Fabrication & Characterization of Atomically-Thin Two-Dimensional Crystals

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Abstract

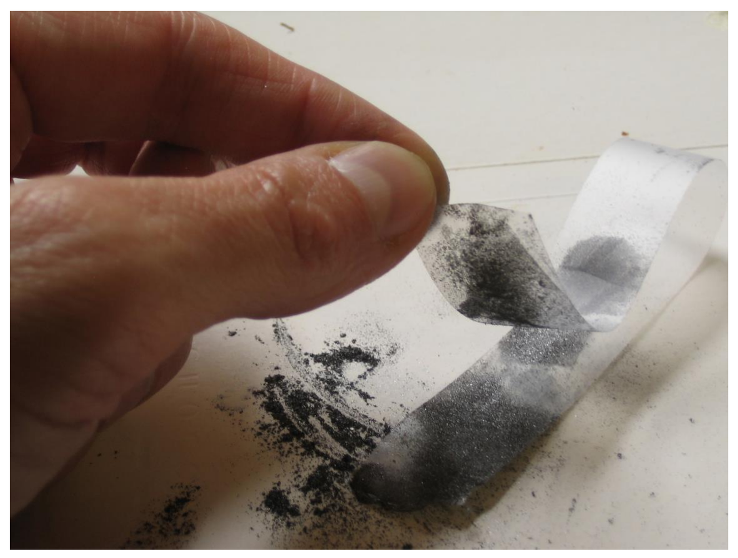
Two-dimensional (2D) materials, like h-BN and graphene, offer an array of unique characteristics and electrical properties. These properties can vary in degree depending on the number of layers that compose each substance. The characteristics of various 2D materials with different layer numbers will be analyzed. Using the mechanical exfoliation method, mono- and few-layer flakes can be produced from bulk crystals with the use of adhesive tape. Once these flakes are produced, they can be transferred onto substrates like SiO2 or quartz. The mono- and few-layer flakes can then be identified with the use of an optical microscope. After ideal flakes have been identified, their characteristics will be tested.

