Dopamine as a Bridge for Tailoring $Ti_3C_2T_x$ MXene Film Properties

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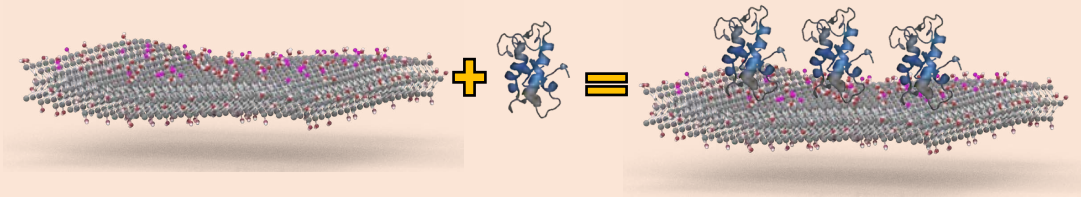
PA #: AFRL-2024-6034

GOAL

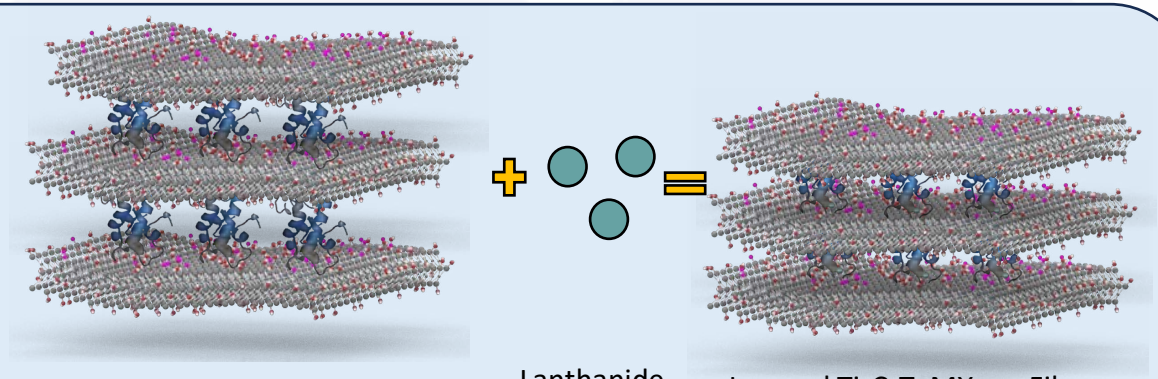
Tune the electrical, mechanical, and optical properties of $Ti_3C_2T_x$ MXene by binding peptides



$Ti_3C_2T_x$ MXene Film | Peptide (LanM) | $Ti_3C_2T_x$ MXene Film and LanM

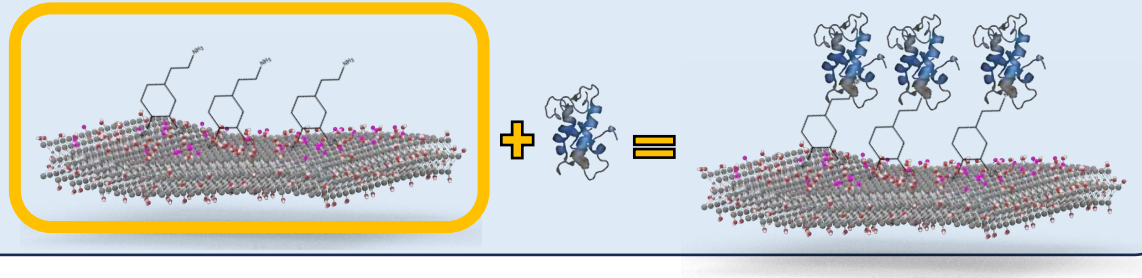
OBJECTIVES

Using LanM's conformational change with lanthanides (e.g. Cerium and Europium) to alter films

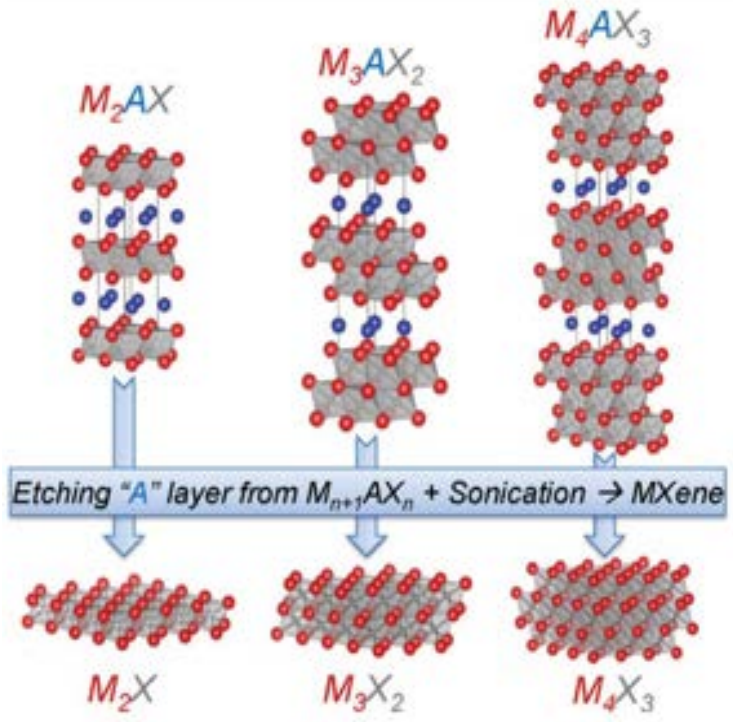


Layered $Ti_3C_2T_x$ MXene Film with LanM | Lanthanide Elements (e.g. EuCl) | Layered $Ti_3C_2T_x$ MXene Film with LanM bound to lanthanides

Bind LanM to MXene with dopamine bridges



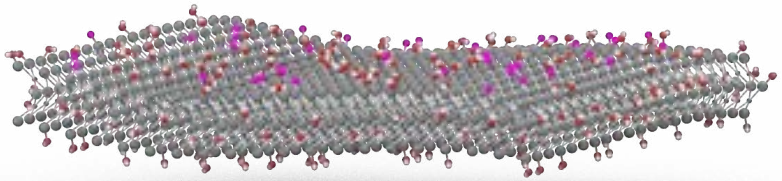
MXene – 2D transition metal carbides/nitrides



Gogotsi, et al. *Advanced Materials* 2014, 26, 992-1005

$M_{n+1}AX_n$, **(MAX)**
M - Early transition metal
A- (mostly IIIA and IVA) element
X - carbon and/or nitrogen.

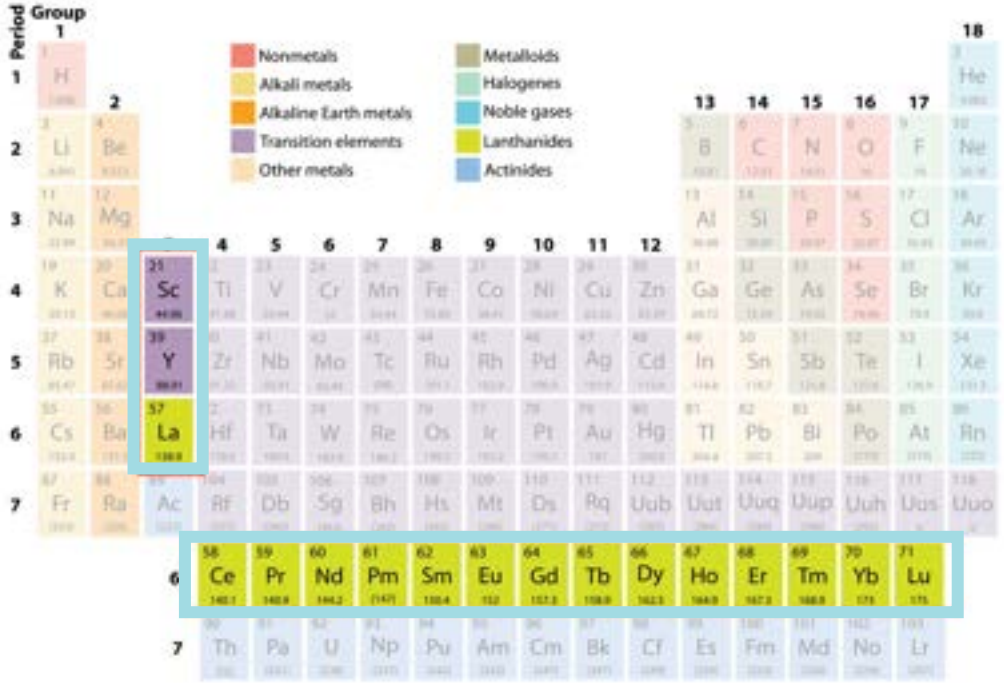
$$M_{n+1}AX_n \rightarrow M_{n+1}X_nT_x$$



