National Nanotechnology Coordinated Infrastructure

HARVARD John A. Paulson School of Engineering and Applied Science

Hybrid Plasmonic Topography for Contaminant Removal

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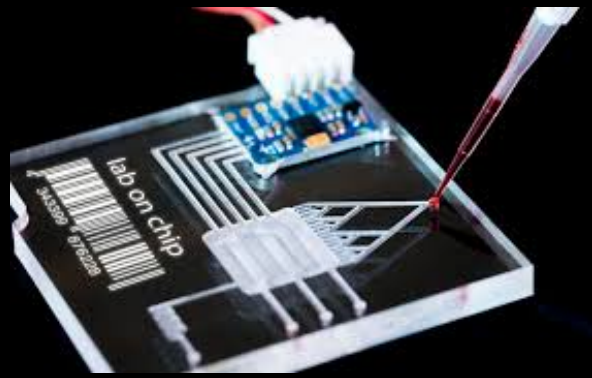
Goal: To develop a low fouling surface that enables localized, remotely controlled removal of contaminants

Motivation: Localized decontamination in hard-to-reach places

Microfluidic devices



(Medical Plastics News)

Fouled photobioreactor

(Algae World News)

Fouled boat propeller

(Ocean Sail)

Catheters

Goal: To develop a low fouling surface that enables localized, remotely controlled removal of contaminants

Motivation: Localized decontamination in hard-to-reach places

Typical solutions:

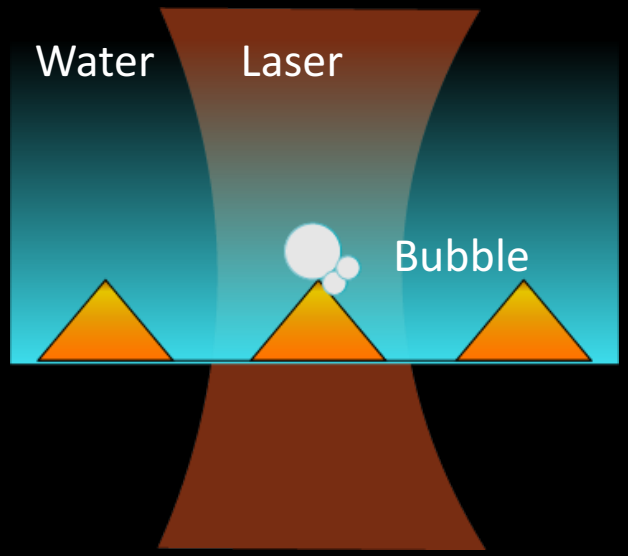
- Flow
- Soap
- Bubbles

--> **Directly impacts operation of the system**

Sonication bubble cleaning

Approach: Hybrid surface with two components

Laser-induced bubble generation on plasmonic topography



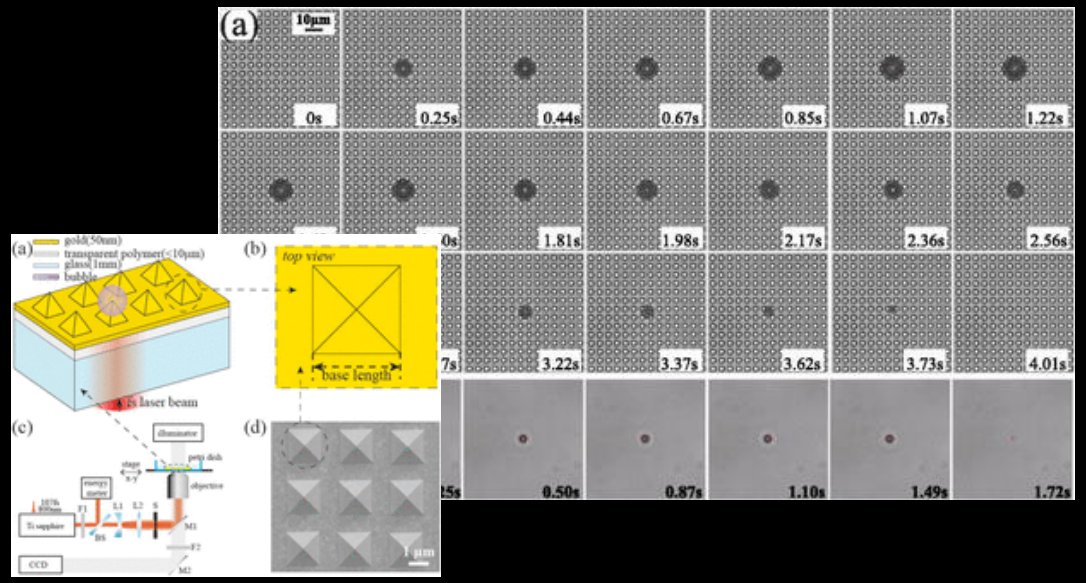
+

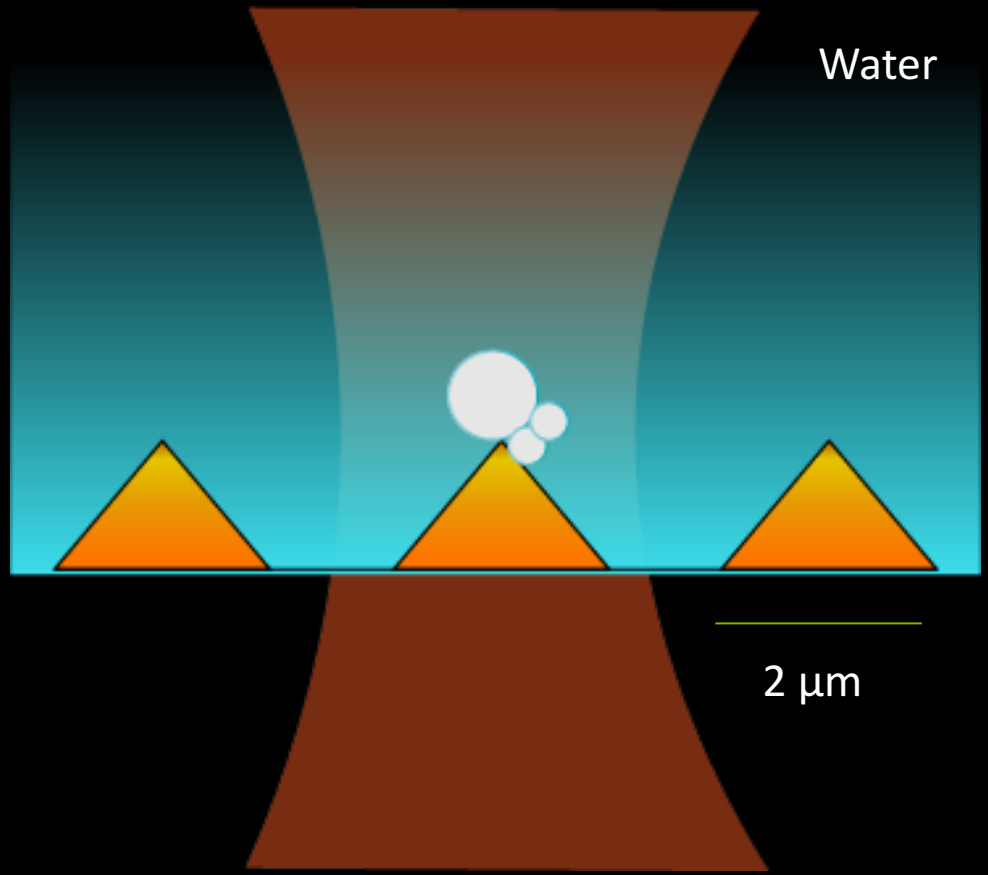
Temperature-responsive hydrogel

Passive and active protection against contaminants?

