The Effect of PBS and Temperature on Adhesion Properties of Artificial Bio-Inspired Micro-Patterned Surfaces

Undergraduate Researcher: Robert Spencer Garland

Advisor: Dr. Carl Frick

NSF EPSCoR Fellowship

Mechanical Engineering

College of Engineering and Applied Sciences

University of Wyoming

Background

What is are Micro-Patterned Surface?

A surface consisting of many micron-sized pillars that provide a large contact area with a substrate, increasing adhesion through intermolecular forces (i.e. Van der Waals interactions)

These surfaces naturally exist on attachment pads of many animals such as:

-spiders

-insects

-geckos

Background

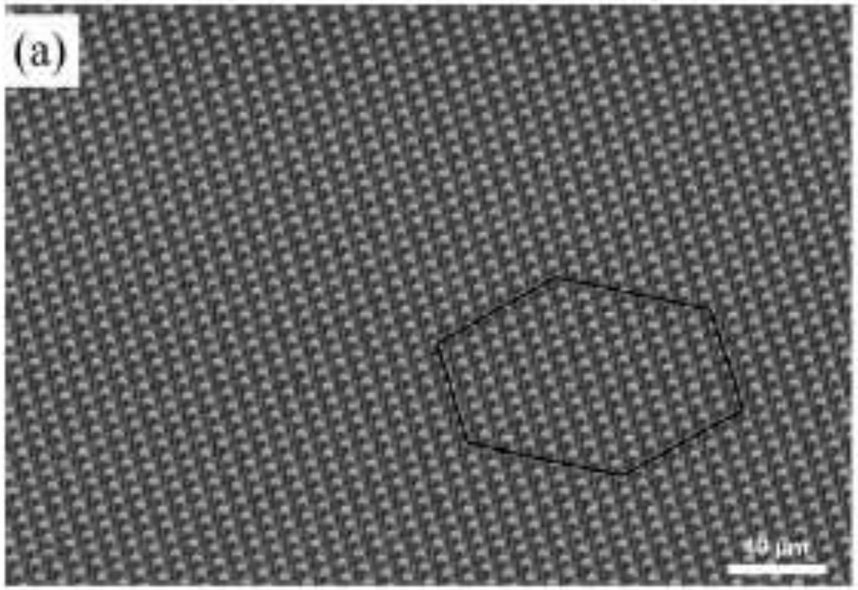
Purpose: To understand the effect of Phosphate Buffered Saline (PBS) and temperature on adhesion properties of artificial micro-patterned surfaces

Can be achieved through the fabrication, preparation, and analysis of polymer micro-patterned surfaces.

Background

Research Strategy:

- 1) Run preliminary DMA tests to determine mechanical properties of the polymer materials
- 2) Fabricate micro-patterned surfaces out of polymer materials
- 3) Adhesion testing (in Germany)
- 4) Analyze the results and modify polymer compositions accordingly.

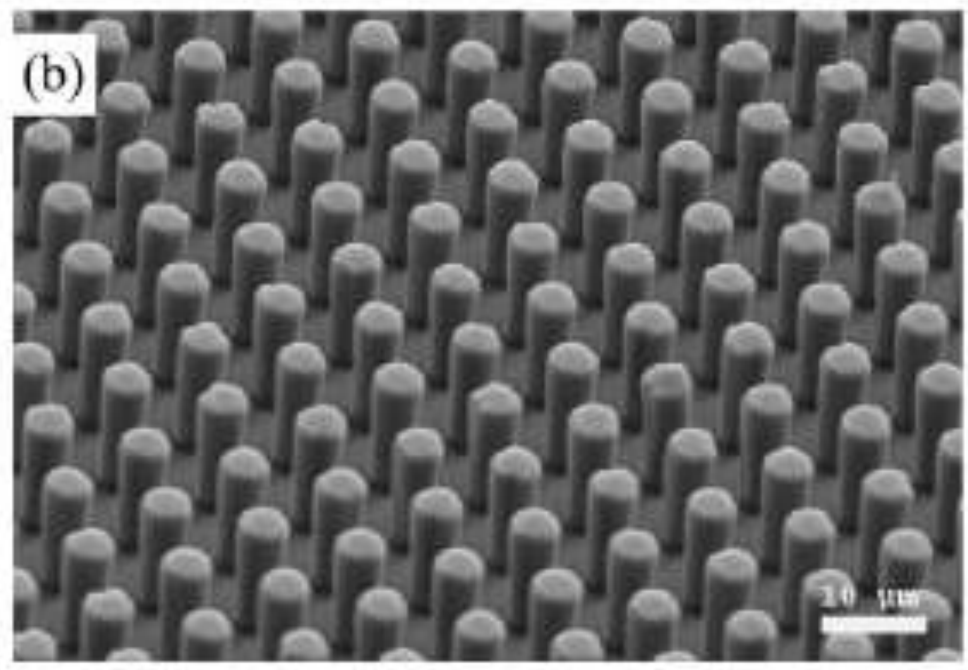


(a) Shows the hexagonal symmetry of the micro-pillars

Background

<u>Key Application: Switchable Adhesion</u>

- Temperature: Adhesive at 75°C but non-adhesive at 0°C
- Environment: Adhesive in PBS but non-adhesive in air

