Crack-Free Transition Metal Dichalcogenide Monolayers for Large-Area Optoelectronic Applications

Tsegereda Esatu, Sujay Desai, Ali Javey

Electrical Engineering and Computer Sciences, University of California, Berkeley

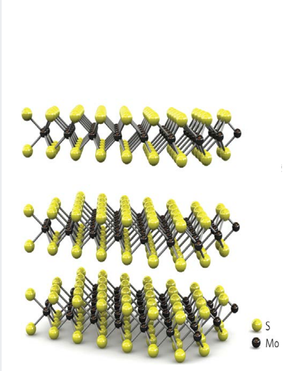
Abstract

Semiconducting transitional metal dichalcogenides (TMDCs) like MoS_2 have attracted immense interest for application in electronic and optoelectronic devices. Gold mediated exfoliation yields ultra large (≈500 µm) size MoS_2 monolayer flakes. These flakes however may be prone to cracking, which mitigates their application for large area electronics. Here, we aim to optimize the gold-mediated exfoliation method to produce high quality, large, crack-free exfoliated monolayers.

Background

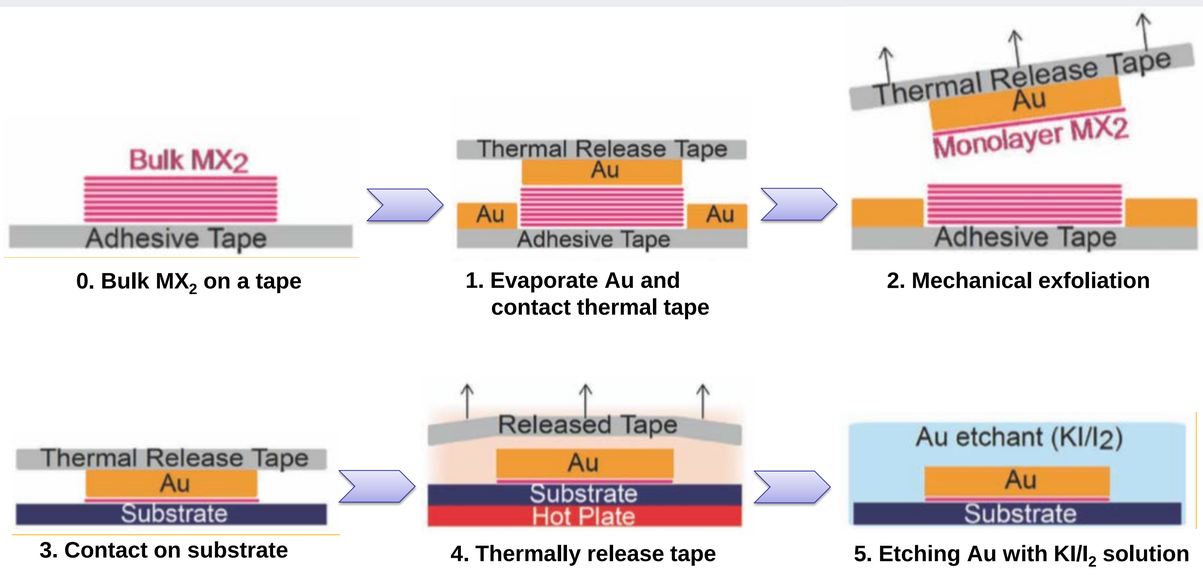
Monolayers of transitional metal dichalcogenides (TMDCs) have attracted a wide range of research interests due to their sizeable bandgaps (≈1–2 eV), atomic scale thickness (≈0.7 nm), and low dielectric constant (≈4). Moreover, the direct bandgap of monolayers of TMDCs, such as MoS_2, WS_2, WSe_2, and $MoSe_2$, guarantee promising applications of transistors, laser diodes, photodetectors and electroluminescent devices.

Among several exfoliation techniques, gold-mediated exfoliation is one of the methods which yields large area monolayers of TMDCs.

