Paul Masih Das[1]
Jothi Priyanka Thiruraman[1,2], Yung-Chien Chou[1], Gopinath Danda[1,2], Marija Drndić[1]
[1]Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, PA, USA
[2]Department of Electrical and Systems Engineering, University of Pennsylvania, Philadelphia, PA, USA

pmasi@sas.upenn.edu

Nanotopography and Ion Transport in Centimeter-Scale MoS_2 Membranes

Nanoporous atomically-thin membranes (NATMs) based on two-dimensional (2D) materials have received attention as catalysts for energy generation and membranes for liquid and gas purification but controlling their porosity and facilitating large-scale production is challenging. In this work, we first show the growth of centimeter-scale molybdenum disulfide (MoS_2) films through a simple sulfurization procedure. Aberration-corrected scanning transmission electron microscopy (AC-STEM) of these films reveals a topography consisting of monolayer grains encased in few-layer thick regions. A semiconductor industry etching technique is then utilized to etch away these thin, primarily monolayer areas with tunable porous areas up to ~10% of the membrane and average nanopore diameters as large as ~30 nm. During the etching process, thicker regions essentially remain intact, thus preserving the mechanical robustness of the membrane. Ionic transport measurements through nanoporous membrane devices yield variable ionic conductance values between 0.1 and 16 uS per um^2 as a function of etch time while AC-STEM imaging is used to provide insights into the pore formation mechanism at the atomic scale. By employing the often under-utilized form of 2D materials, this work affords a new route for the scalable production of NATMs.

References

[1] P. Masih Das, J. P. Thiruraman, Y. C. Chou, G. Danda, M. Drndić, Centimeter-Scale Nanoporous 2D Membranes and Ion Transport: Porous MoS_2 Monolayers in a Few-Layer Matrix, Nano Lett. 19 (2019) 392-399.
[2] J. P. Thiruraman, K. Fujisawa, G. Danda, P. Masih Das, T. Zhang, A. Bolotsky, N. Perea-Lopez, A. Nicolai, P. Senet, M. Terrones, M. Drndić, Angstrom-Size Defect Creation and Ionic Transport through Pores in Single-Layer MoS_2, Nano Lett. 18 (2018) 1651-1659.
[3] G. Danda, P. Masih Das, M. Drndić, Laser-Induced Fabrication of Nanoporous Monolayer WS_2 Membranes, 2D Mats. 5 (2018) 035011.

Figures

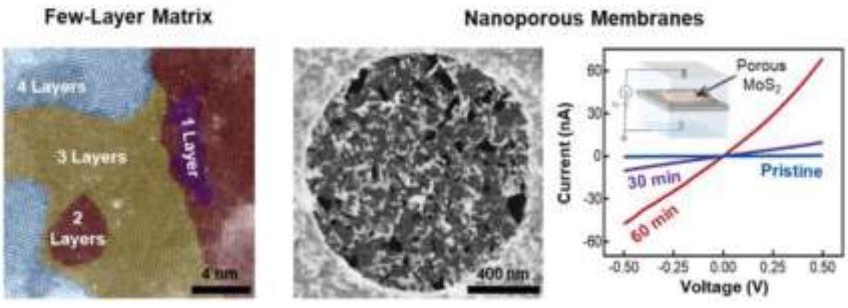

Figure 1: (Left) High-angle annular dark field (HAADF) AC-STEM image of few-layer matrix-like structure in MoS_2 films grown via Mo foil sulfurization. (Middle) Low-magnification AC-STEM image of nanoporous MoS_2 membrane etched for 90 minutes. (Right) Ionic conductance measurements for pristine and variably-etched nanoporous membranes.