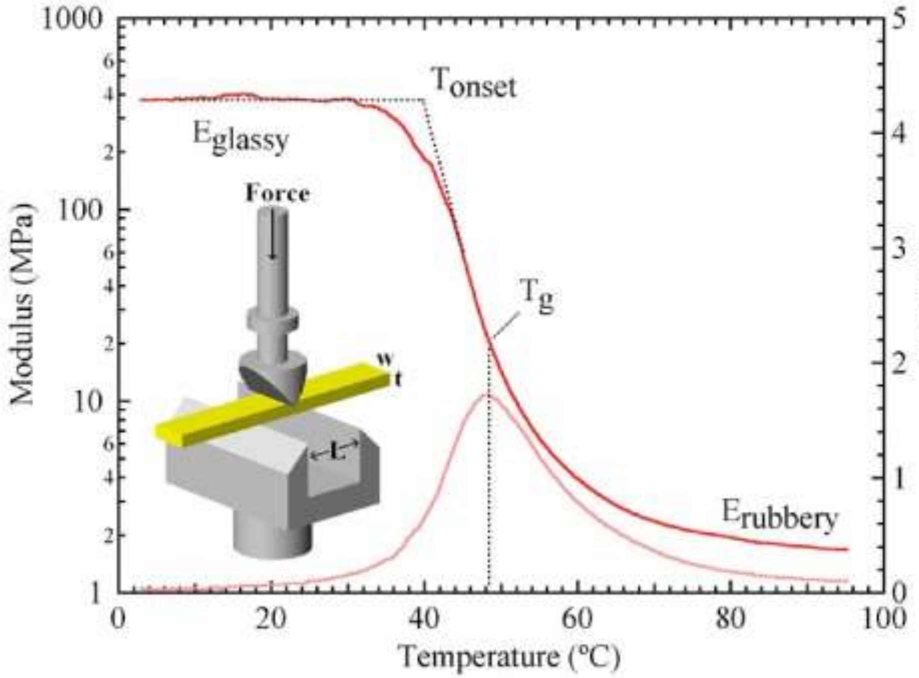


(b) depicts the shapes and spacing of the pillars.

Background

Mechanical Properties:

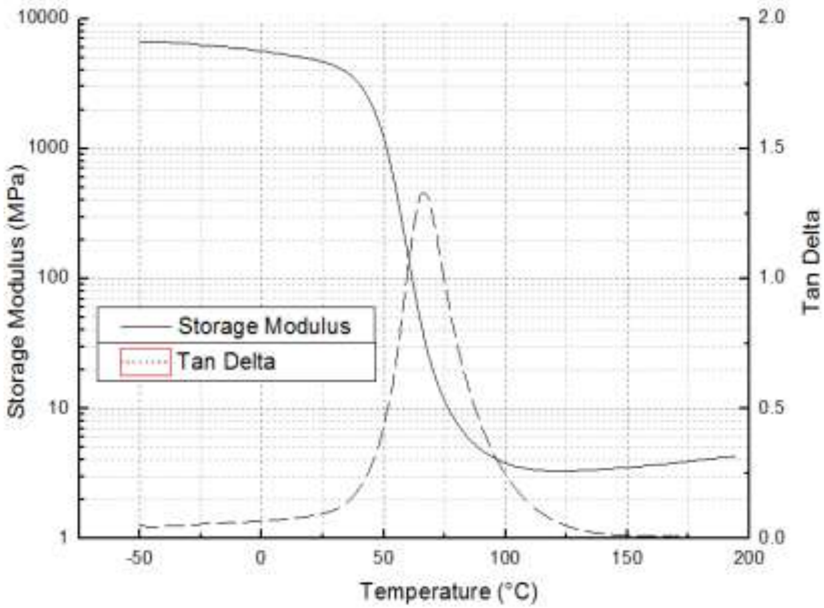
- Glass Transition Temperature (Tg)–a function of chemistry
    - a function of chemistry
    - generally decreases with water absorption
- Storage Modulus (Modulus of Elasticity)
    - –Glassy Modulus
    - –Rubbery Modulus



