Polymer-Free Anodic Oxidation Nanolithography of Monolayer Transition Metal Dichalcogenides

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Abstract

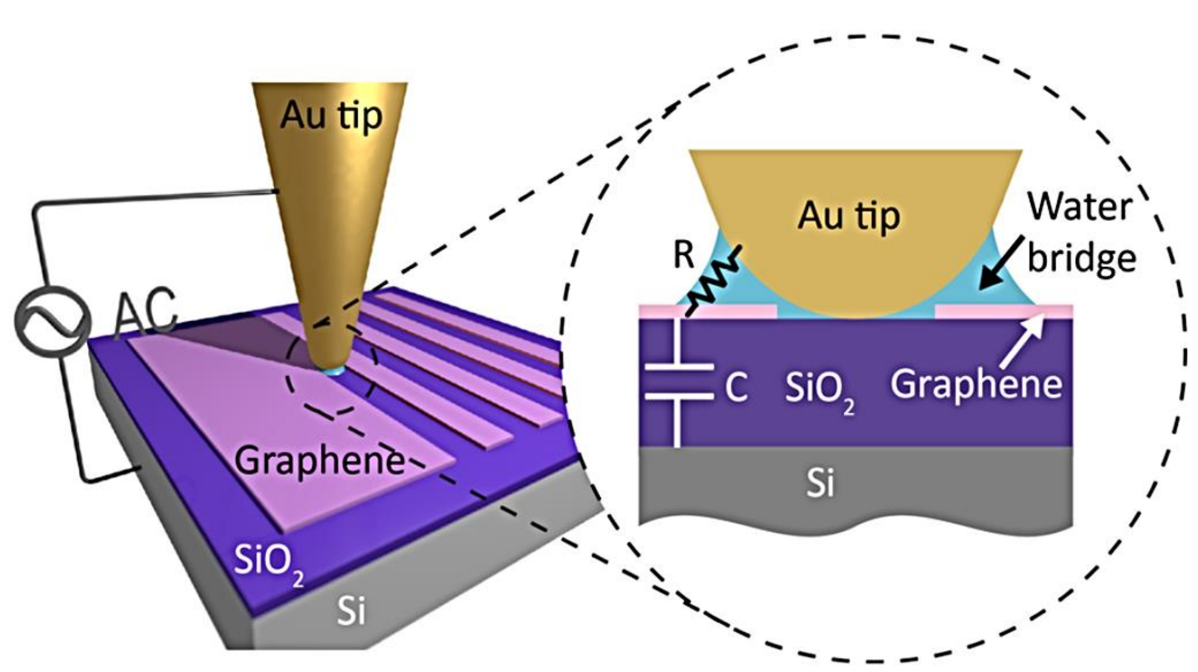
- Two-dimensional Transition Metal Dichalcogenides (TMDs) have high mechanical flexibility with desired electrical and optical properties for electronics applications.
- Precision in shaping monolayer TMDs remains a challenge, as the reliance on polymers for e-beam lithography introduces unwarranted contamination.
- Successful optimization of parameters allowed us to demonstrate a polymer-free, electrode-free flexible nanolithography on monolayer TMDs, thereby bolstering the fabrication of nanoscale devices and heterostructures.

Research Aim

- The objective of this research is to replicate the high-quality etching from the polymer-free anodic oxidation nanolithography method known for exceptional results for graphene on monolayer TMDs.
- Our hypothesis is that modifying parameters such as tip velocity and frequency will optimize precision and quality.

Methods

- Monolayer WSe_2 is exfoliated on the SiO_2 chip.
- An atomic force microscope (AFM) is augmented with a humidifier to form the water bridge between the conductive tip and monolayer TMD.
- AC voltage is applied through the SiO_2/Si to drive the electrochemical reaction within the water bridge.
- Platinum-plated AFM tip approaches the surface to begin scanning and produce the desired nano etching.



