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Cleaning graphene using the NanoBroom

Christian Dolle[1,3], Peter Schweizer[1], Daniela Dasler[2], Gonzalo Abellán[2,3], Frank Hauke[2], Andreas Hirsch[2], Erdmann Spiecker[1]

[1]Institute of Micro- and Nanostructure Research (IMN), Cauerstrasse 3, 91058 Erlangen, Germany
[2]Chair of Organic Chemistry II, Nikolaus-Fiebiger-Strasse 10, 91058 Erlangen, Germany
[3]Instituto de Ciencia Molecular (ICMol), Catedrático José Beltrán Martínez nº 2, 46980 Paterna, Spain
christian.dolle@uv.es

Ultrathin layered materials in solid state are ***never*** clean. Especially in the case of mono- or bilayers, the extent of the physisorbed contamination easily surpasses the materials' thicknesses. This contamination layer crucially influences the resulting physical properties [1] and, as it cannot be avoided, needs to be removed.

We will demonstrate the site specific *in situ* mechanical removal of surface contamination from freestanding graphene using the NanoBroom (a). Hereby a micromanipulator setup directly in the high vacuum of a SEM, as well as a TEM allows the exhaustive cleaning of both free surfaces of the freestanding membrane and therefore gives access to atomically clean surfaces (b).

The cleaned membranes enable, among other, the study of dislocations in transmission SEM (tSEM) [2], complete suppression of metal catalyzed C-C bond scissoring (c) [3] and the observation of the surface-diffusion driven *in situ* growth of a nanocrystalline graphene layer [4].

References

[1] Cheng *et al.*, Nano Lett. 11 (2011) 767
[2] Schweizer, Dolle *et al.*, Sci. Adv. 4, 8 (2018) eaat4712
[3] Ramasse *et al.*, ACS Nano 6, 5 (2012) 4063
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Figures

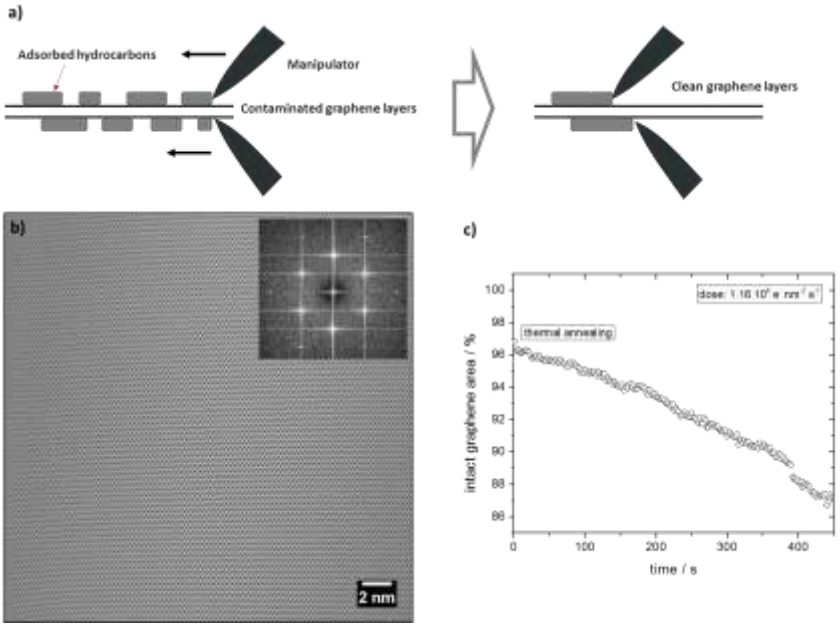

Figure 1: a) Schematic process for mechanically cleaning freestanding graphene with manipulators (NanoBroom). Contamination is mechanically pushed away from region of interest. b) HRTEM data of mechanically cleaned monolayer graphene (inset shows FFT). Graphene is atomically clean over more than 5µm². c) Heteroatom-catalyzed hole-growth of thermally annealed graphene at electron dose of 10^6 e $nm^{-2}s^{-1}$.