Mechanical deformation of self-assembled inverse structures

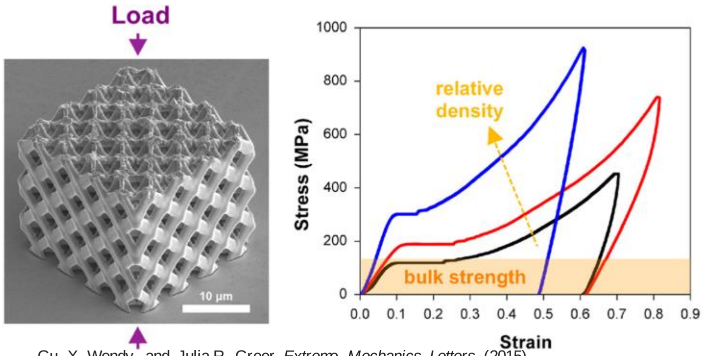
David Doan, John Kulikowski

Mentor: Swaroop Kommera

Stanford University

Motivation

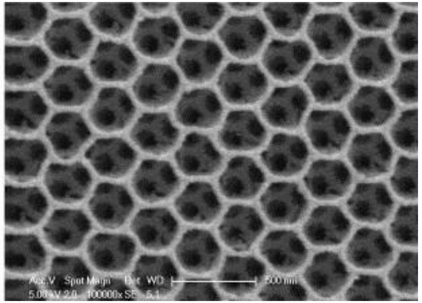
Architected structures at the micron scale show unique mechanical behavior as compared to macroscale



Gu, X. Wendy, and Julia R. Greer. *Extreme Mechanics Letters* (2015).

Objectives

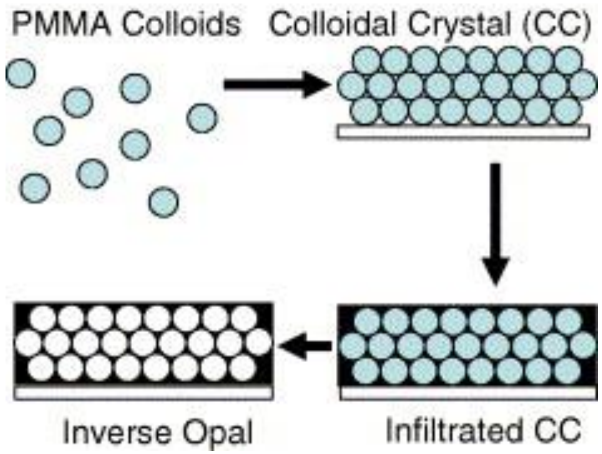
1. Create mm-sized ordered structures from self-assembled structures
2. Create bi-periodic structures from two different shapes
3. Test mechanical properties



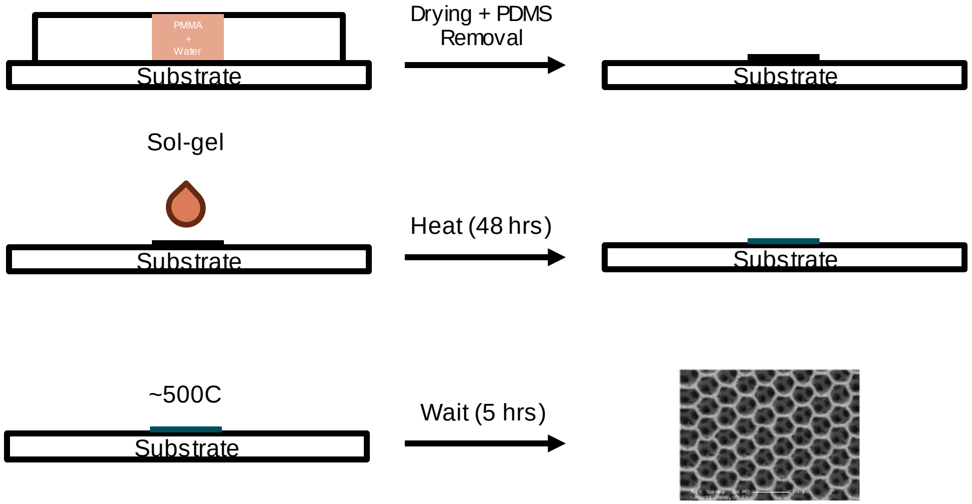
Waterhouse, Geoffrey, and Mark R. Waterland. *Polyhedron* (2007).