Background

<u>Temperature Effects on Adhesion Properties</u>

- –Large change in stiffness (storage modulus)
- –Stiffer materials are less compliant and make poor contact
- –The stiffer the material, the less adhesive
- –Adhesive at low temperatures and non-adhesive at high temperatures

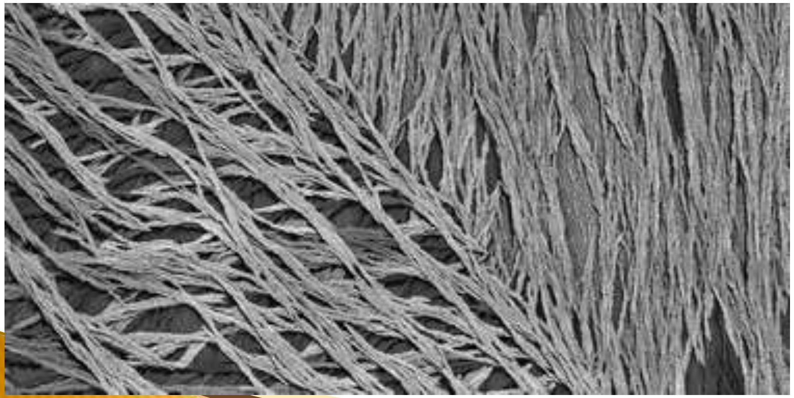


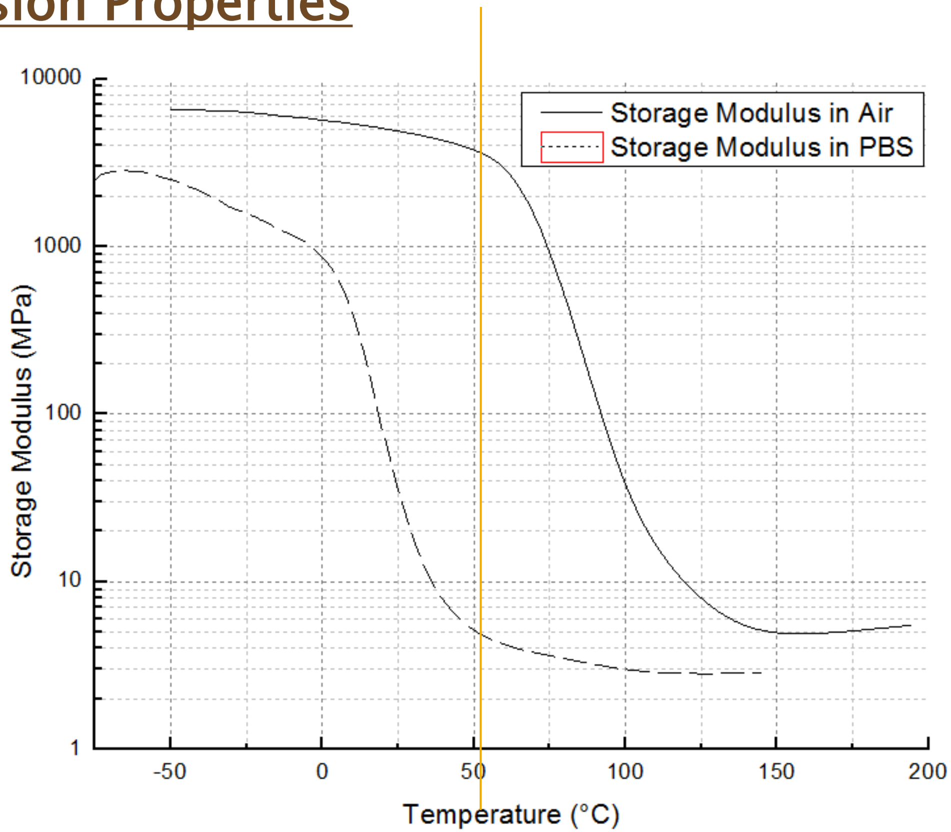
Dynamic Mechanical Analysis in air for 50% BZA-co-50% 2HEMA-co-10% PEGDMA depicting the Storage Modulus and Tan Delta Curves.

