chem2Dmat
September 03-06, 2019 ● Dresden, Germany
European Conference on Chemistry of Two-Dimensional Materials

A new route to make WS_2-polymer composites

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2D materials can be produced by liquid phase exfoliation (LPE). This process can be applied to a whole host of layered structures and gives access to high quality nanosheet dispersions in the liquid phase. Major issues such as low monolayer contents and sample polydispersity could be addressed the past years by improved post exfoliation size selection. Recently, it was shown that stabilization in aqueous surfactant yields dispersions with higher monolayer contents. [1] However, for some applications, such as the preparation of polymer composites, the exfoliated materials needs to be compatible with organic solvents.

However, when transferring from aqueous to organic media, restacking of nanosheets occurs and leads to the loss of their monolayer characteristics such as photoluminescence of single layered transition metal dichalcogenides (TMDs). By using WS_2 as model substance, we show that the rate of aggregation depends on the nanosheet concentration. While it is possible to remove aggregates by mild centrifugation and produce thin films with monolayer properties of the WS_2 retained, this procedure is only poorly reproducible.

In this report, we present a new method to prevent aggregation on transfer that facilitates the preparation of thin films from LPE WS2 in a polymer matrix on arbitrary substrates with monolayer properties of the nanosheets retained. The secret is to a polymer which is not water soluble (such as poly vinyl carbazole, PVK) to the aqueous WS2 mixture prior to sonication. The sonic energy also “exfoliates” the polymer which is forced to adsorb on the most hydrophobic area in the aqueous dispersion which is the interface between surfactant and nanosheet. Hence, a densely packed thin layer of the polymer is formed on the WS_2. Its presence facilitates transfer to organic solvents without aggregation occurring. When preparing nanosheet thin films in this way, the polymer coverage also prevents communication between the sheets after deposition so that no loss of monolayer photoluminescence compared to the dispersion is observed. This new route works for a range of polymers and can be used to produce films of outstanding optical quality (Figure 1). Such films will be interesting for integration into optoelectronic devices.

References

[1] Backes, C.; Campi, D.; Szydlowska, B. M.; Synnatschke, K.; Ojala, E.; Rashvand, F.; Harvey, A.; Griffin, A.; Sofer, Z.; Marzari, N.; Coleman, J. N.; O'Regan, D. D., ACS Nano 13 (2019) 7050−7061.

Figures

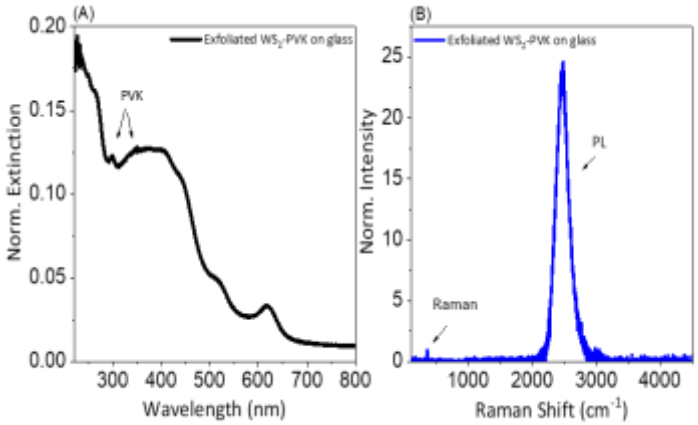

Figure 1: A) optical extinction spectra of high quality liquid exfoliated WS_2-PVK thin film. B) Raman/photoluminescence spectra of high quality liquid exfoliated WS_2-PVK thin film.