Creation of mm-sized inverse structures using self-assembly

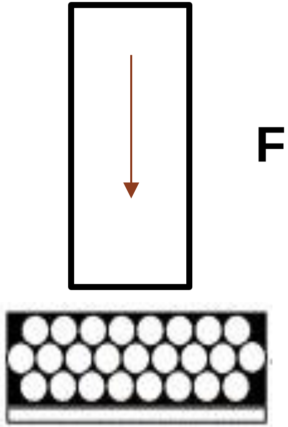
Creating Inverse Opals



Waterhouse, Geoffrey IN, and Mark R. Waterland. *Polyhedron* (2007)

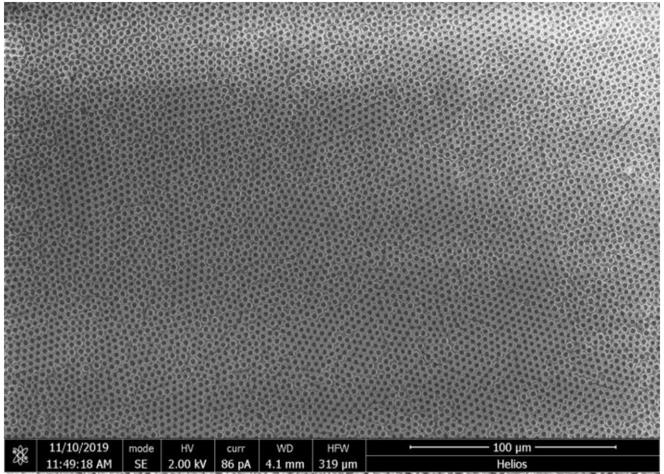


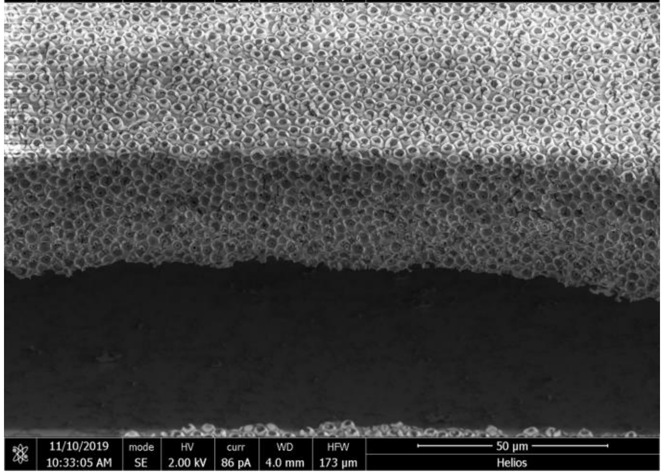
Compression Testing



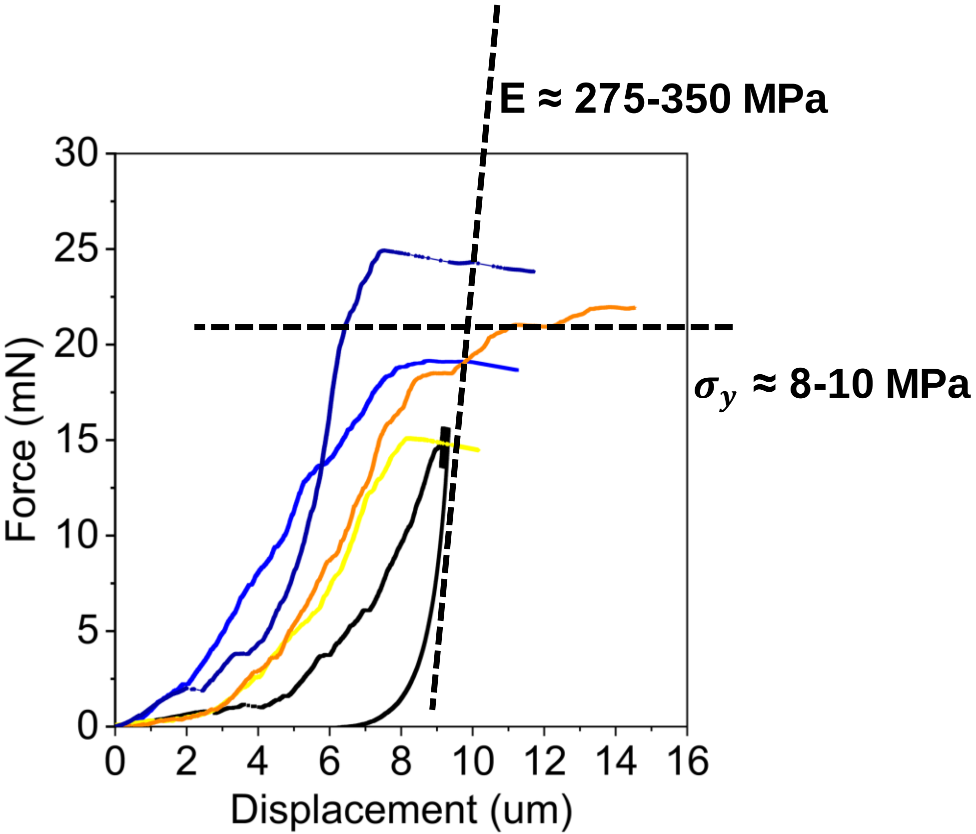
