Automated Marangoni Monolayer Technique

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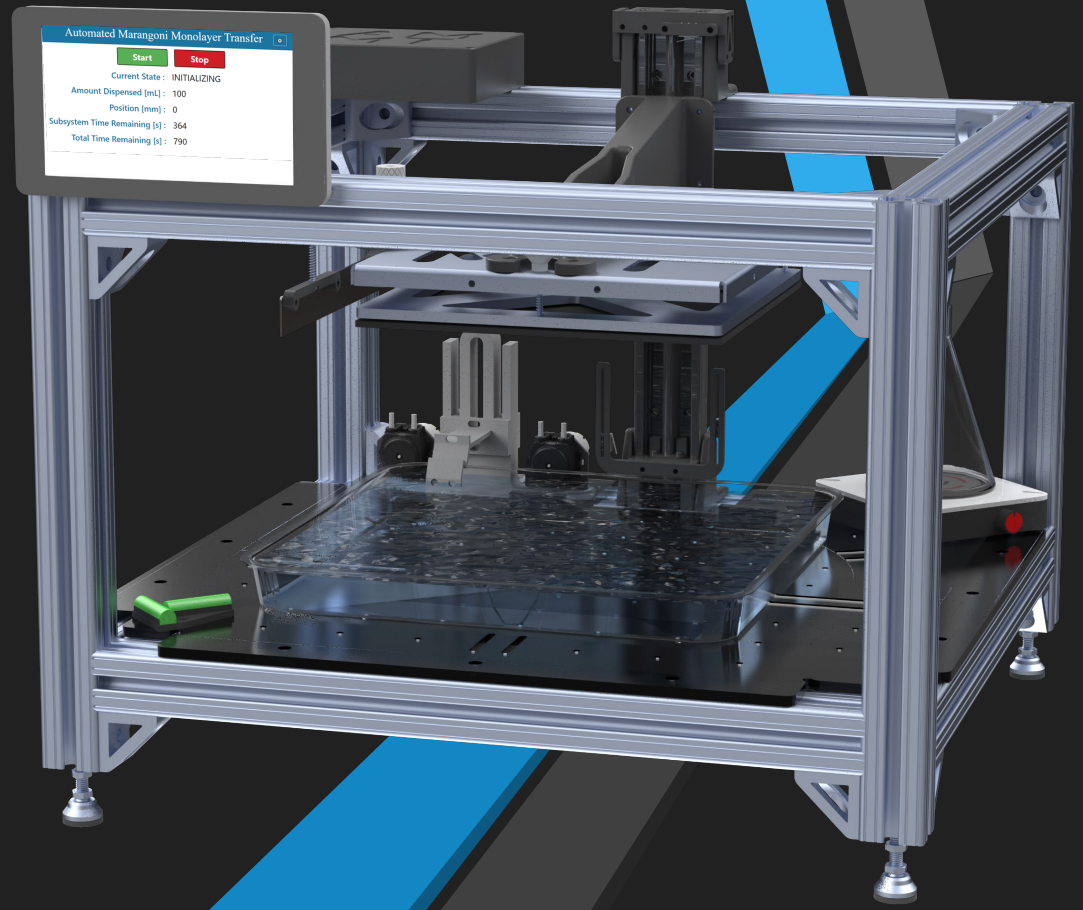
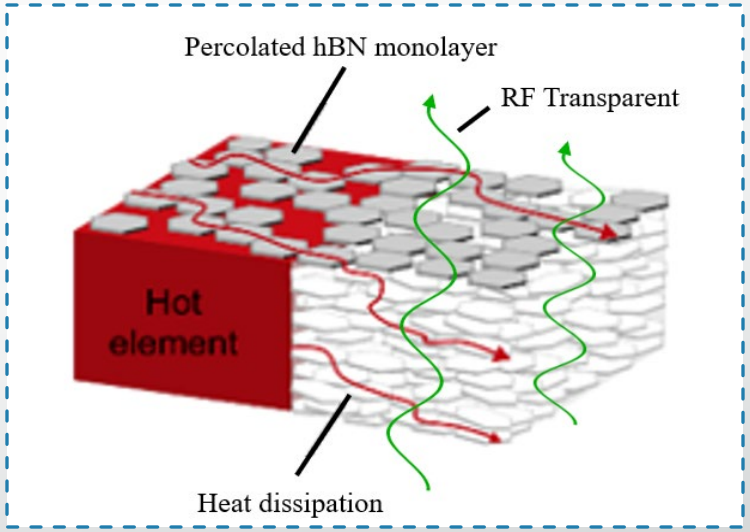


Motivation

- Percolated monolayers of hexagonal boron nitride (hBN) provide:
  - Low radio frequency (RF) interference due to single particle thickness
  - High thermal conductivity due to percolation