Background

Environmental Effects on Adhesion Properties

- Use PBS to mimic water
- PBS absorption usually weakens polymer
  - Lower stiffness
  - Lower strength
- At a given temperature:
  - adhesive in PBS
  - non-adhesive in air



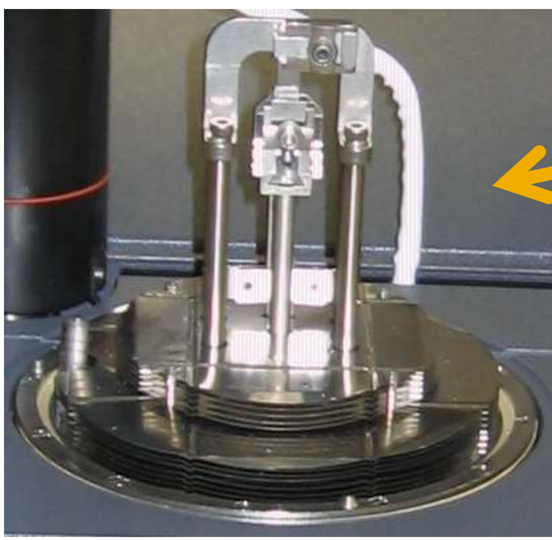


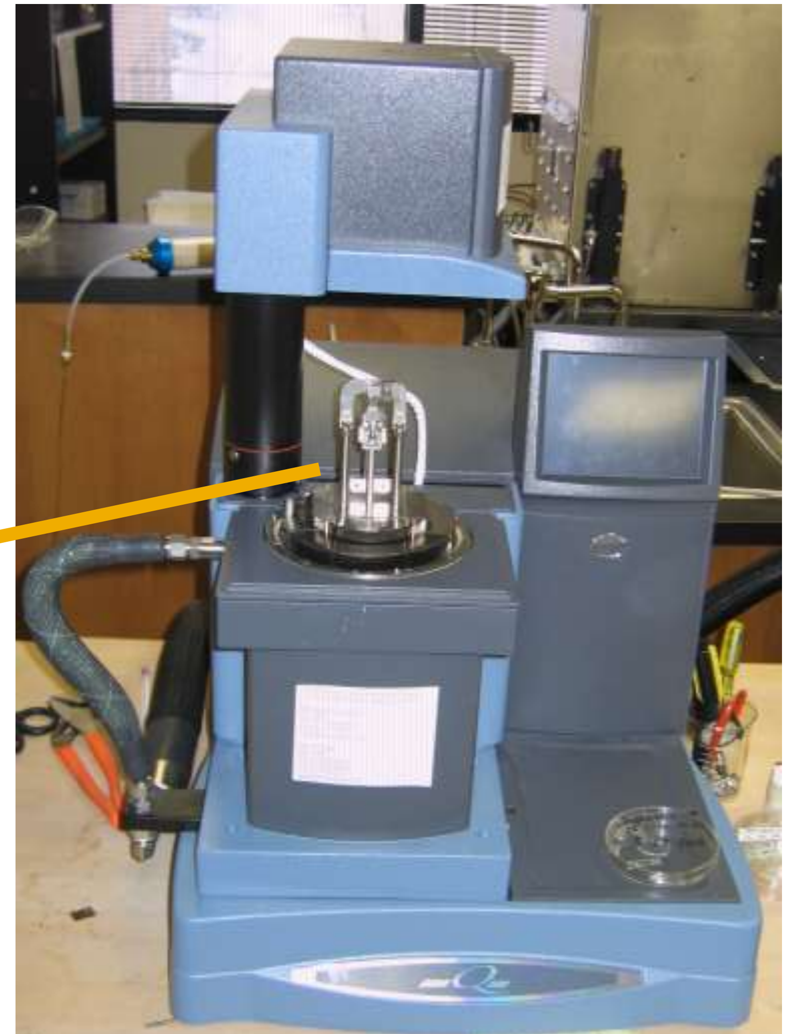
Dynamic Mechanical Analysis in air and PBS for 20% BZA-co-80% 2HEMA-co-10% PEGDMA depicting the shift in Storage Modulus due to PBS absorption.

