Emerging Nano and Advanced Materials (ENA)

IIT DELHI INDUSTRY DAY 2019

Economical and Efficient Room Temperature Liquid Phase Exfoliation Route to Few Layer MoS_2

Priyanka Yadav, Anirban Das, Manoj Sharma and Ashok K. Ganguli *

Department of Chemistry, Indian Institute of Technology, New Delhi 110016, India

**Corresponding author:* ashok@chemistry.iitd.ac.in

Abstract

2-Dimensional transition metal dichalcogenides (TMD) are of interest due to their immense potential for applications in water splitting to produce H_2 and in Li or Na ion batteries. Here, using MoS_2 as a model compound we report the development of solvent-surfactant systems that can potentially result in large scale exfoliation of 2D-TMD using non-toxic and inexpensive solvent systems.

Introduction

Among the large family of Transition Metal Dichalcogenides (TMDs), the group VI based compositions MX_2 (M = Mo, W; X = S, Se) are particularly interesting because they are semiconductors with indirect band gaps which lie in the visible region (in the range of 1.1−2 eV). They possess layered structures having strong lateral covalent bonding in between the atoms and weak interlayer non-covalent interactions that make them unique. 2D-TMDs have been demonstrated to be useful in the field of electronic, optoelectronic and spintronic devices, sensors, high performance electrodes and nanocomposites. The aim of this work is to come up with simple methodologies for low temperature chemical routes to obtain two dimensional TMDs and related materials.

Materials and Methods

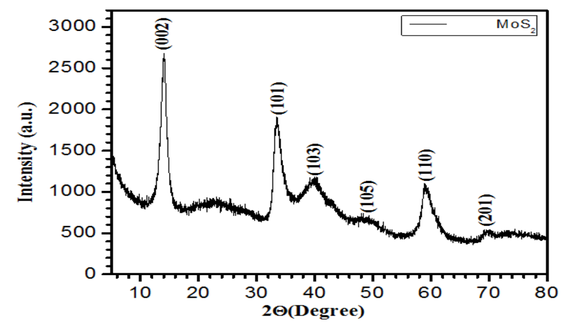
Bulk Synthesis

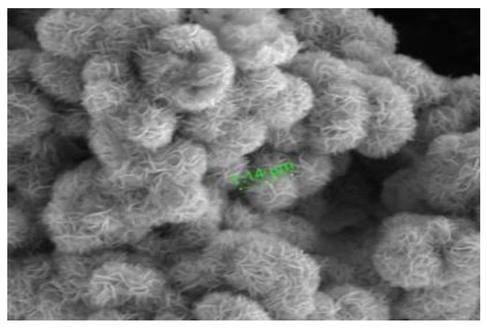
Ammonium heptamolybdate dispersed water → Added Thiourea → Continuous Stirring for 2-3 hrs → Reaction mixture transferred to a hydrothermal autoclave, kept at 180°C for 36 hrs.

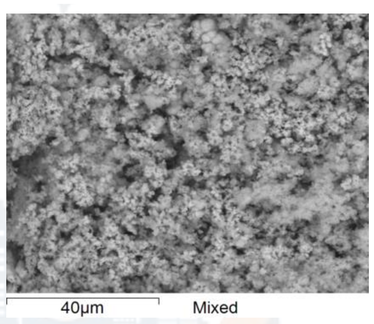
Exfoliation Method

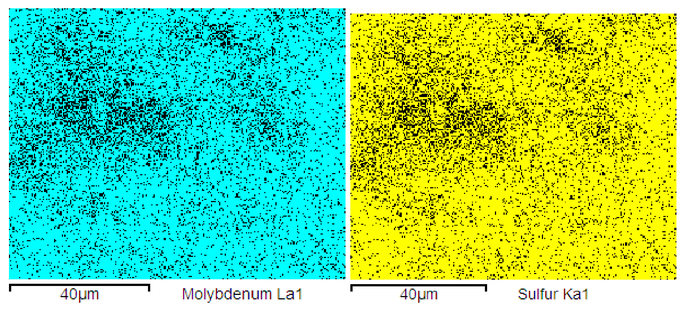
MoS_2 + Surfactant/ Polymers in Organic Solvent → Ultrasonicated for 5 hrs ⇄ Centrifuged for 30 min at 4000 rpm