KYMETA Radome



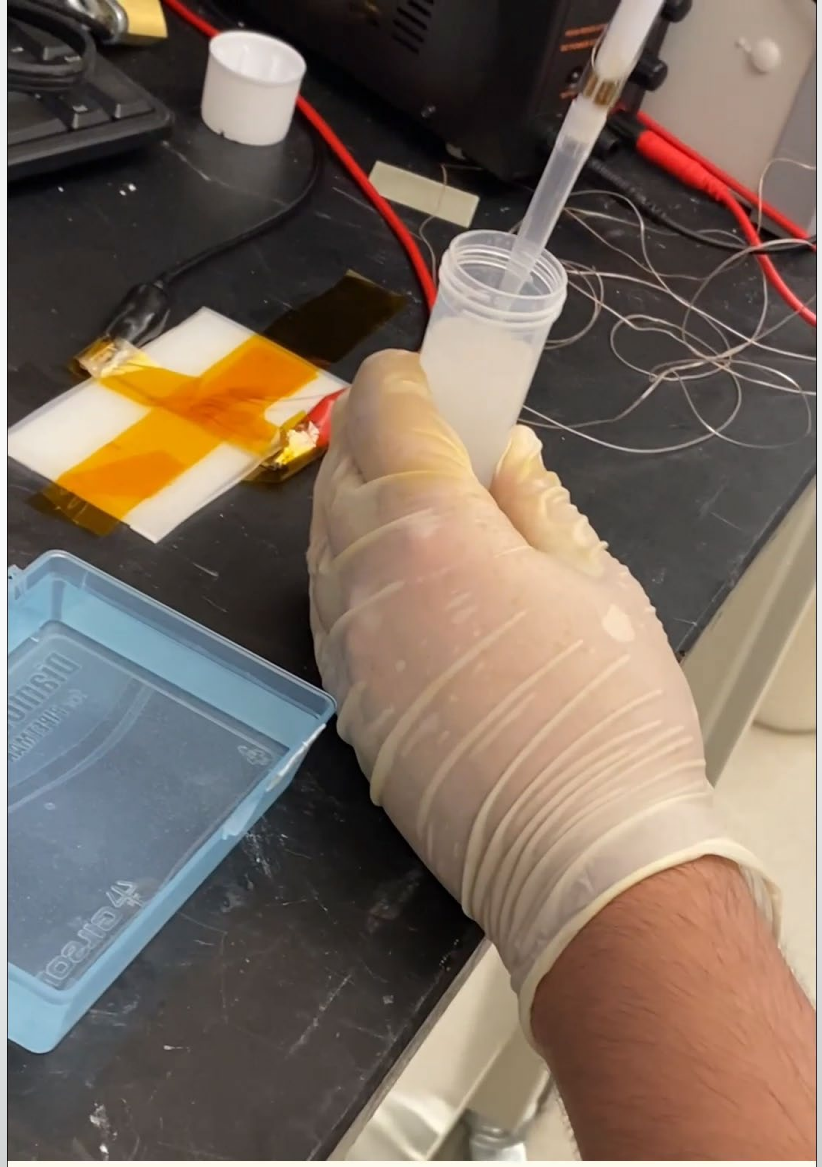
Percolated hBN monolayer

- A small-scale approach to create percolated hBN monolayers has been developed at Northeastern's DAPS lab
- Industry desires a larger-scale monolayer to test insertion loss of the material

Previous Approach

- Manually done at demo scale
  - Needs to be scaled up
    - KYMETA requires 9in by 9in substrate to test RF interference
  - Needs to be automated
    - Too difficult to be accurately done by hand at large scale

- Three Major Steps:
  1. Creation of monolayer
  2. Marangoni Effect to percolate the monolayer
  3. Monolayer transfer to a solid substrate



Marangoni, Langmuir-Blodgett

Problem Statement

To design an apparatus that autonomously injects an hBN, ethanol solution into the trough, uses the Marangoni effect to densify particles into a percolated monolayer, then transfers the monolayer onto a 9in x 9in substrate in a repeatable and precise manner.

