Exfoliation and Sorting of Graphite flakes and inorganic two-dimensional materials

F. Bonaccorso[1], F. Torrisi[1], G. Privitera[1], V. Nicolosi[2], T. Hasan[1], G. Savini[1], N. Pugno[3], A.C. Ferrari[1]

[1] Department of Engineering, University of Cambridge, JJ Thomson avenue, Cambridge CB3 0FA, UK
[2] School of Chemistry, School of Physics & CRANN Trinity College Dublin Dublin 2 Ireland
[3] Dept. of Structural Engineering, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

fb296@cam.ac.uk

Liquid-phase exfoliation of graphite [1] is a promising tool for mass production of single and multi-layer graphene flakes, as well as inks [2], thin films [1], and composites [3,4]. Here we report high yield production of graphene via low power sonication of graphite in sodium deoxycholate (SDC) followed by ultracentrifugation. There are two main approaches to ultracentrifugation: sedimentation-based separation (SBS) and isopycnic separation. The former discriminates particles by their difference in mass. The latter exploits density differences between particles in a density gradient medium [5,6]. Our results suggest that graphite exfoliation via sonication produces flakes with lateral sizes increasing with the number of layers. We thus exploit SBS to separate graphite flakes by number of layers [8]. TEM and Raman spectroscopy indicate that ~65% of the flakes produced by SBS are monolayer with average size ~600nm^2 [9,10]. Isopycnic separation allows us to obtain larger flakes than SBS. This requires the creation of density differences between flakes with different number of layers. Surfactants provide this density variation [11]. In this case, sorting is strongly dependent on the surface/volume ratio and the coverage and clustering of the surfactant molecules. SDC is the most effective surfactant for exfoliation and sorting of graphite flakes, with ~60% of the flakes in the topmost fraction being monolayers, with average size 1μm^2. Ultracentrifugation can also be used to sort nanodiamonds in terms of shape and dimensions, and can also be applied to inorganic layered materials, such as Boron Nitride, Tungsten Disulfide, Molybdenum Disulfide, etc.[12].

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