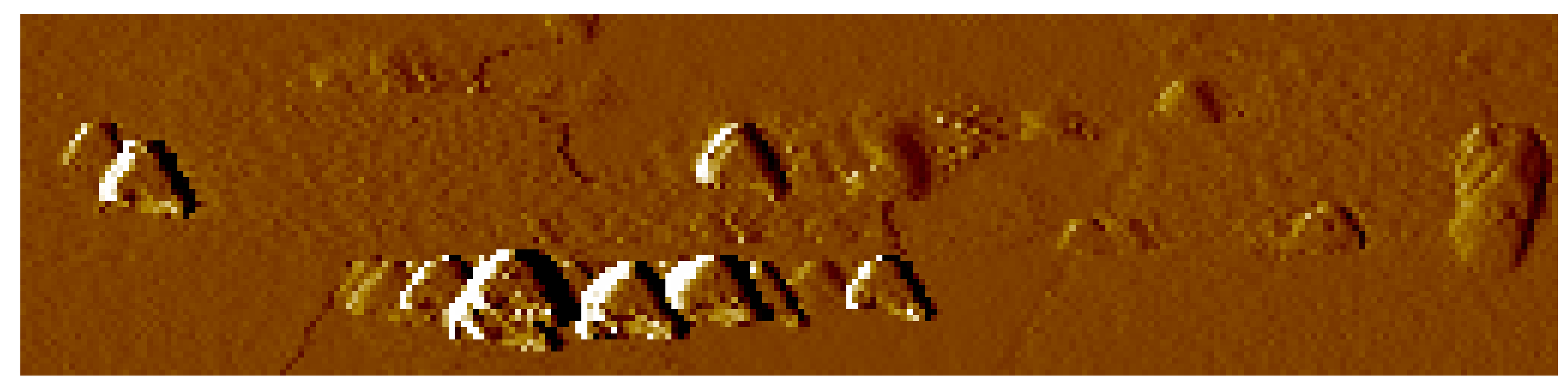
Visual description of the setup replicated for this study

Problem Setup

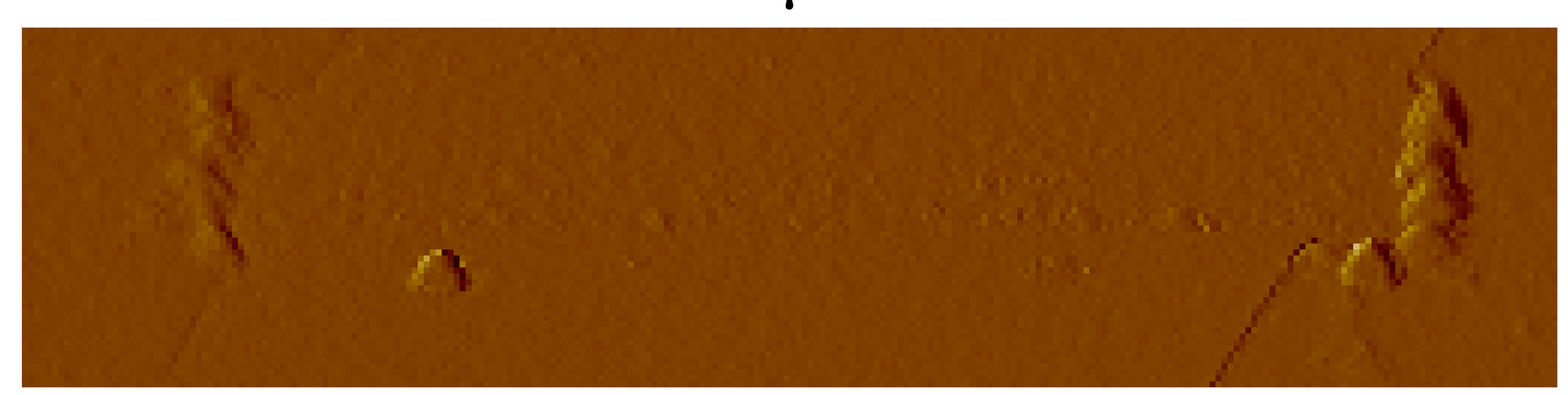
- During this study, the control parameters are as follows; drive voltage = 10 V, and humidity = 55-60%.
- The change in the value of scan rate, and voltage frequency is demonstrated to prove their effects on the residues and overall etching quality.

