

TEXAS
The University of Texas at Austin



Review of Graduate Research and Experience

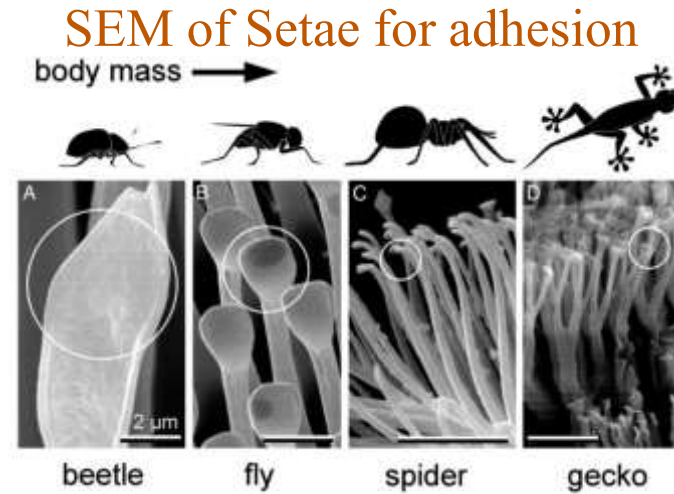
Andrew Tunell

The University of Texas at Austin, PI: Dr. Chih-Hao Chang

2026

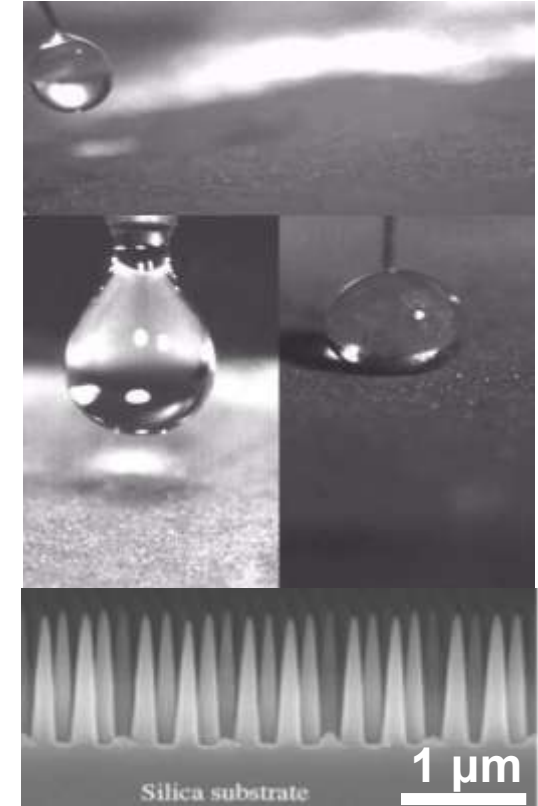
Research Group/ Exposure

- Bioinspired Nanostructures for unique:
 - Wetting,**
 - Optical,**
 - and Adhesion properties.**



E. Arzt et al. *PNAS* (2003)

Self-Cleaning Surface

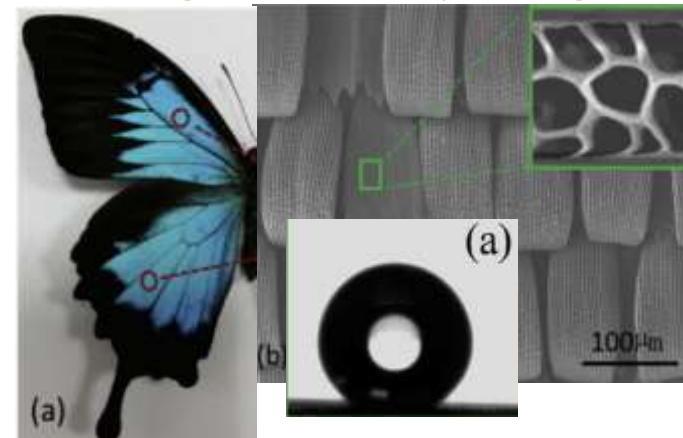


K.-C. Park et al., *ACS Nano* (2012)



Chang Lab Group 2025

Wetting of Butterfly Wing

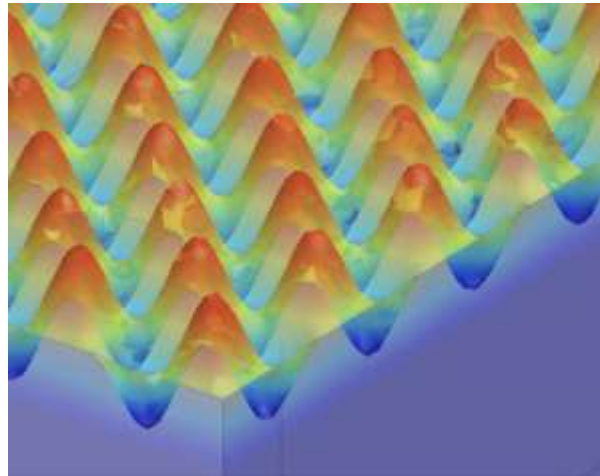


Z. Han et al, *Colloids and Surfaces* (2001)

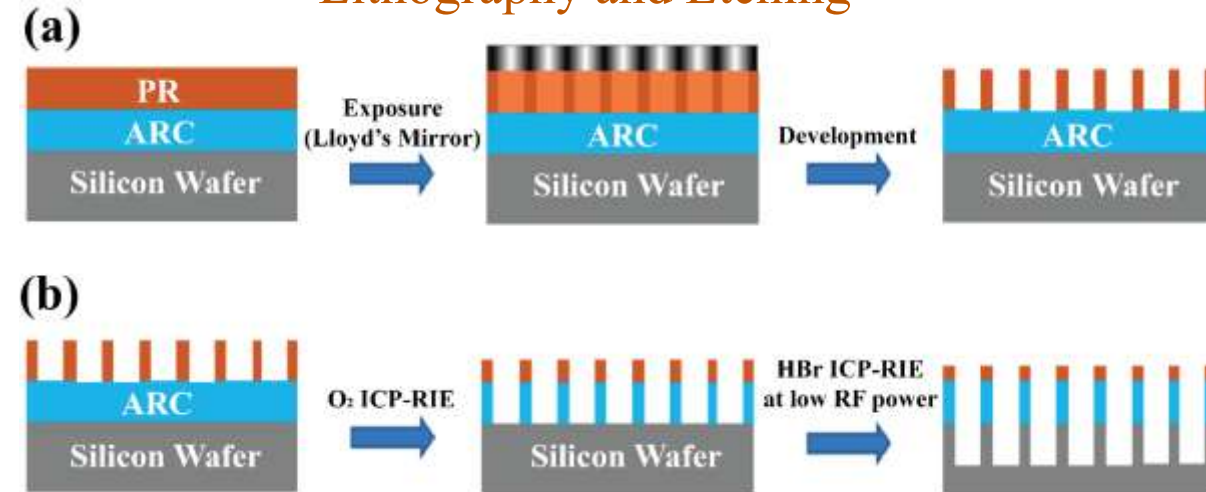
Process

- **Design**
 - COMSOL
 - Analytical modeling
- **Lithography**
 - EUV
 - 325 nm HeCD
- **Etching**
 - ICP/ RIE
- **Deposition**
 - PVD/ ALD/ Sputtering
- **Characterization**
 - AFM/ SEM/ Confocal

