Automated Mechanical Exfoliation of Few Layer MoS2 and MoTe2

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Abstract

Two-dimensional materials are of great interest due to their unique electronic and optical properties. Graphene has received much attention for its excellent electron mobility and other unique properties. Its use as a gas sensing material has also been tested due to its excellent surface to volume ratio[1]. Unfortunately, graphene lacks the semiconducting properties that gas sensing layers (such as indium tin oxide) traditionally possess[2]. Molybdenum disulfide (MoS_2) is another two dimensional material that is analogous to graphene in its lattice structure and is made of stacked layers of molybdenum sandwiched between layers of bonded sulfur. However, bulk MoS_2 has an indirect band gap of 1.2 eV while monolayer MoS_2 has a direct band gap of 1.8 eV. Molybdenum ditelluride ($MoTe_2$) is a similar material to MoS_2, made of tellurium layers, taking sulfur's place, and sharing the lattice structure of MoS_2 and graphene. $MoTe_2$ has an indirect band gap of 0.86 eV in bulk and a direct band gap of 1.8 eV as a monolayer, reinforcing its similarity to MoS_2. These two materials have potential for use in applications such as gas sensing[2, 3] where a semiconducting film is more useful than a material with no band gap. One of the challenges of using two dimensional films in devices such as gas sensors is the difficulty of mass producing these materials at an acceptable quality and performance level. The methods of producing few layer films of MoS_2 or $MoTe_2$ currently include mechanical exfoliation and chemical vapor deposition (CVD) or other growth techniques. Mechanical exfoliation stands out not only for not being a chemically driven growth technique but also for its ability to produce pristine films of two dimensional materials[4]. However, mechanical exfoliation is hard to reproduce and produces small sample footprints. A programmable machine would be useful for adding consistency to the technique of mechanical exfoliation. A rheometer is a tool which can apply stresses to soft solid materials and gather data about their mechanical properties. This makes it a candidate to reproduce the pressing and peeling of flake-covered pieces of adhesive that is normally done by hand to achieve mechanical exfoliation. We show that automating the mechanical exfoliation using a rheometer adds greatly to the reproducibility of this fabrication technique. It also establishes machine parameters that can be varied to optimize and standardize a mechanical exfoliation recipe for that machine.

References

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Figures

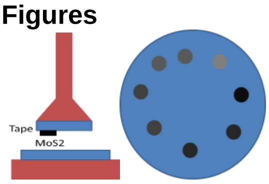

Figure 1: The rheometer presses together and peels apart pieces of tape while the rheometer rotates between each exfoliation. This results in progressively thinner sheets of material down to only a few molecular layers.

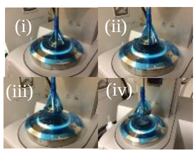

Figure 2: Rheometer tool and stage as the two pieces of tape are brought into contact and then peeled apart.

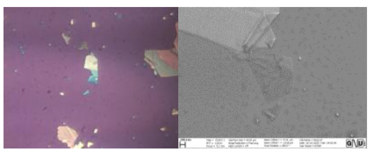

Figure 3: Optical and SEM images of a monolayers MoS_2 flake.

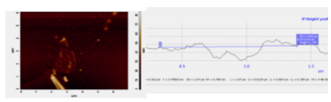

Figure 4: AFM image of monolayer MoS_2 flake an height profile of monolayer MoS_2 flake.