Remotely controlled, localized bubble generator: Plasmonic micropyramids

Plasmonic micropyramids localize laser heating to tips, increasing temperature of water and **creating bubbles.**

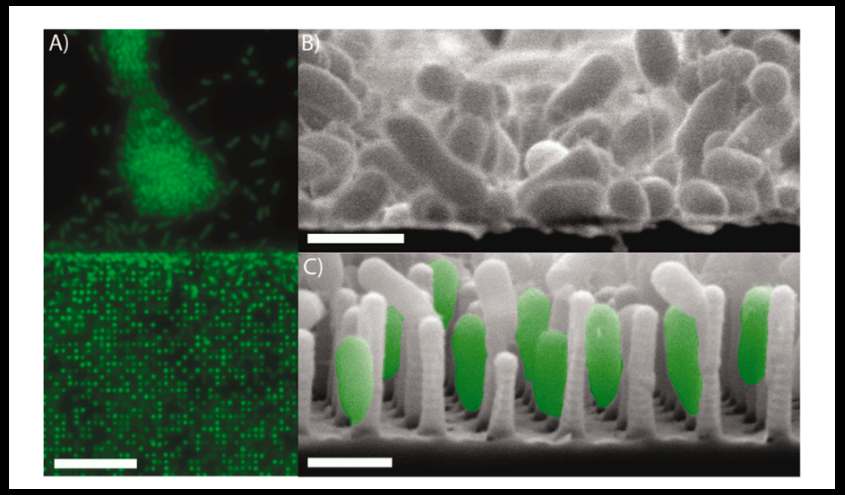




Chen et al. (Applied Physics Letters 2017)

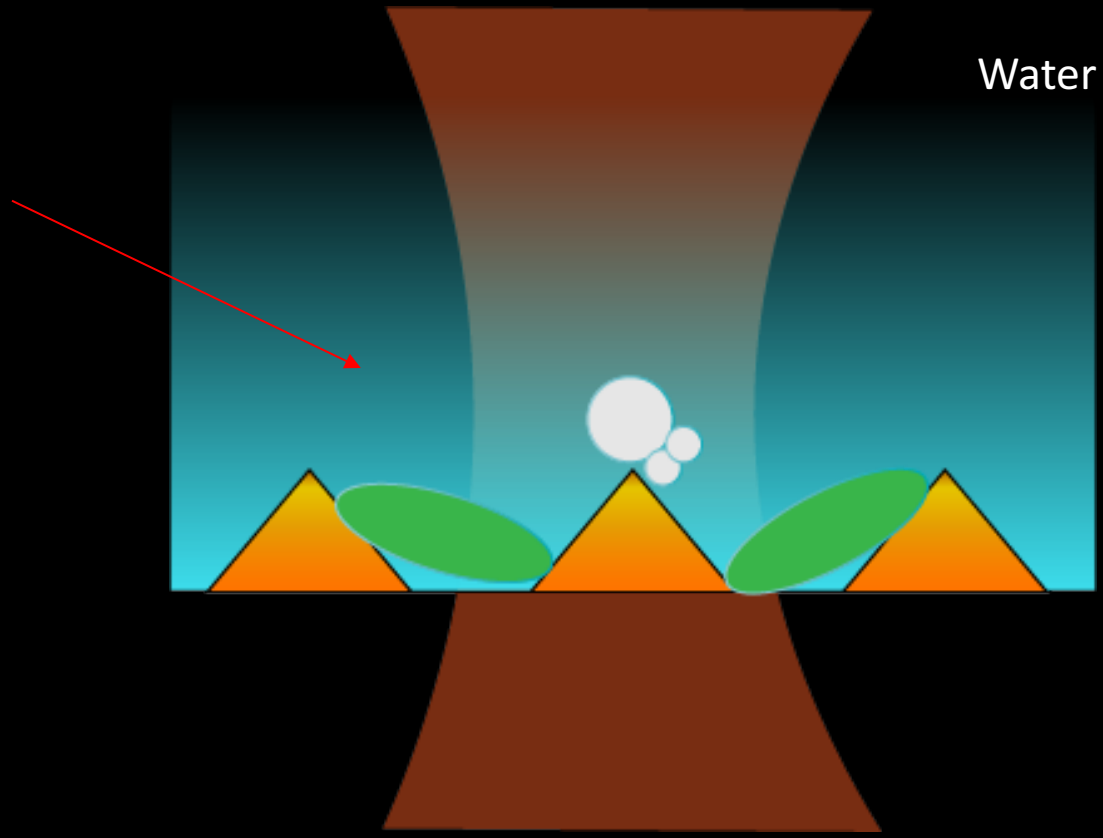
Remotely controlled, localized bubble generator: Plasmonic micropyramids

However, topography at this scale presents **crevices and solid contact** for micron-scale contaminants.



10 µm

Friedlander et al. (ACS Nano 2015)

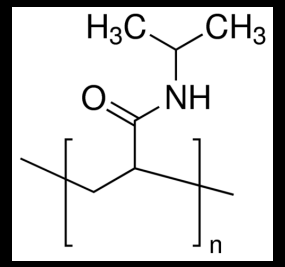


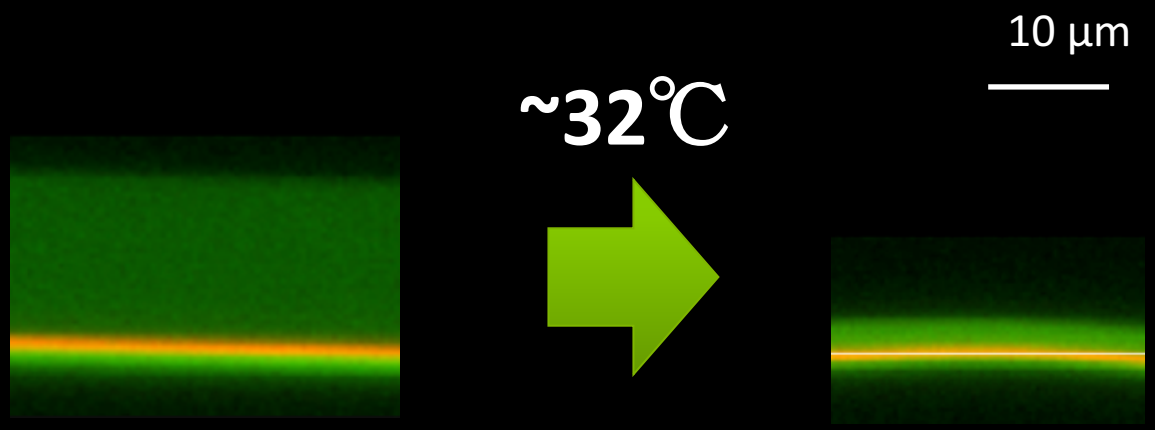
Non-sticky, smooth surface: Thermoresponsive hydrogel:

Hydrogel: polymer network swollen in water

- Smooth surface
- Relatively low adhesion

Poly N-isopropylacrylamide



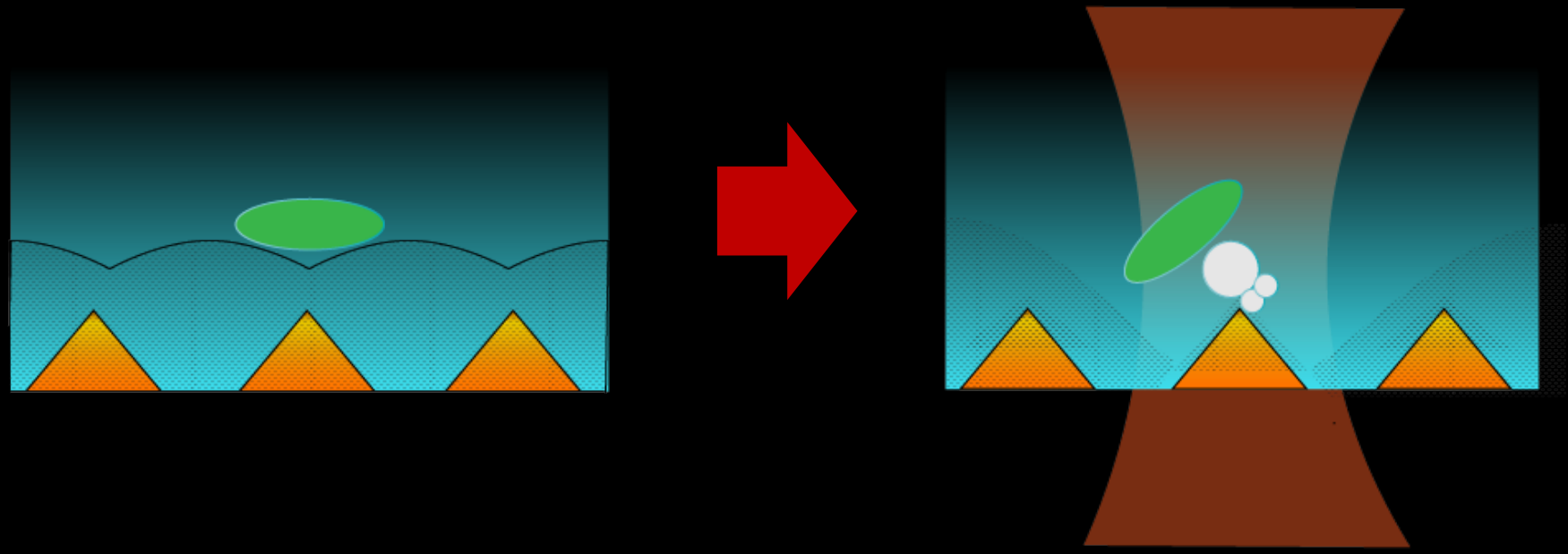


Hybrid thermoresponsive gel-plasmonic topography

Can we remotely trigger the removal of typically sticky contaminants from hydrogel using light-generated bubbles?