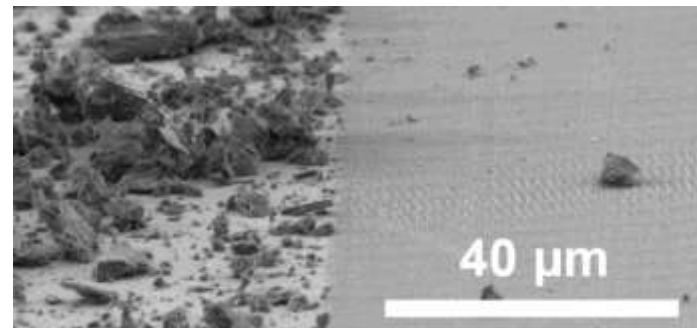
Simulation Guided Design



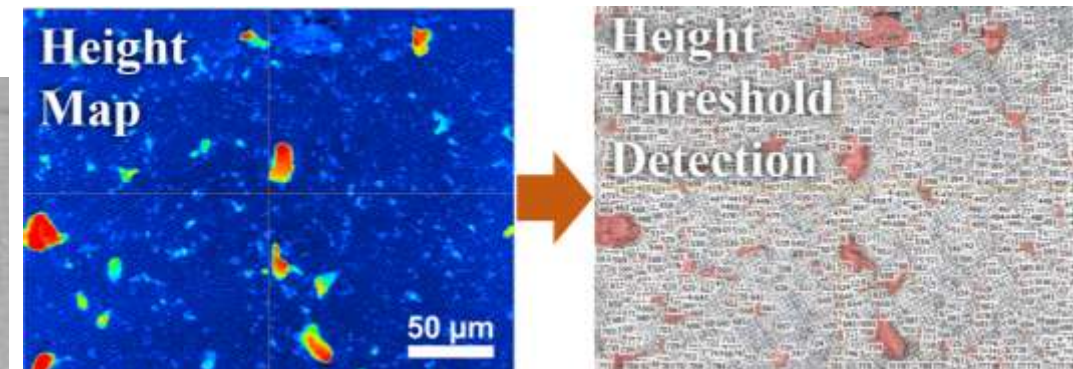
Lithography and Etching



SEM inspection

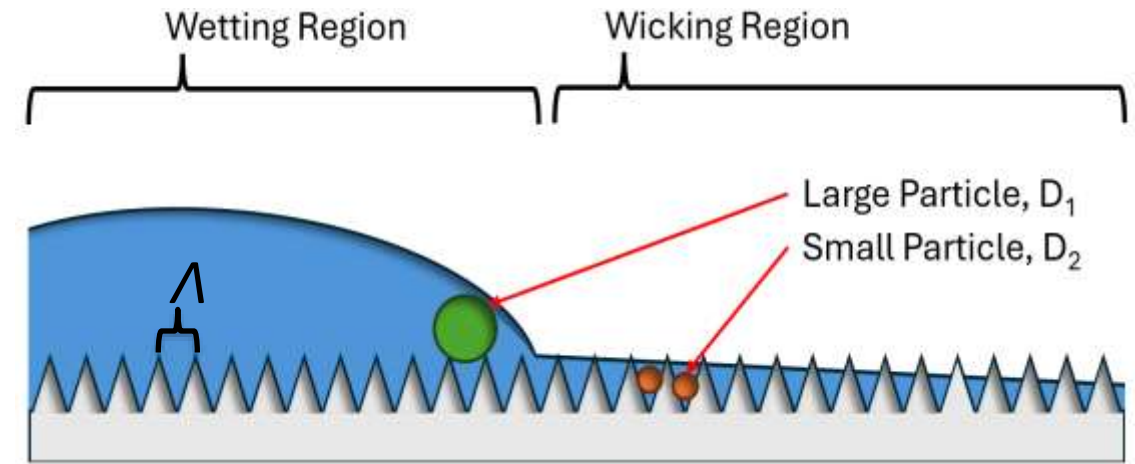


Confocal/ Software Characterization

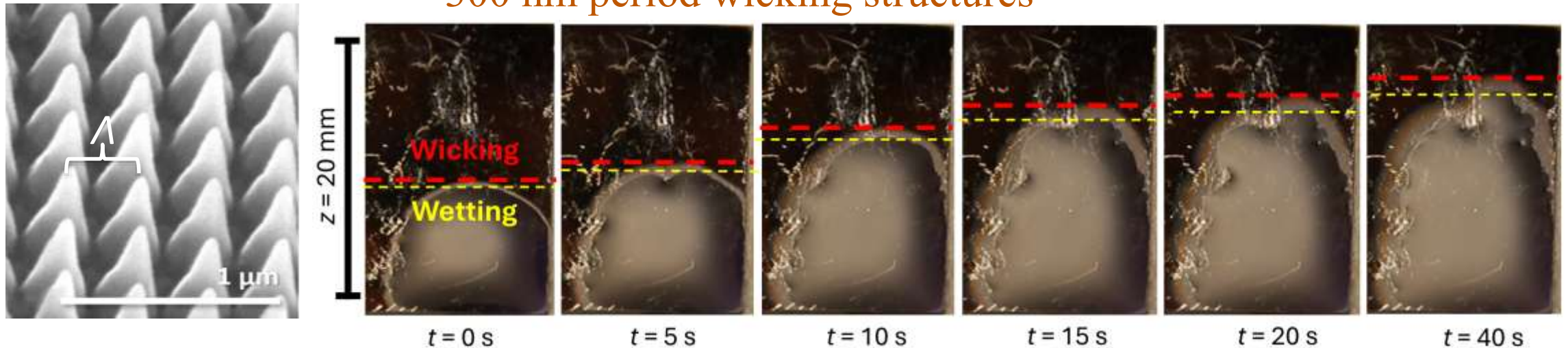


Wetting Research

- Fabricated super-hydrophilic structures.
- Characterize diffusion and wicking rates
- Investigate particle interactions during wicking



300 nm period wicking structures

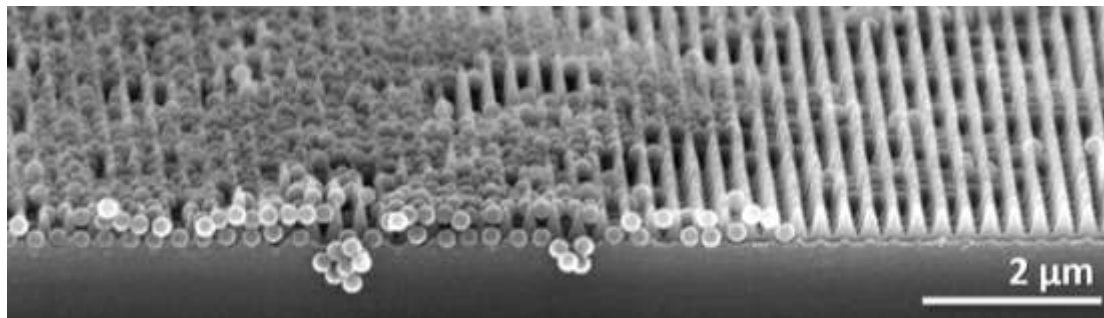
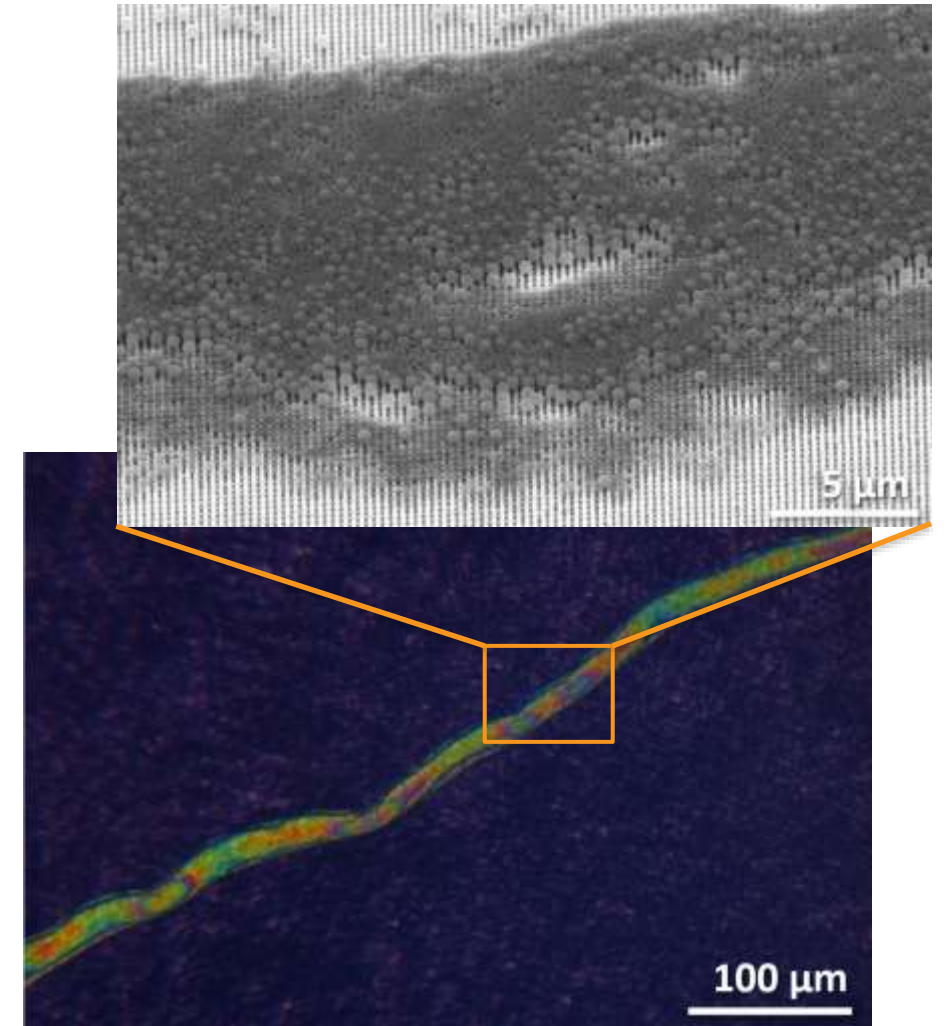
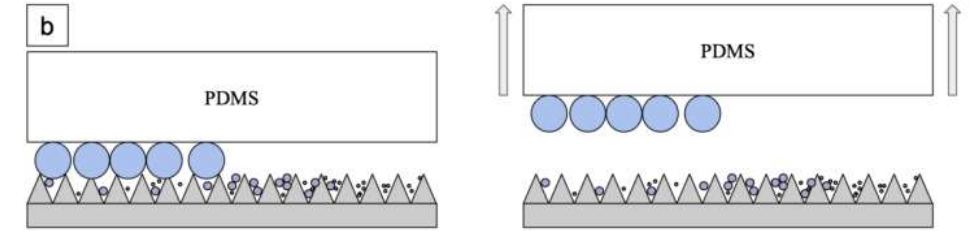


Filtration by Wetting

- Demonstrated filtering by particle diameter
- **Continued work:** Nanoplastic filter for Austin, TX river water.



