

Tuning the morphological properties of graphene and 2d crystals in centrifugal fields

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Abstract

We show how to produce graphene flakes with controlled morphological properties, via low power sonication of graphite in sodium deoxycholate (SDC) followed by ultracentrifugation. There are two main approaches to ultracentrifugation [1]: sedimentation-based separation (SBS) [2,3,4] and density gradient ultracentrifugation (DGU) [5]. The former discriminates particles by their difference in mass. The latter exploits density differences between particles in a density gradient medium (DGM) [6,7]. If the ultracentrifugation is stopped before the particles achieve their isopycnic point, i.e. the point where the particles match the density of the DGM, a rate zonal separation (RZS) is achieved [8]. RZS is based on difference in masses and shapes of particles in the centrifugal field [8]. Indeed, particles with different masses and shapes will move with different sedimentation velocity along the DGM [8]. We exploit SBS to separate graphite flakes by number of layers [9,10], achieving a yield of ~65% monolayers, with ~600nm² average size [9,10]. Isopycnic separation allows us to obtain larger flakes than SBS. Surfactants provide this density variation [5], with a 60% yield of monolayers in the top fraction, with ~1μm² size. Inorganic layered materials [11], such as Boron Nitride, Tungsten Disulfide, Molybdenum Disulfide, etc., have a density that cannot be supported by common DGMs, thus cannot be separated via isopycnic separation. We show here how to obtain dispersions with controlled lateral size via RZS, see Fig.1.

References

- [1] F. Bonaccorso *et al.* *Materials today*, **15** (2012) 564.
- [2] Y. Hernandez *et al.* *Nature Nanotech.*, **3** (2008) 563.
- [3] T. Hasan, *et al.* *Phys. Status Solidi B* **247** (2010) 2953.
- [4] F. Torrisci, *et al.*, *ACS Nano*, **6** (2012) 2992
- [5] A. A. Green *et al.*, *Nano Lett.* **9** (2009) 4031.
- [6] M. S. Arnold *et al.*, *Nature Nanotech.* **1** (2006) 60
- [7] F. Bonaccorso *et al.*, *Journal of Physical Chemistry C* **114** (2010) 17267
- [8] M. K. Brakke, *Arch. Biochem.* **45**, (1953), 275.
- [9] O.M. Marago' *et al.*, *ACS Nano*, **4** (2010) 7515.
- [10] F. Bonaccorso *et al.*, *Nature Photonics* **4** (2010) 611.
- [11] J.N. Coleman *et al.* *Science* **331** (2011) 568.

Figure

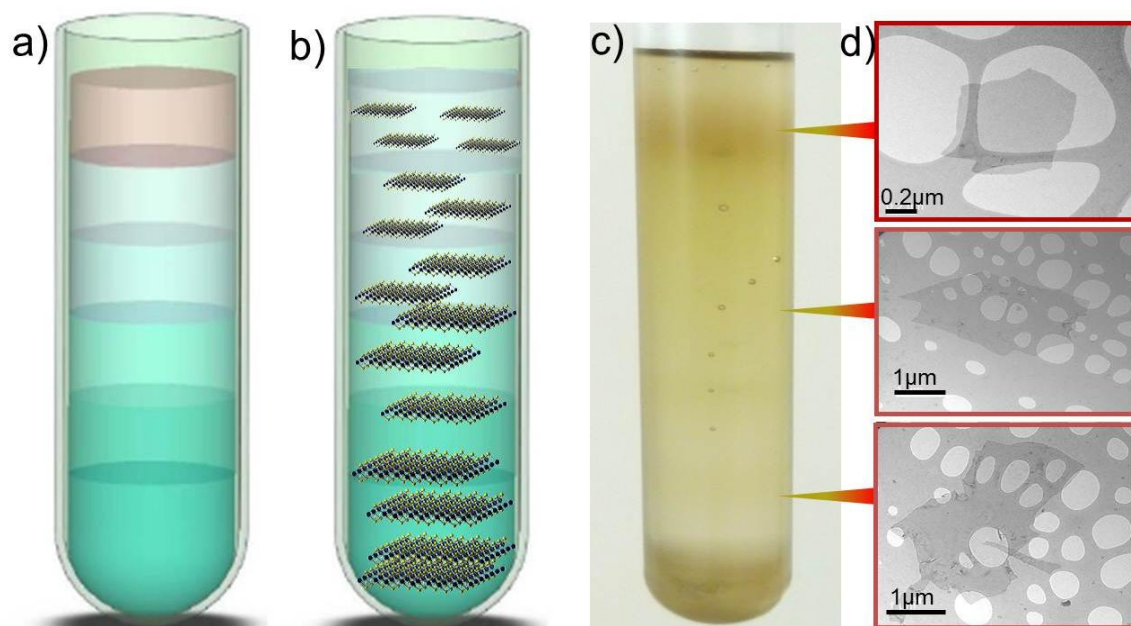


Figure 1: Sorting of layered materials (MoS_2) via RZS. (a) Formation of step gradient by placing a density gradient medium with decreasing concentration. (b) During RZS flakes with different sedimentation coefficient will travel along the cuvette at different sedimentation velocities. This will cause a spatial separation along the cuvette between smaller and larger flakes. (c) Photograph of cuvette containing sorted MoS_2 after RZS. (d) TEM images of flakes extracted along the cuvette.