Polymer-Free Anodic Oxidation Nanolithography of Monolayer Transition Metal Dichalcogenides

Katherine Alcazar[1], Zhiying Wang[2], and James Hone[2]

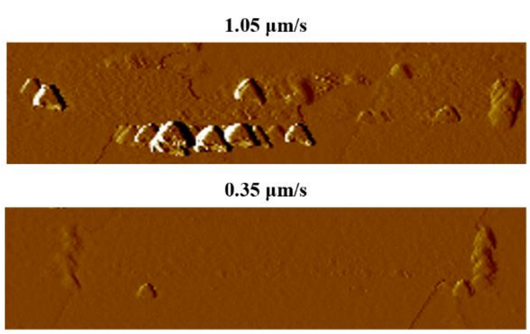
[1] Department of Aerospace and Mechanical Engineering, Ira A. Fulton Schools of Engineering, Arizona State University, Tempe, AZ

[2] Department of Mechanical Engineering, Fu Foundation School of Engineering and Applied Science, Columbia University, New York, NY

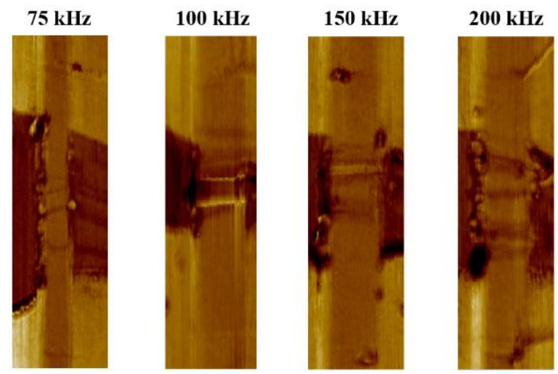
Introduction: Two-dimensional Transition Metal Dichalcogenides (TMDs) have high mechanical flexibility with desirable electrical and optical properties, which have shown great potential for application in electronics and optoelectronics. However, the precision and accuracy in shaping monolayer TMDs remains a challenge. Although e-beam lithography provides a commendable accuracy in etching TMDs, its reliance on polymers introduces unwarranted contamination. Scanning probe lithography combined with local anodic oxidation, known for its exceptional etching quality on graphene leaving no oxide residues, has shown great promise. The objective of this research is to realize the high-quality etching on monolayer TMDs by using the polymer-free anodic oxidation nanolithography method. The atomic force microscope is controlled to include varying conditions to optimize precision and quality. The successful optimization of parameters including voltage frequency, and tip velocity allowed us to demonstrate a polymer-free, electrode-free flexible nanolithography on monolayer TMDs, thereby bolstering the fabrication of nanoscale devices and heterostructures.

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.

Results:



AFM image of etched WSe_2 with varying scan rates



AFM image of etched WSe_2 with increasing frequency

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. The optimal frequency for etching quality is 75 kHz. Our hypothesis is proven correct as fluctuating the parameters can benefit this application of nanolithography. We have achieved promising results to realize high-quality etching on monolayer TMDs; however, more studies are still needed to further optimize the process.

References: Hongyuan Li, et al, Nano Letters, 2018, 18(12), 8011–8015

Acknowledgments I would like to thank Dr. Hone and Ph.D. candidate Zhiying Wang for their mentorship throughout this research project.