Background

<u>Dynamic Mechanical Analyzer (DMA)</u>

- Used for preliminary testing
- Tension Tests



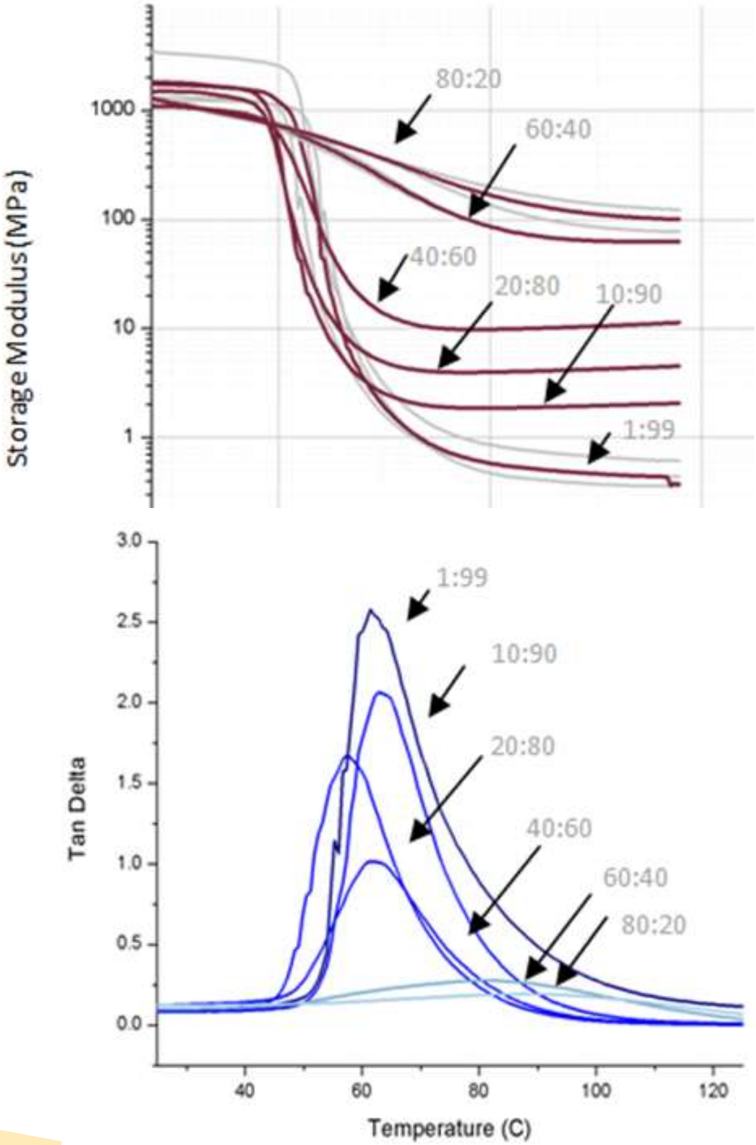


Background

Preliminary DMA Results

-Large variation in the rubbery storage modulus as the ratio of cross-linker to tBA is varied

-Relatively constant glass transition temperature

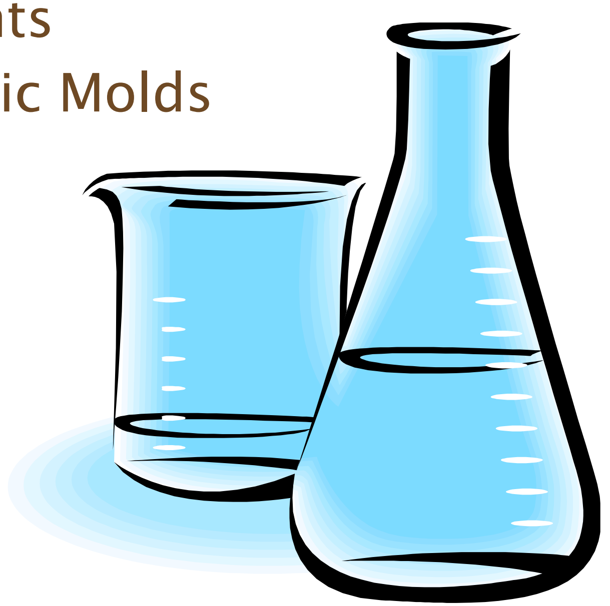


Methods

Fabrication Tools:

- Fume hood
- Scale
- Glass cutter
- Mechanical mixer
- Ultraviolet lamp
- Light shield
- Oven

- Glass Slides
- Pipette
- Beaker
- Dessicator
- Safety goggles
- Polymer components
- Sylgard Lithographic Molds