Flat punch compression

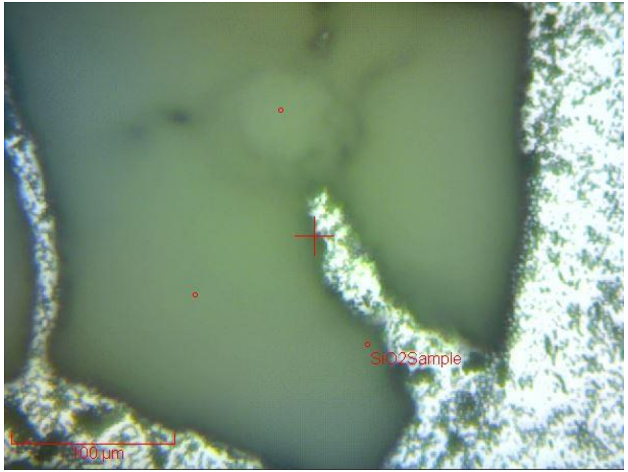
Diameter: 55 um
Thickness > 30 um





Compression Testing Results



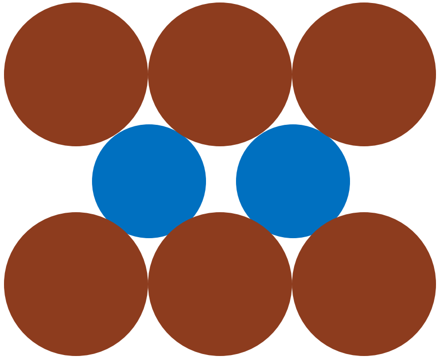


$$\frac{E^*}{E_{lig}} = \rho^2$$

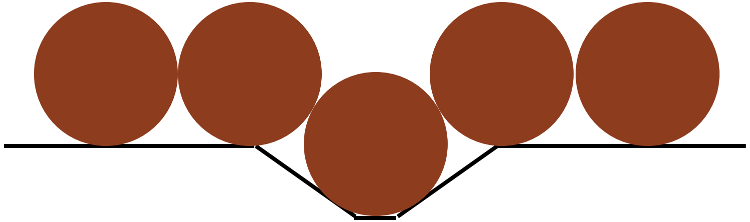
$$\frac{\sigma^*}{\sigma_{lig}} = 0.3\rho^{\frac{3}{2}}$$