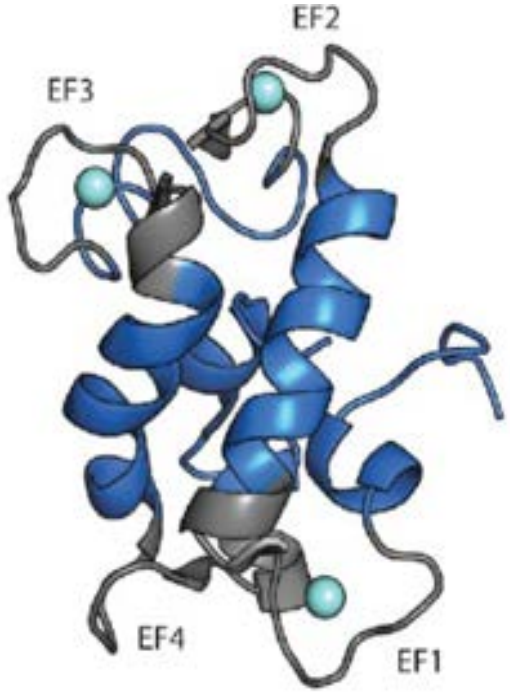
Lipatov et al., Sci. Adv. 2018;4: eaat0491

- ✓ **Highly Conductive**
- ✓ **Excellent Mechanical Properties**
- ✓ **Tailorable optical properties**
- ✓ **Excellent thermal conductivity**
- ✓ **30+ different compositions**
- ✓ **Hydrophilic Surface**

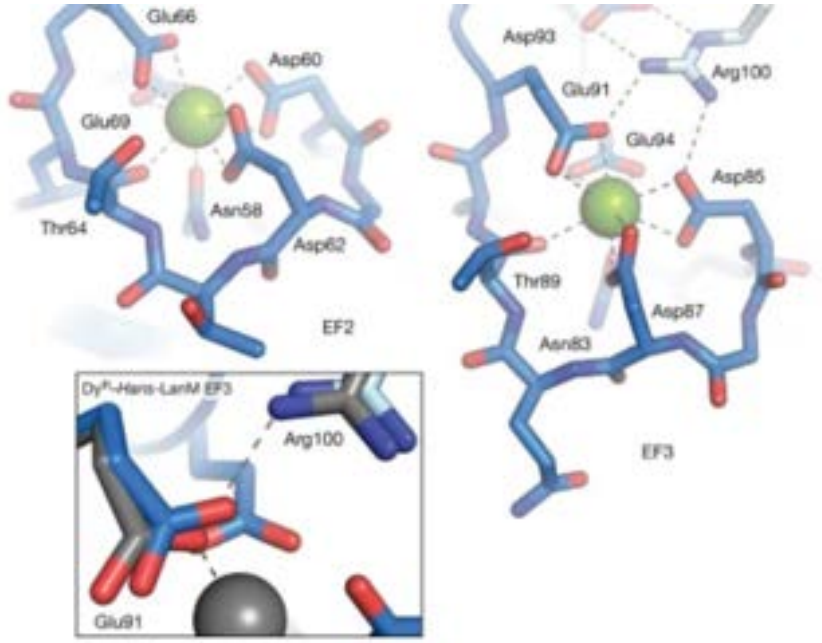
The EF-hands of LanM obtain pico-molarity affinity for lanthanides



Source: Rare Earth Elements (rareelementresources.com)



Lanmodulin as a model system to study biological principles of... | Download Scientific Diagram (researchgate.net)



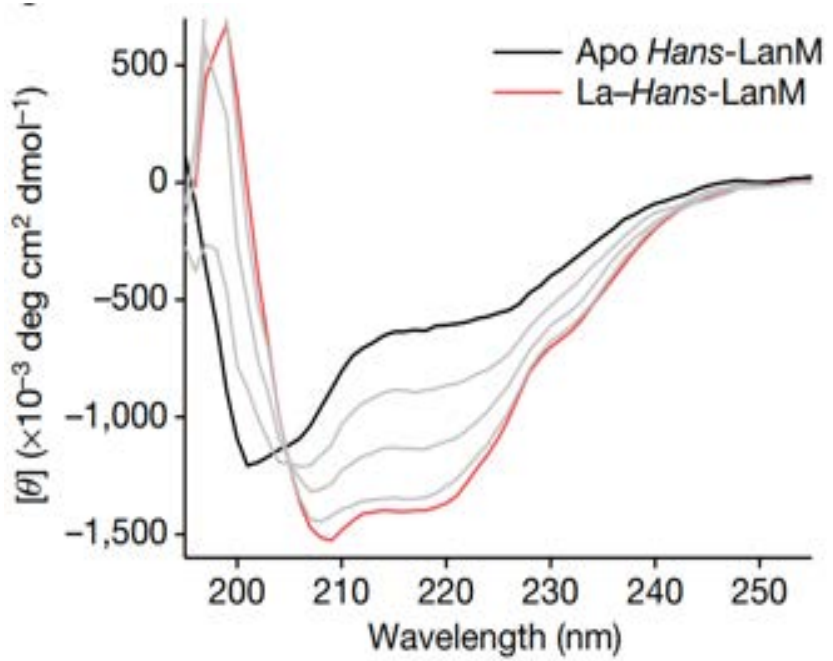
EF1	34	N	K	D	N	D	D	S	L	E	I	A	E	45
EF2	58	N	P	D	G	D	T	T	L	E	S	G	E	69
EF3	83	N	K	D	G	D	Q	T	L	E	M	D	E	94
EF4	107	D	A	N	K	D	G	K	L	T	A	A	E	118

Enhanced rare-earth separation with a metal-sensitive lanmodulin dimer | Nature (oclc.org)

- LanM was discovered in methylotropic bacteria to obtain unique lanthanide binding properties
- The bind occurs at EF hands (12 amino acids that form metal-binding loops)
  - LanM has 4 EF hands, 3 of which have a pico-molarity affinity to lanthanides

Using LanM's conformation change in multilayered MXene films

Using circular dichroism (CD) spectrum, showed meal associated conformational response



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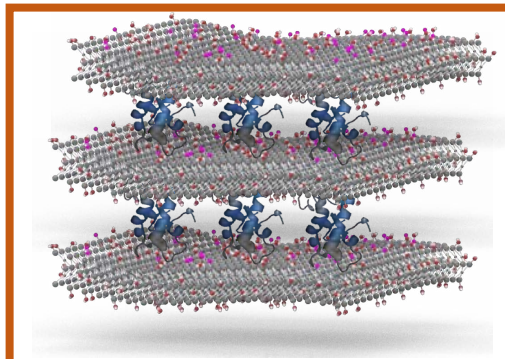
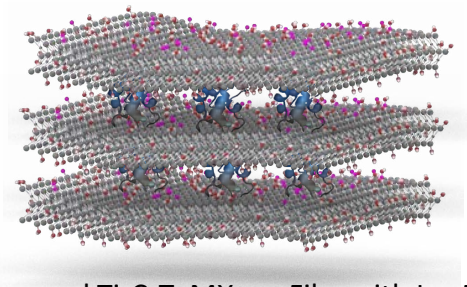
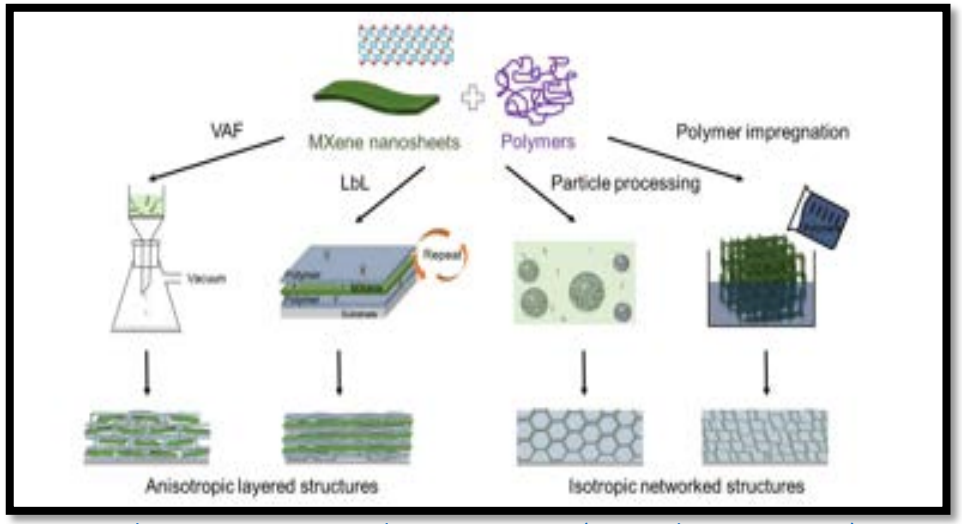