Methods

<u>Polymer Components:</u>

-**PEGDMA:** Cross-linker

-**DEGDMA:** Cross-linker

-**Photoinitator:** Reacts with UV light

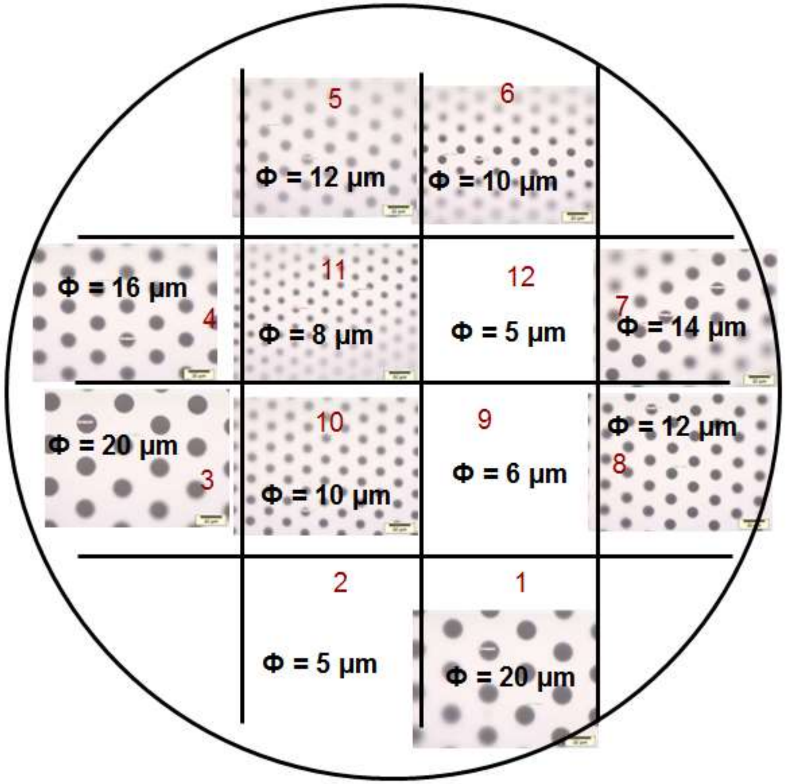
- **tBA:** Monomer component

- **DMPA:** Monomer component

Methods

<u>Salinization Procedure:</u>

- Prepare Hexane and PFT mixture
- Place mixture (w/o cap) in dessicator
- Place Slygard mold in dessicator
- Pull a vacuum for 30 minutes



Methods

<u>Sample Fabrication:</u>

-Cut PDMS molds into individual quadrants

-Attach mold quadrants to square glass slide using caulking

-Apply vacuum grease along the perimeter of the PDMS mold quadrant

-Outline another square slide with caulking, leaving a gap to allow for injection of the polymer solution.

-Let the caulking dry for 24 hours

Methods

Sample Fabrication cont.:

-Place glass slide with perimeter caulking on top of the mold quadrant set up.

-Secure the new set up with rubber bands

-Place set up and polymer solution in freezer for at least 20 minutes

-Inject the polymer solution into the slide set up and fill the gap with vacuum grease

-Place set up under UV light for 15 minutes

-Carefully remove the now solid polymer sample from the PDMS mold

Results

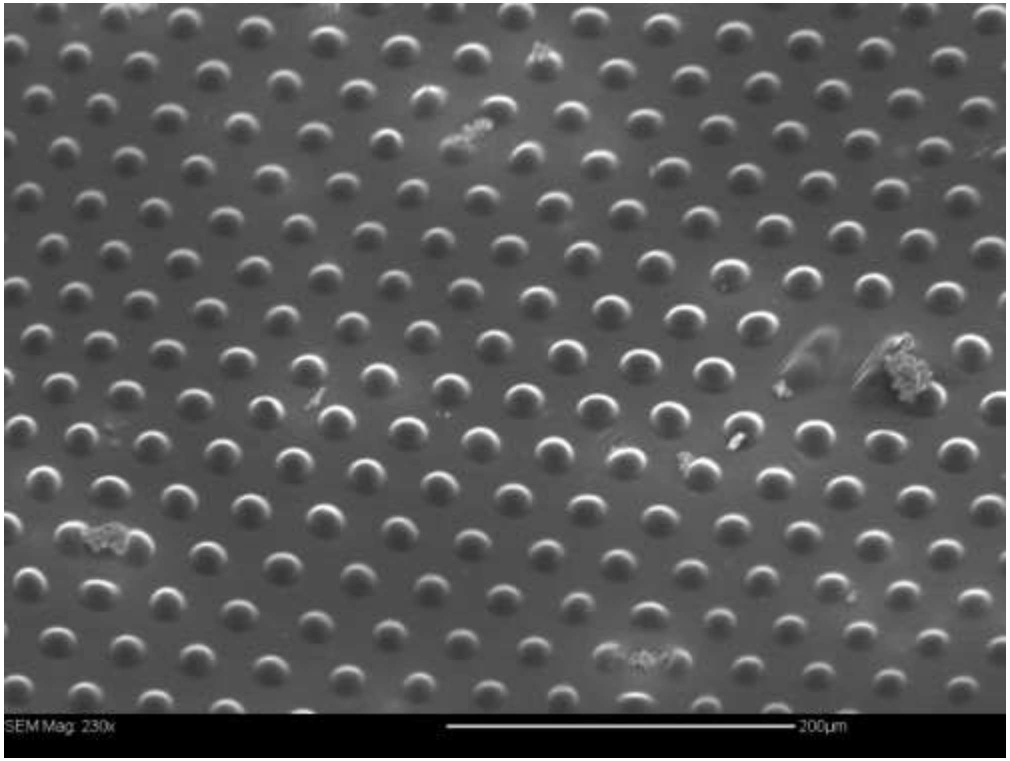
Micro-Pillar Formation:

-unable to form complete pillars

-Two Possibilities:

-salinization material partially filled the micro-pillar holes in the PDMS mold

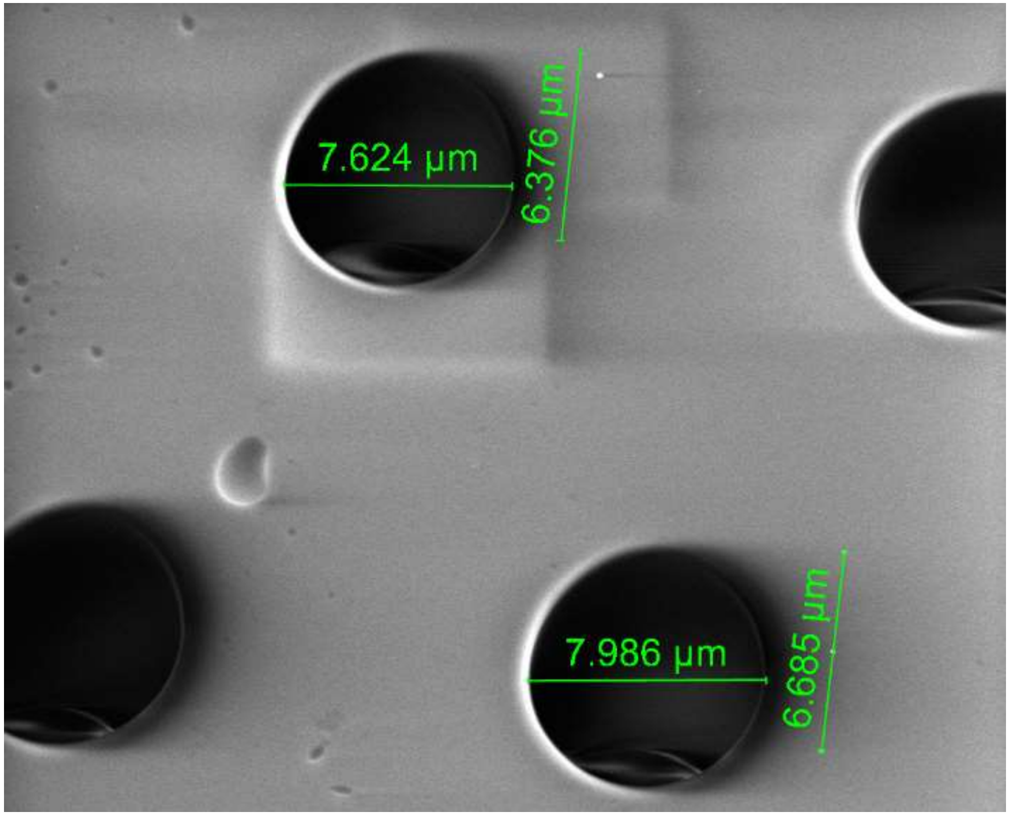
-shrinkage during solidification caused the polymer material to pull out of the mold



Results

Incomplete Pillars:

- –Measured the hole depths
- –SEM picture taken at an angle
- –Simple trigonometry used to determine micro-pillar hole depth
- –Conclusion:
  - –Salinization material not filling micro-pillar holes
  - –Shrinkage during solidification a problem

