Stability of nanoporous graphene in ambient conditions

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Bottom – up grown nanoporous graphene (NPG) [1], is one of the most promising 2D materials for numerous applications, e.g., in electronics, optoelectronics, or sensing. This is due to its electronic properties, including the presence of a technologically relevant electronic bandgap (~1-2eV), and a well-ordered network of atomically sharp nanopores.

Here, we perform a long-running, systematic study of the stability of NPG in ambient conditions, by exposing it to various environmental factors (air, humidity, light, liquid environments), relevant for its future applications and processing routes. We find that the NPG degrades rapidly and destructively when placed on an Au (111) surface in humid air and ambient light. The degradation processes appear to be photocatalytic in nature and temperature-activated. Relevant reaction rates are estimated based on semi-quantitative Raman spectroscopy measurements, performed over the course of a few months.

We demonstrate that capping the surface by hexagonal boron nitride (hBN), or coating it with PMMA, stabilizes the material and prevents its degradation. Effects of water and oxygen are investigated and the interplay between different degradation pathways is studied. Additional experiments are done in ultra-high vacuum (UHV), after controlled dosing of chosen gases, suspected of inducing degradation of the material, to gain further insights. We also show that samples transferred to silicon dioxide (SiO_2) are more stable than the as-grown samples on Au (111), showing the photocatalytic effect promoted by the substrate.

Our results show that the environmental stability of low-dimensional materials has to be taken into account when designing and performing any experiments outside of UHV and is crucial for enabling their real-world applications. Degradation processes need to be systematically studied and understood to design effective strategies for preventing or minimizing the unwanted effects, which might end up hindering their future performance.

References

[1] César Moreno et al., Science, 360 (2018), 199-203

Figures

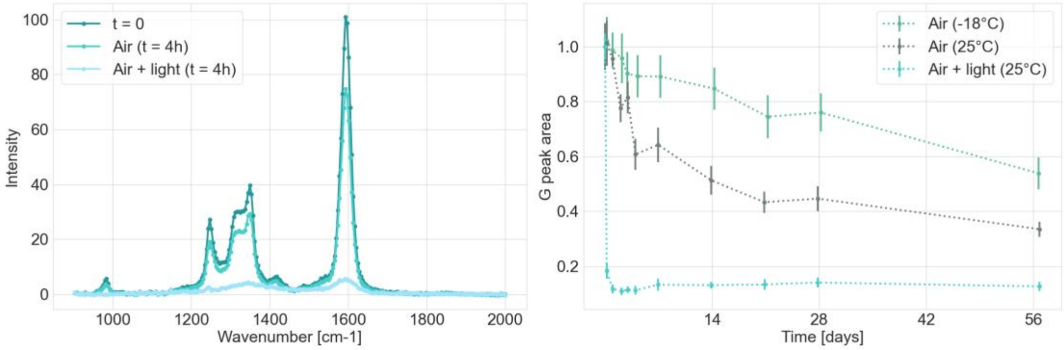

Figure 1: Raman spectrum of NPG samples, as grown, and exposed to air/air+light for 4h (left); evolution of normalized G peak intensity of the samples under these conditions for 2 months (right).