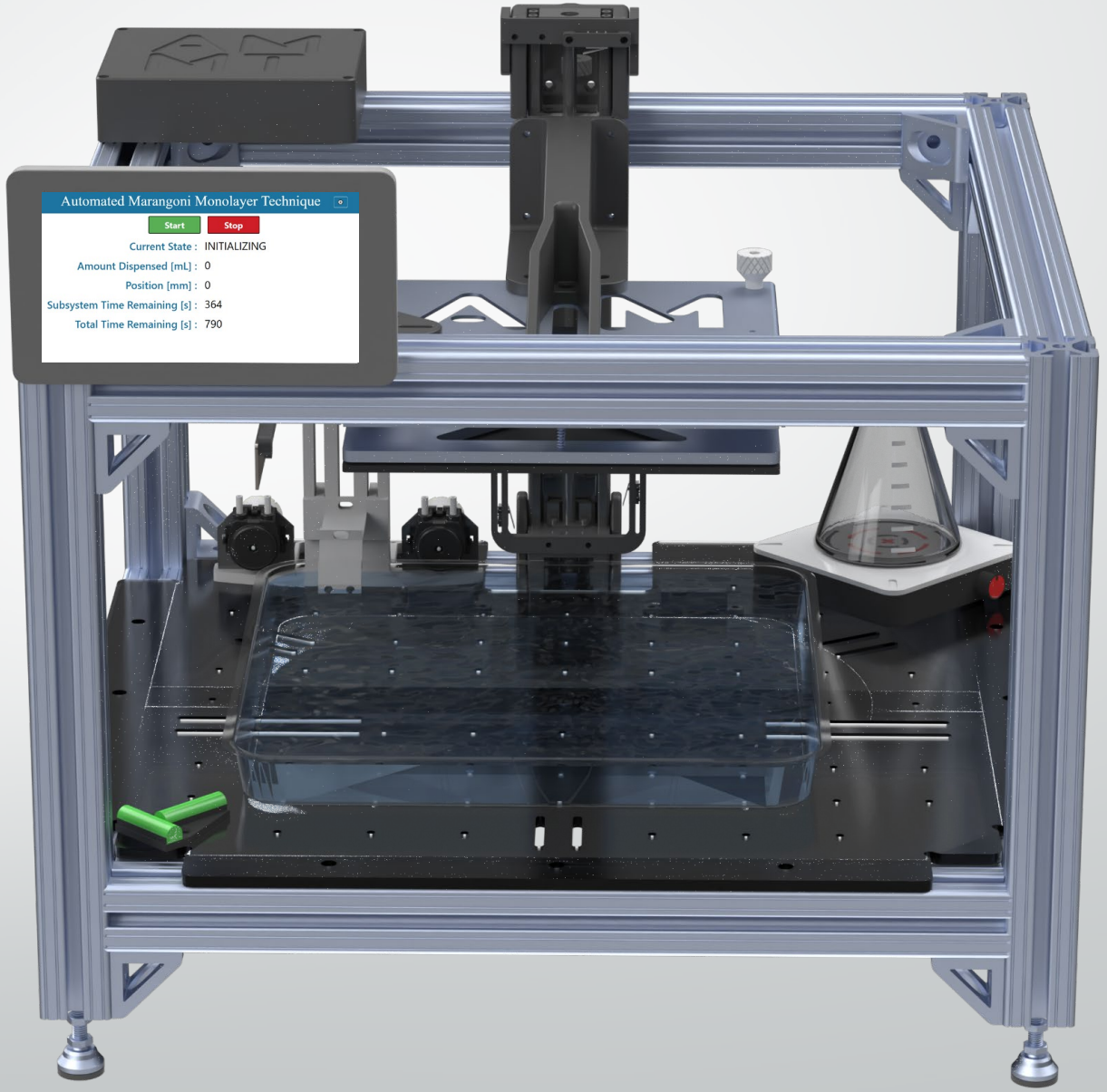
Full-Scale Design

- Built from the knowledge gained from many small-scale prototypes and tests

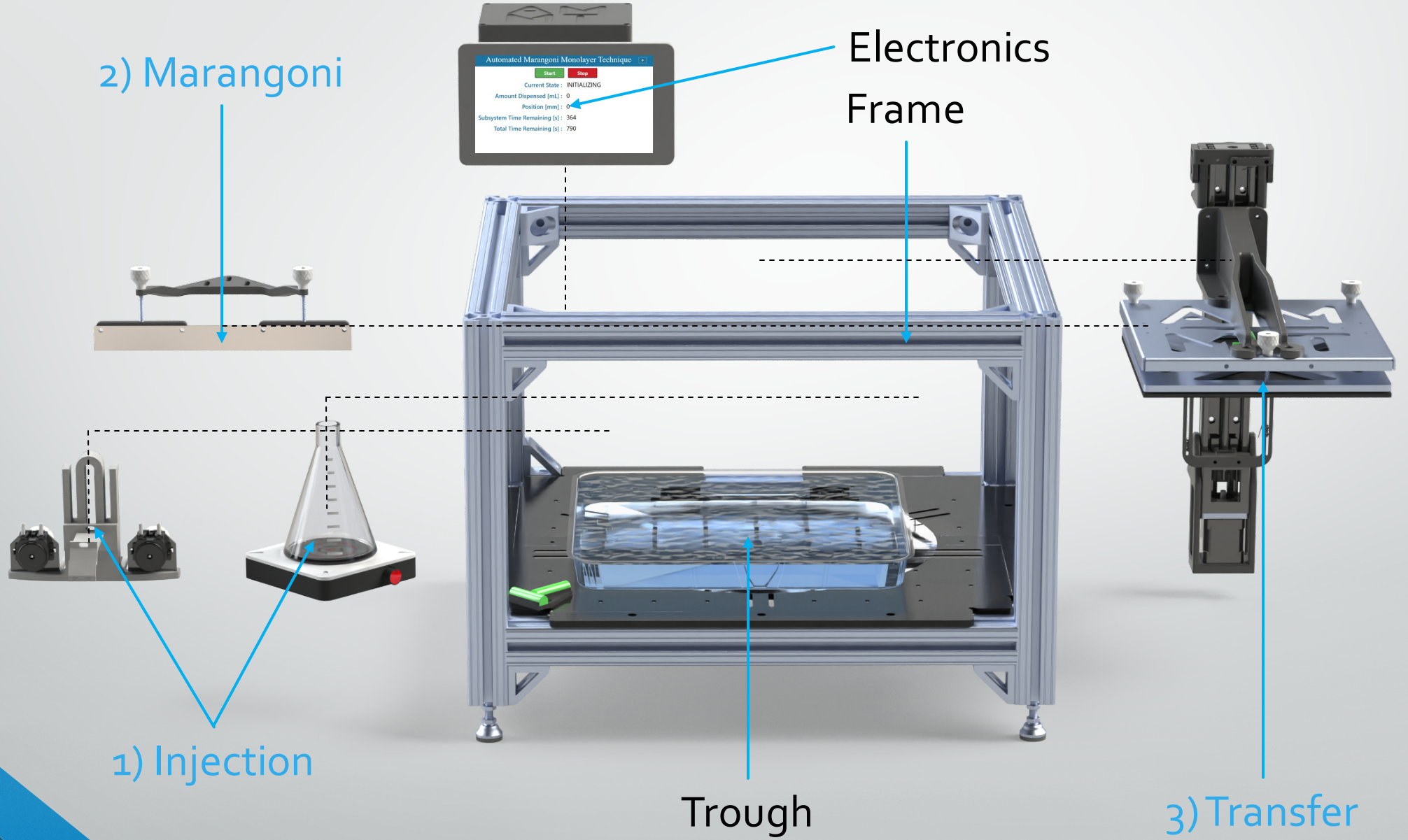
- Design cornerstones:

1) Modular
2) Adjustable

- Modular allowed for rapid iteration
- Adjustable allowed for fine tuning of process parameters



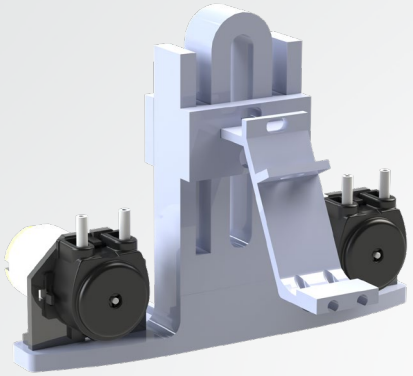
Full-Scale Design



1) Injection

Purpose

- Inject a homogenized mixture of hBN and ethanol onto the fluid-air interface



Biggest Challenge

- Sedimentation of hBN

Design Solution

- Magnetic stirrer used to maintain homogenization
- Lines are reversed after injection to send all remaining fluid to reservoir
- Adjustable injection arm to reduce height from outlet to interface