Layered $Ti_3C_2T_x$ MXene Film with LanM

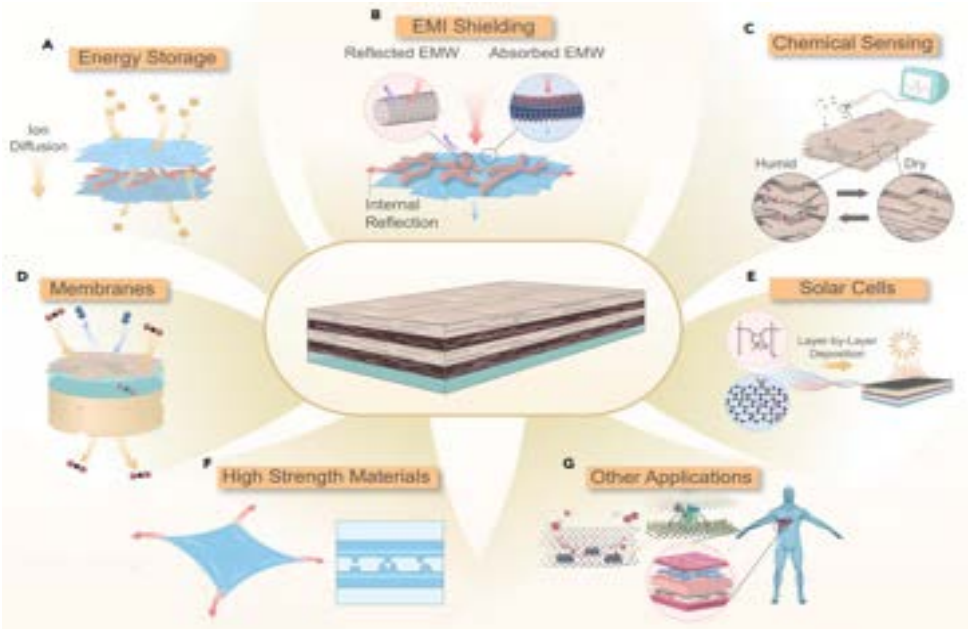
Lanthanide Elements (e.g. EuCl)



Layered $Ti_3C_2T_x$ MXene Film with LanM bound to lanthanides

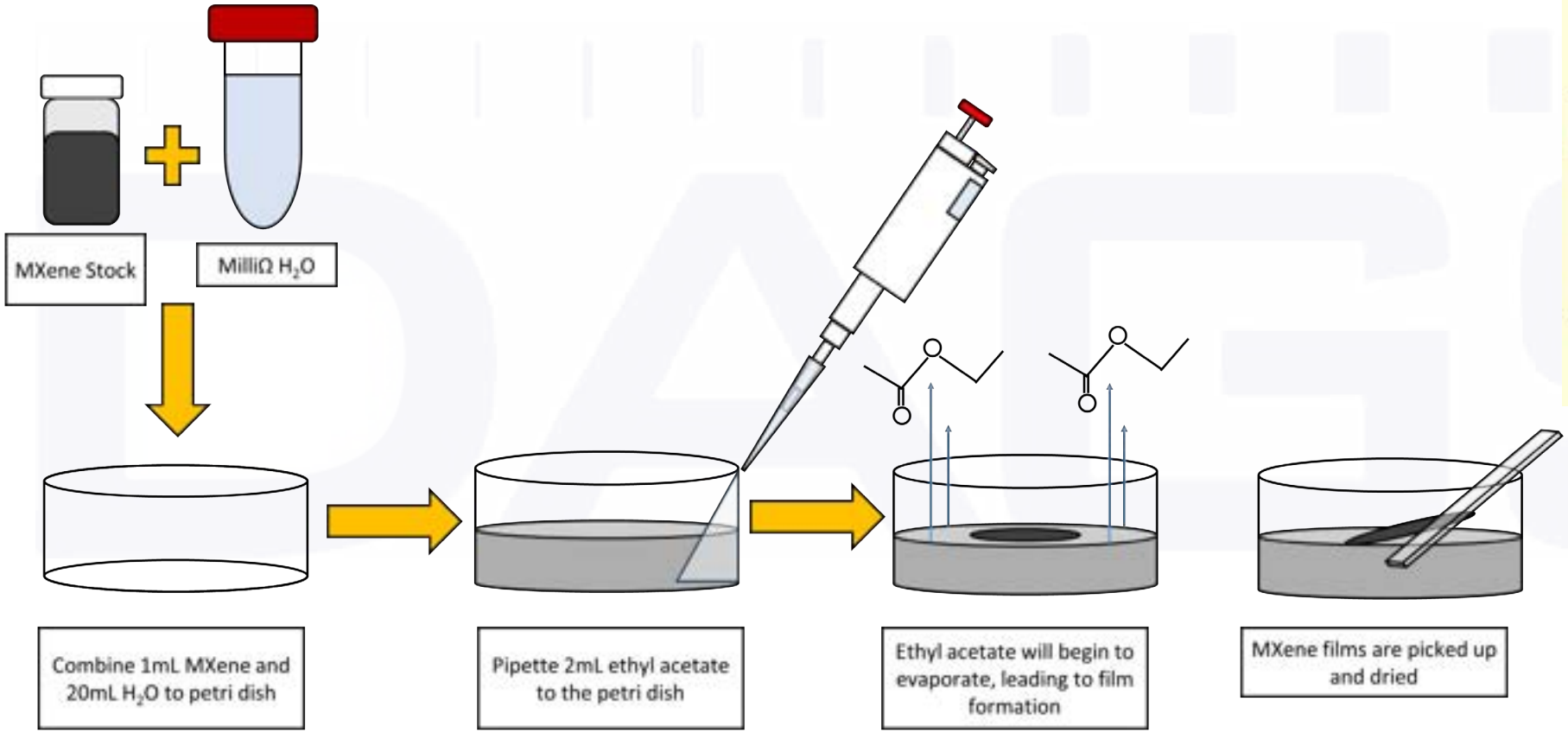


Architecting MXenes in polymer composites (sciencedirectassets.com)