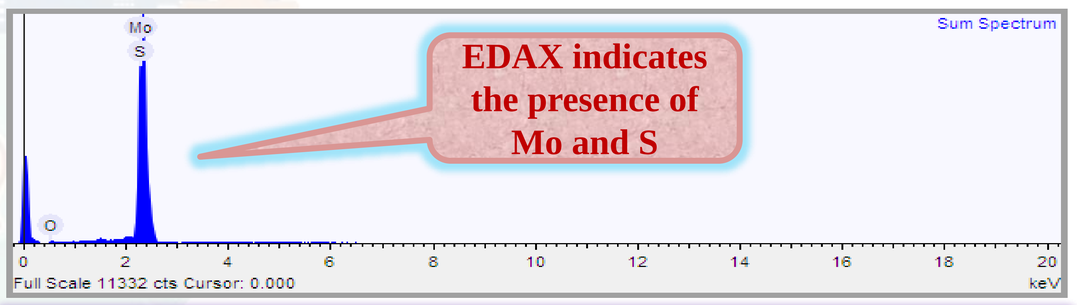
Results



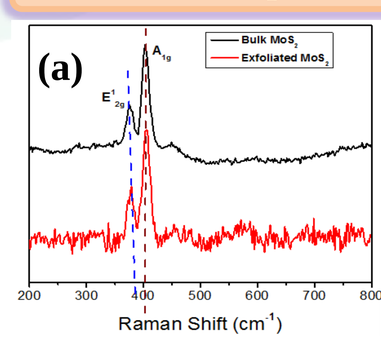


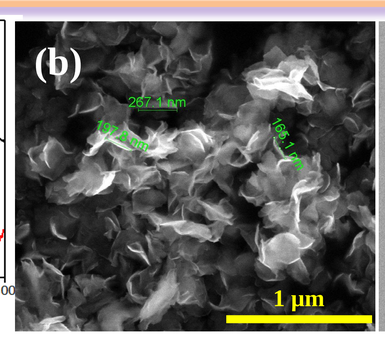


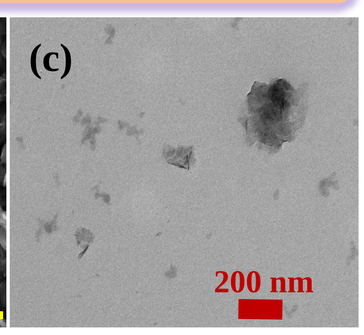


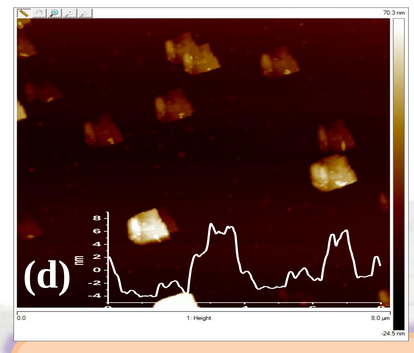


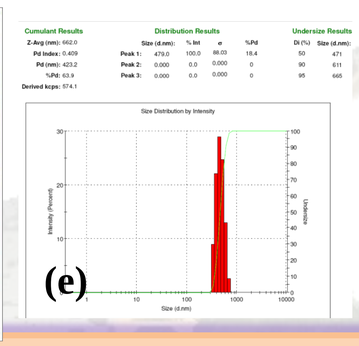
Powder XRD pattern, FESEM and EDAX analysis of Bulk MoS_2

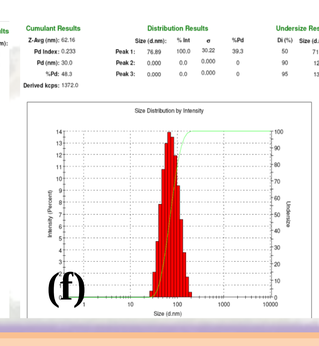












(a) Raman spectra of bulk as well as Exfoliated MoS_2 (b) FESEM (c) TEM (d) AFM Images of Exfoliated MoS_2 and Dynamic light scattering analysis of (e)Bulk MoS_2 [Av. size: 662 nm] and (f) Exfoliated MoS_2 [Av. size: 62 nm]

Conclusions

- A simple and economical chemical route was developed to exfoliate bulk MoS_2 into 2D nanoflakes.
- AFM studies shows exfoliation of bulk MoS_2 into monolayer to few layer MoS_2.
- Raman spectroscopy shows the signature of exfoliation i.e., shifting in peak positions.

Industrial Significance

- 2D TMD have been demonstrated to be excellent useful in the field of electronic, optoelectronic and spintronic devices, sensors, high performance electrodes and nanocomposites.
- We have been successful in identifying a solvent- surfactant system that is cheap and non-toxic and is able to produce exfoliated MoS_2 on a large scale.

Technology Readiness Level:

Lab scale trials are showing positive results. Scale up in pipeline.

References

[1] Wu, Z.; Wang, D.; Zan, X.; Sun, A. Synthesis of WS_2 Nanosheets by a Novel Mechanical Activation Method. *Mater. Lett.* 2010, *64*, 856.

[2] Cao, S.; Zhao, C.; Peng, L. The 3D WS_2 Microspheres: Preparation, Characterization and Optical Absorption Properties. *Mater. Lett.* 2016, *164*, 452.

[3] Gupta A; Sakthivel T; Seal S. Recent development in 2D materials beyond graphene , *Progress in Materials Science 2015*, 73, 44–126.

[4] Ojha, K.; Saha, S.; Banerjee, S.; Ganguli, A. K. Efficient Electrocatalytic Hydrogen Evolution from MoS_2-Functionalized Mo_2N Nanostructures. *ACS Appl. Mater. Interfaces* 2017, *9* , 19455.

Acknowledgement

The authors thank IIT Delhi. PY acknowledges MHRD, India for fellowship through IIT Delhi. AD thanks CSIR Pool scheme for SRA. AKG thanks Nanomission & DST, Govt. of India for financial support.

Department of Chemistry