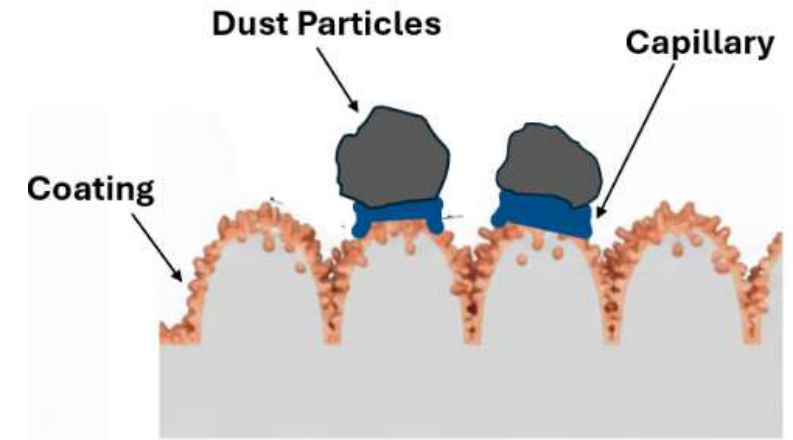
A. Tunell *et al.*, *RSC Applied Interfaces* (2025), 2(5)



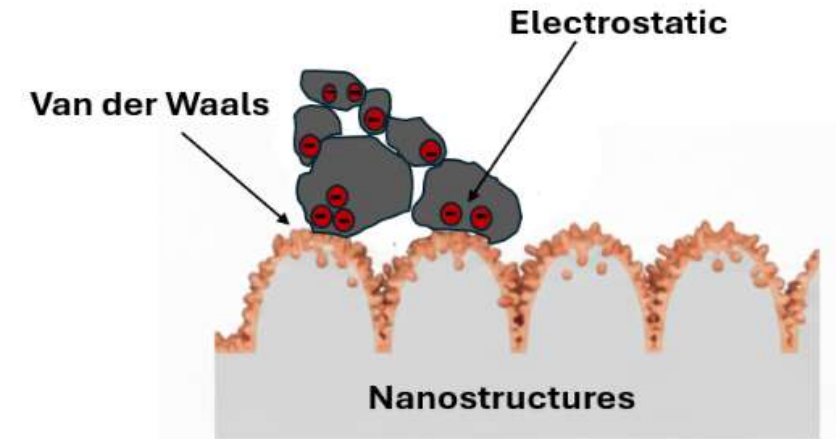
Main Focus: Adhesion

- Application driven investigation of environmental factors for the design of low-adhesion/ dust mitigating nanostructures
- Study Van der Waals, Capillary, and Electrostatic forces in detail

High Humidity Environment



Low Humidity Environment



$$F_{adh} = F_{vdw} + F_{cap} + F_{elec}$$

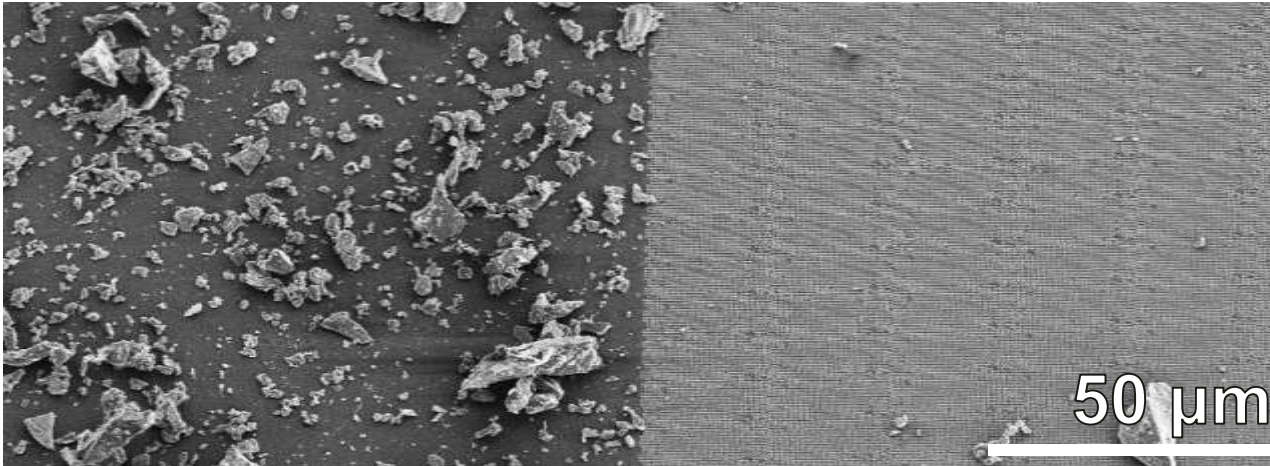
F_{vdw} → van der Waal Forces
 F_{cap} → Capillary Forces
 F_{elec} → Electrostatic Force

Dust Mitigating Performance

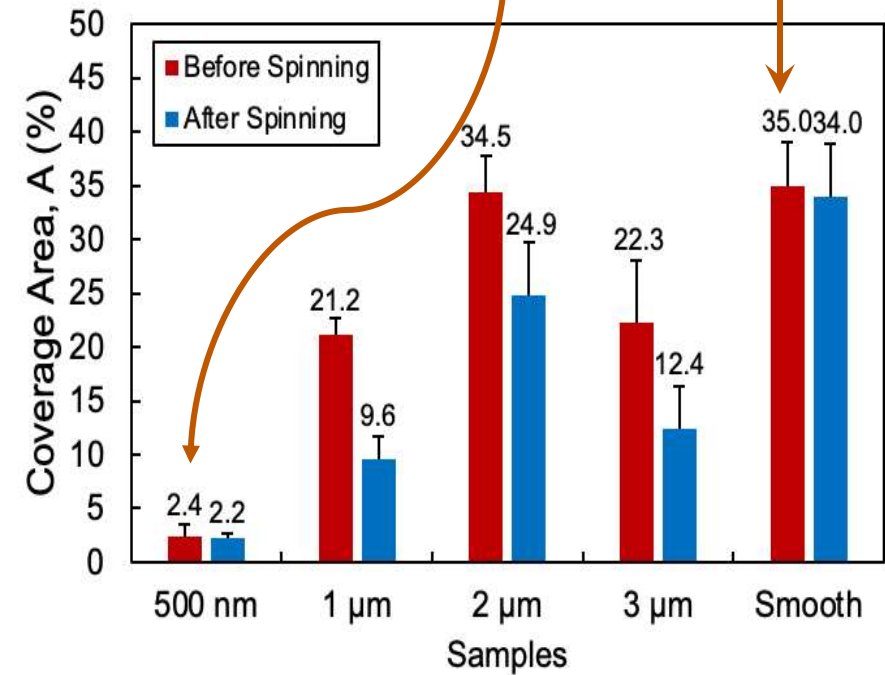
- 500 nm periodic nanostructure on polycarbonate
- **93.1% Reduction in dust** at ambient conditions (50% RH/ 20°C)

Planar

500 nm



$$\% \text{ Reduction} = \frac{A_{\text{smooth}} - A_{500\text{nm}}}{A_{\text{smooth}}} = 93.1\%$$



Dust Mitigating Video Demonstration

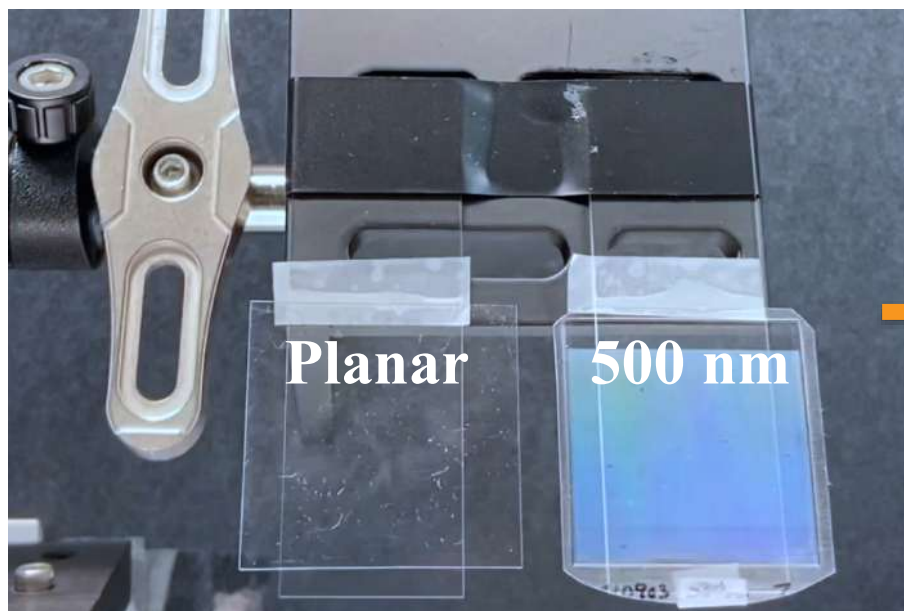


Snapshots from Video Demonstration

- Applied dust heavily in ambient conditions
- Rotate stage to allow removal by gravity.