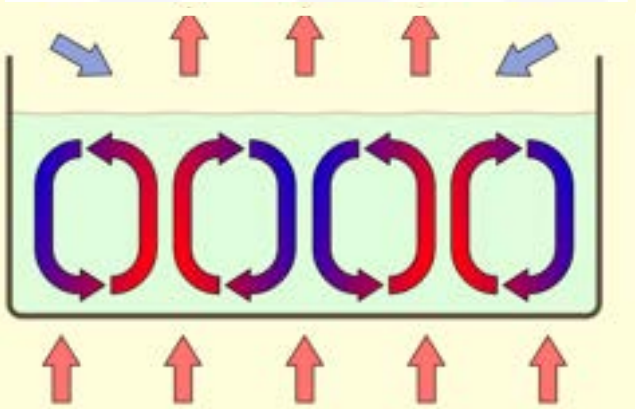


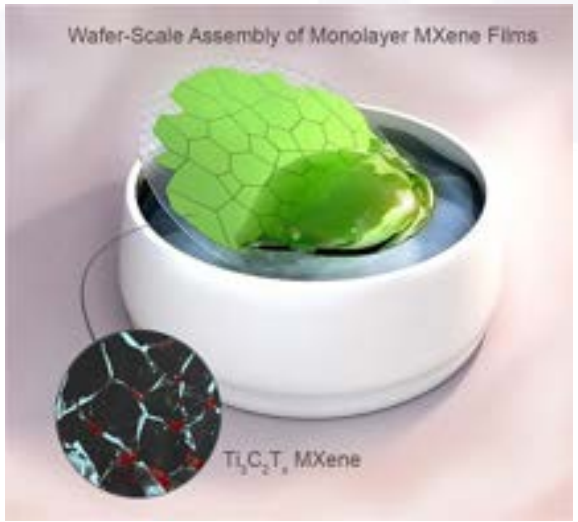
Layer-by-Layer Assembly of Two-Dimensional Materials: Meticulous Control on the Nanoscale (cell.com)

Making $Ti_3C_2T_x$ MXene Films



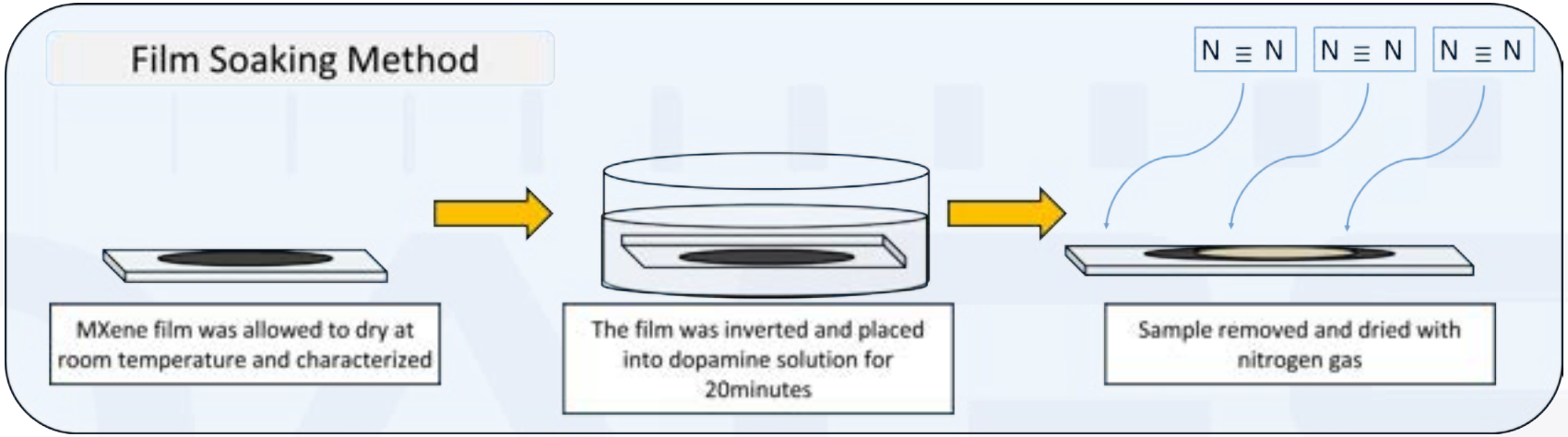
Marangoni Forces induce assembly at the air-liquid interface

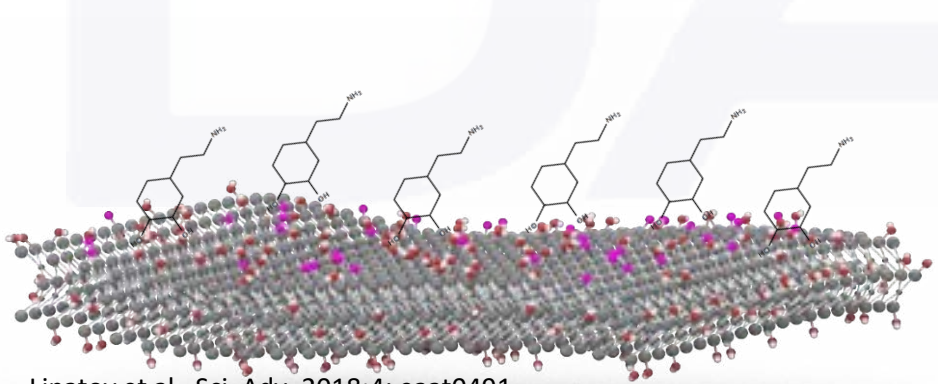




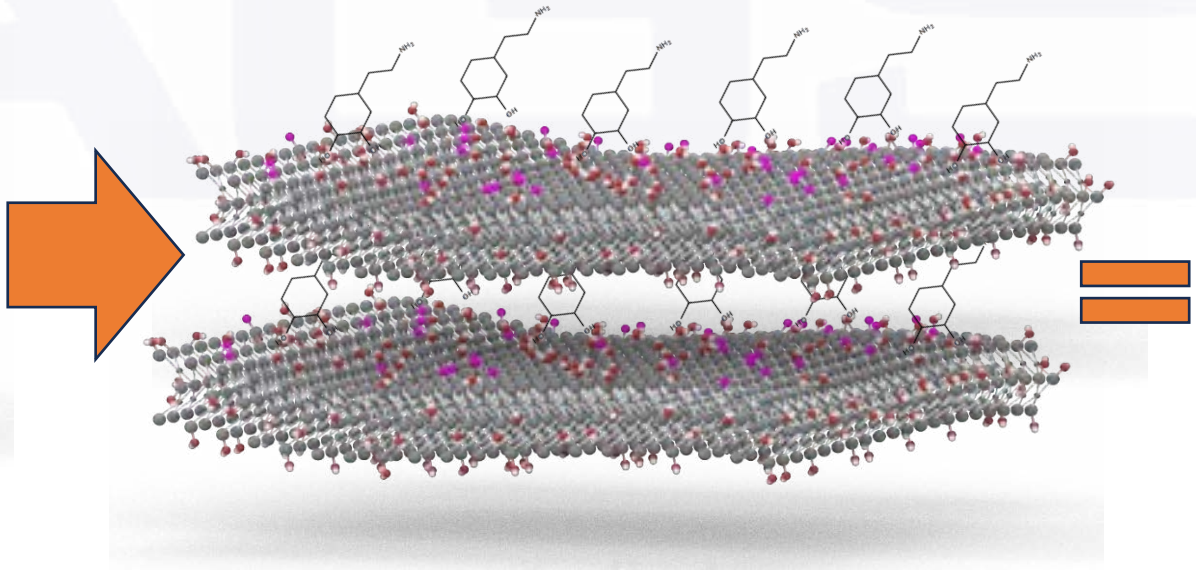
Mojtabavi et. al. *ACS Nano* 2021, 15, 1, 625–636