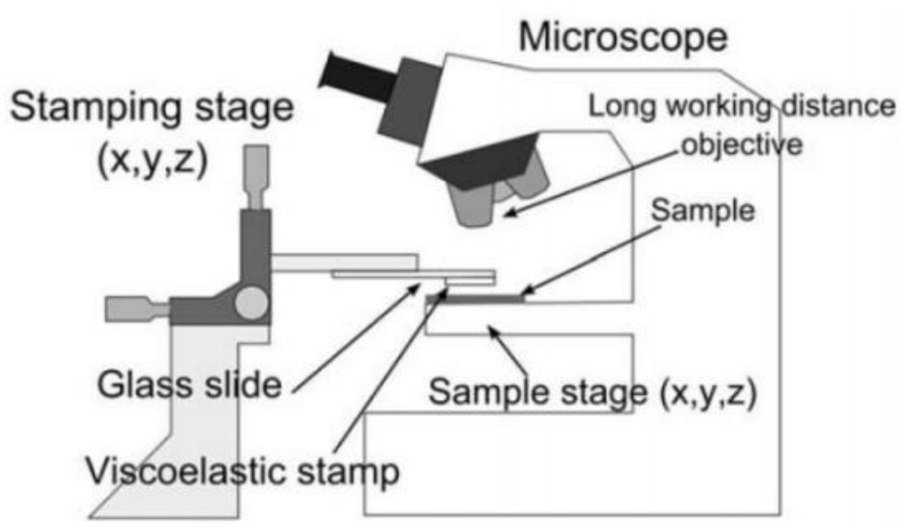
Background

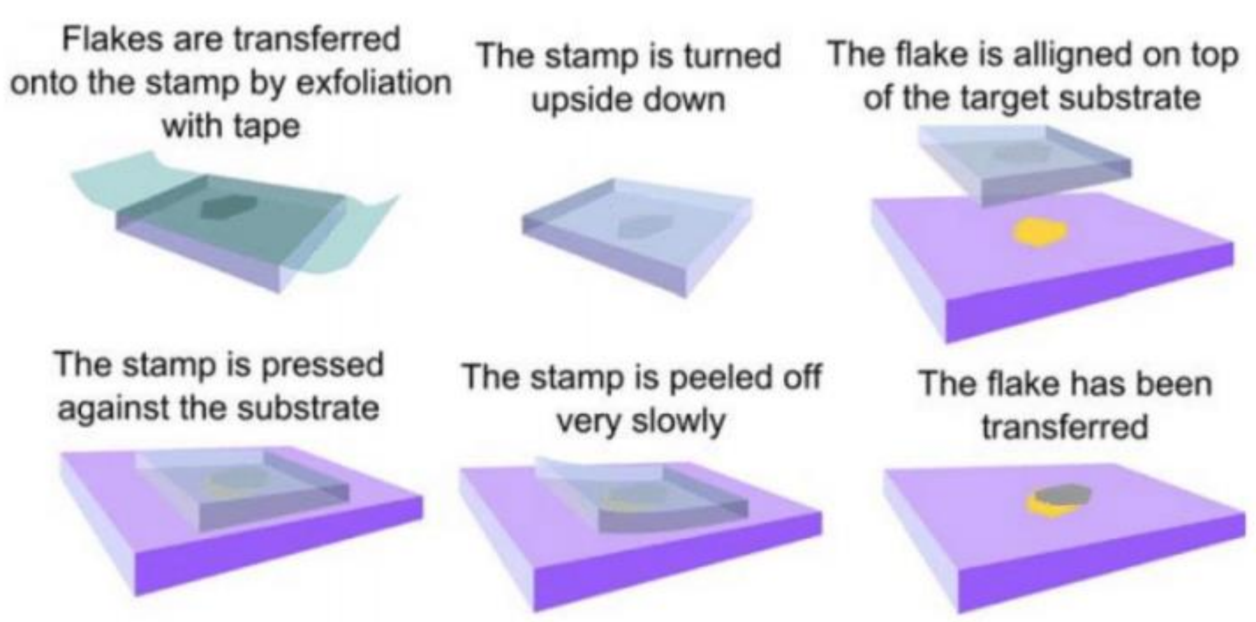
Starting with the discovery of graphene in 2004, by Andre Geim and Konstantin Novoselov, there has been a profusion of research into the study of two-dimensional (2D) materials and their possible applications. Additional two-dimensional materials discovered have even shown insulating and semiconducting properties. Identifying and characterizing more of these materials expands the selection available for current and future applications.

Methods

1. Use tape to exfoliate bulk crystal
2. Exfoliate onto substrate
3. Inspect substrate under optical microscope
4. Using contrast between the flake and substrate determine the thickness
5. Transfer to a different substrate if necessary
6. Characterize material properties using different characterization techniques