Injection with major sedimentation

Injection with minimal sedimentation

2) Marangoni

Purpose

- Adds soap to the interface to induce percolation

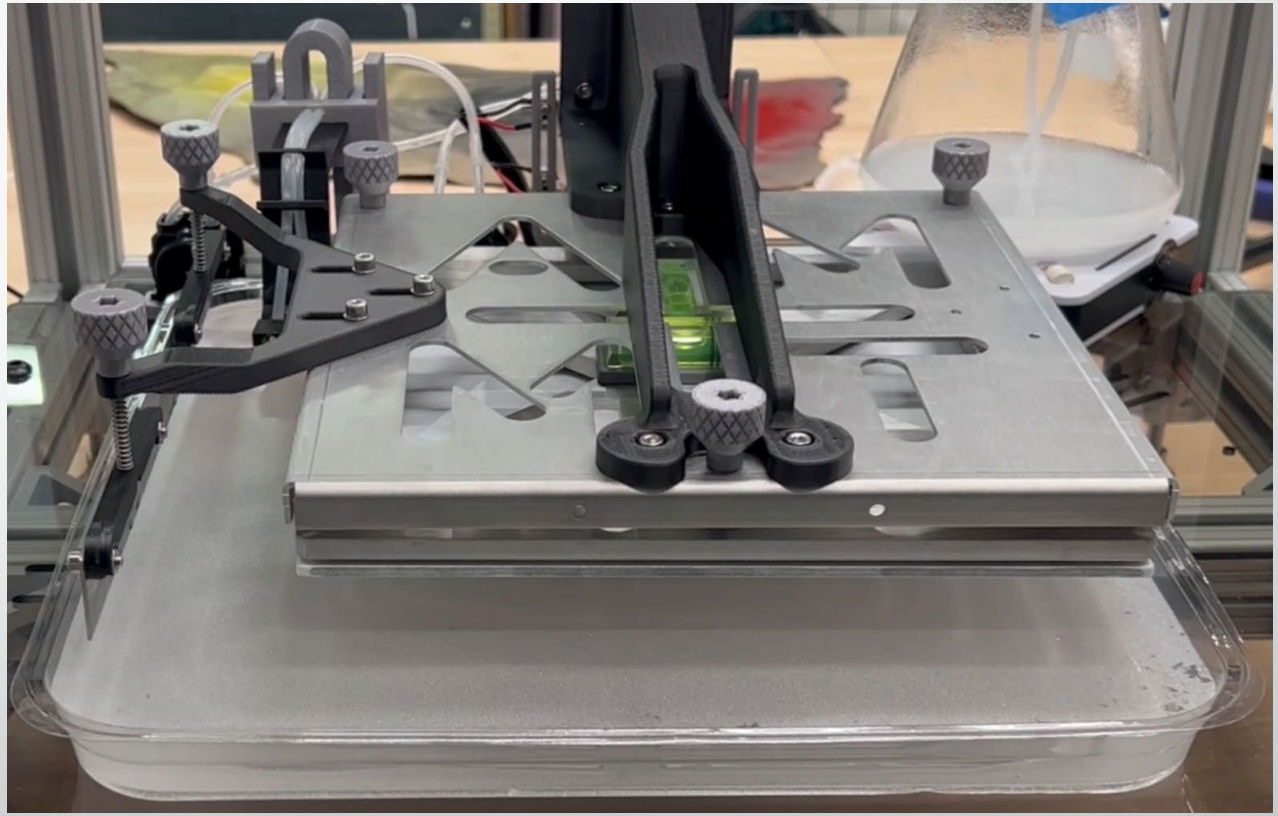
Biggest Challenge

- Contamination

Design Solution

- Disposable troughs are used
- No mechanical components are placed in the trough