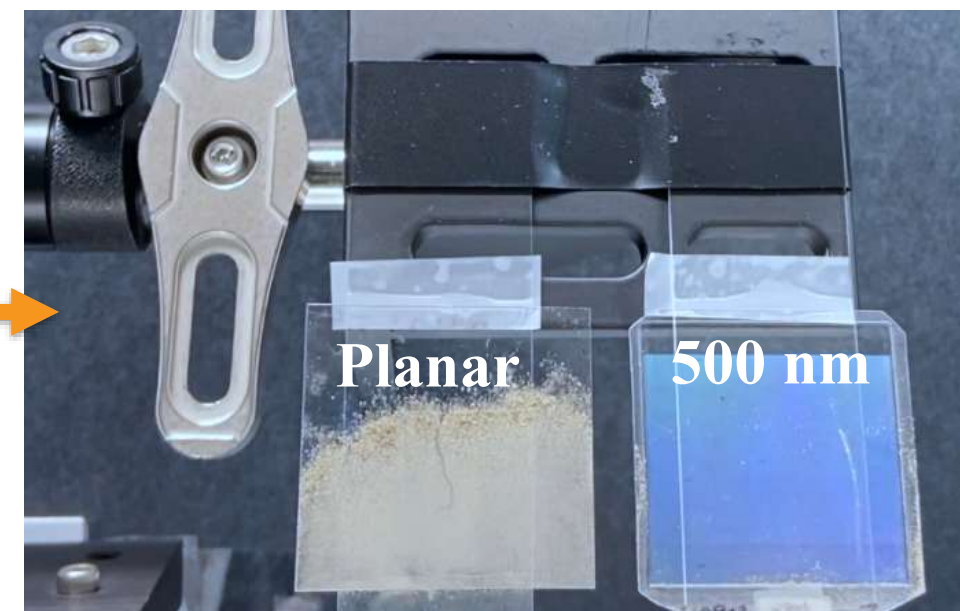
Before



Dust Application



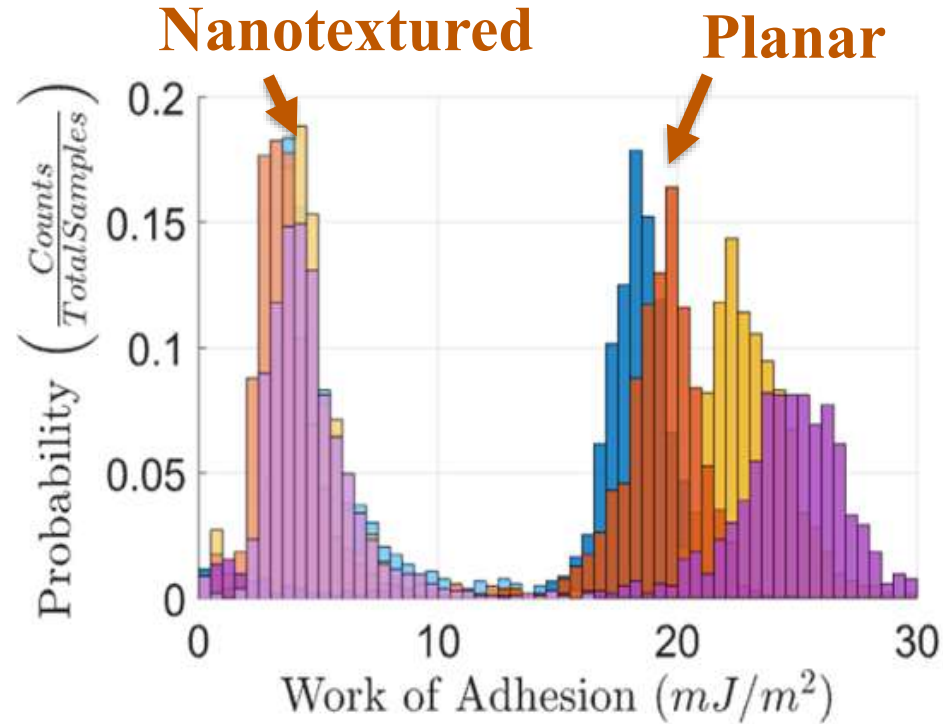
After



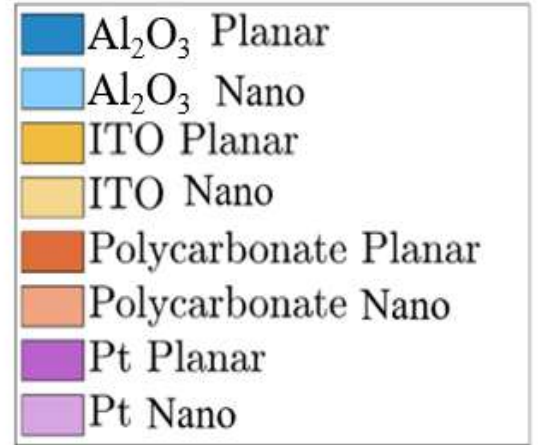
Roughness Effects (F_{vdw})

- Work of Adhesion measured by AFM pull-off force
- Roughness changes from Metal Oxides
- Reduced contact area = reduced adhesion

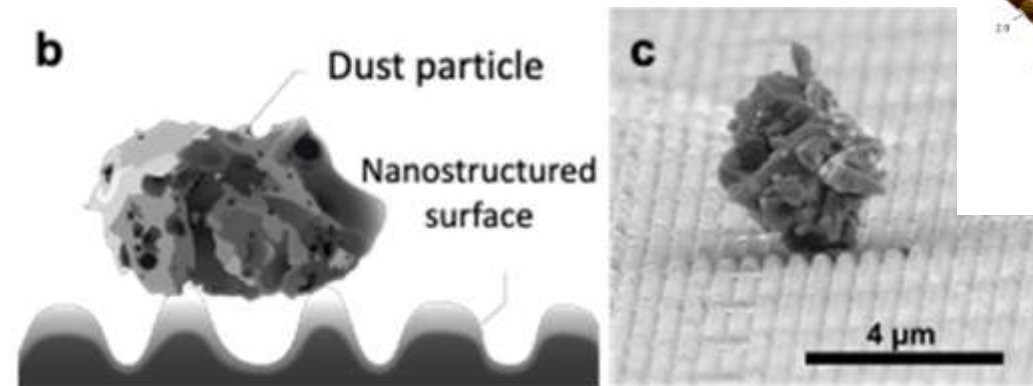
$$F_{adh} = \frac{3\pi}{2} R^* (\gamma_{dust} + \gamma_{surface}) \left[\frac{1}{1 + \left(\frac{2R^*}{RMS}\right)^2} + \frac{1}{\left(\frac{RMS}{H_0}\right)^2} \right]$$



A. Tunell, EIPBN 2024

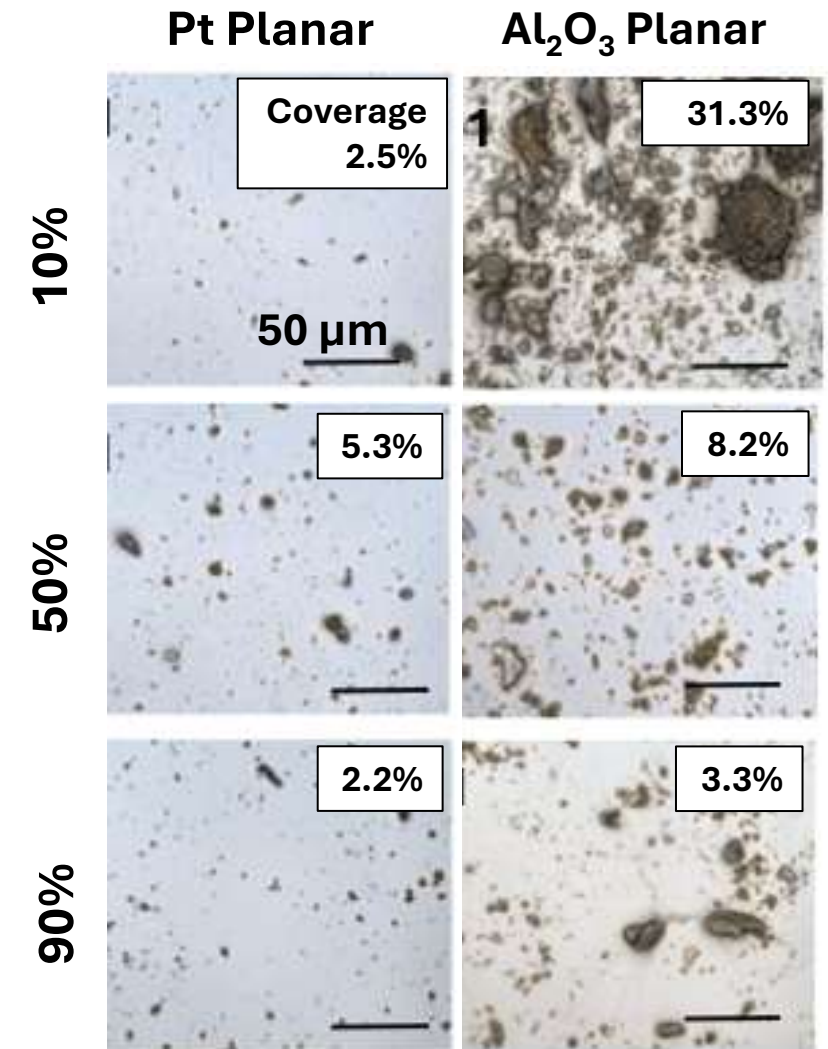
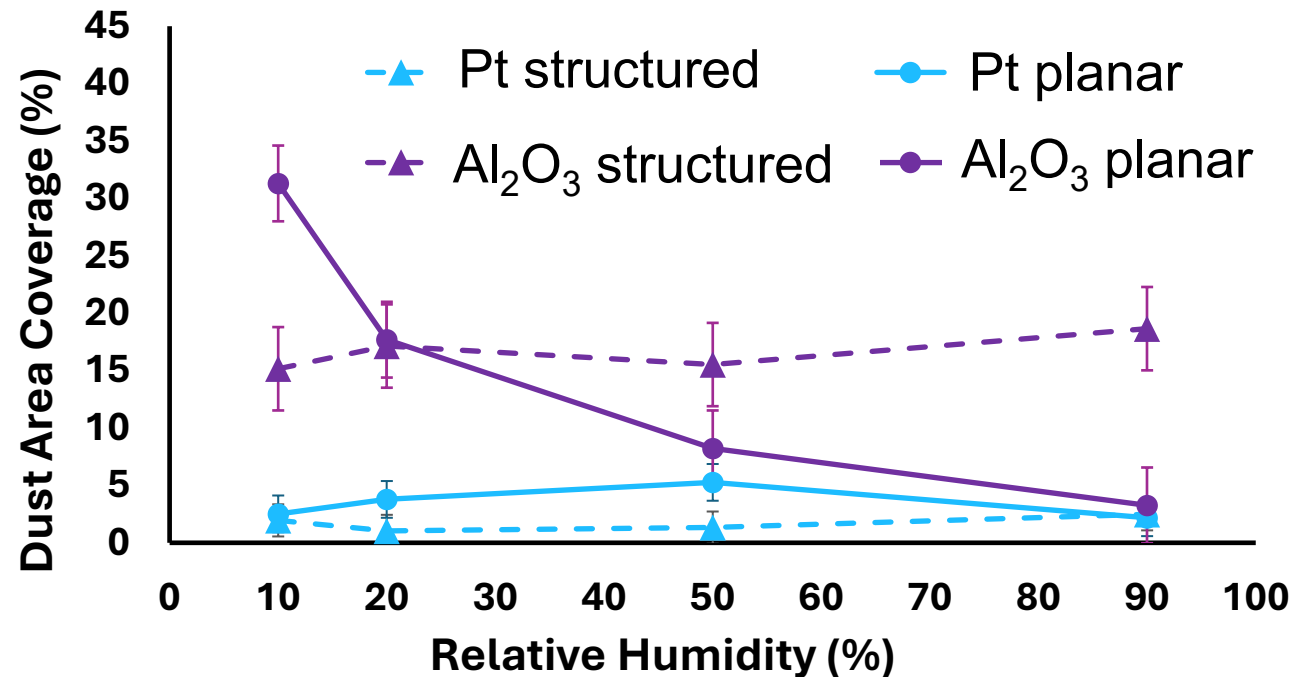