Results

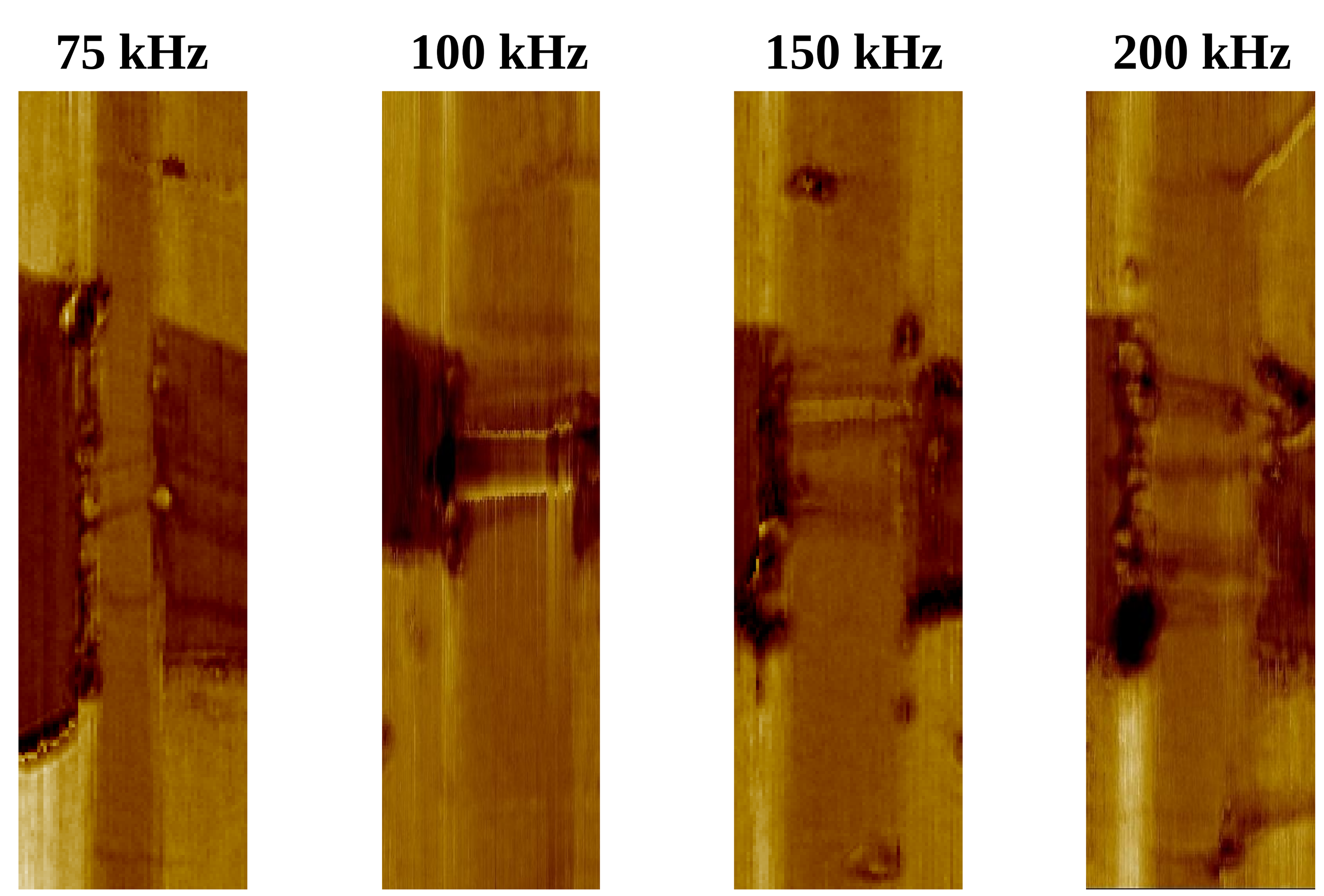
1.05 µm/s



0.35 µm/s

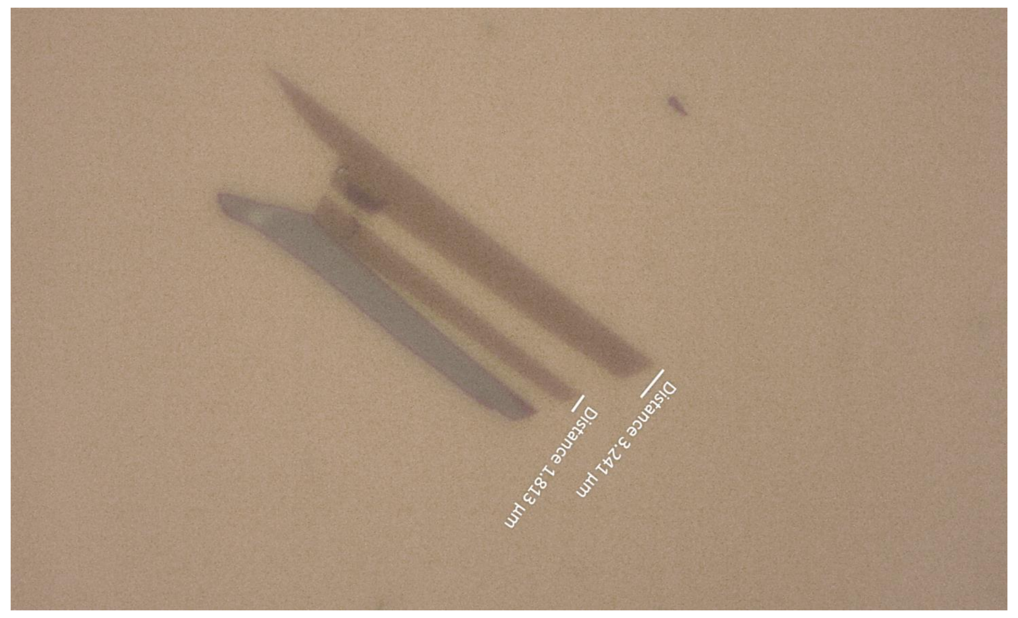


AFM images of etched WSe_2 with varying tip velocities

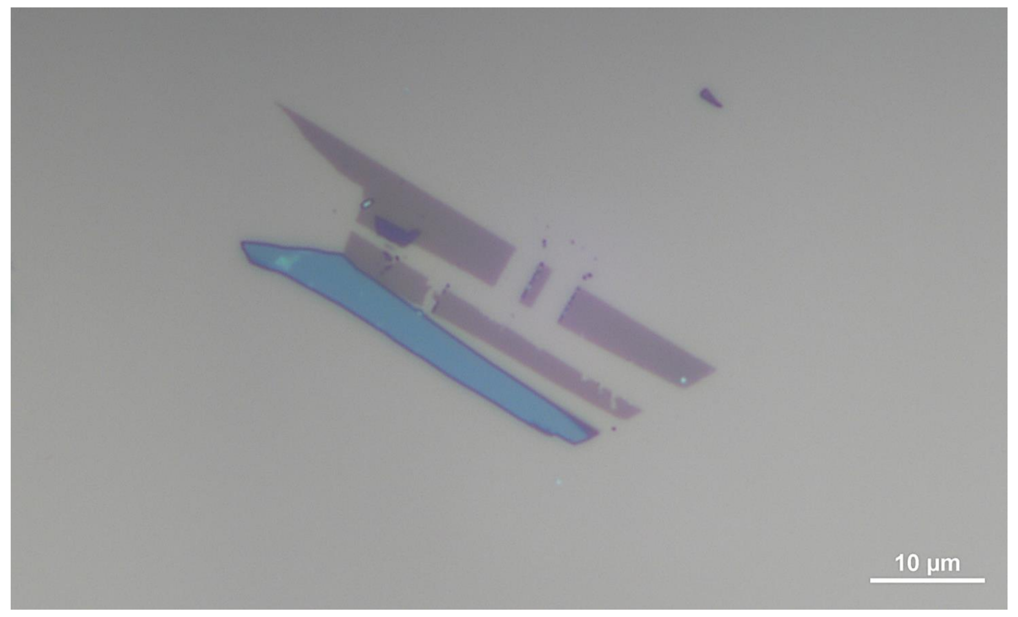


AFM images of etched WSe_2 with increasing frequency

Results



Optical image of WSe_2: before scanning probe lithography



Optical image of WSe_2: after scanning probe lithography

Conclusion

- Decreasing the scan rate will produce far less residue.
- Optimal voltage frequency for etching quality is 75 kHz.
- Hypothesis is proven correct as fluctuating the parameters can benefit this application of nanolithography.
- We have achieved promising results for high-quality etching on monolayer TMDs; however, more studies are needed to further optimize the process.

References

Li, H., Ying, Z., Lyu, B., Deng, A., Wang, L., Taniguchi, T., Watanabe, K., & Shi, Z. (2018). Electrode-free anodic oxidation nanolithography of low-dimensional materials. *Nano Letters*, *18*(12), 8011–8015.

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