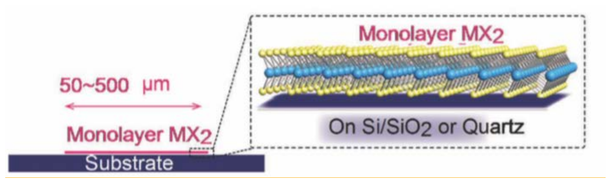


Method

Gold-Mediated Exfoliation



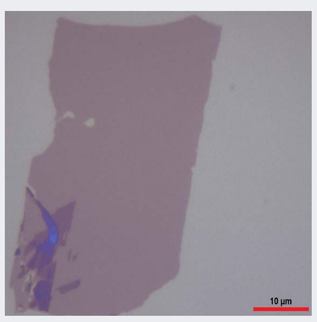
0. Bulk MX_2 on a tape
1. Evaporate Au and contact thermal tape
2. Mechanical exfoliation
3. Contact on substrate
4. Thermally release tape
5. Etching Au with KI/I_2 solution



6. Monolayer on substrate

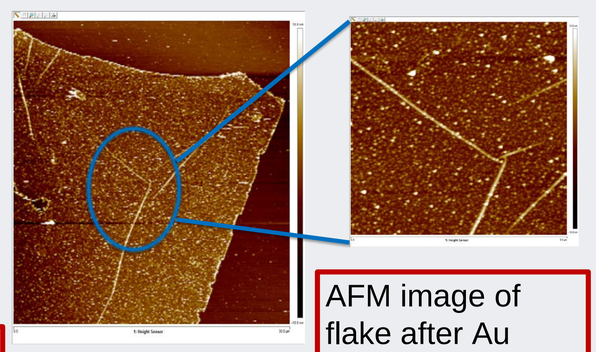
Gold Nanoparticles Decoration

Au nanoparticles (NPs) selectively decor edges of cracks.



Optical Image of MoS_2 flake

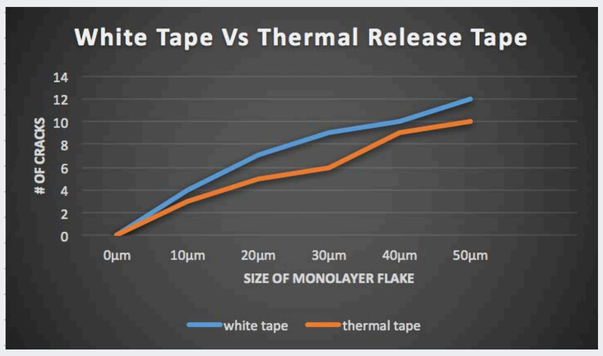
AFM image of flake before Au NPs decoration



AFM image of flake after Au NPS

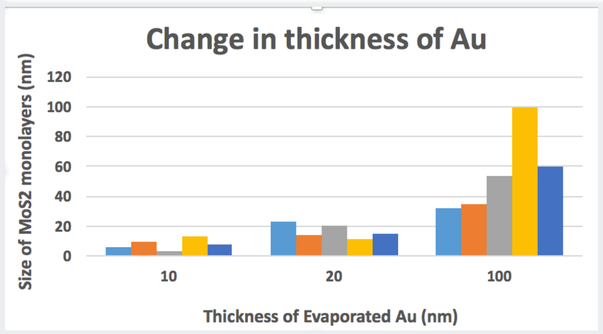
Results

1. Replacing Adhesive Tape



- White adhesive tape, used for gold-exfoliation method, is replaced by thermal release tape.

2. Change in Thickness of Gold



- As the thickness of evaporated gold increases, the size of the monolayer also increases.
- 10 nm and 20 nm of gold are very thin to exfoliate large area flakes.

3. Annealing

- Large number of small-sized Au nanoparticles nucleating on bulk MoS_2
- This technique increments the quantity of large size flakes (≈50-70µm) per specific area.

Conclusion

- Gold- mediated exfoliation method uses the strong interaction of Au and chalcogens to produce large areas of monolayer TMDCs.
- Au NPs are used to selectively mark the edges of cracks.
- Stiffer surface of thermal tape helps reducing cracks of flakes.
- The propensity of crakes increases as thickness of gold decreases.
- Quick annealing of gold enables the production of large monolayer.

Next Steps

- Use other metals for exfoliation (Ag, Pd, etc.)
- Evaporating in low temperature using Cryo – evaporator.

References

1. Sujay B. Desai, et al. *Gold-Mediated Exfoliation of Ultralarge Optoelectronically-Perfect Monolayers,* (2016).
2. Yumeng Shi, et al. *Selective Decoration of Au Nanoparticles on Monolayer MoS2 Single Crystals,* (2013).

Acknowledgement

1. Professor Ali Javey and Sujay Dasia, for their supervision and continued support during the project.
2. E^3S and UCB HBCU for their undergraduate research opportunities in the form of Summer Undergraduate Research Program.

Contact Information
Tsegereda K. Esatu
tsegesatu@yahoo.com

Center for Energy Efficient Electronics Science