AFM



Humidity Effects (F_{cap})

- Dust coated at 10-90% relative humidity
- High surface conductivity (Pt) greatly decreases adhesion at low humidity – dissipates charges



Electrostatic Analytical Modeling

“I think dust is probably one of our greatest inhibitors to a nominal operation on the moon”

- Gene Cernan, Commander Apollo 17

Electrostatic Dust Lofting

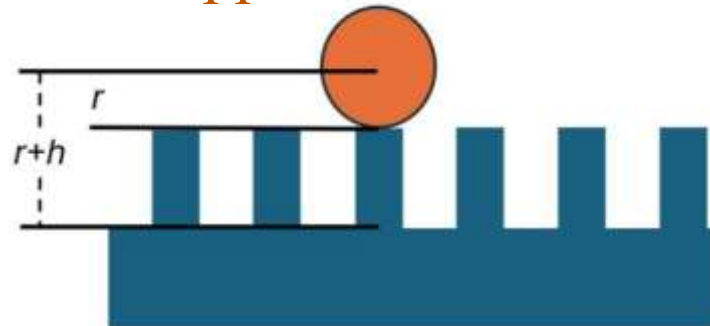


X. Wang et al., *Geophys. Lett.* (2016)

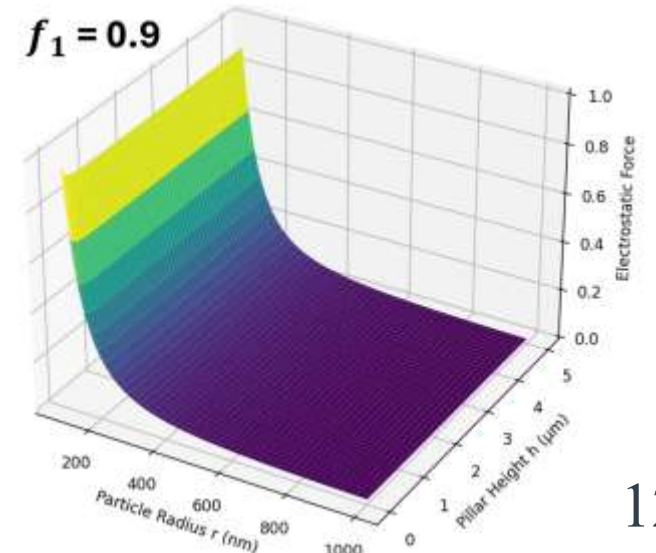
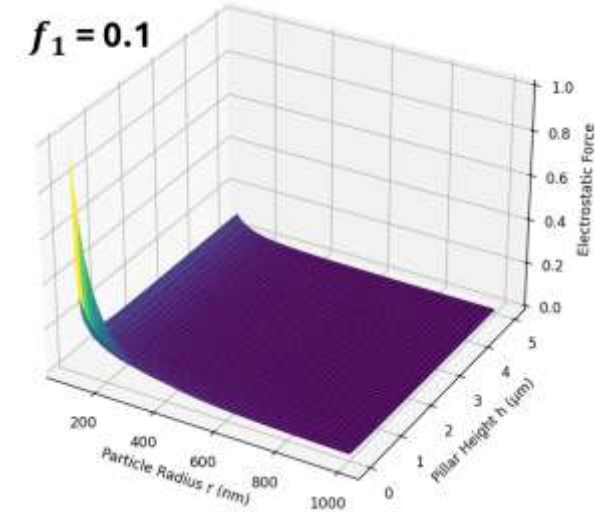
Electrostatic Two-Plane Approximation

$$F_{elec} = \frac{\sigma q_p}{2\epsilon_0} \left(\frac{f_1}{r^2} + \frac{1-f_1}{(r+h)^2} \right)$$

Diagram of two-plane approximation



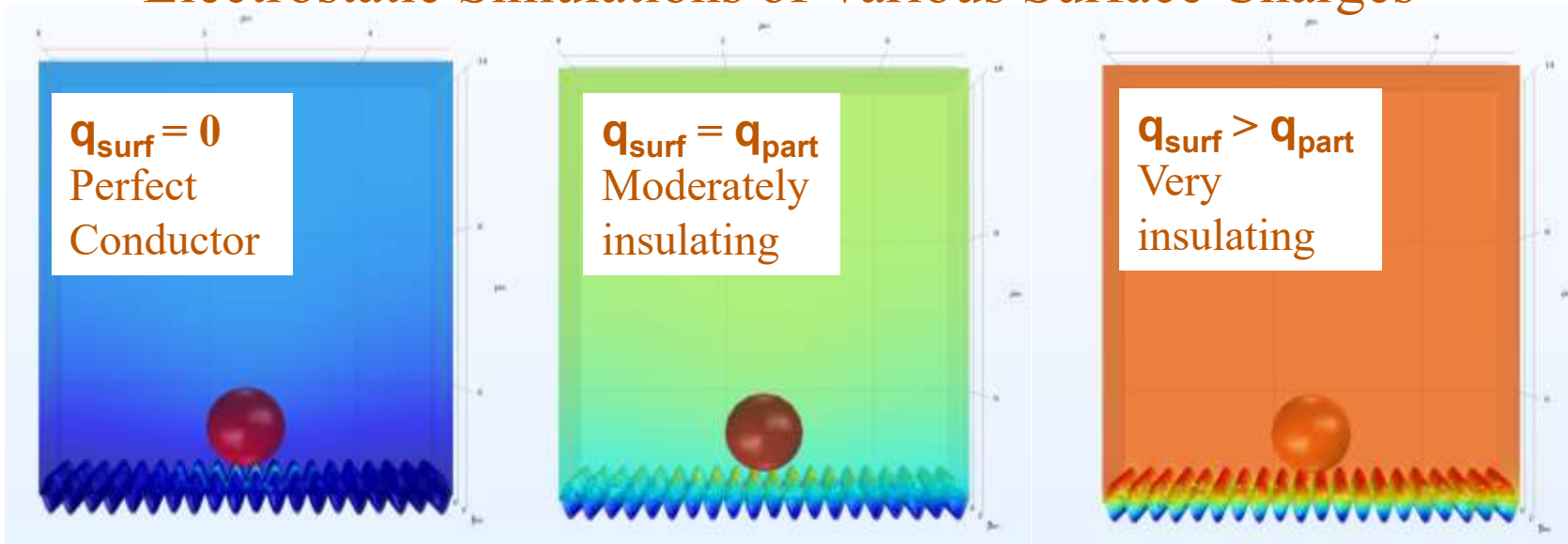
Electrostatic force with respect to radius, height, and contact area, f_1