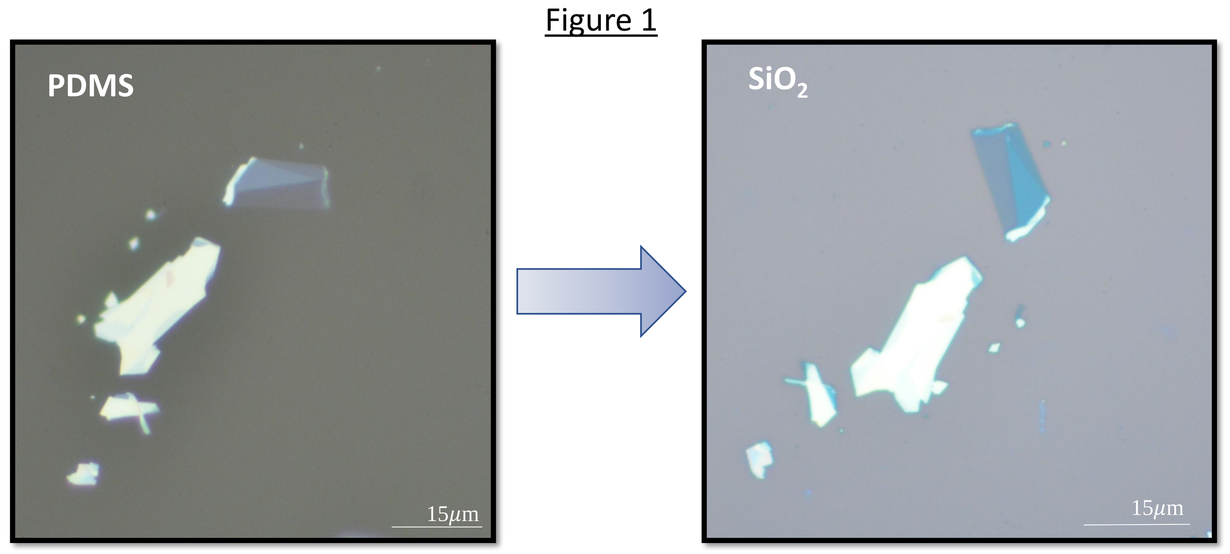


A. Castellanos-Gomez, et al. 2D Materials 1 (2014) 011002

Results

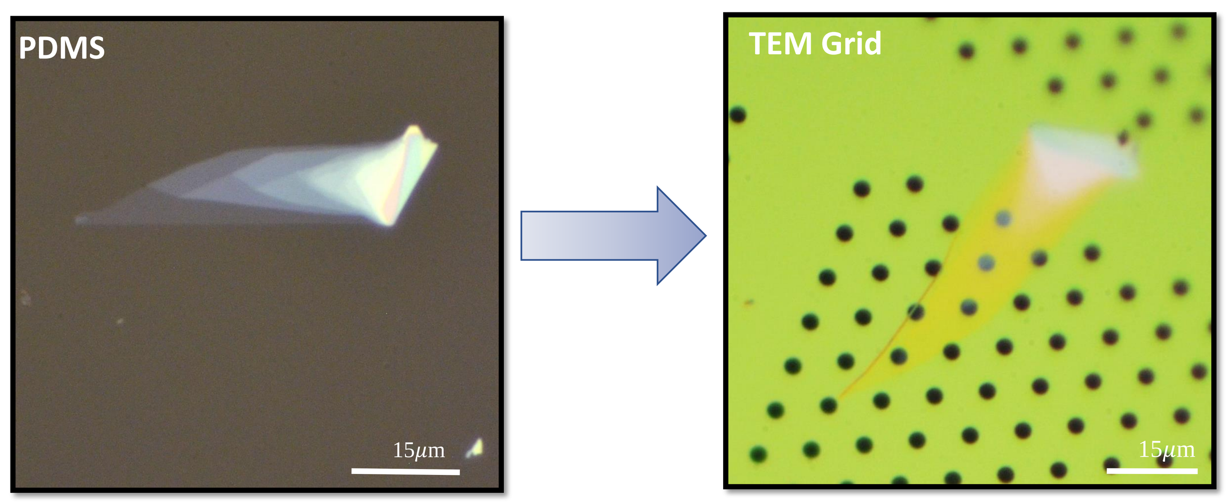
Deterministic Transfer

Figure 1



- Transfer of a flake from PDMS to SiO_2 substrate
- Change in contrast of the flakes can also be noted as it differs depending on the substrate.

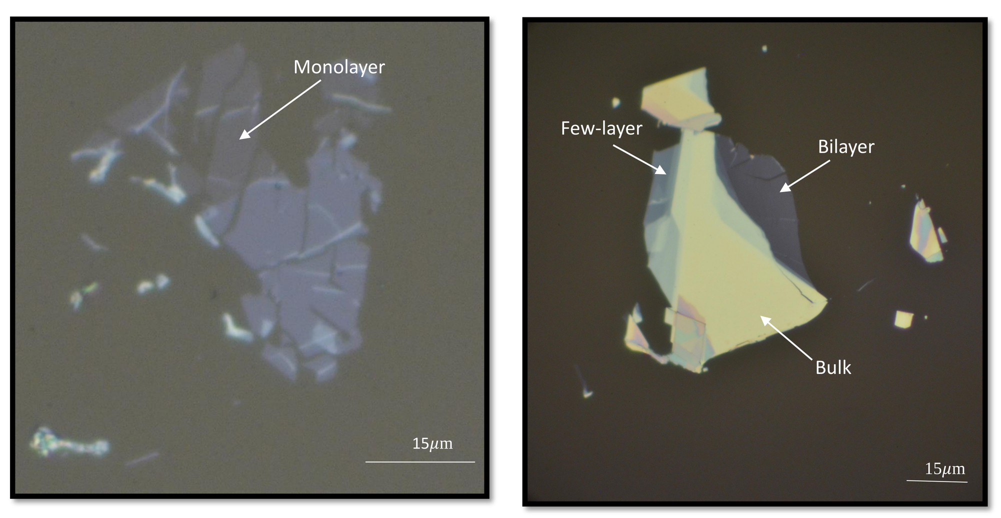
Figure 2



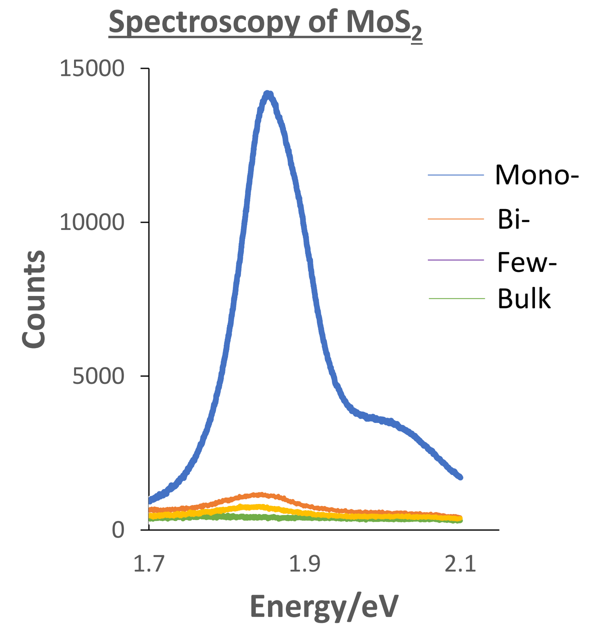
- Transfer of a flake from PDMS to a transmission electron microscope (TEM) grid
- Layers that need to be measured cover holes in the grid
- Characterize the atomic structure and chemistry of 2D materials.