Functionalization of MXene Surface with Dopamine





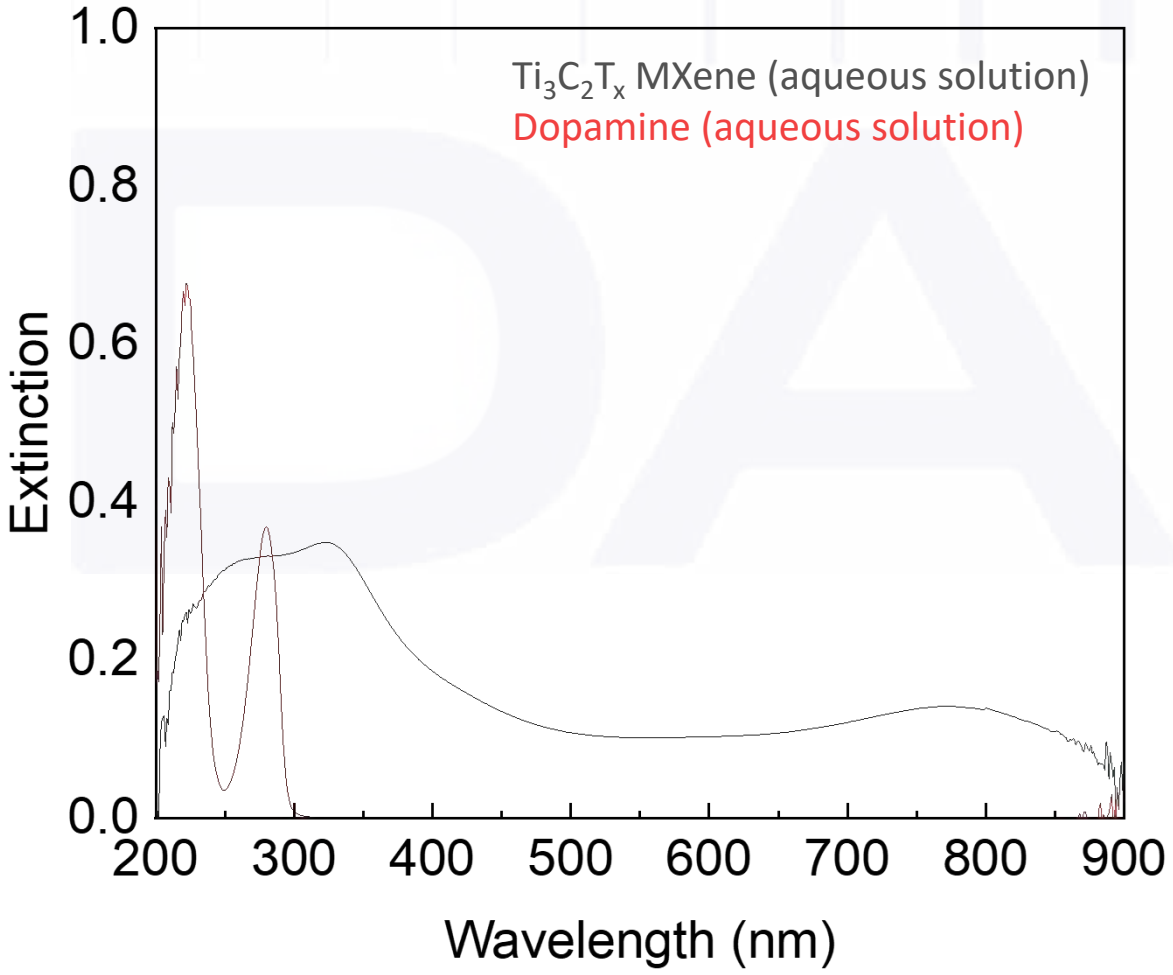
Lipatov et al., Sci. Adv. 2018;4: eaat0491

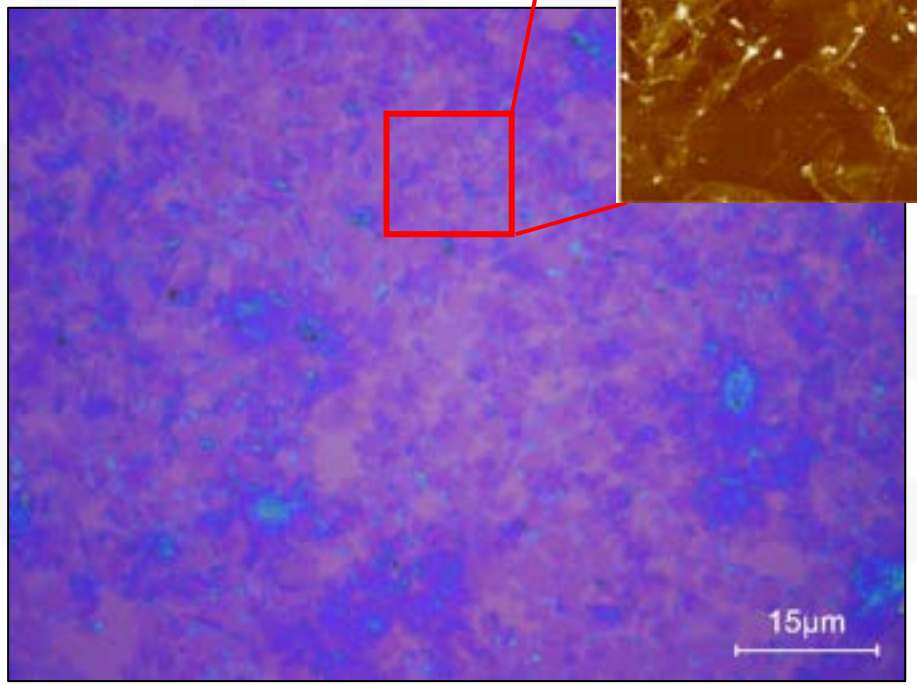


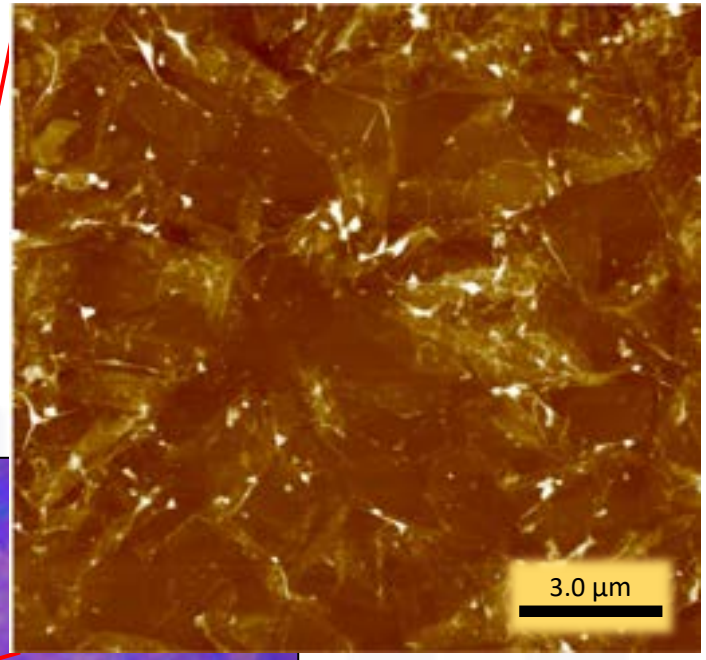
Dopamine
MXene
Dopamine
MXene
Quartz

Characterization of MXene films and Dopamine

UV-Vis Spectra of $Ti_3C_2T_x$ MXene (black) and Dopamine (red) in solution.