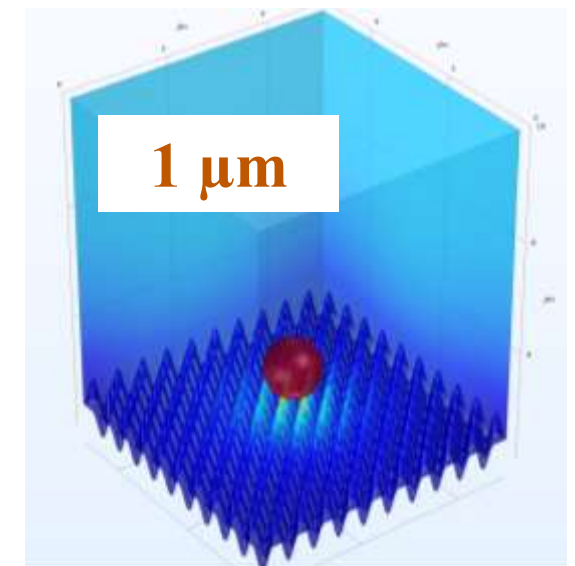
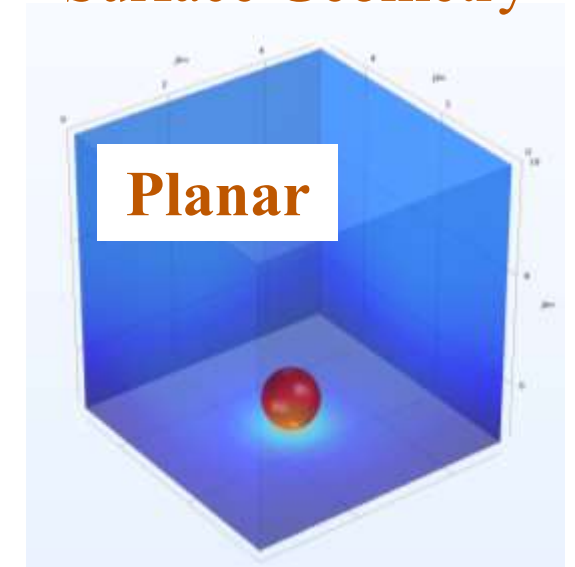
Electrostatic COMSOL Simulations

- Many limitations of 2-plane approx.
- COMSOL utilized to model full geometry & surface conductivity

Electrostatic Simulations of Various Surface Charges

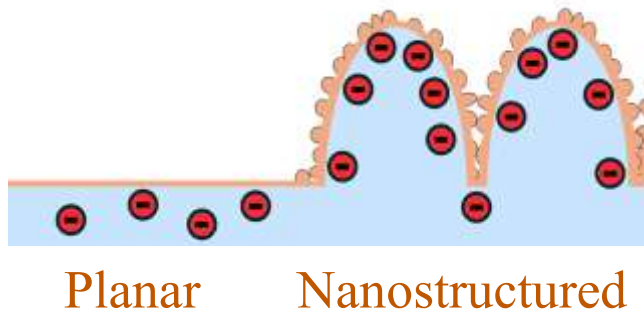


Surface Geometry

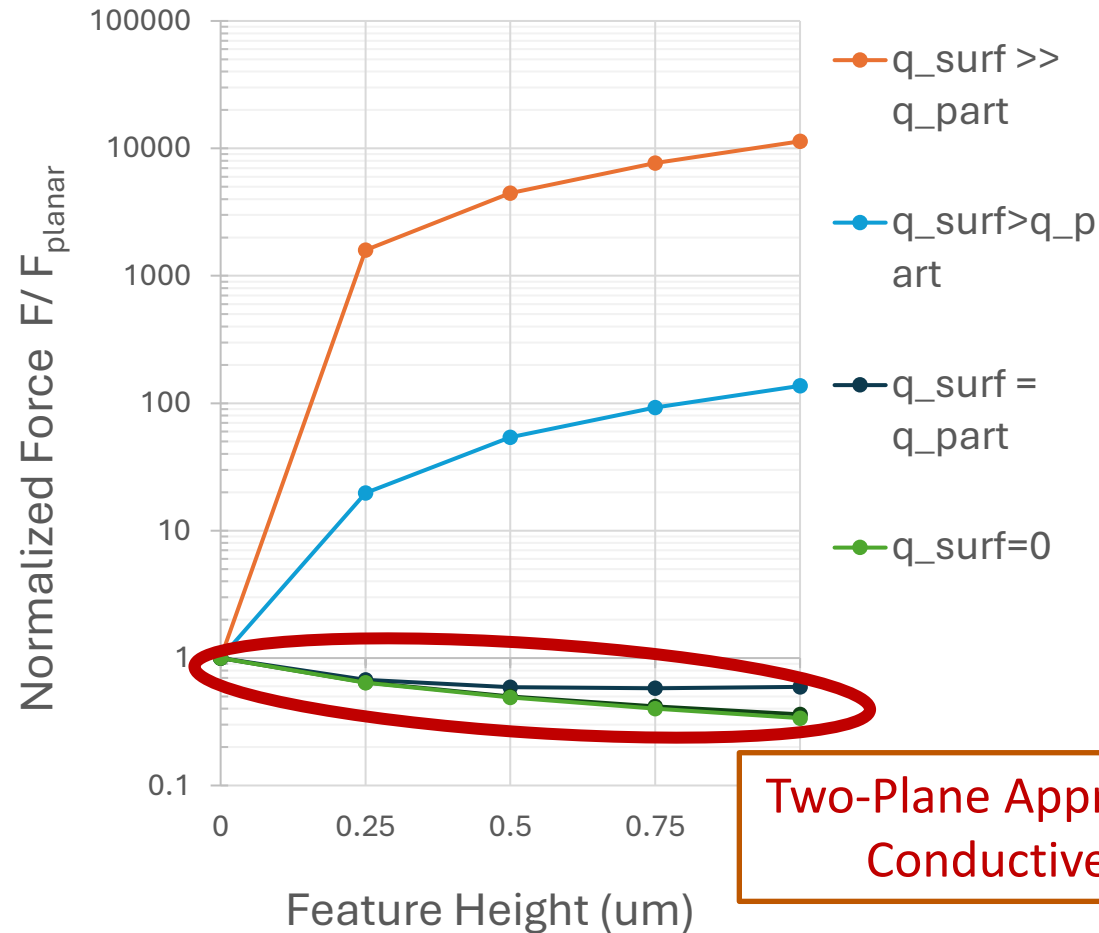


Simulation Results (F_{elec})

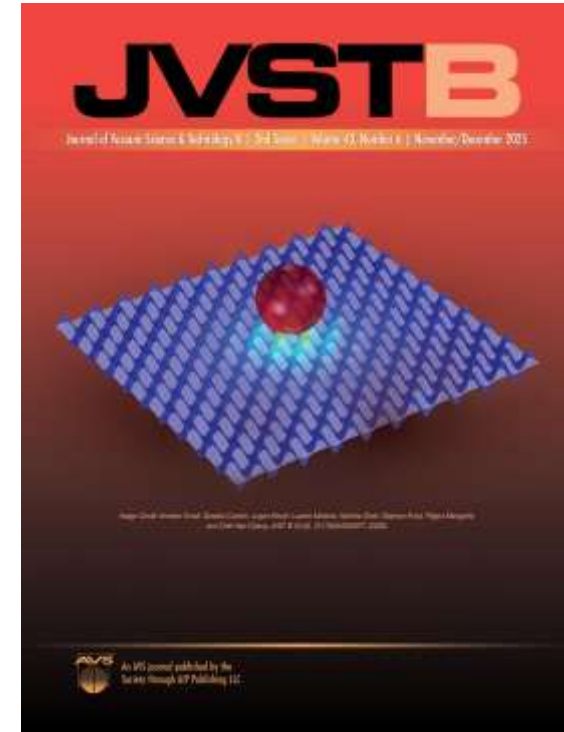
- Two distinct responses to nanostructuring
- 2-plane approx. models conductive surface well, decrease F_{elec}
- Insulating substrate increase F_{elec}