Photoluminescence Measurements

Figure 3



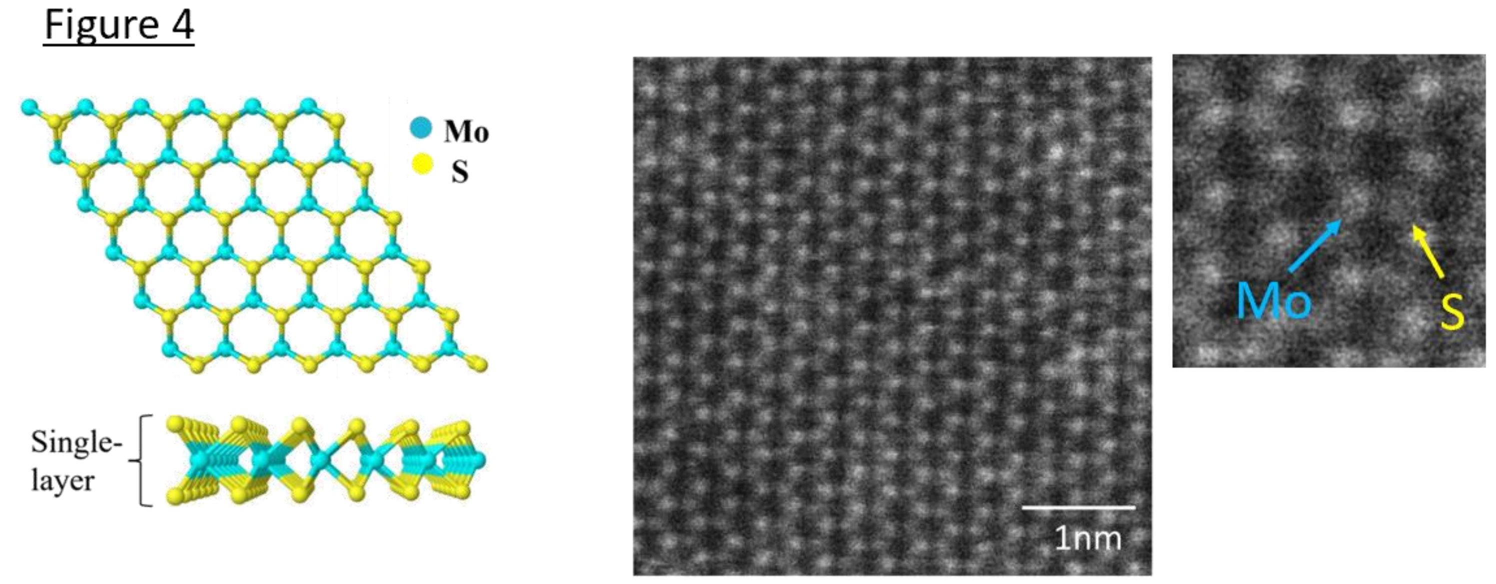
Photoluminescence Spectroscopy of MoS_2



- Enhanced PL intensity of the monolayer MoS_2 is attributed to its direct band gap.

MoS_2 Structure

Figure 4



- Structural model of MoS_2 alongside an ADF-STEM image of MoS_2.

Conclusion

This research verifies the unique properties and characteristics of 2D materials. Through the use of mechanical exfoliation, optical identification and deterministic transfer flakes were able to be tested and analyzed. Analysis of the optical properties displayed the effects that layer number has on the properties of a given material in this case MoS_2. Through further research and investigation it is hoped that one day the unique properties offered by these materials will be able to be fully utilized.

References

[1] Castellanos-Gomez, A., Buscema, M., Molenaar, R., Singh, V., Janssen, L., Van Der Zant, H. S. J., & Steele, G. A. (2014). Deterministic transfer of two-dimensional materials by all-dry viscoelastic stamping. *2D Materials*, *1*(1). https://doi.org/10.1088/2053-1583/1/1/011002

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