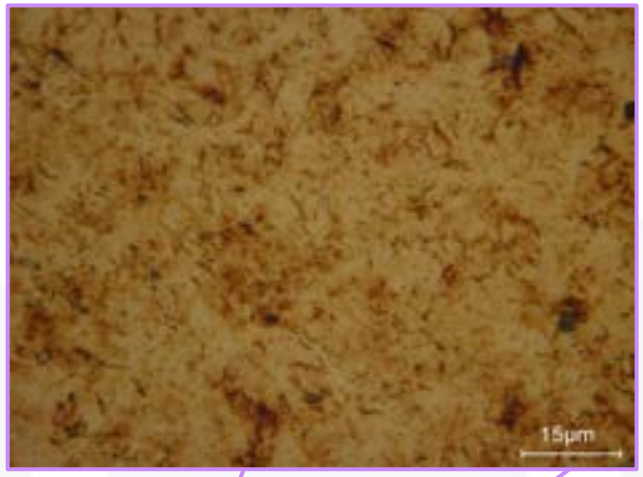


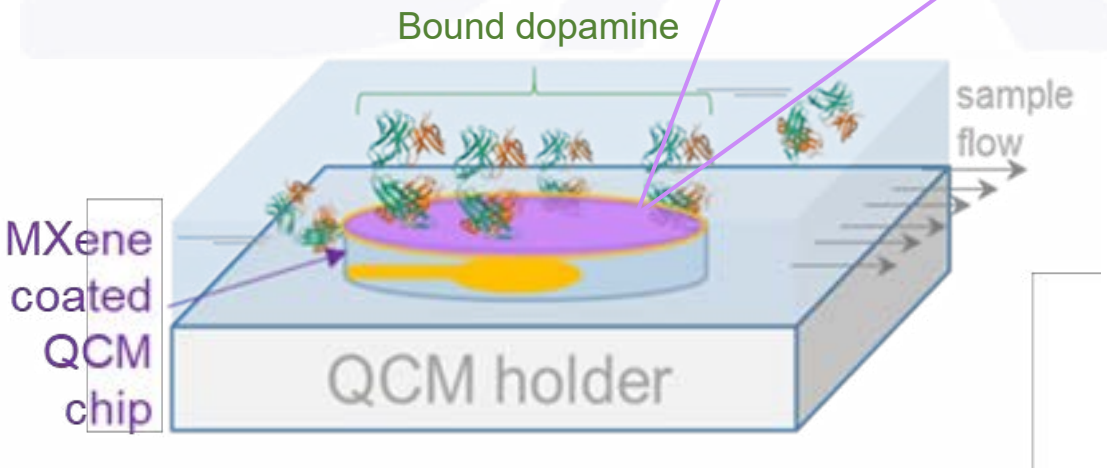


Ultrathin uniform $Ti_3C_2T_x$ MXene film over a large area. (Right Image) Optical image at 150X magnification and (Left Image) AFM topography image zoomed into the film to see individual flakes.

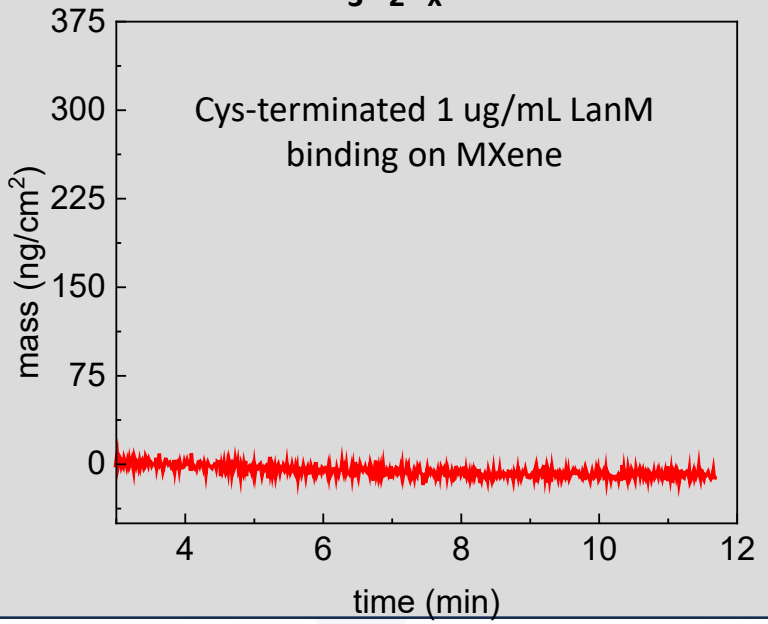
Will Dopamine Bind to $Ti_3C_2T_x$ MXene?

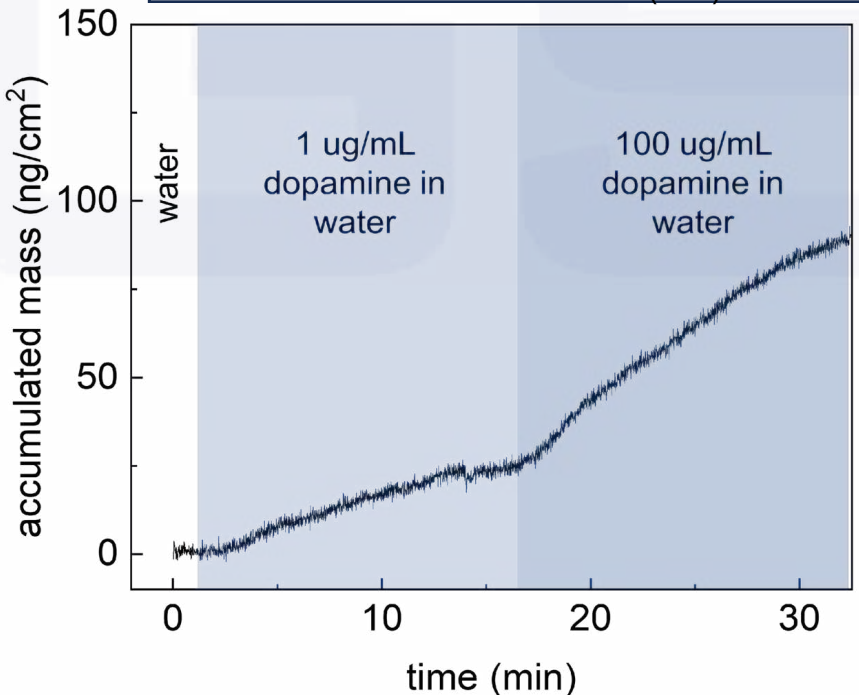
Quartz Crystal Microbalance (QCM) was used to determine surface adhesion of either LanM or dopamine onto $Ti_3C_2T_x$ MXene surface