Geometric Effects on Electrostatic Force



Two-Plane Approx. +
Conductive



A. Tunell *et al.*, *JVST-B*
(2025), 43(6)

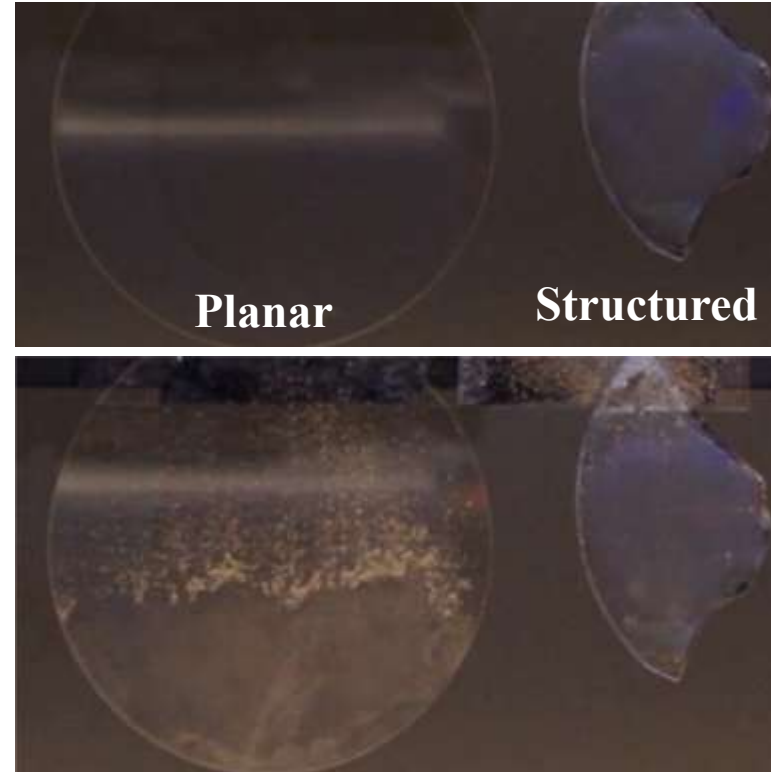
Sapphire

- 330 nm periodic, 2.1 aspect ratio structures
- Scratch Resistant

Material	Young's Modulus
Sapphire	350 GPa
Glass	70 Gpa
Polycarb.	2 Gpa

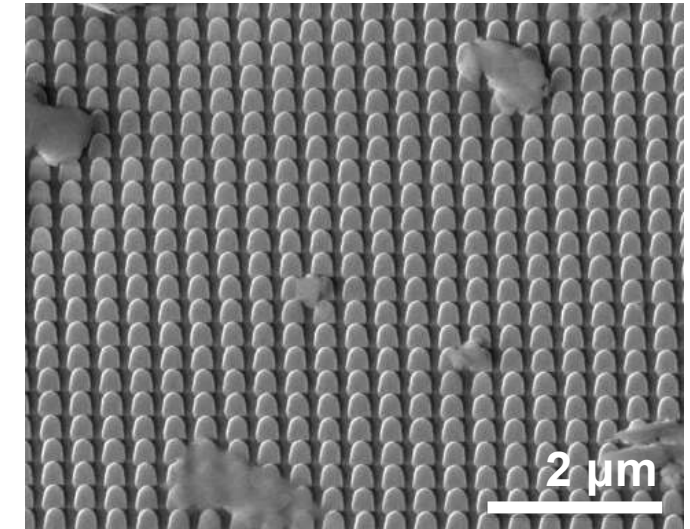
- Low-Adhesion/
Self Cleaning

Before and After Dusting

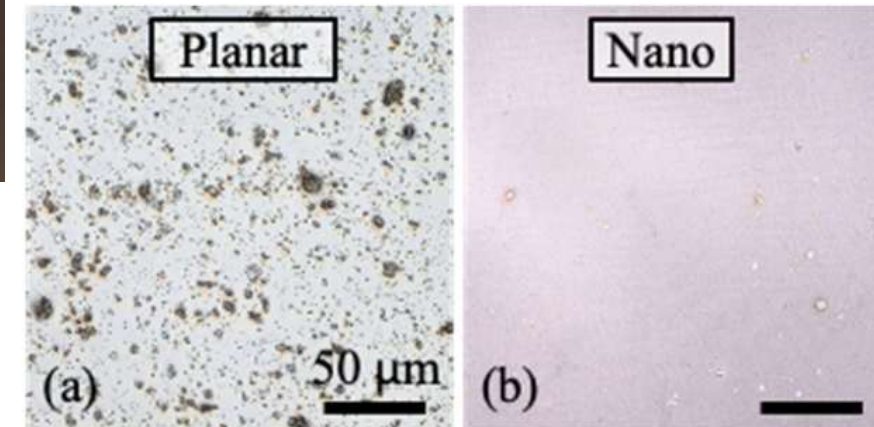


95.9% reduction in residual dust coverage!

SEM nanotextured Sapphire



Residual dust

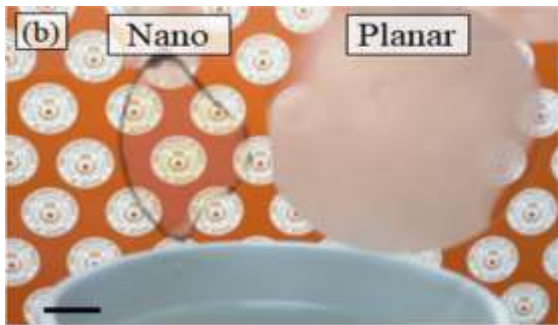


Sapphire Properties

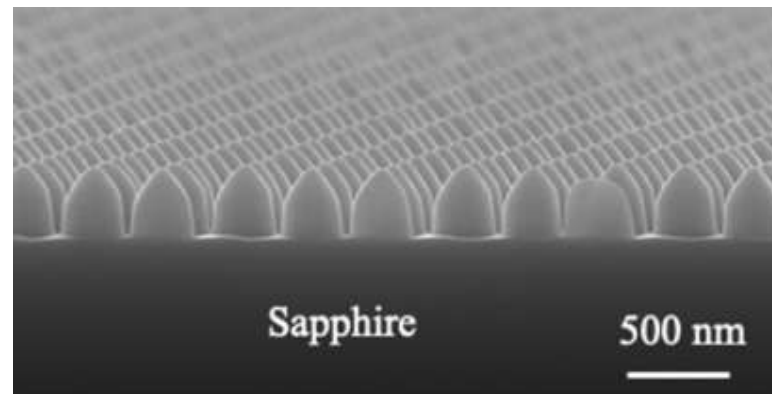
- High Optical Transmission (9.9% enhancement)
- Anti-Fogging (Wicking/Hydrophilic)
- Self-Cleaning (Hydrophobic)



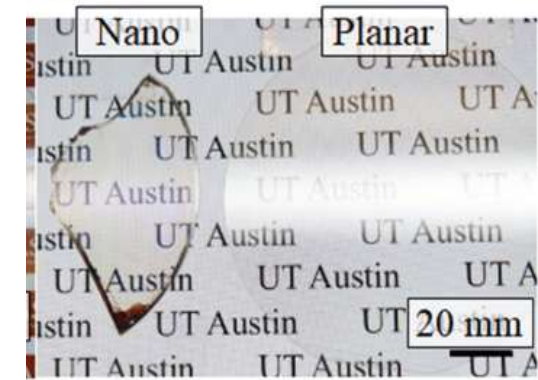
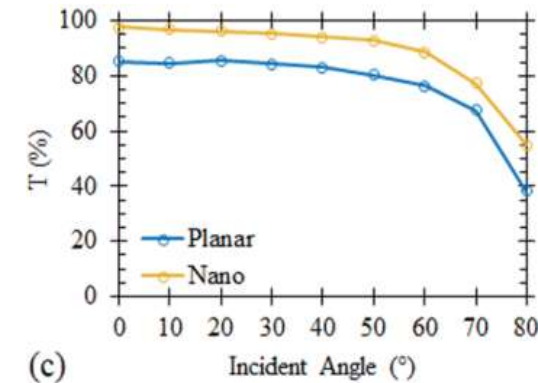
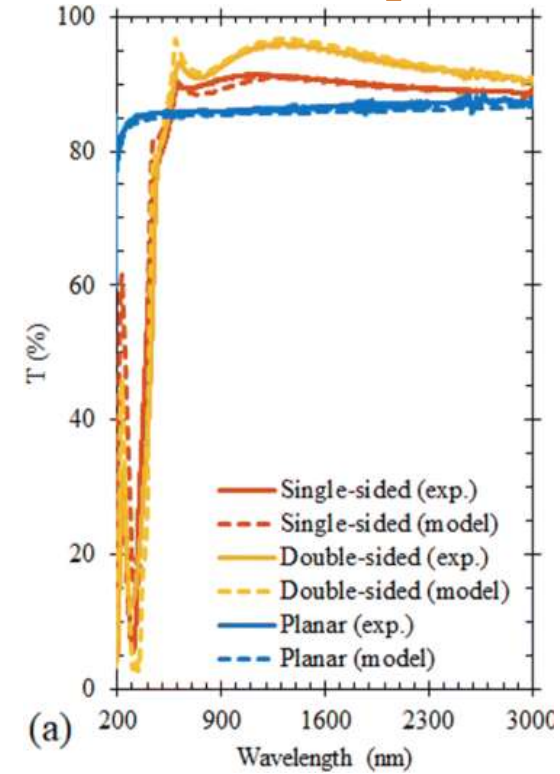
Anti Fogging



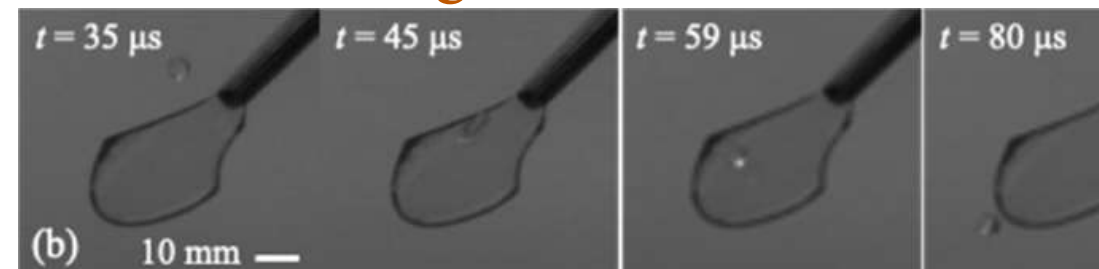
Cross Section SEM



Optical Transmittance



Self-Cleaning

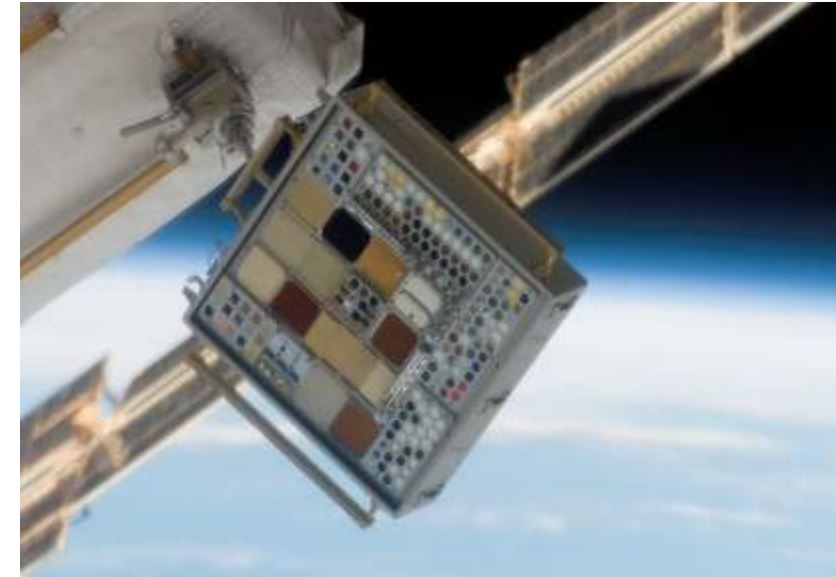


MISSE-23/24

- (MISSE 23) Sapphire selected for ISS flight
- Study resilience to space conditions
- (MISSE-24) ITO and Pt coatings added to reduce damage via local charge buildup