Contaminated interface



2) Marangoni

Purpose

- Adds soap to the interface to induce percolation

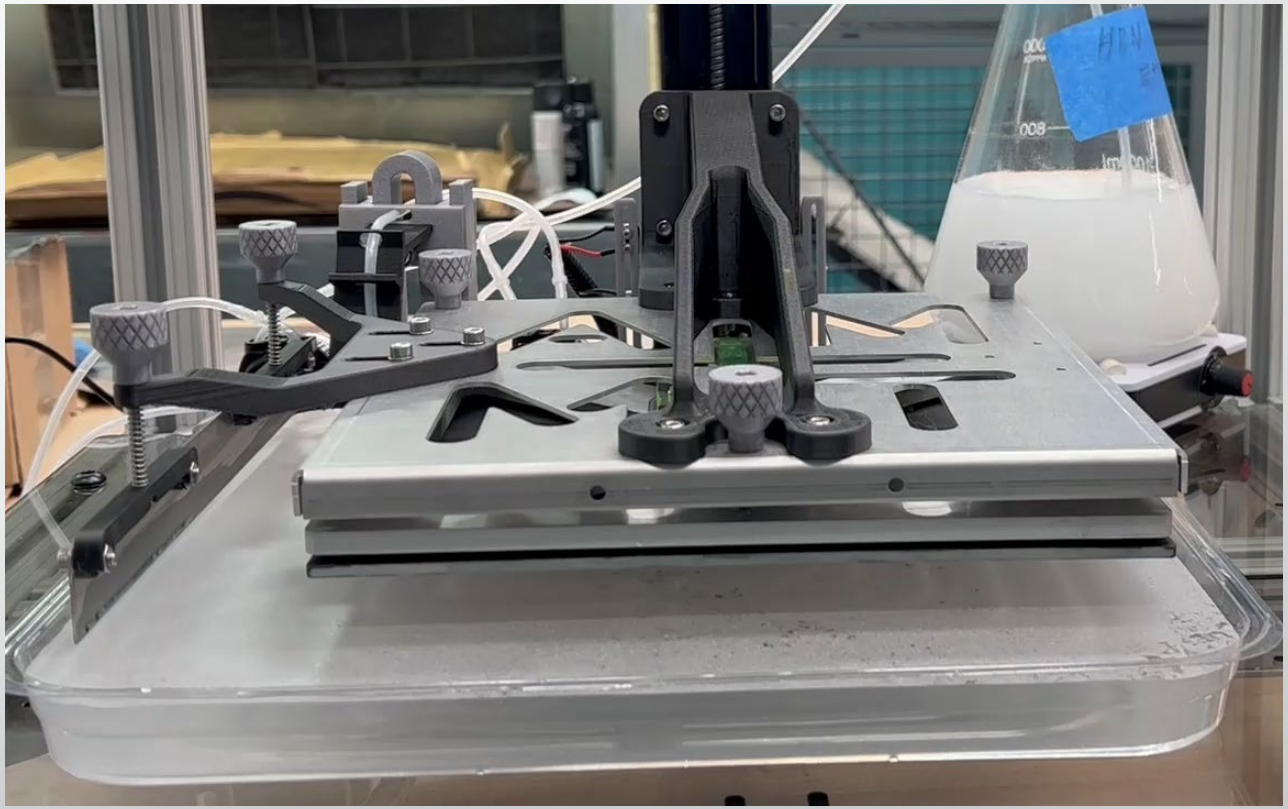
Biggest Challenge

- Contamination

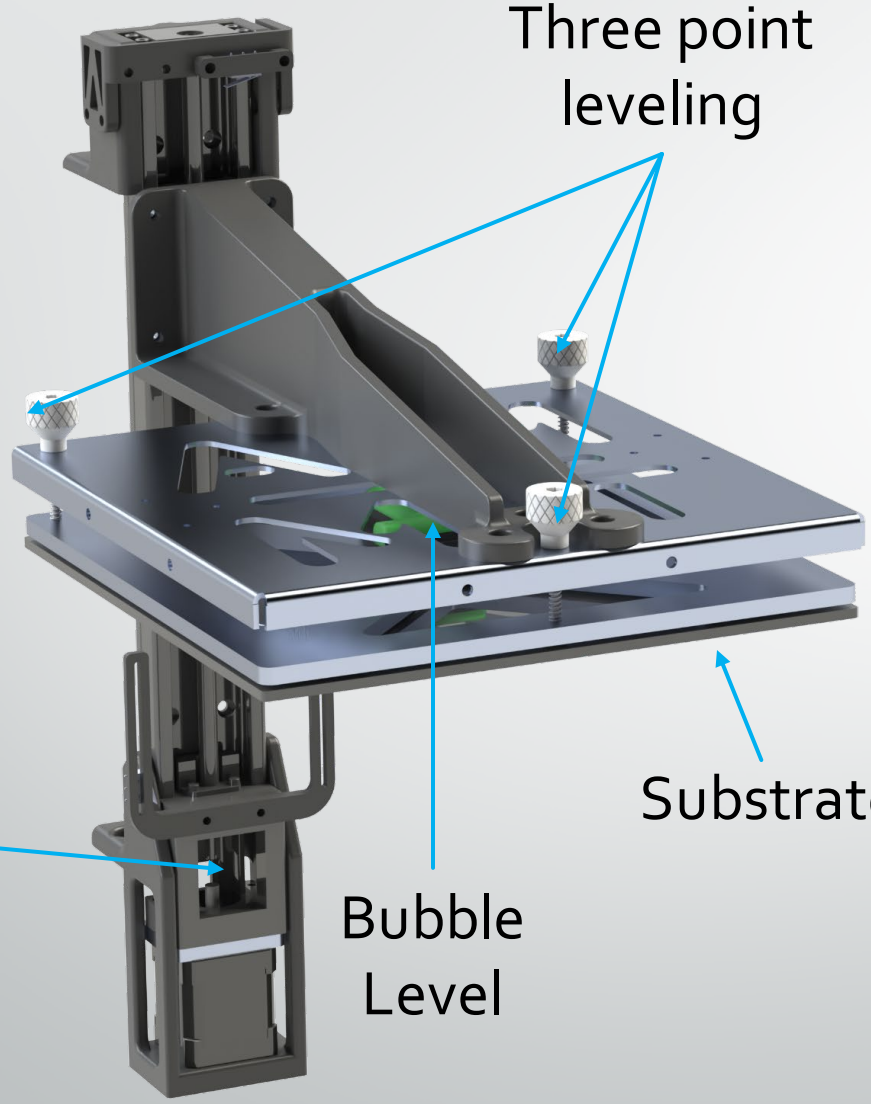
Design Solution

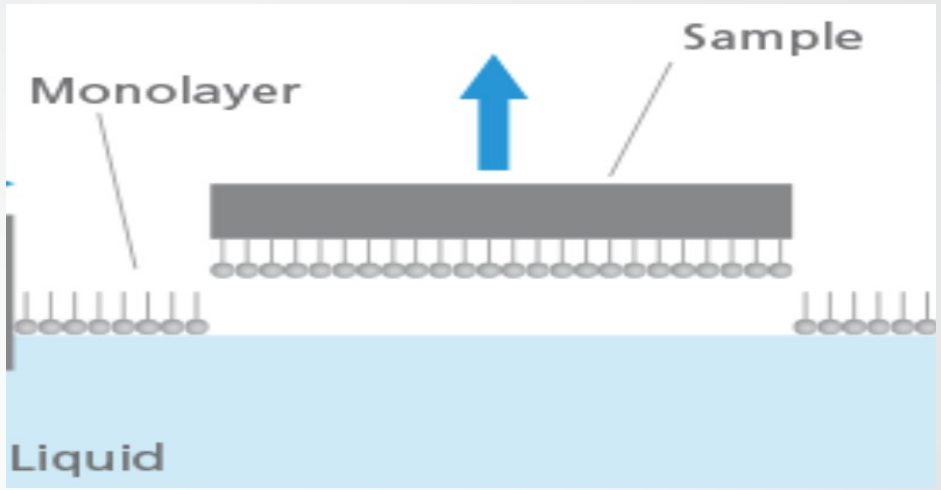
- No mechanical components are placed in the trough
- Disposable troughs are used