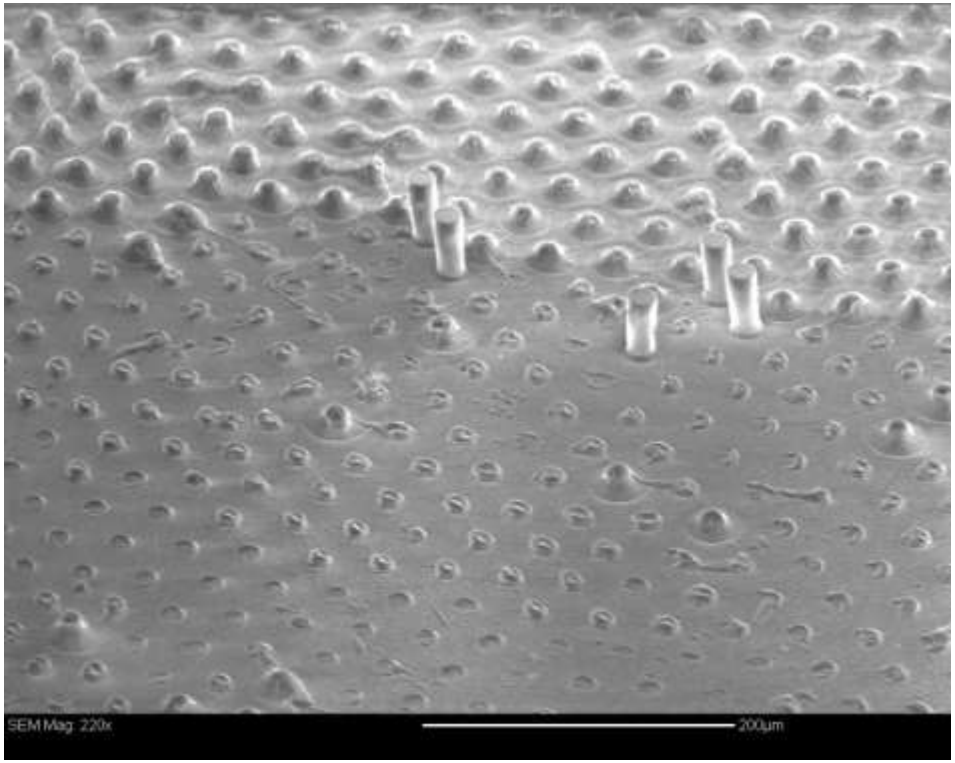


Results

Broken Micro-Pillars:

-Two Possibilities:

- -incomplete salinization resulting in polymer adhesion to PDMS mold
- -sheared off during sample removal from the PDMS mold

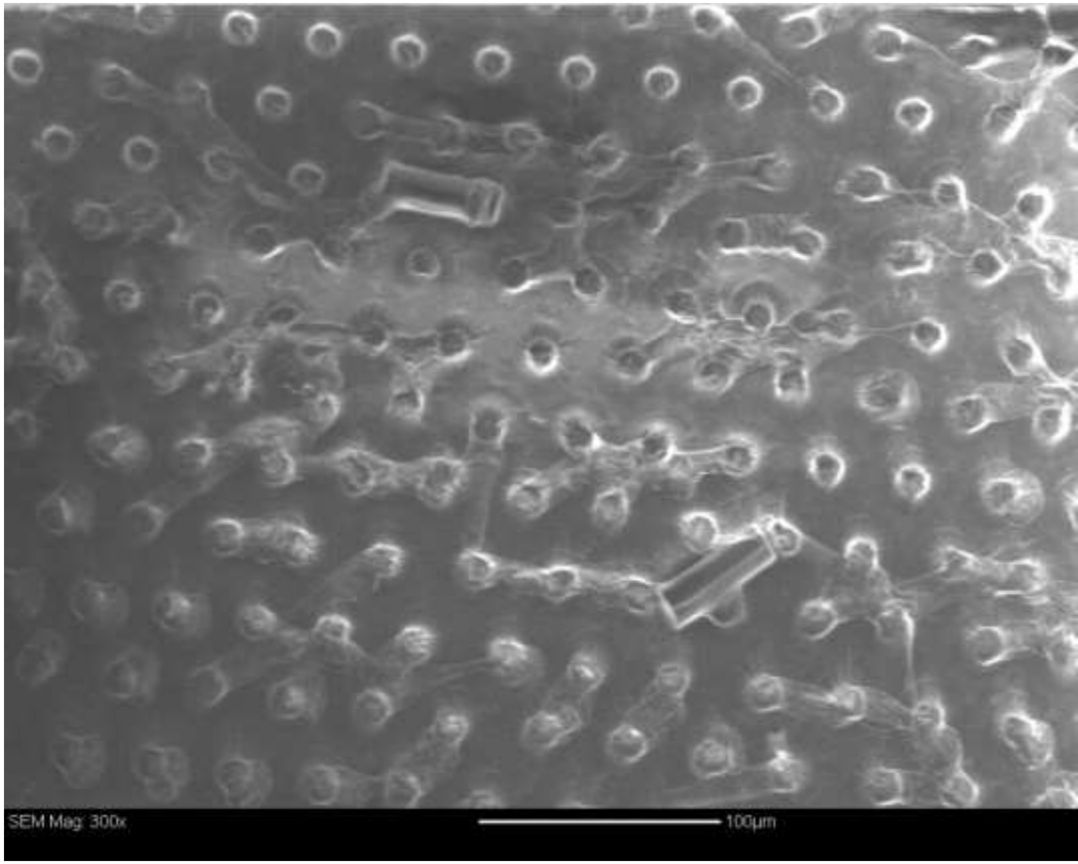


Results

Broken Micro Pillars

-some micro-pillars found laying on polymer surface

-likely do to difficult removal process, not incomplete salinization



Conclusions

-Difficult to establish a set of procedures that works for making micro-patterned surfaces using the polymer materials vs. PDMS

-Difficult to create a sealed slide set-up

-Problems with polymer contraction during solidification

-Inconsistency of polymer samples due to complex fabrication procedure

-Broken micro-pillars due to difficult removal process

Conclusions

Future Research

-Try solidifying the polymers through use of a thermal initiator

-Consider a more easy-to-construct slide set up

-Refine the polymer removal process to avoid shearing micro-pillars