Evolution of shape and size of 2D nanosheets during sonication, studied by automatic image processing

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Abstract

2-dimensional (2D) nanosheets such as graphene, graphene oxide, boron nitride or transition metal dichalcogenides can be produced on large scale by exfoliation techniques.[1] The lateral shape of these 2D materials is typically considered random and irregular, and their average size is often estimated using techniques characterized by strong approximations or poor statistical significance.

The lack of a clear metrology and of quality control is creating confusion among industrial end-users. Despite a nomenclature[2] has been proposed for 2D graphene-based materials, a clear agreement on metrology and standards is still missing.

Here we measure in a quantitative, objective way the size and shape of 2D monoatomic nanosheets using a combination of optical, electronic and scanning probe techniques (Fig.1).[3] We measure, one by one, the size and shape of thousands of sheets of graphene oxide as they undergo a standard ultrasonication treatment. Thanks to automatic image processing and statistical modelling we identify two different fragmentation processes in 2D at the nanoscale, related to two populations of nanosheets described by gamma and exponential size distributions respectively (fig. 2). The two populations of sheets coexist during the fragmentation process, each one retaining its average size, average aspect ratio and shape. Our results allow to explain the reduction of nanosheets' size commonly observed upon sonication as an effect of changes in the respective weight of the two populations of nanosheets present in the material.

References

[1] Coleman *et al.* Science (2011)331 56, 71.
[2] Bianco *et al.* Carbon (2013) 65, 1.
[3] Liscio *et al.* 2D Materials (2016), just accepted.

Figures

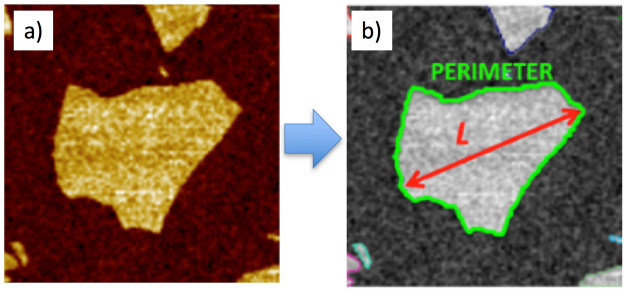

Figure 1: a) Typical AFM image of one of the monoatomic nanosheets used for the statistical analysis. b) Representation of the statistical parameters measured by image processing for the analysis.

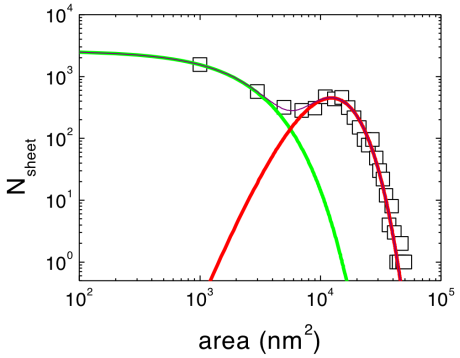

Figure 2: Histogram of the size distribution of the nanosheets (in this case after 40 h sonication) showing the presence of two different populations.