Séminaire

Mercredi 5 Février 2020 à 10h30

Salle de réunion du SRMP – Bâtiment 520 - Pièce 109

SELF-HEALING AT GRAIN BOUNDARIES IN PLASMA-TREATED *sp*^{2} CARBON

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Extensively encountered in radiation damage studies for its role in fission and fusion reactors, *sp*^{2}-carbon has gained a surge of interest this last decade owing to the exfoliation of monolayer graphene films in 2004. Nowadays, despite the absence of a large-scale production method, the synthesis of polycrystalline monolayer graphene is well-controlled using chemical vapour deposition. It has enabled numerous studies of ion-induced damage in 2D materials. Recently, a peculiar phenomenon has been evidenced in CVD-grown sheets under low-ion energy argon plasma irradiation: the self-healing of the graphene grain boundaries (GBs) [1]. While this has been theorized [2] and experimentally demonstrated [3] in 3D materials, this is the first occurrence of such process in 2D materials.

This seminar introduces the discovery of this phenomenon in graphene using a new hyperspectral Raman spectroscopy system [4]. The plasma environment and its 12-eV argon ion irradiation lead to a high density of Frenkel pairs during the treatment. The resilience of the GBs, evidenced by the Raman mappings (**Fig. 1** [1]), is explained by their role as defect sinks which results in preferential adatom-vacancy annihilation in their vicinity. The phenomenon is further described as a function of the different plasma irradiation conditions.

In the last part of the talk, a few interesting features arising from the graphene GB resilience under plasma irradiation are discussed. For example, this phenomenon leads to the formation of hexagonal nano-pyramids during argon plasma treatment of graphite substrates (**Fig. 2** [5]). Whilst adatoms/interstitials instigate the synthesis of these new structures, they might also feed the formation of the loops zipping the basal planes observed along the pyramidal facets (**Fig. 3** [5]). Additionally, the boundaries plays an important role in graphene functionalization: one may observe different doping behaviours when treated in nitrogen or diborane plasmas; N-incorporation is inhibited at GBs in the former while B-incorporation is favoured at the domain boundaries in the latter.

[1] Glad & Vinchon *et al.* (2020) "Self-Healing at Grain boundaries in plasma-treated graphene" currently under major revision in *Nature Materials*
[2] Bai *et al.* (2010) "Efficient annealing of radiation damage near grain boundaries via interstitial emission" *Science* **327**
[3] Zhang *et al.* (2018) "Radiation damage in nanostructured materials" *Progress in Materials Science* **96**
[4] Gaufrès *et al.* (2018) "Hyperspectral Raman imaging using Bragg tunable filters of graphene and other low-dimensional materials" *Journal of Raman Spectroscopy* **49**
[5] Glad *et al.* (2014) "Plasma synthesis of hexagonal-pyramidal graphite hillocks" *Carbon* **76**

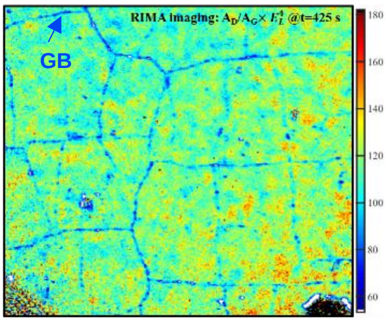

Figure 1. *120×120 µm^2 Raman mapping (90k spectra) of argon plasma-treated graphene displaying extracted D over G band area ratios, proportional to the lattice disorder [1].*

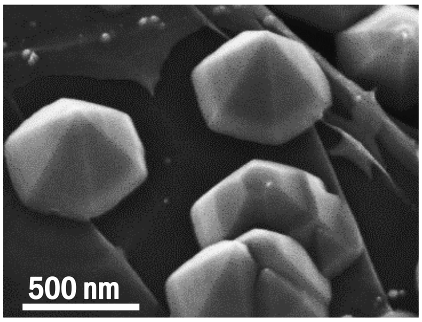

Figure 2. *Scanning electron micrograph of hexagonal graphite pyramids obtained in argon plasma treatment of graphite substrates [5].*

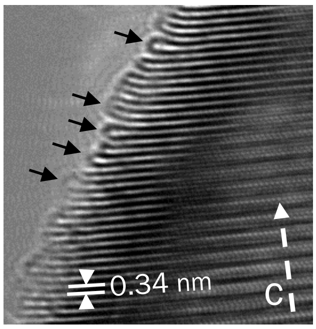

Figure 3. *HRTEM image of a graphite pyramid along its c axis with loops terminating the (002) planes [5].*

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