Uncontaminated interface



3) Transfer





Langmuir-Schaefer Method

Purpose

- Remove monolayer off air-water interface onto a solid substrate

Biggest Challenge

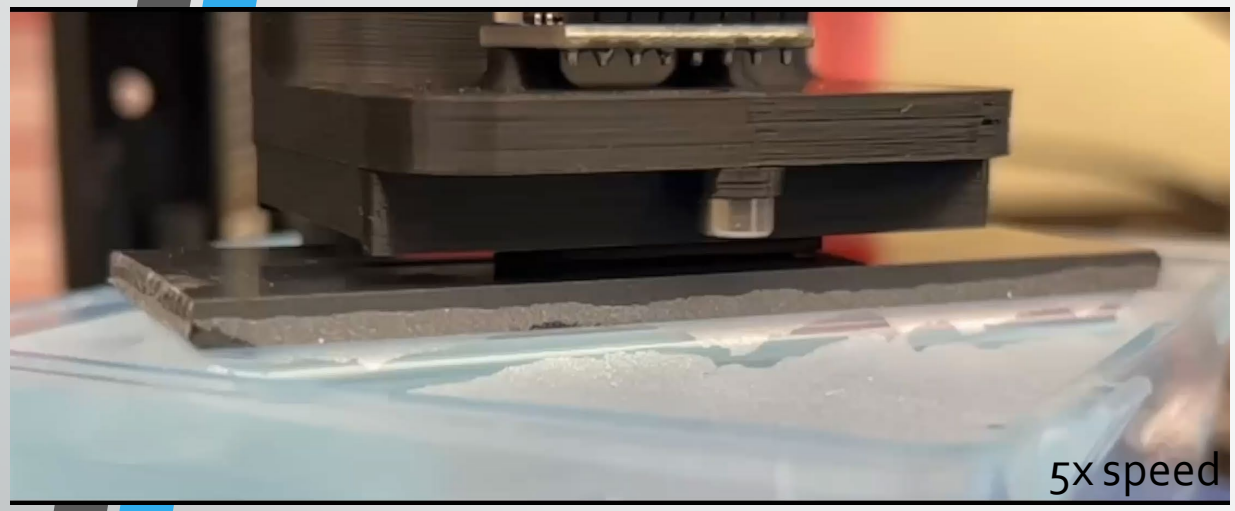
- Parallelism and tilt

Design Solution

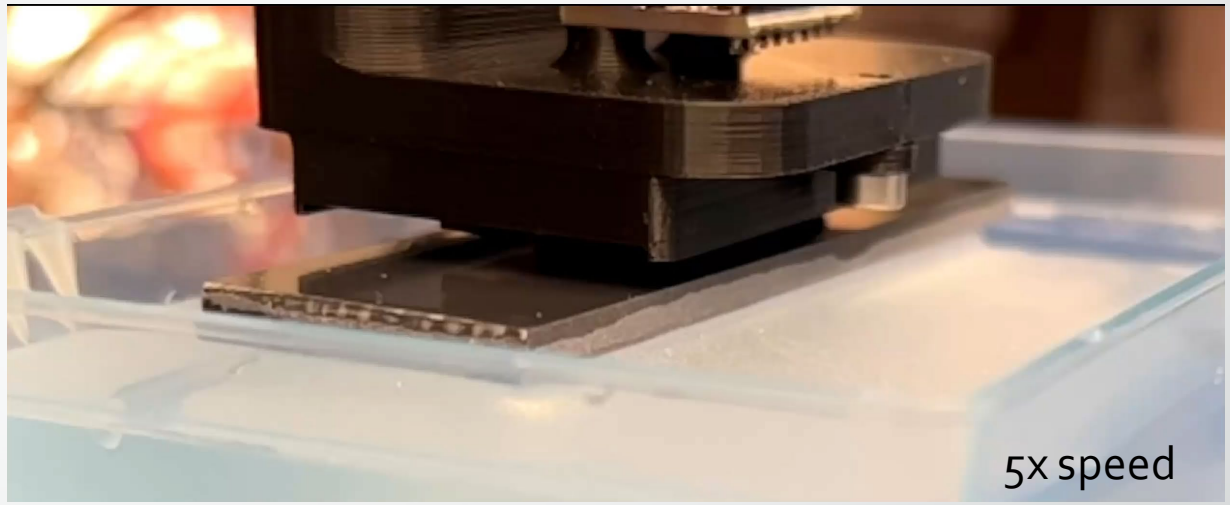
- Three point leveling with bubble levels to tune pitch and roll angles

