Exfoliation of MoS2

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Introduction

Semiconductors have been topic of discussion in the field of science for many years, and it's only going to grow. The discovery of graphene has encouraged many researchers and scientists to focus more on semiconductors. Molybdenum disulfide is a semiconductor that has one atom of Molybdenum and two atoms of sulfide. It's caught the attention of many scientists due to its large bandgap (~1.8 eV) and distinctive structures which makes it a suitable substitute for graphene and other semiconductor devices. It has many different applications which include biosensors, optical sensors as well as energy applications such as battery cells, microwaves, etc.

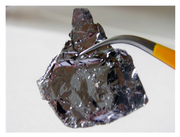


Figure 1: A hexagonal piece of MoS2 with a lateral size of 15- x 20mm

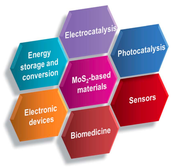


Figure 2: MoS2 based applications

Methodology

There are many methods to exfoliate and achieve monolayers of MoS2. Some of the popular methods are mechanical exfoliation, chemical vapor deposition, and atomic layer deposition. Each method has its own advantages and disadvantages and is used based on these relative merits. In the table below, we can see the advantages and disadvantages of these various methods

Method	Advanatages	Disadvantages
Mechanical exfoliation	great for lab use, suitable for fabricating individual devices	Low yield, uncertain layer numbers
Chemical vapor deposition	controllable size and layers large scale	High temperature
Atomic layer deposition	High Quality, Uniformity	High material waste, Time consuming

Objective

The main goal of this project is to read and discuss articles about Molybdenum Disulfide. To exfoliate MoS2, we used mechanical exfoliation to exfoliate and use an optical microscope to find monolayers.

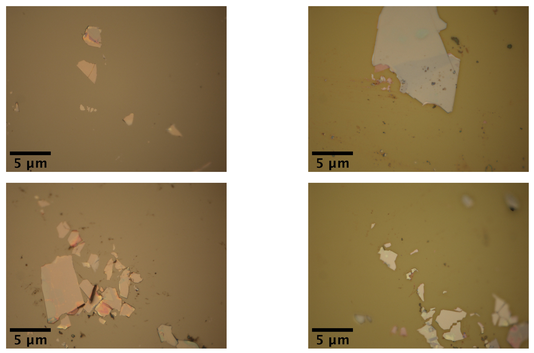
Mechanical Exfoliation

Scotch Tape Method

- Clean your working area with wipes and wear gloves
- Break the substrate (SiO2) into appropriate sizes
- Wash it off with isopropyl alcohol and dry them (use tweezers when washing them)
- Take your MoS2 and peel it off with scotch tape (color tape)
- Repeat this step multiple times to get very thing layers
- After you thin layers, press it against the substrate
- Slowly and very carefully, remove the tape from the substrate
- Wash it off again to remove any dust particles

Example of the scotch tape method with SiO2 substrate

Results/Findings



Microscopic images of mechanically exfoliated MoS2 flakes on a SiO2 substrate. The contrast in colors differentiates the multilayers from single and double layers

Analysis

Using mechanical exfoliation, I was able to obtain very few monolayers as it was very difficult to differentiate using an optical microscope. Using the 100x microscope, we could the shades of pinkish red contrast as it shows the different layers. Mechanical exfoliation gives a low yield as we're only using a very small amount of MoS2. The weak Vander Walts forces between the layers allow the layers to peel off and we could see the different layers by contrast

Applications

MoS2 has the potential to be a part of many electronic, biosensing, and energy devices. It has good biocompatibility and bio absorbability which can be used to detect cancer, Alzheimer, and even Coronavirus. It's use in electronic devices can vary as it can be used be in analogue circuits as well as ax-ray imaging devices. Using its biosensing capability, we can detect DNA, cancer biomarkers, and amino acids.

Mastery

- Reading and discussing articles about semiconductors
- Mastery of optical microscopy
- Exfoliation of a semiconductor

Conclusion

MoS2 is a promising semiconductor that is known for its wide range of applications. Its properties and bandgap allow it to be used in biosensing, energy, and electronic applications. There are many challenges with the exfoliating techniques such as the impurities and lattice imperfections of MoS2. Future work in the exfoliation of semiconductors could be useful for finding further exfoliation techniques. The purpose of this research internship is to exfoliate semiconductors and learn about their characteristics. This project has helped me learn various skillsets from learning about semiconductors to identifying monolayers. I learned how to exfoliate a monolayer of MoS2 from bulk layer as well as identifying them.

Future Work

Even though there are many ways to obtain MoS2 flakes, it's still very hard to control and maintain the size and quantity of the flakes. Further work needs to be done in order to get the specific parameters such as how many times you should peel off the MoS2, its size and shape, and the time spent on exfoliating monolayers. Atomic Force Microscopy (AFM) can be used in the future to accurately measure the number of layers and can help find more characteristics of these MoS2 flakes.

References

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