$$\rho \approx 5\text{–}10\%$$

Creation of more complex self-assembled structures

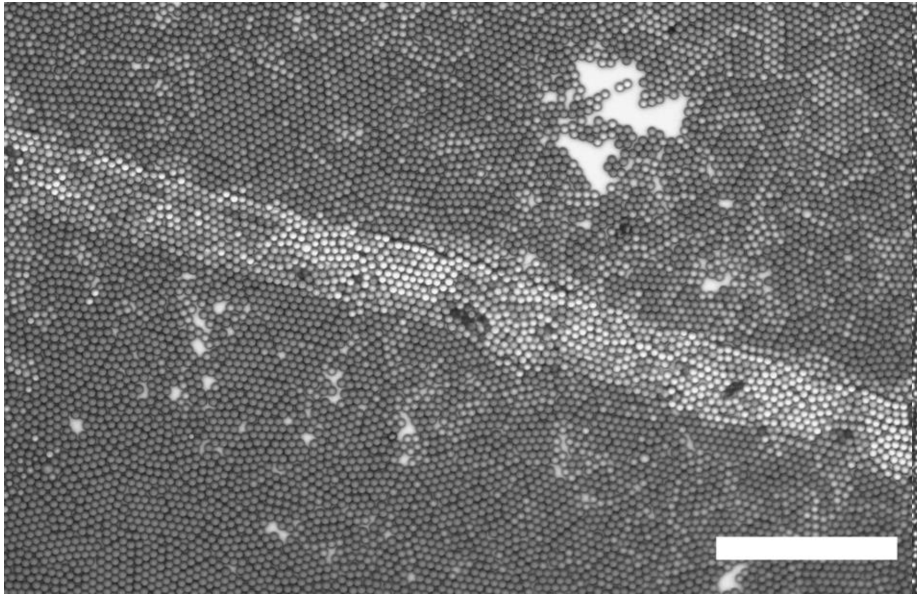


Bi-layered self-assembly

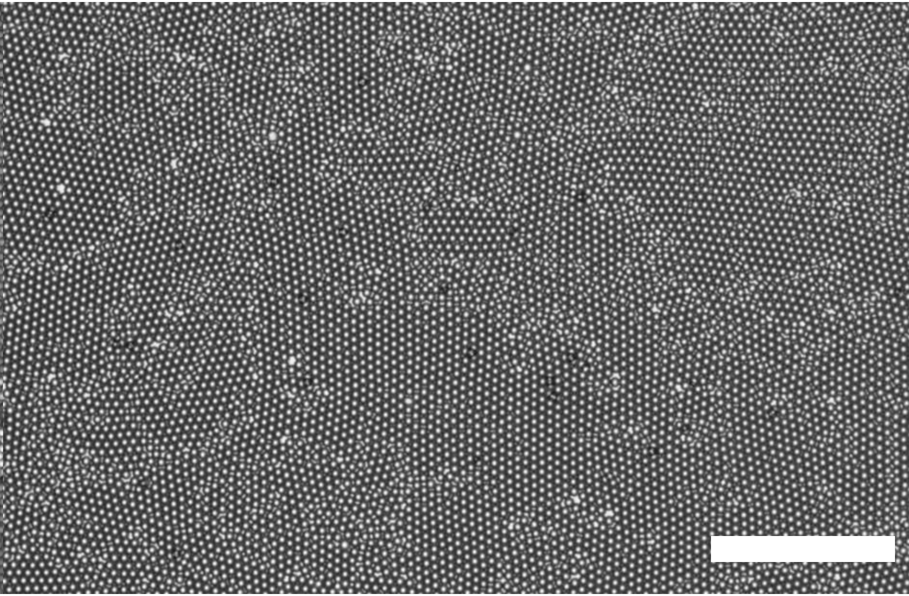


Templated self-assembly

Monolayered 4μm PMMA spheres



Scratched silicon wafer substrate



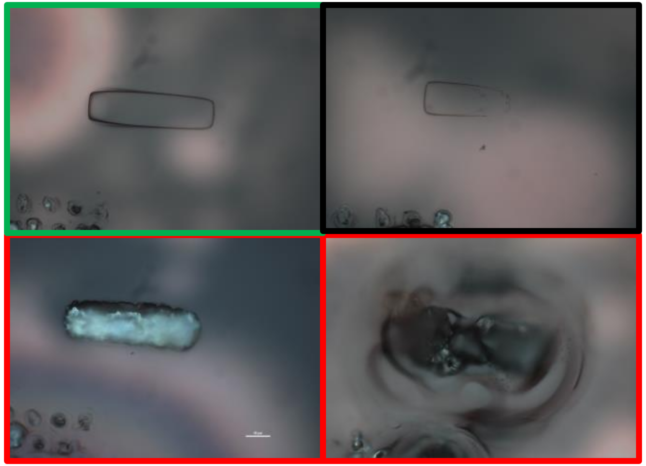
Spheres shaken using shaker table on glass substrate

Positive Photoresist (AZ4620) Dosing parameters

Scan Speed x 10^2 (μm/s); Laser Power (%)

Laser Power (%)	10	57.5	105	152	200
20	+	+	–	–	–
40	x	+	+	+	+
60	x	x	+	+	+
80	x	x	x	x	x
100	x	x	x	x	x

+ good exposure
– under-exposed
x over-exposed



From left to right: top: good exposure (60, 105), under-exposure (20, 152); bottom: over-exposure (80, 105; 40, 10)

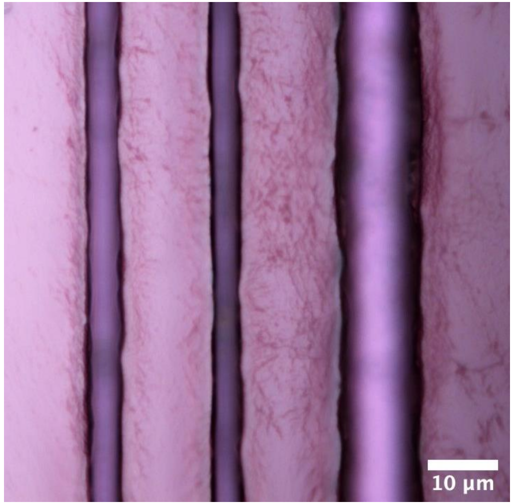
Positive Photoresist (SPR220-7)

Effect of shape on roughness of resulting print:

- SPR220-7 exposed at 30% laser power, 12,000 μm/s scan rate
- Can expect trends to be the same across resists

Average Roughness

- Flat: 2.7nm
- Circular: 25nm
- Triangular: 47nm
- Rectangular: 131nm



