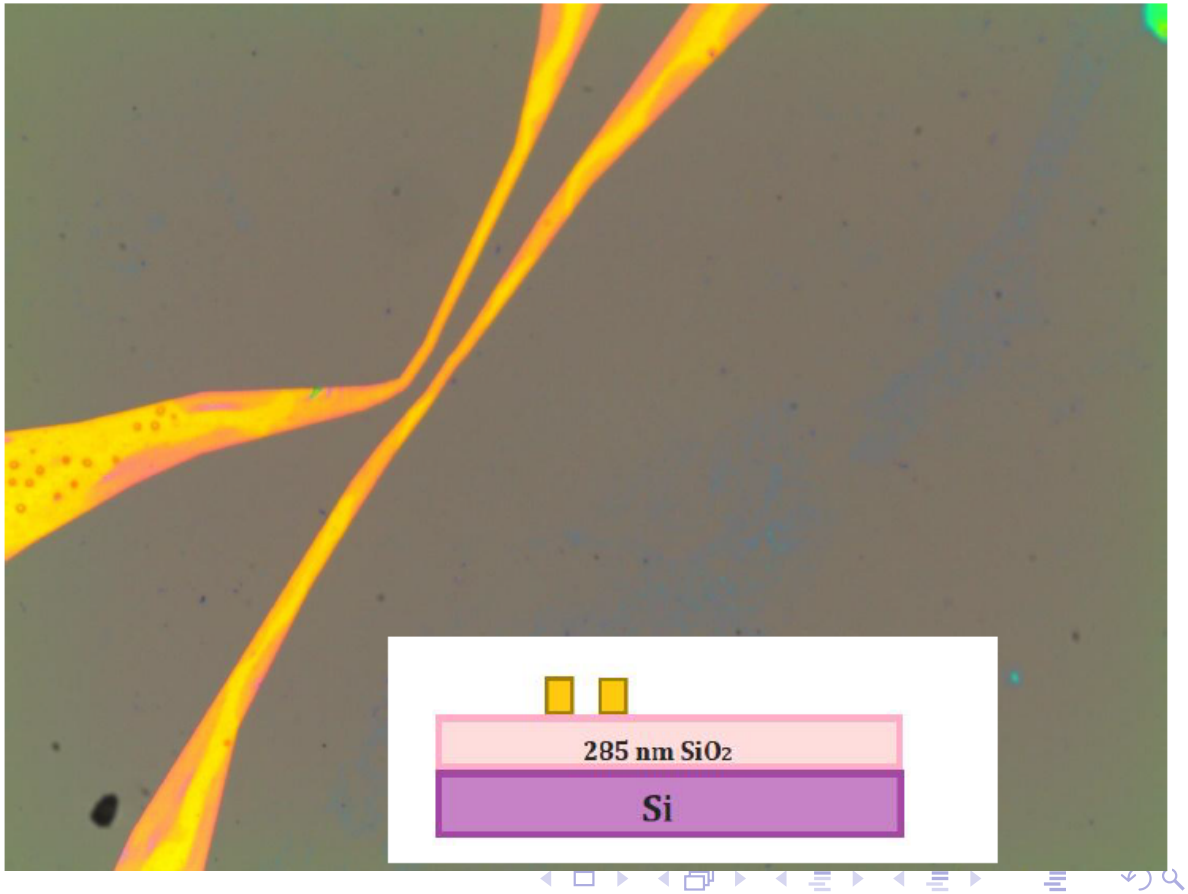






The preparation of the electrodes

LITHOGRAPHY & EVAPORATION



The graphene-based field-effect transistor