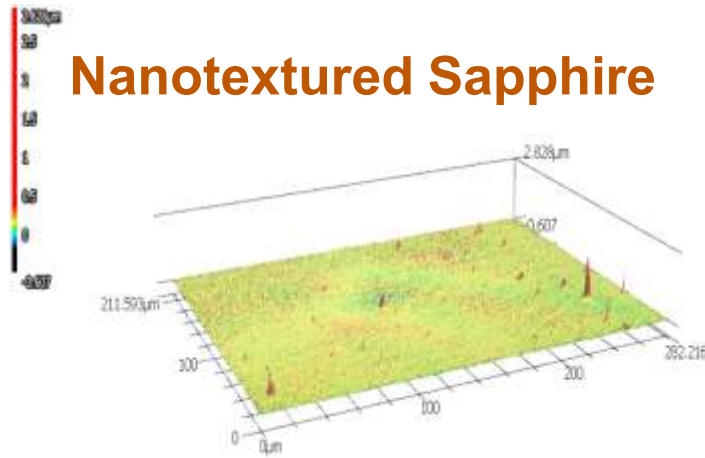


MISSE-8 Images

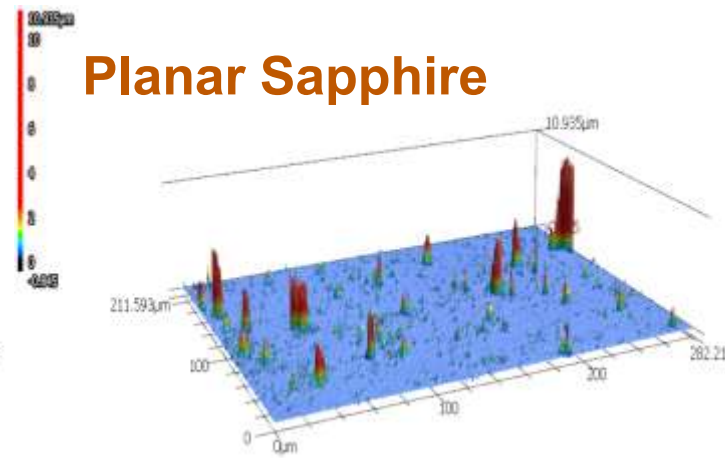


Residual Dust 3D Mapping

Nanotextured Sapphire



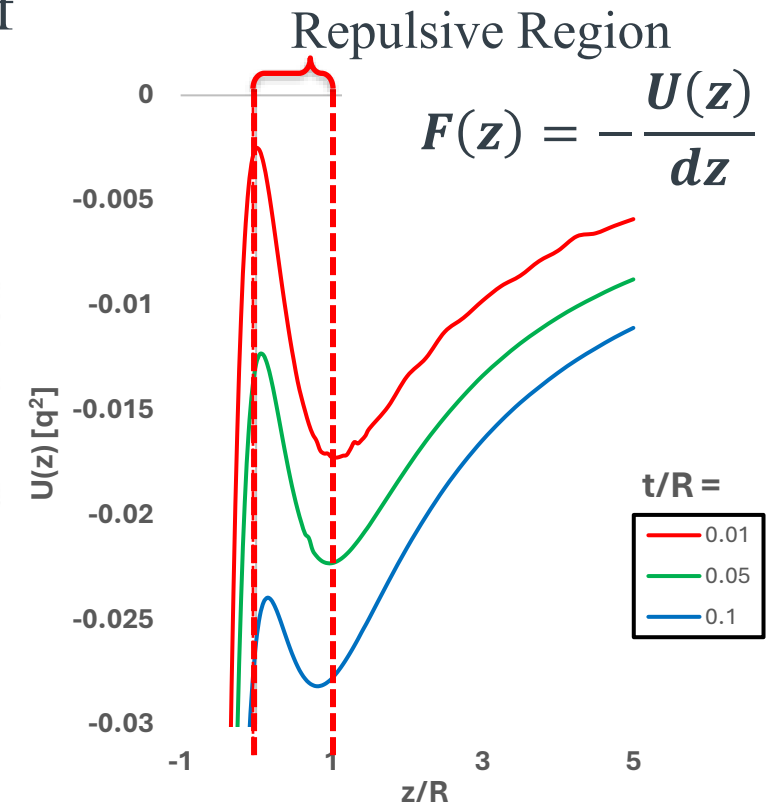
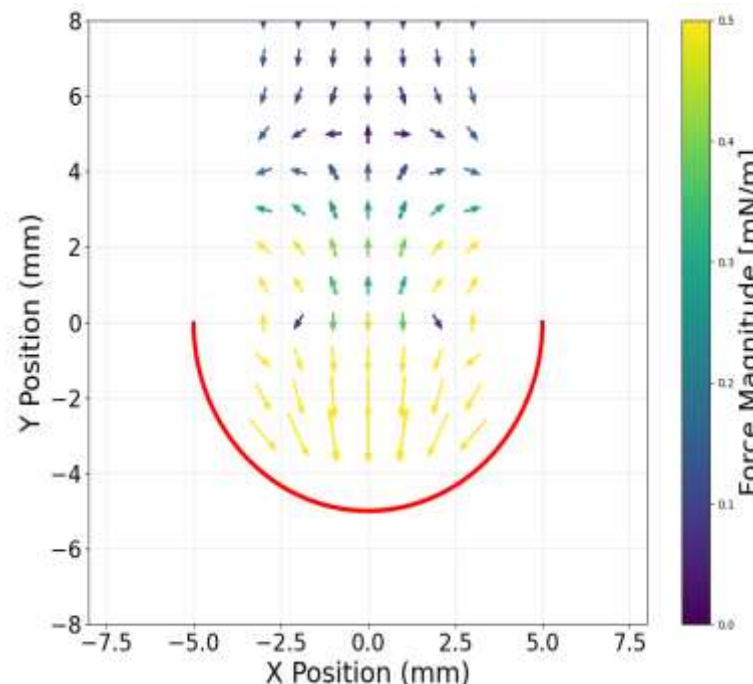
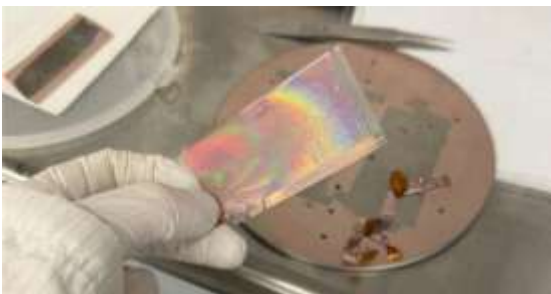
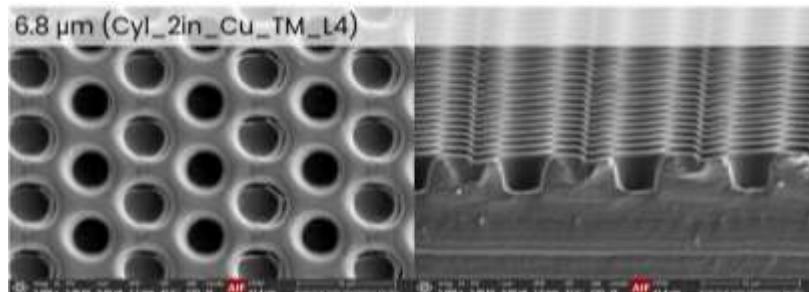
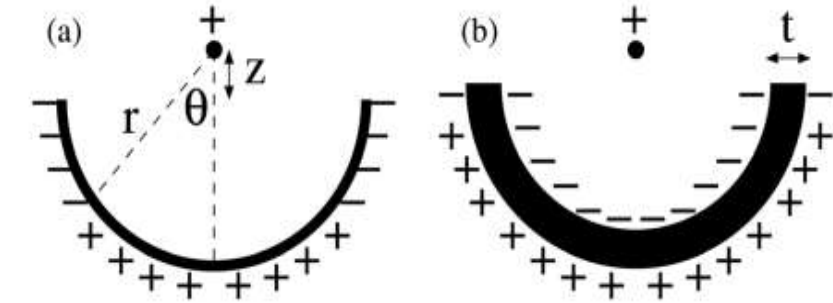
Planar Sapphire



Brief Review of Active Research

- Design Surface geometry to have repulsive image charging
- Thin metal hemisphere polarizes with net negative force on a point charge.
- **Currently:** Fabricating, AFM Probe Testing, Simulation of Parabolic/ periodic geometry.

Polarization of thin metal hemisphere





Thank You!
