Gaining control over liquid-exfoliated nanosheets and their networks

Claudia Backes
Physical Chemistry of Nanomaterials and CINSaT, University of Kassel, Heinrich Plett Str. 40, 34132 Kassel
backes@uni-kassel.de

Liquid phase exfoliation (LPE) has become an important production technique giving access to single and few-layered nanosheets in colloidal dispersion. It has been shown to be applicable to a whole host of inorganic crystals with the nanosheet morphology being defined by the in plane and out of plane binding strength in the parent crystal.[1] In addition to layered inorganic crystals, organic materials such as 2D polymers,[2] metal organic frameworks[3] or even organic molecular crystals such as rubrene[4] can be exfoliated this way continuously increasing the palette of available materials. While size selection by centrifugation can be used to gain control over nanosheet size and thickness distributions, it is still challenging to fabricate nanosheet networks of high optical quality where the properties of the individual constituents are retained.
Here, we show progress in the deposition of nanosheets after preassembly at the liquid-liquid interface through a Langmuir-Schaefer type technique. In contrast to deposition by spraying or printing which produces porous networks, the nanosheets are well aligned parallel to the substrate. Due to the minimal overlap between the sheets, optical properties such as fluorescence of monolayer transition metal dichalcogenides is retained in the film. Subsequent stacking, also of different types of nanosheets is feasible, giving rise to the possibility to build up thicker films or heterostructures. We show the potential of this strategy by embedding WS_2 nanosheets in optical microcavities and the observation of the formation of exciton polaritons.
Further, we explore possibilities to further control the nanosheet dimensions by chemical means. Particular emphasis is given to increasing the length thickness aspect ratio. Following our work on site selective oxidation of WS_2 nanosheets in the presence of certain surfactants,[5,6] we now show that reaction parameters for MoS_2 can be tuned in such a way to achieve selective destruction of few-layers over monolayers resulting in increased length/thickness aspect ratio of the mono-layered constituents.

References

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