Determined that LanM does not bind directly to $Ti_3C_2T_x$ MXene

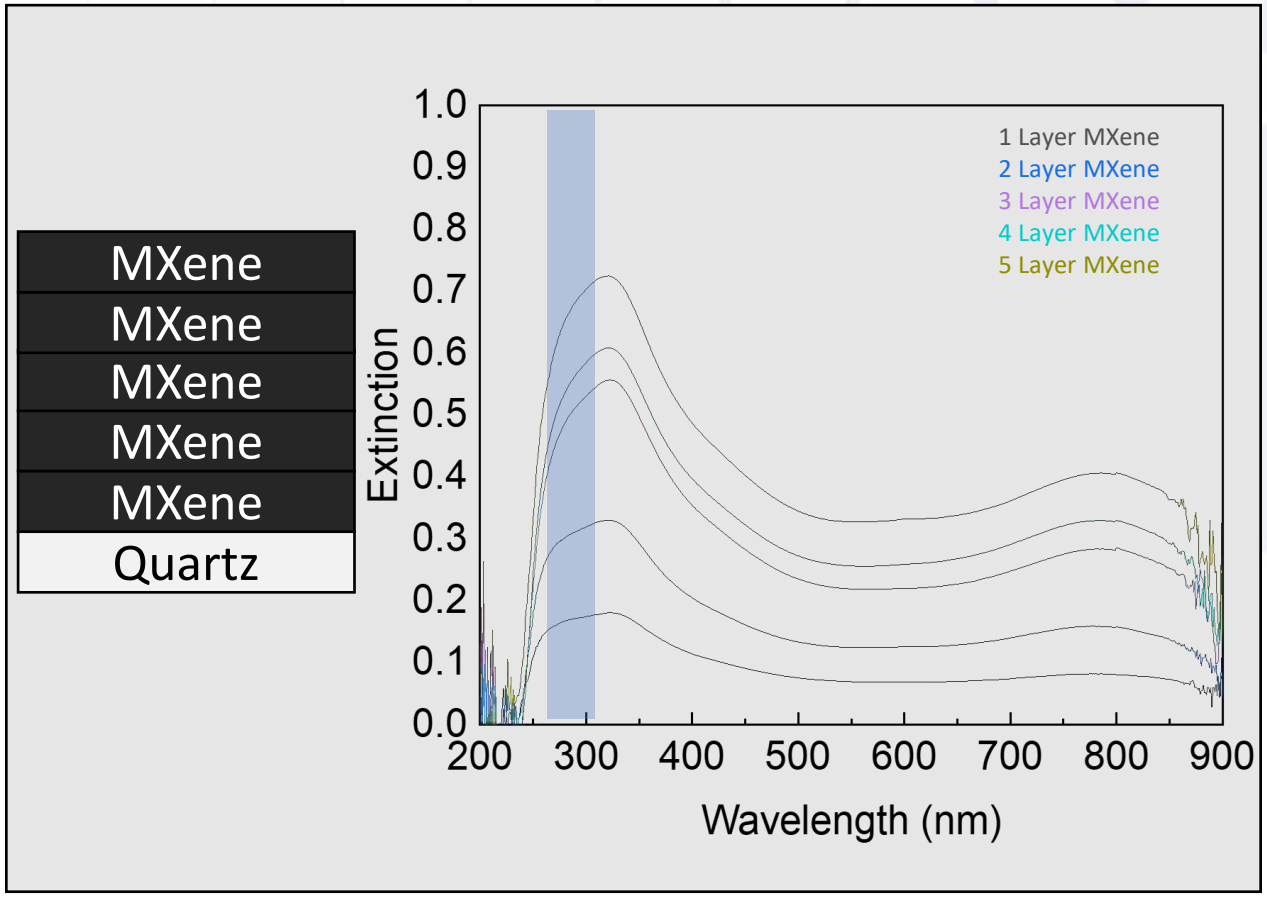


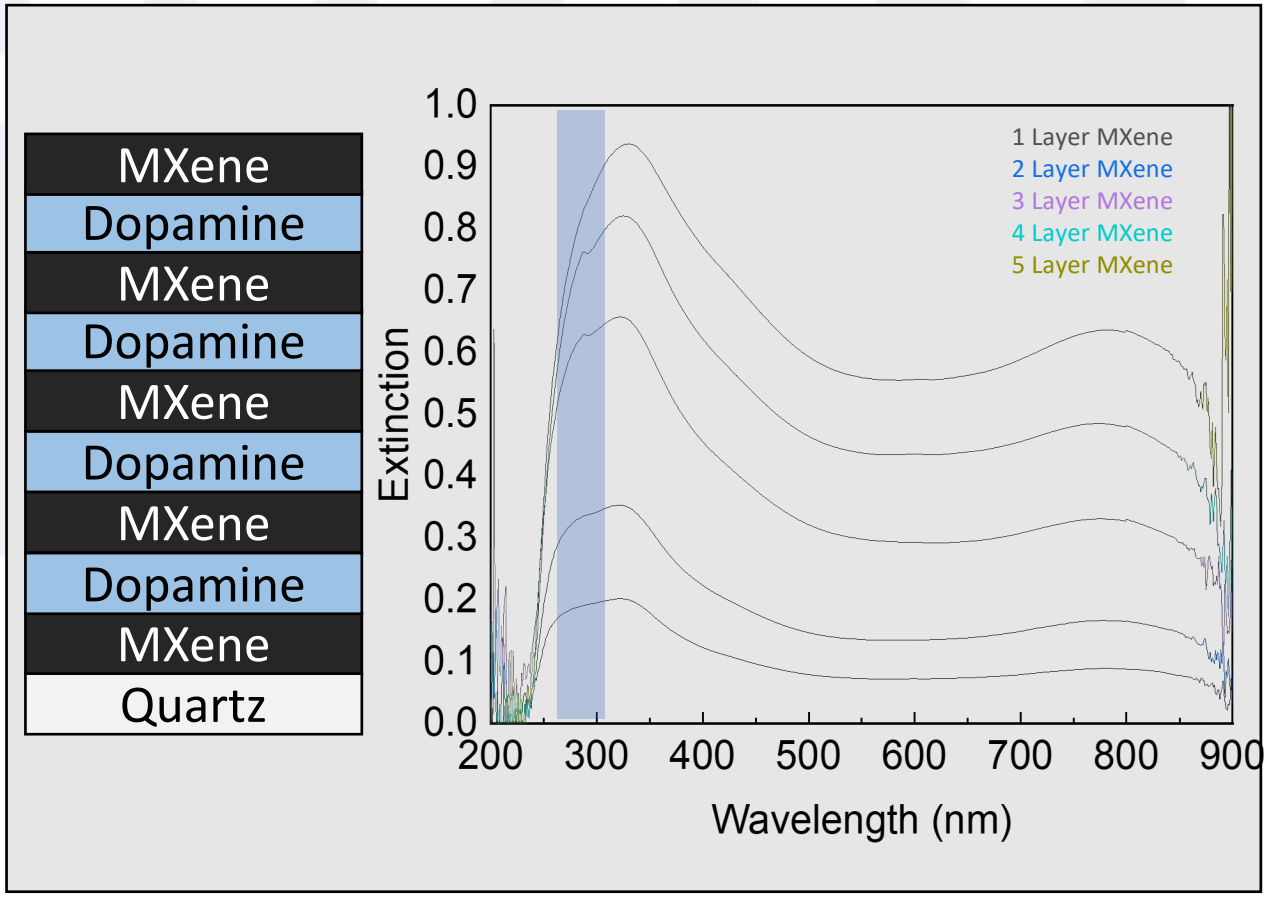


QCM data displayed adhesion of dopamine onto the surface of $Ti_3C_2T_x$ MXene

Characterizing MXene + Dopamine Layered Films

UV-Vis Spectra was taken to monitor layer growth

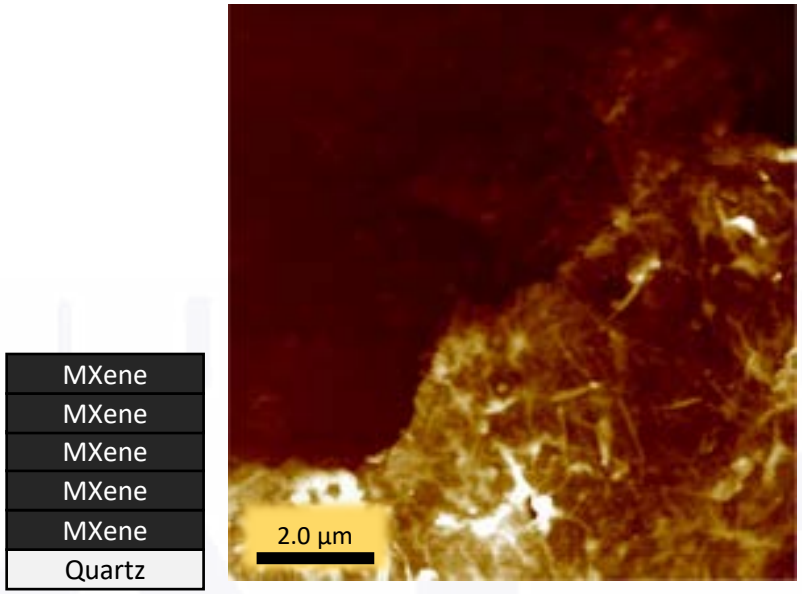


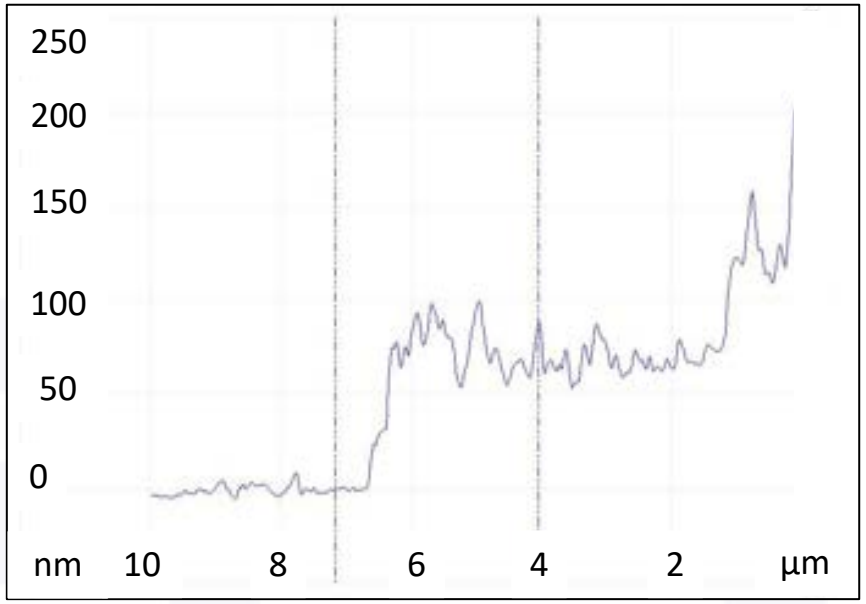


Height Changes with the Presence of Dopamine

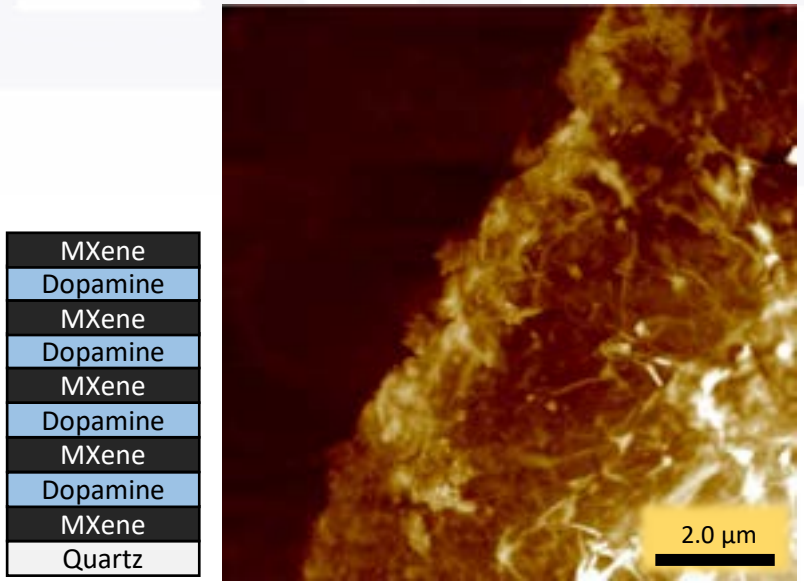
- Using an AFM Height image, the thickness of the 5 layered film could be measured
- MXene-MXene films had a thickness ~50nm
