Title: Controlling the electronic properties of graphene structures obtained on inert or weakly reactive surfaces

Host laboratory : FEMTO-ST

Speciality of PhD: Physics, Nanosciences

Keywords : STM, Silicium, surface science, AFM

Job description

Introduction / Context

The synthesis of graphene nanostructures with atomic precision remains a major challenge, especially on semiconductor and insulating substrates.[1] Most methods developed to date rely on metallic substrates, which are essential to catalyze planarization reactions and ensure electronic conjugation.[2] However, the use of metallic substrates considerably limits applications that exploit the electronic and/or magnetic structure of graphene derivatives, due to coupling between substrate and adsorbed molecule electrons. Currently, the formation of nanographene on non-metallic substrates is mainly restricted to the lateral fusion of fluorinated polyaromatic molecules.[3]

Recently, a significant breakthrough was made by the group of Godlewski, who proposed a new molecular planarization approach using atomic hydrogen to induce planarization of polycyclic molecules.[4] This discovery opens new avenues for synthesizing graphene nanostructures on inert surfaces, a challenge that this PhD project aims to address.

Contribution to the State of the Art by the Nanosciences Group

The Nanosciences group enjoys international recognition for its work in synthesizing supramolecular[5] and polymeric6 structures on inert surfaces. Notably, it has helped elucidate the mechanism of graphene ribbon formation on surfaces[7] and more recently demonstrated the interest of atomic hydrogen in synthesizing Kagomé graphene and studying its electronic properties.[8] With this expertise, the group is ideally positioned to explore this new research path.

Planned Work

The main goal of this thesis is to experimentally demonstrate that the synthesis of graphene-like (1D or 2D) nanostructures is feasible on inert or weakly reactive surfaces such as boron-doped silicon or salt surfaces deposited on semiconductors. To overcome this scientific obstacle, the candidate will explore the use of atomic hydrogen as a catalyst for polymerization and cyclodehydrogenation.

The work will be structured as follows:

- Study of the structural properties of organic precursor deposits (specifically developed by the Nanosciences group) on semiconductor surfaces using scanning tunneling microscopy (STM) under ultra-high vacuum and at very low temperature (10K).
- Analysis of the cyclodehydrogenation reaction induced by atomic hydrogen under various conditions (temperature, exposure time, pressure, etc.).

- Comparison of the results in terms of efficiency (conversion rate), selectivity (detection of by-products), and quality (defect count) with literature data.
- Study of the electronic properties of the synthesized nanostructures by tunneling spectroscopy.
- Exploration of the possibility to create radical-type defects by modulating the energy of hydrogen atoms, to finely control the electronic properties of the nanostructures.

If successful, additional tunneling spectroscopy studies under magnetic fields may be conducted in collaboration with E. Meyer's group at the University of Basel, with whom we maintain active collaboration.8 The PhD student will also benefit from theoretical support from Alain Rochefort (Montreal, Canada) to complement experimental results with numerical simulations.

Should this approach fail to achieve the desired properties, an alternative option will be to explore photo-induced radical generation as a backup solution.

Supervision and Funding

PhD supervision will be provided by F. Palmino and F. Chérioux, who are not currently supervising any PhD students. Notably, all PhD students supervised since 2006 have defended their theses in under 39 months. The candidate will be financially supported by ongoing Nanosciences group projects and encouraged to attend national and international conferences and participate in short stays at partner labs to strengthen their skills and scientific network.

Bibliography

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2. J. Bjork *et al.*, *Angew. Chem. Int. Ed.* **2022**, *61*, e202212354

3. M. Kolmer *et al.*, *Science* **2019**, *363*, 57

4. R. Zuzak et al., *Nature Comm.* **2025**, *16*, 691

5. Y. Makoudi *et al. Surf. Sci. Rep.* **2017**, 72, 316

6. F. Para *et al., Nature Chem.* **2018**, *10*, 1112

7. E. Geagea *et al.*, *Chem. Commun.* **2021**, *57*, 6043

8. R. Pawlak *et al., ACS Nano* **2025**, *19*, 4768

Applicant profile

The ideal candidate is an innovative and analytical thinking person, who has good communication skills and a very good knowledge in surface science, physics as well as in scanning probe microscopies (STM, AFM).

Preferred selection criteria:

- knowledge in surface science

- knowledge in scanning probe microscopies (STM, AFM).

Personal characteristics:
- Good communication skills

Financing Institution: MESRI Etablissement **Application deadline: May 11** Start of contract: October 1, 2025 Gross monthly salary: €2200 (from January 1, 2026: €2300 gross)
Thesis Supervisor Prof. Dr. Frank Palmino (50%)
Thesis Co-supervisor Dr. Frédéric Chérioux (50%)
Applicants are invited to submit their application to the PhD supervisors. Application must contain the following documents: - CV - Cover letter - At least 1 reference letter