Synthesis and characterization of water-based inks of 2D-materials

Oliver Read1, Yuyoung Shin1, Marco Zarattini1, Vaiva Nagyte1, Cinzia Casiraghi1

1 Department of Chemistry, University of Manchester, Manchester, M13 9PL, UK

Extensive research into the field of advanced materials and most notably 2-dimensional (2D) materials has been undertaken since the isolation of graphene, owing to its exceptional physical properties including high electrical and thermal conductivities, mechanical and chemical stability and high optical transparency [1].

Liquid phase exfoliation (LPE) offers one of the most promising routes to large-scale solution processing of defect-free 2D materials, in which ultrasonic waves are used as the exfoliation method whilst careful choice of solvent is required to stabilise the nanosheets [2]. Typically, layered materials are exfoliated in non-green organic solvents such as N-methyl-pyrrolidone (NMP) or dimethylformamide (DMF) which are expensive, toxic and difficult to remove thereby limiting scalability. Ideally, water should be used as solvent. Owing to graphenes hydrophobic nature, LPE in water can be performed only by using stabilising agents, which assist exfoliation and, at the same time, avoid the re-aggregation of the exfoliated sheets in solution.

In our group we use pyrene derivatives as exfoliating agents to exfoliate graphite and other layered materials in water [3-6]. These molecules have shown to be very effective at exfoliating graphite, owing to their π-π interactions with graphene, whilst maintaining high solubility due to the hydrophilic nature of their functional groups. This method has been used to produce highly concentrated dispersions of mostly few-layer nanoflakes of a large range of different layered materials. The produced dispersions are stable over time and have been used to make several devices by inkjet printing, including photodetectors [5,7], capacitors [8] and transistors [8-9].

In this work we show an extensive characterization study of the lateral size and thickness of graphene nanosheets produced using different pyrene derivatives by Atomic Force Microscopy (AFM). In a previous work on graphene produced by LPE in NMP [10], a correlation between thickness and lateral size was found, which was attributed to the processes happening during sonication. Thus, we aim at comparing this model with the results obtained by LPE in water, when pyrene derivatives are used as stabilizing agents, in order to elucidate if these molecules do also participate in the exfoliation, by affecting the lateral size and thickness distribution of the flakes. This would help getting more insights on the fundamental processes happening during LPE with exfoliating agents, which are largely unknown.

References


Acknowledgements - The authors would like to thank the following funding agencies: the Lloyds foundation, the EPSRC in the framework of the 2DHealth project, and NPL in the framework of the CDT graphene. MZ acknowledges funding by the Hewlett-Packard Company.