From left to right: rectangular, circular, triangular

Future Plans (Winter Quarter)

- Expand on templated self assembly
- Move toward more complex, bi-layered assemblies
- Create structures using nanoscribe printed particles
- Compression testing of these more complex structures

Budget

	QTY/Hours	Unit Cost	Total
Trainings			
General SNF	1	$ 80.00	$ 80.00
Nanoscribe	2	$ 80.00	$ 160.00
Wetbench	1.5	$ 80.00	$ 120.00
HPDCVD	2	$ 80.00	$ 160.00
AFM	8	$ 80.00	$ 640.00
Headway 3	0.5	$ 80.00	$ 40.00
Characterization Equipment			$ -
SEM	5.7	$ 75.00	$ 427.50
Thermolyne	96.851	$ 5.00	$ 484.26
Headway	2.95	$ 10.00	$ 29.50
wbexfab_solv	0.05	$ 10.00	$ 0.50
wbexfab_dev	1.55	$ 10.00	$ 15.50
Nanoscribe	4.683333	$ 35.00	$ 163.92
AFM	2.55	$ 20.00	$ 51.00
Yes2	3.233333	$ 35.00	$ 113.17
Chemicals			
Melamine Particles	2	$ 254.13	$ 508.26
		TOTAL	**$ 2,993.60**

Acknowledgements

Mentor: Swaroop Kommera

Stanford Nanofabrication Facilities

Stanford Nano Shared Facilities

SNF staff

E241 instructors

- Professor Jonathan Fan
- Professor Roger T. Howe
- Charmaine Chia (TA)