Laser OFF

Laser ON

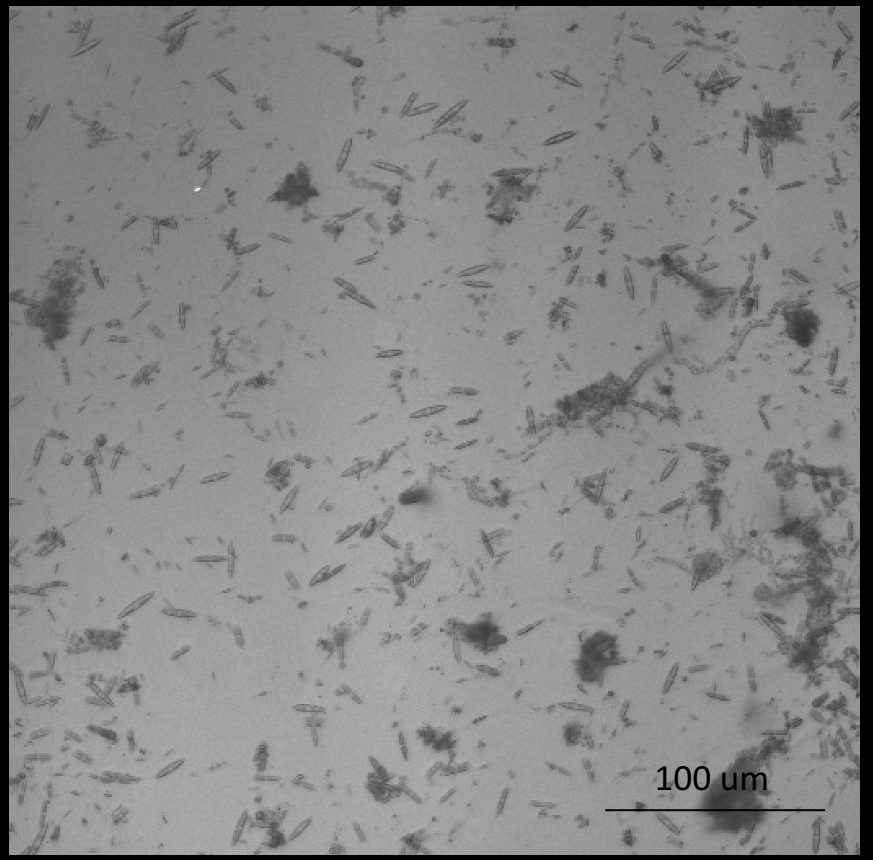


Model fouling contaminant: Diatoms

Diatoms on gel

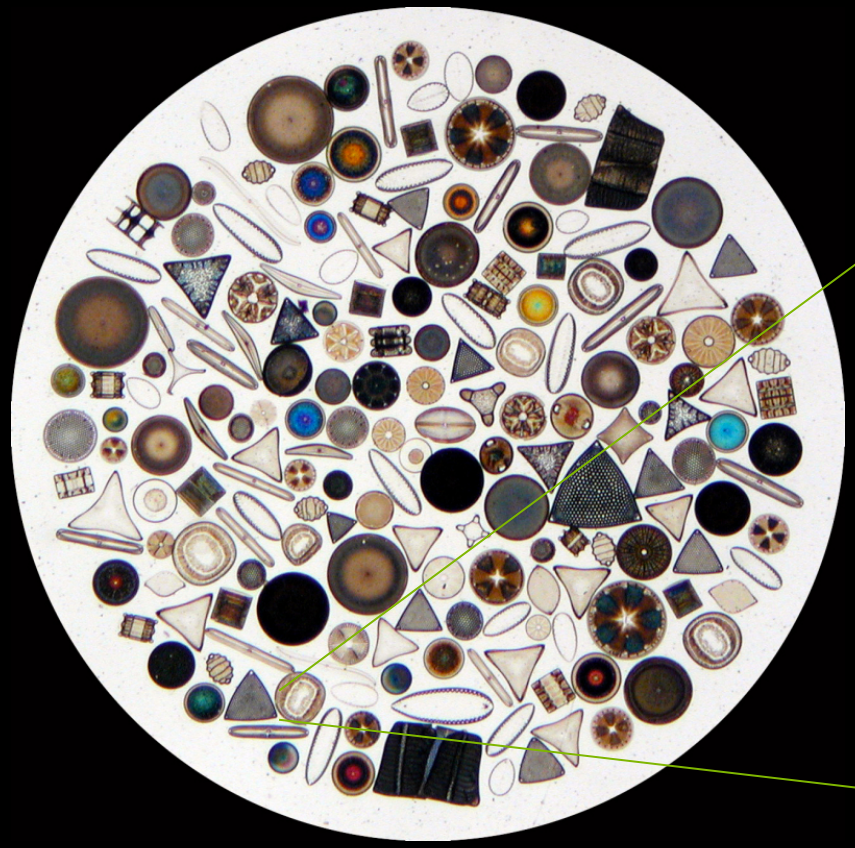
Field test in Scituate, MA – Fall 2016

After 1 week:

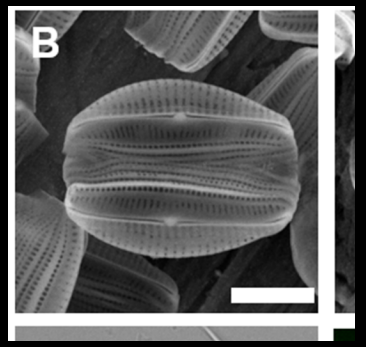


Model fouling contaminant: A. *coffeaeformis*

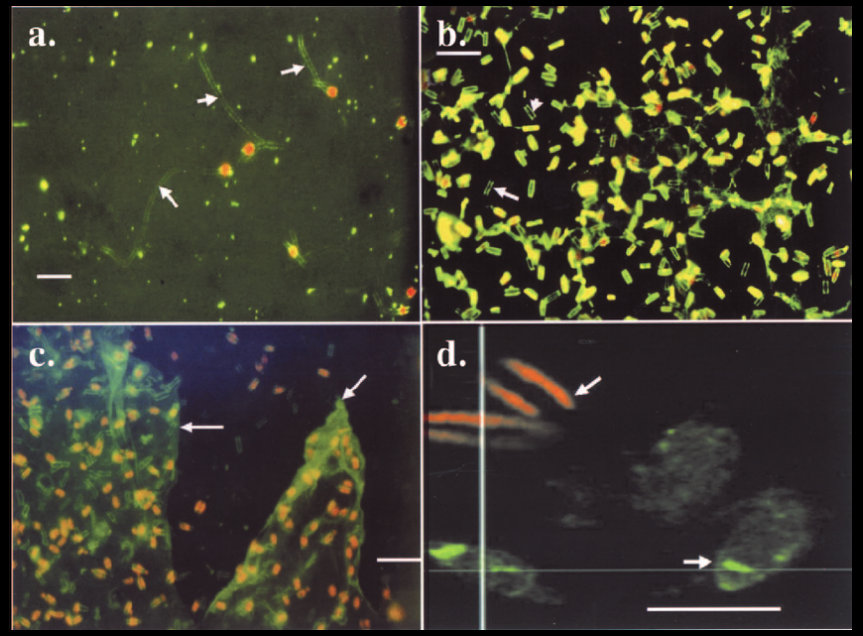
Diatoms



A. coffeaeformis



5 microns



Buhmann et al. (ACS Nano 2014)

Hybrid thermoresponsive gel-plasmonic topography

Can we remotely trigger the removal of sticky contaminants from hydrogel using light-generated bubbles?

1. Fabricate hybrid surface
2. Develop bubble visualization setup

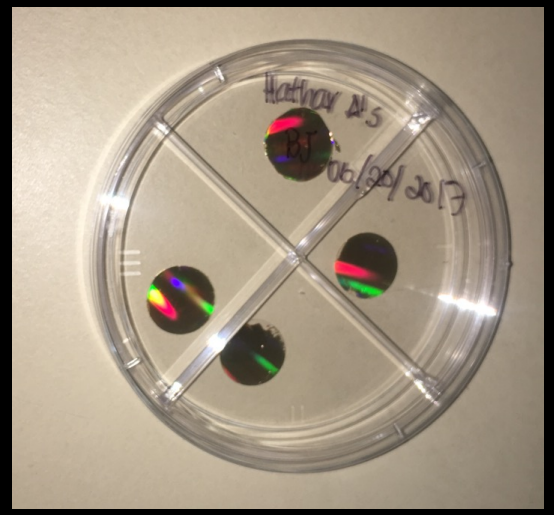
What is the effect of gel on bubble generation?

What is the effect of bubble generation on contaminant removal?

Fabrication Procedure

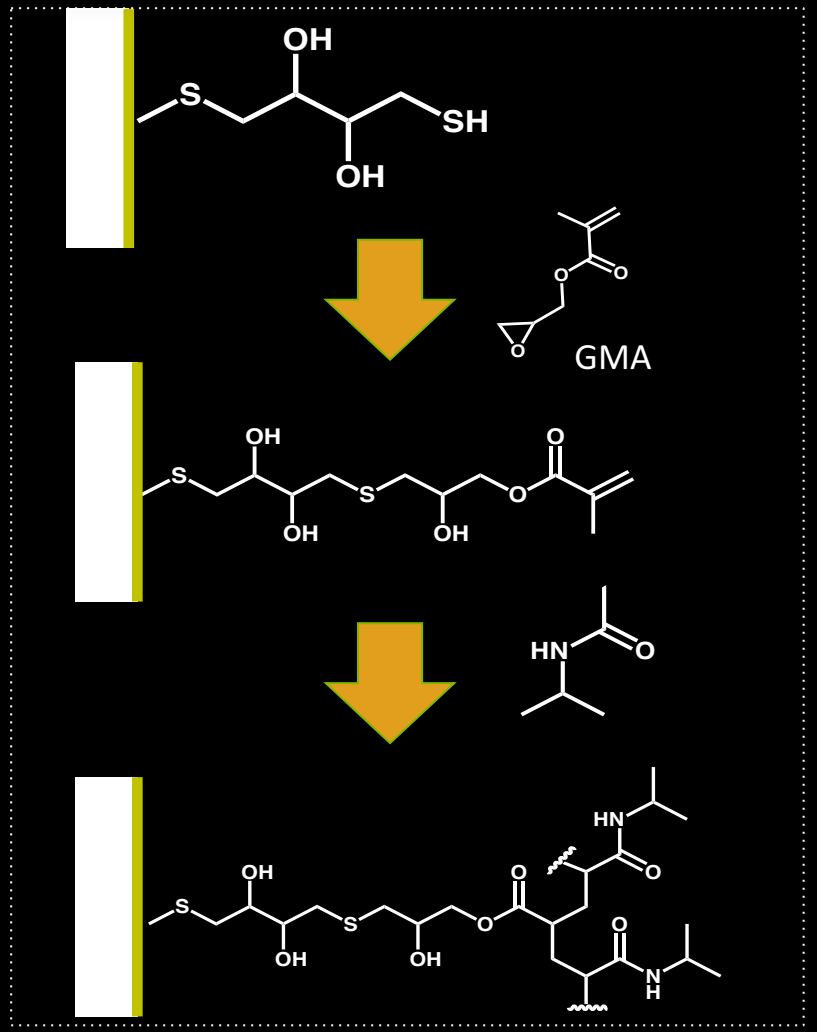
Photolithography and Etching to create inverted pyramids