3) Transfer

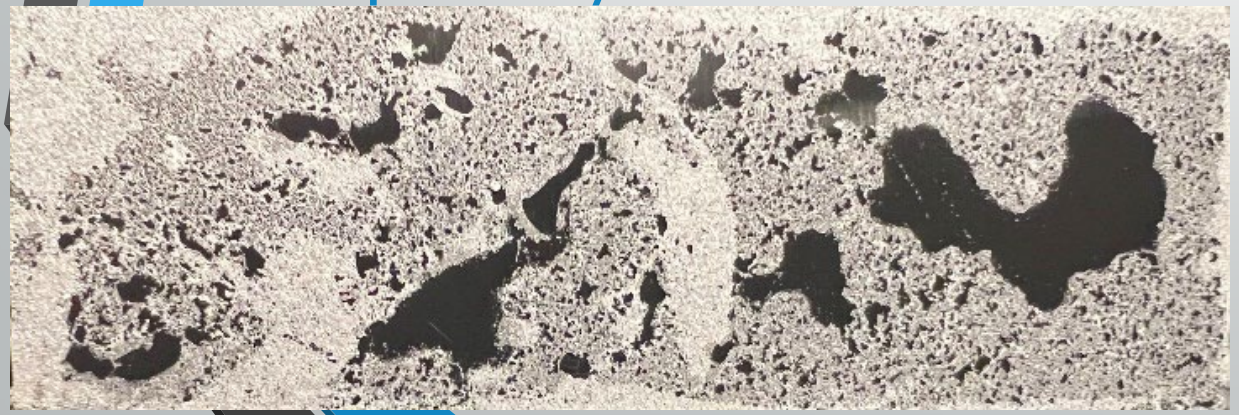
Rough transition



Smooth transition



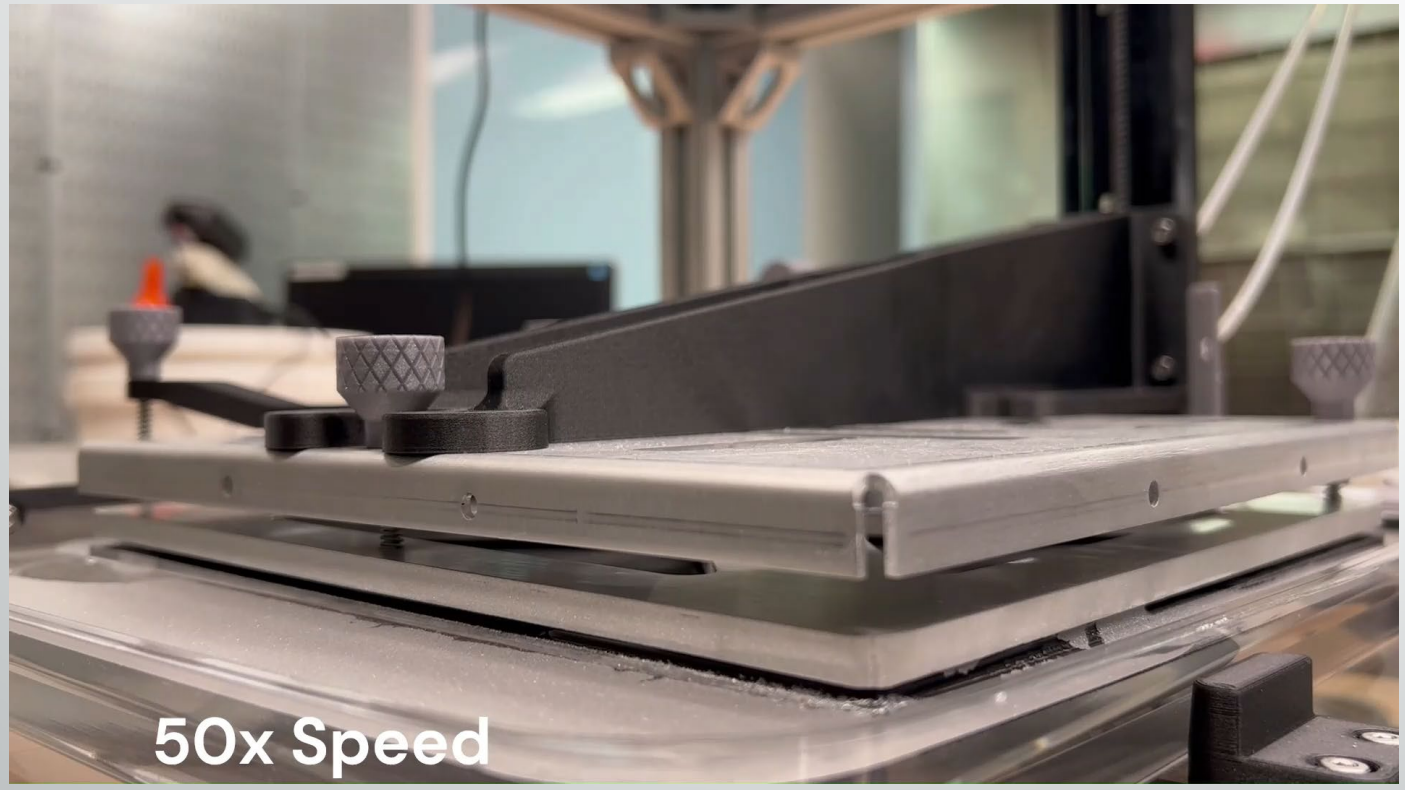
Sparsely coated



Fully coated

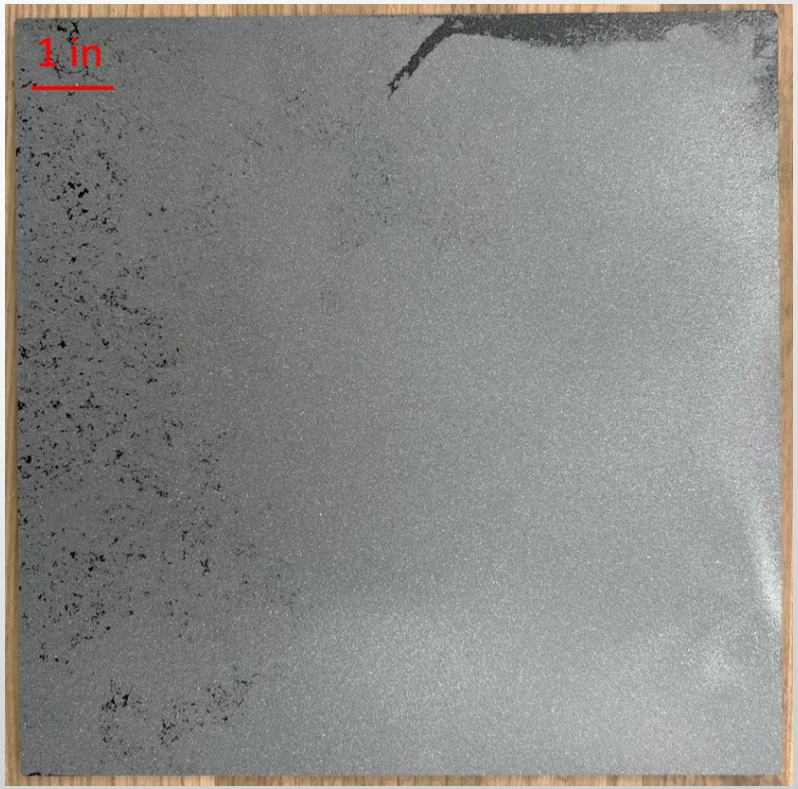
3) Transfer

Smooth transition at scale



Smooth fluid-substrate separation with o. 90° tilt angle

Substrate

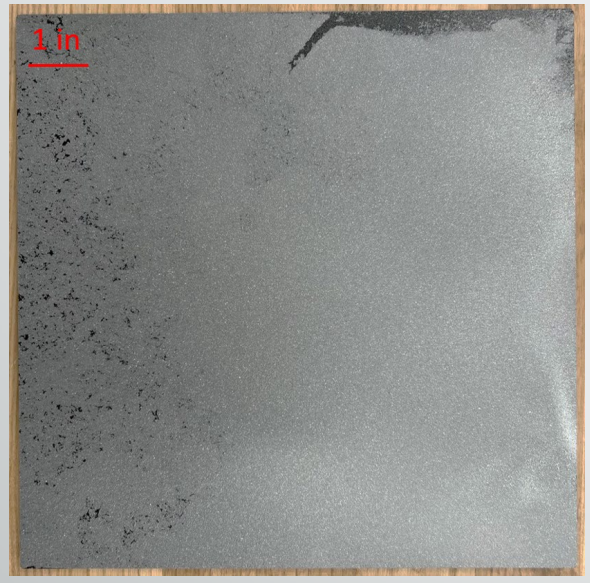


→ Fully Coated Substrate

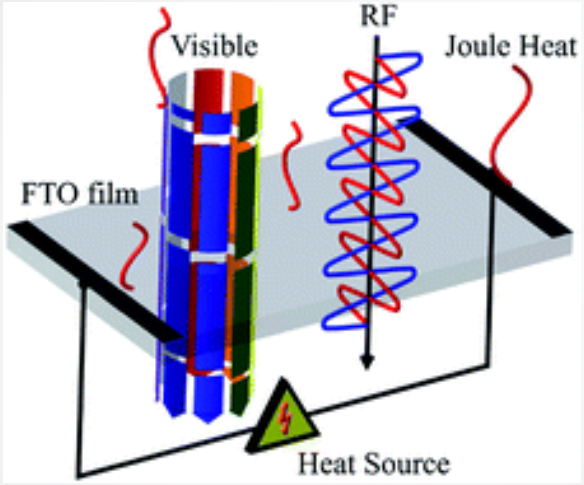
Anticipated Impact and Exit Strategy

- Hand-off to DAPS lab for continued development

Coated Substrate



Kymeta Insertion Testing



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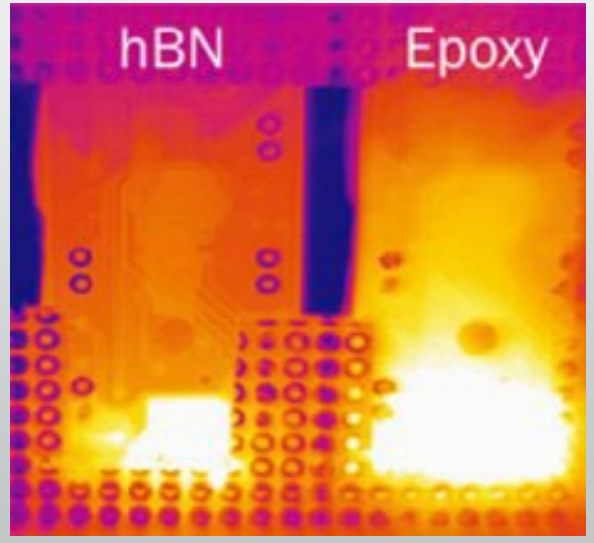
DAPS Lab Heat Transfer Testing



[2]

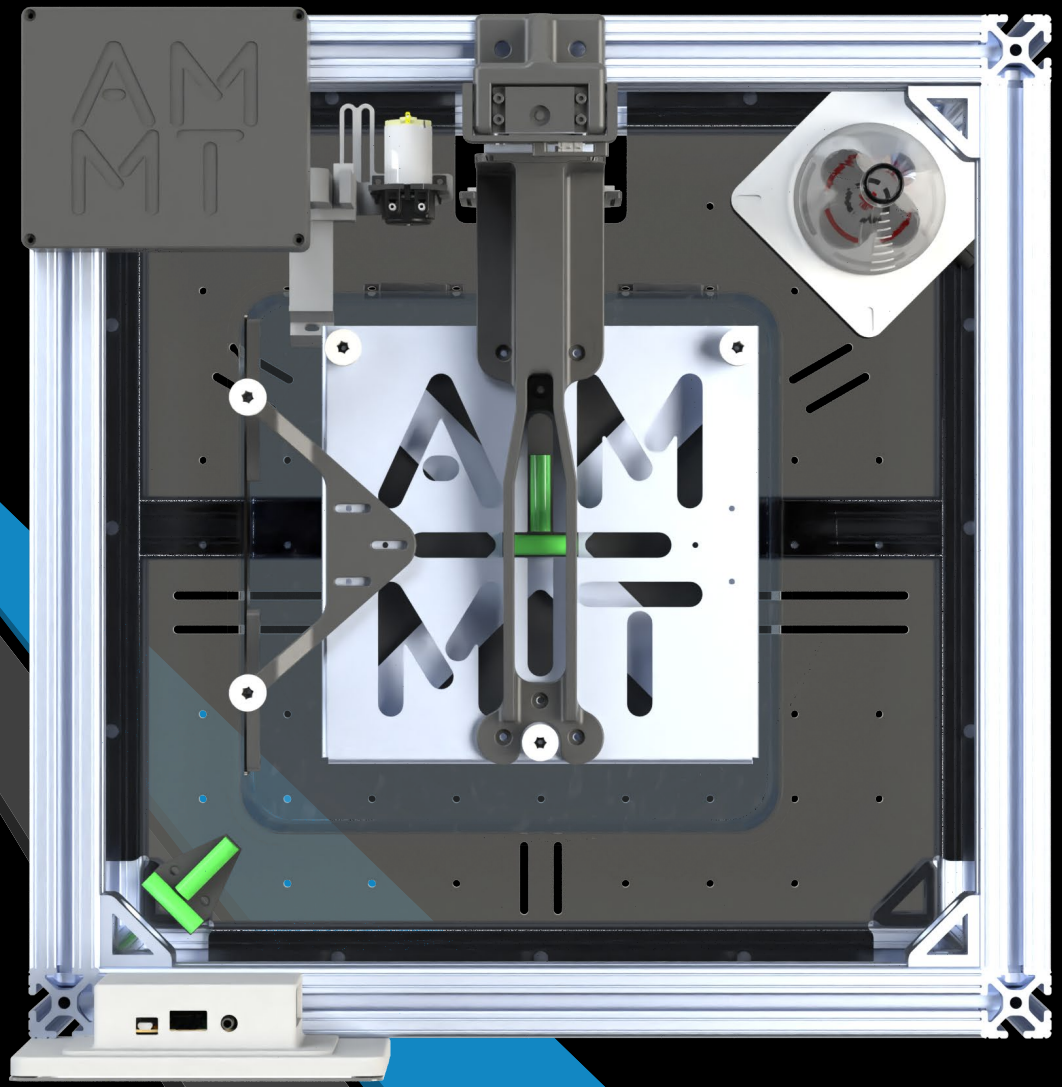
Use in Radomes

[3]

[1] Y.-R. Kim, J.-W. Park, S.-H. Park, and S.-J. Lee, "Radio-frequency and optically transparent radome de-icing materials: fluorine-doped tin oxide," RSC Adv., vol. 10, no. 59, pp. 35979–35987, Sep. 2020, doi: 10.1039/D0RA04981F.

[2] A. Gurijala, R. B. Zando, J. L. Faust, J. R. Barber, L. Zhang, and R. M. Erb, "Castable and Printable Dielectric Composites Exhibiting High Thermal Conductivity via Percolation-Enabled Phonon Transport," *Matter*, vol. 2, no. 4, pp. 1015–1024, Apr. 2020, doi: 10.1016/j.matt.2020.02.001.

[3] "North America's Arctic radar shield is due for an upgrade," *The Economist*. Accessed: Jul. 23, 2022. [Online]. Available: https://www.economist.com/the-americas/2021/07/29/north-americas-arctic-radar-shield-is-due-for-an-upgrade



Questions?