

Large-scale exfoliation of Molybdenum Disulphide in solvent mixtures

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We demonstrate preparation of high quality dispersions of single- and few-layer MoS₂ using mild sonication of bulk MoS₂ in an alcohol-water binary solvent mixture. The key issue for dispersion is ensuring that the solvent properties, including the surface energy and the Hansen solubility parameters, are well matched to those of the layered material [1, 2, 3]. In this case, exfoliation becomes energetically favourable, and sonication becomes sufficient to overcome the van der Waals forces between the layers, leading to stable dispersions of single- and few-layer 2-dimensional (2d) crystal flakes (Fig. 1). This can be typically achieved through the use of single solvents, e.g. N-Methylpyrrolidone (NMP) [1, 2] or via the addition of surfactants [1, 3]. The latter is useful as it can allow the use of solvents with poorer solubility parameter matching, but with more desirable properties, such as lower boiling point and lower toxicity. However, this requires removal of surfactants at a later stage. The use of binary-solvent mixtures has many of the advantages of the aqueous-surfactant based dispersions, while not introducing the need to remove surfactants [4]. We sonicate bulk MoS₂ crystals in 50/50 vol% water-alcohol mixture; Fig. 1. Following sonication, the dispersions are centrifuged to remove un-exfoliated material, and then characterised by optical absorption spectroscopy, Raman and photoluminescence spectroscopy, transmission electron and atomic force microscopy. These reveal a concentration of up to 0.02g/l, with average lateral flake size ~2 microns. This is lower than concentrations previously reported with solvents such as NMP [1], although with comparable flake size. When compared to organic solvents, the increased ease of handling and the lower boiling point of the solvent mixtures (~80°C [4] against ~202°C for NMP [5]) makes these dispersions suited for coating or printing on polymeric substrates.

References

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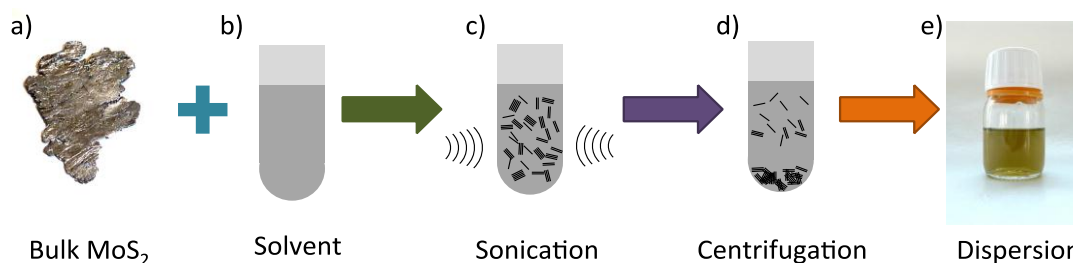
Figures

Fig. 1: Liquid phase exfoliation of MoS₂: a) MoS₂ flake is added to b) solvent/solvent mixture. c) The mixture is ultrasonicated, producing a dispersion with varying flake thickness d) The dispersion is centrifuged to sediment unexfoliated MoS₂. e) The supernatant is enriched with mono- and few-layer flakes.