Gold deposition and template stripping



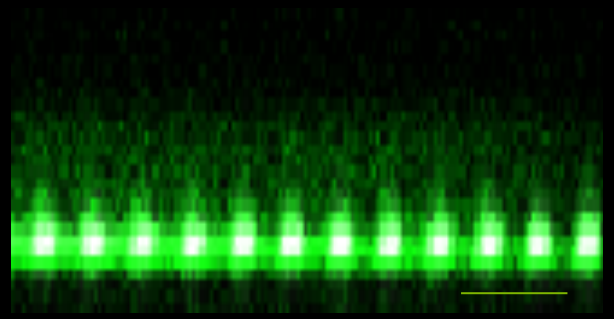
Templates courtesy of Mazur group

pNIPAAm on thiolated gold



Cathy's procedure
Schematic courtesy of Tanya

Hybrid surface
Confocal image (side view)

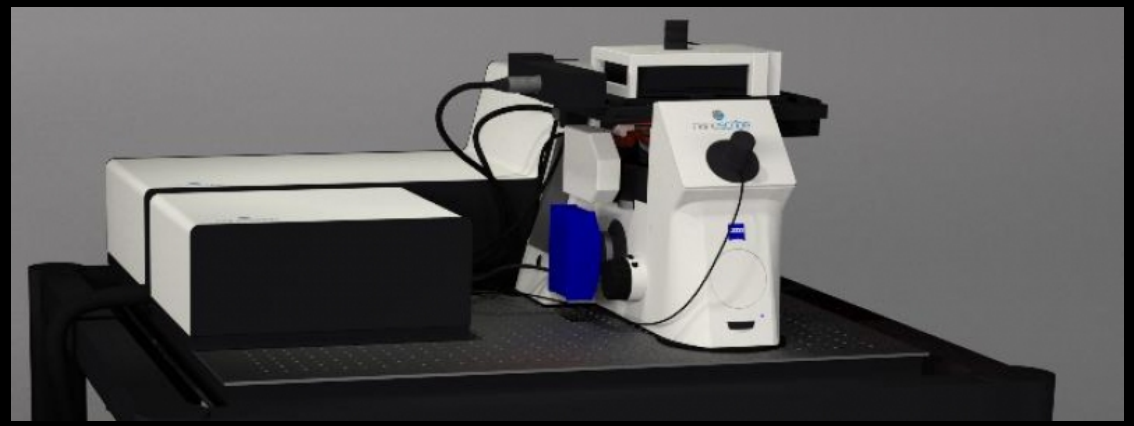


4 microns

Laser setup

Final setup that we are using:

Nanoscribe 3D lithography femtosecond laser setup



https://watchers.news/2013/02/14/nanoscribe-builds-worlds-fastest-microscopic-3d-printer/

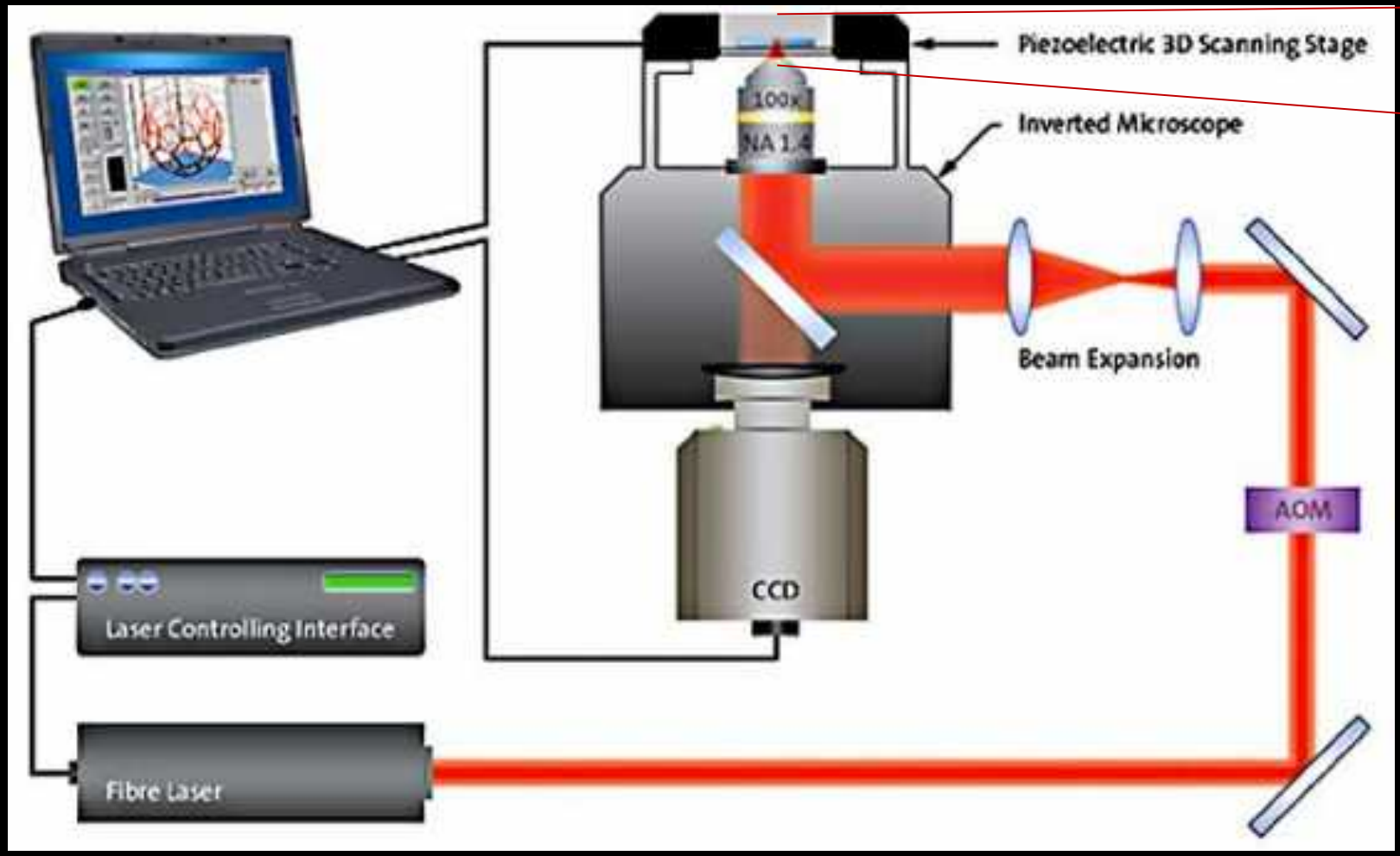
Other setups that we tried:

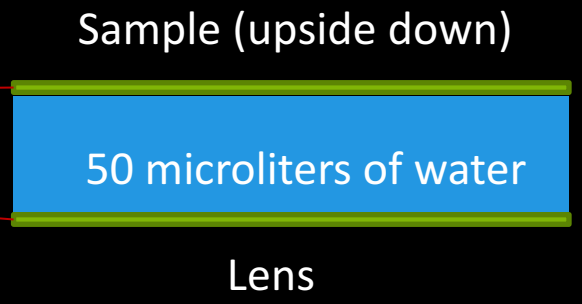
- Zeiss Confocal
- Leica DMRS - Continuous Microscope
- Mazur's group Femtosecond laser setup

Issues:

- No visualization setup
- Low control over parameters

Laser setup



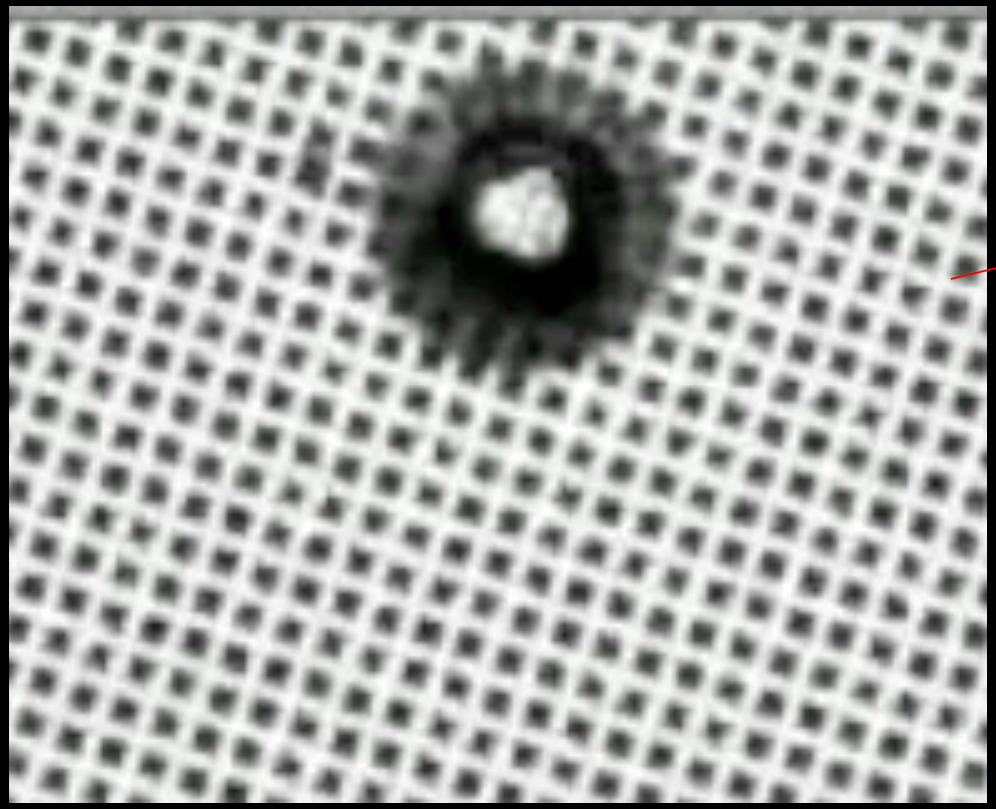


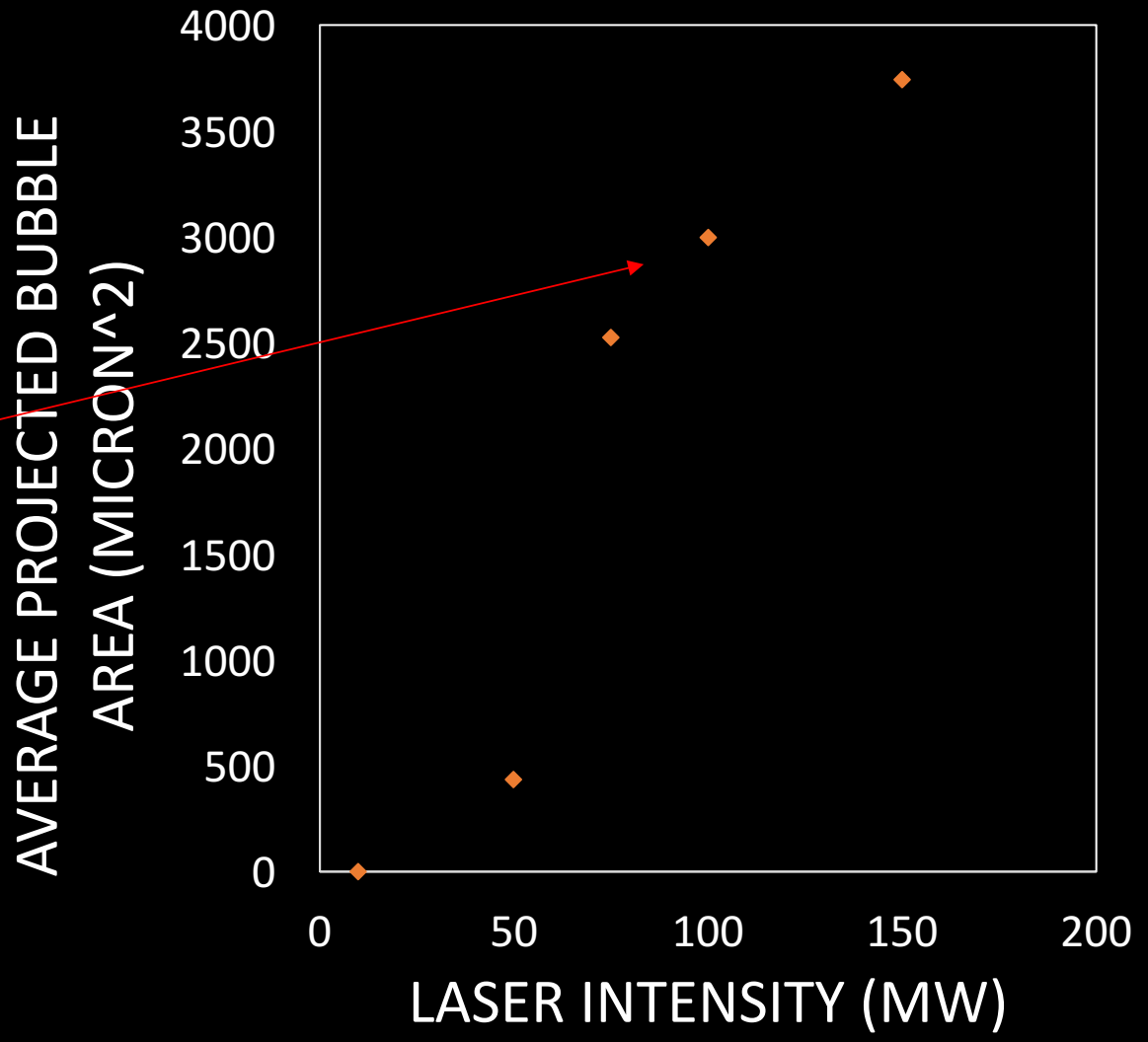
Control over:

- Laser Intensity (<180mW)
- Scanning region

Selection of Laser Parameters

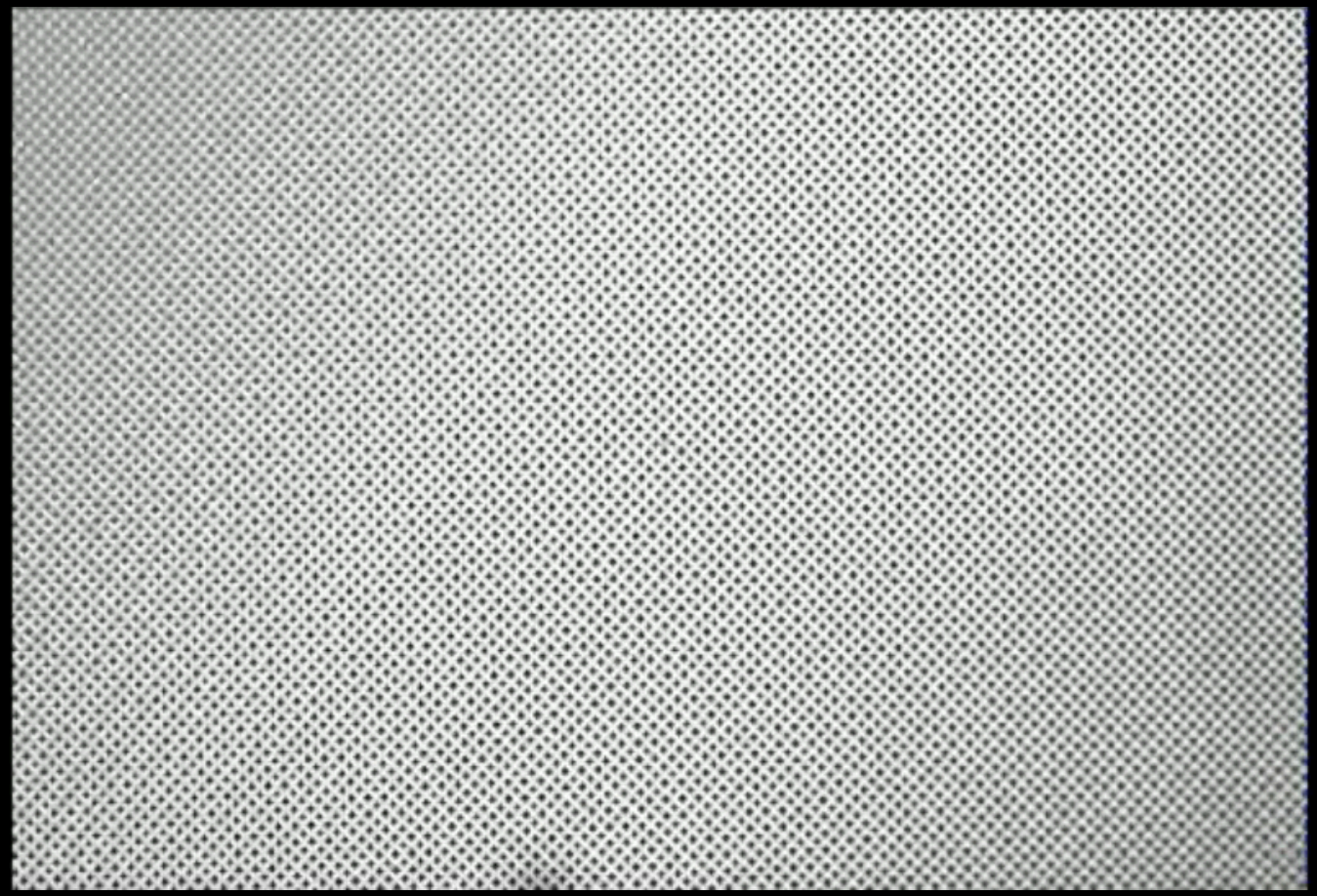
Microbubble on
Nanopyramids (no hydrogel)





Hybrid plasmonic hydrogel surface introduces new features into bubble

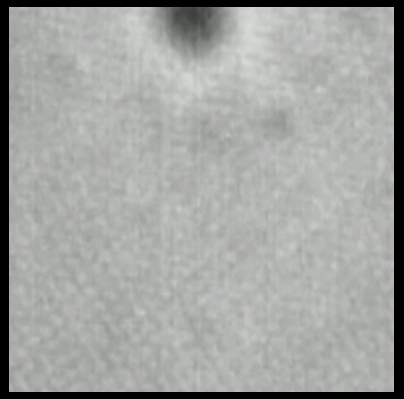
We documented that bubble generates differently on hyrdrogel surface compared to no hydrogel surface