  - 10nm per layer
- MXene-Dopamine films had a thickness ~100nm
  - 20nm per layer
  - The surface was overall rougher

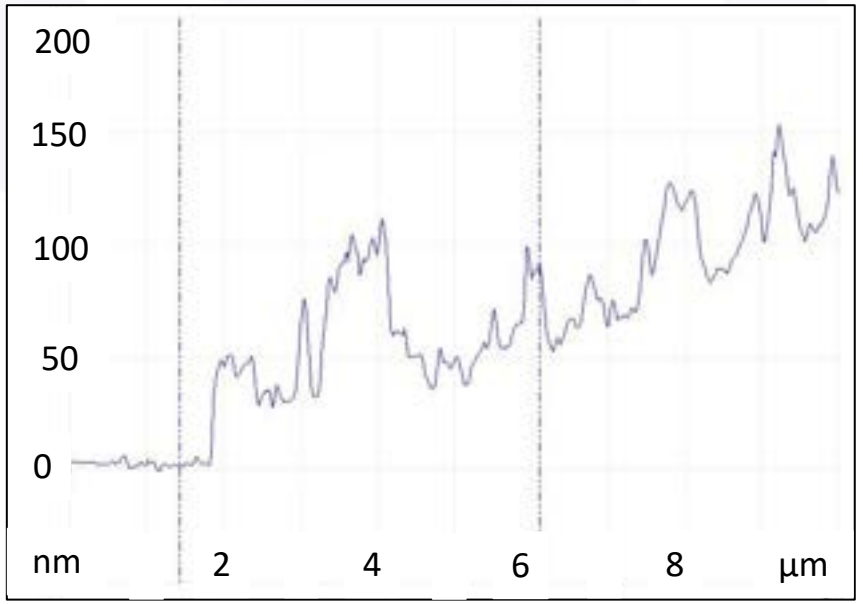
MXene-MXene Layered Sample





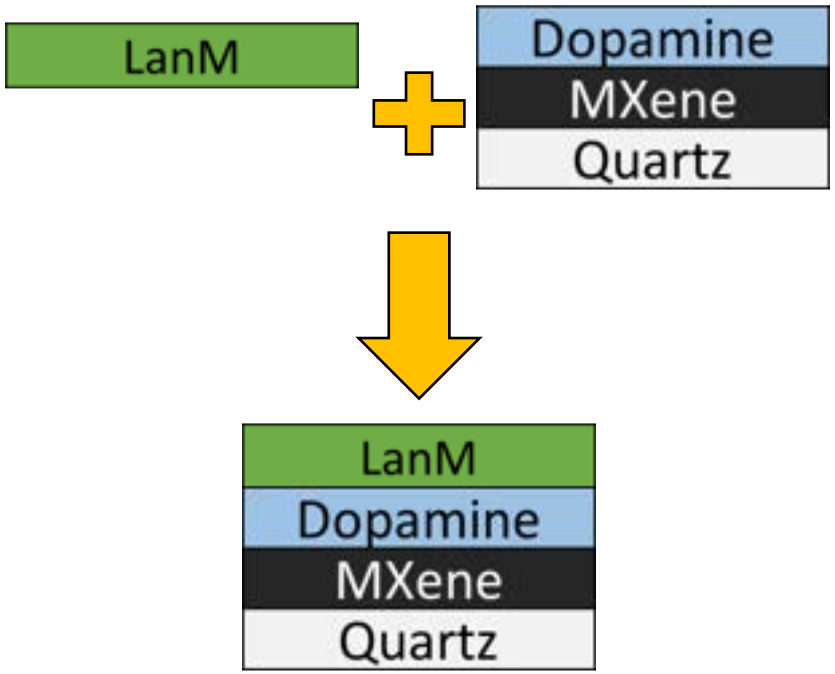
MXene-Dopamine Layered Sample



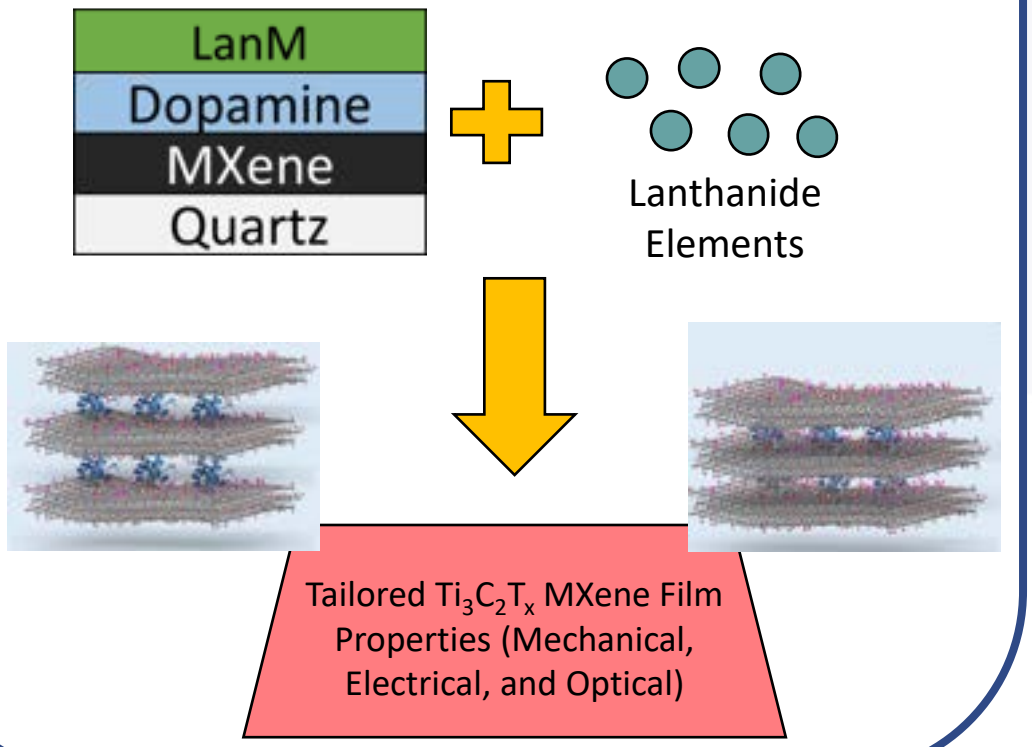


Future Work

Step 1: Determine if MXene-Dopamine films can bind LanM peptide



Step 2: Introduce various lanthanides to these films and determine if properties are altered



Acknowledgements

- AFRL: Mark Anayee, Micheal Carey, Chia Hung, and Joe Slocik
- Georgia Tech: Madeline Buxton and Justin Brackenridge

Title