Hybrid plasmonic hydrogel surface

Comparing hydrogel height with best parameters

Height: 1-2um

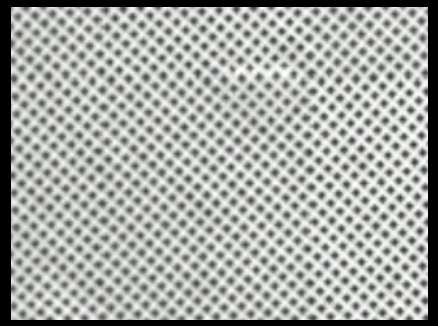


32 µm

Height: 10um

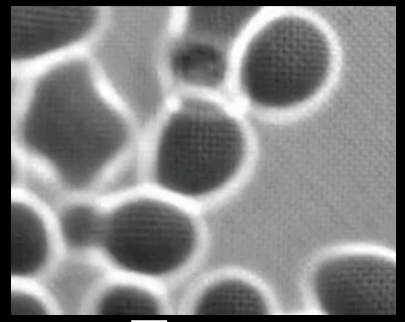
10µm

Height:3um



40 µm

Height: 20um



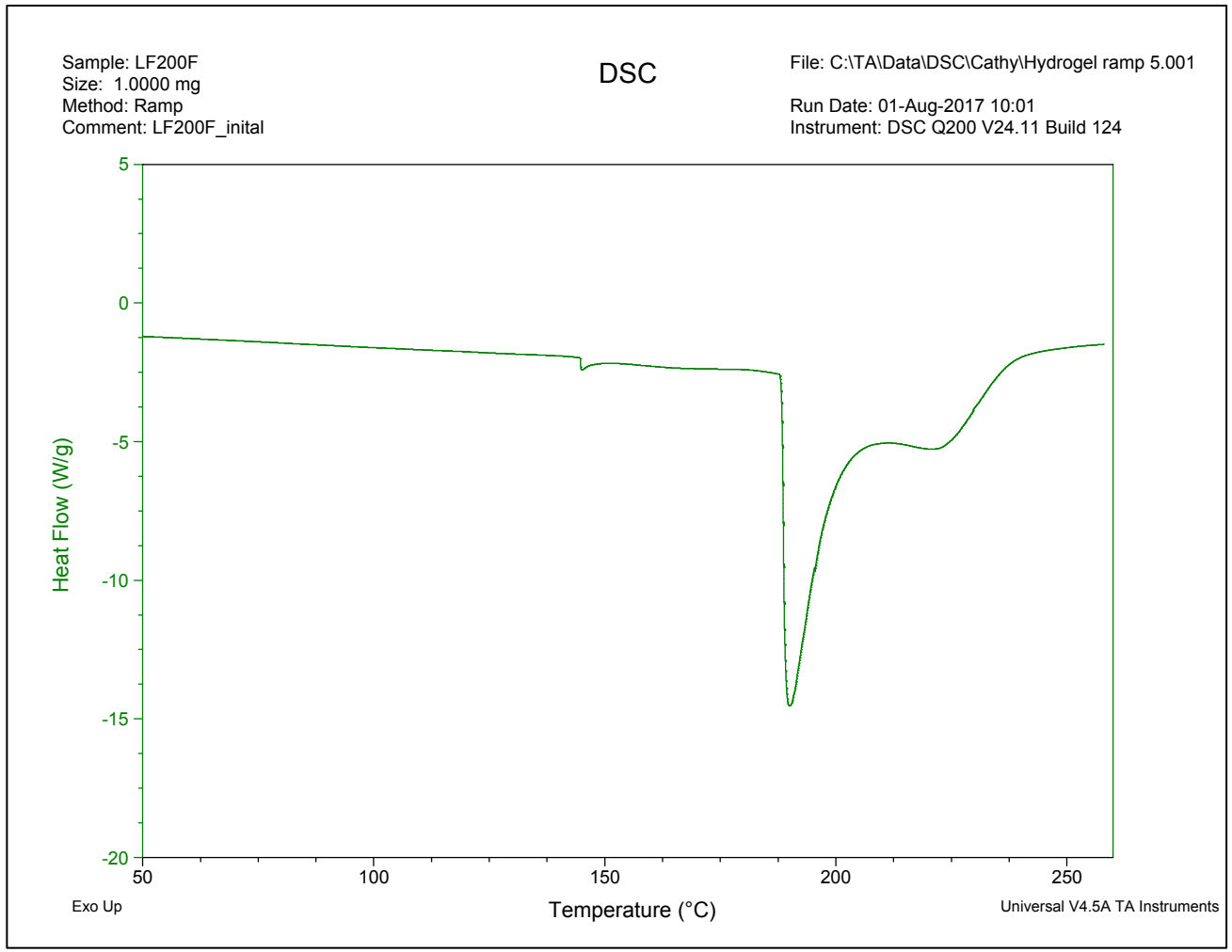
14µm

Height: 4um

20µm

Acrylamide control (no temperaure responsiveness) and plain gold all did not produce microbubbles.

Analysis of gel decomposition



Next step: Check the extent of hydrogel decomposition using SEM and other optical methods

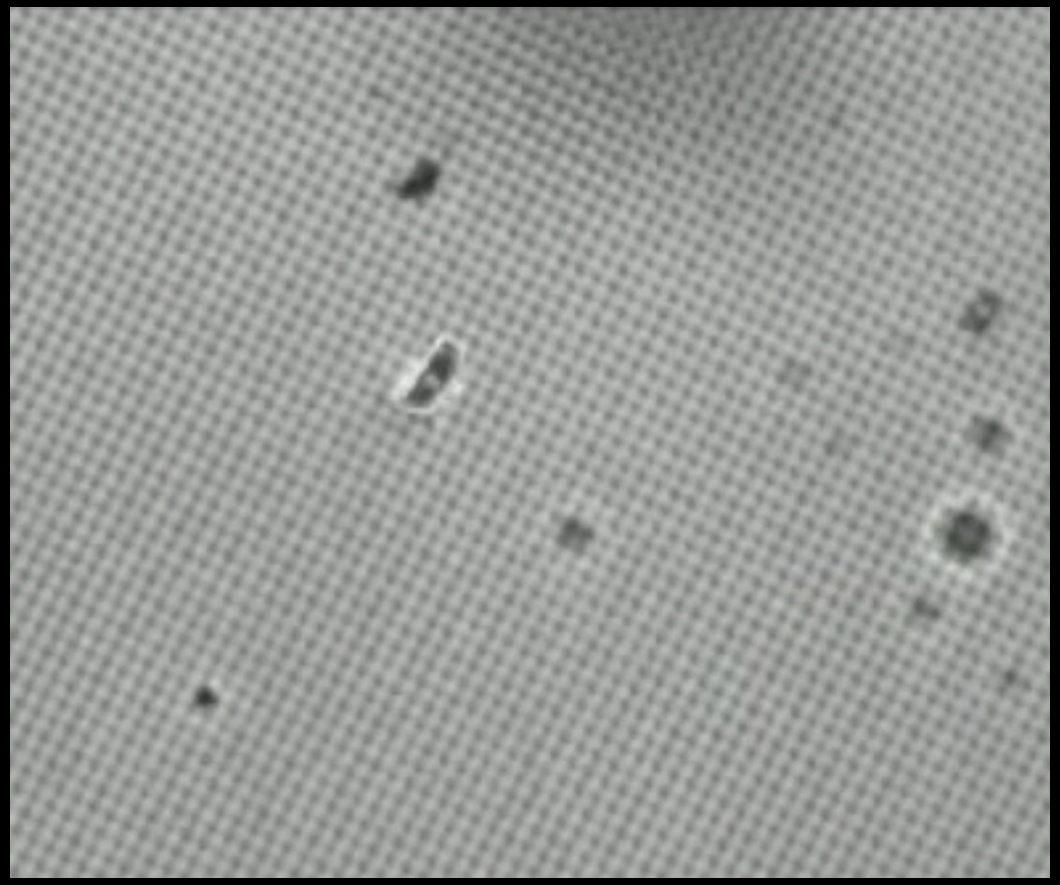
Hybrid thermoresponsive gel-plasmonic topography

Can we remotely trigger the removal of contaminants from hydrogel using light-generated bubbles?

What is the effect of gel on bubble generation properties?

What is the effect of bubble generation properties on contaminant removal?

Preliminary result



Zoom at 225%

14µm

This video illustrates the reaction between the bubble generation and diatom when the algae is added to the surface. The parameters used are laser intensity 100 and scan speed 10000.

Conclusions and Outlook

What is the effect of gel on bubble generation properties?

- ✓ Laser intensity has effect on bubble size.
- ✓ Bubble generation differs between surface with hydrogel and without hydrogel
- ✓ The effect is dependent on gel height

- Is the surface decomposing in any way?

What is the effect of bubble generation properties on contaminant removal?

- ✓ Bubble generation shows potential for removing contaminants.

- How does gel height affect removal of contaminants?
- How does contaminant type affect bubble removal?

Acknowledgements

Dr. Joanna Aizenberg

Cathy Zhang

- Shucong, Stefan Kolle, Tanya, Elijah, Guixiong, Anna
- Marinna Madrid (Mazur group)
- Cindy and Carla
- NSF- NNCI
- Dr. Kathryn Hollar