SAND2014-15011PE

Biologically and laser-driven lithographies

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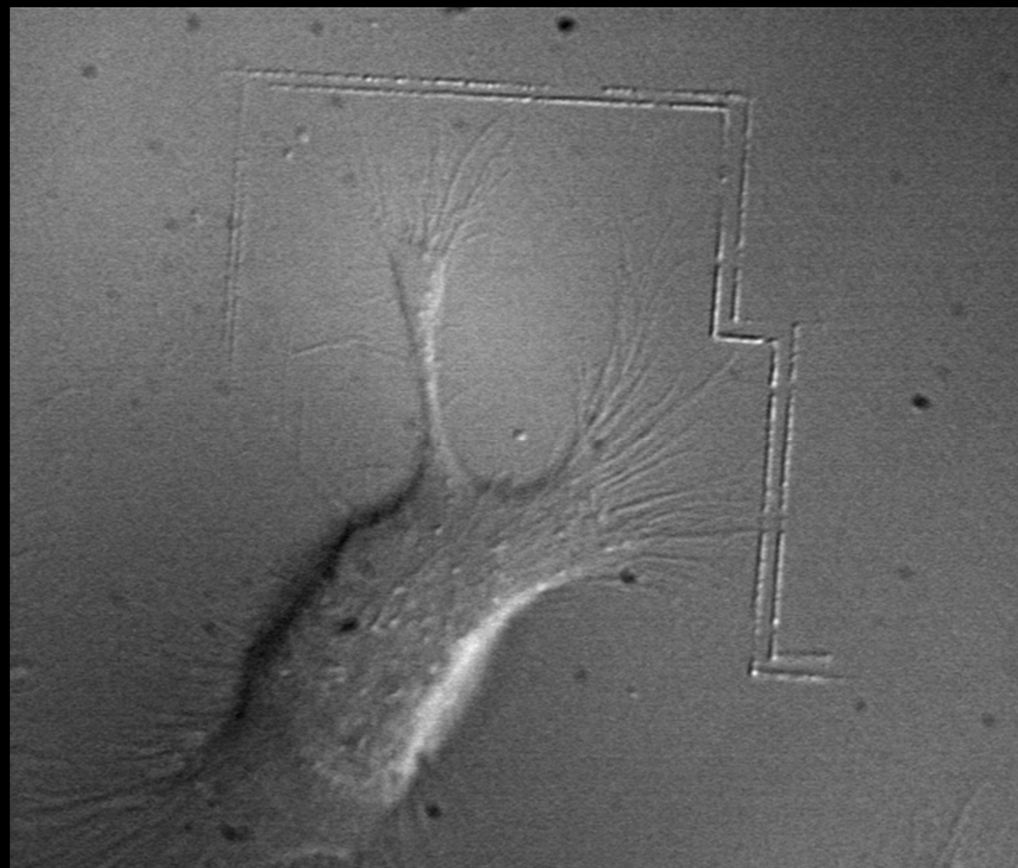
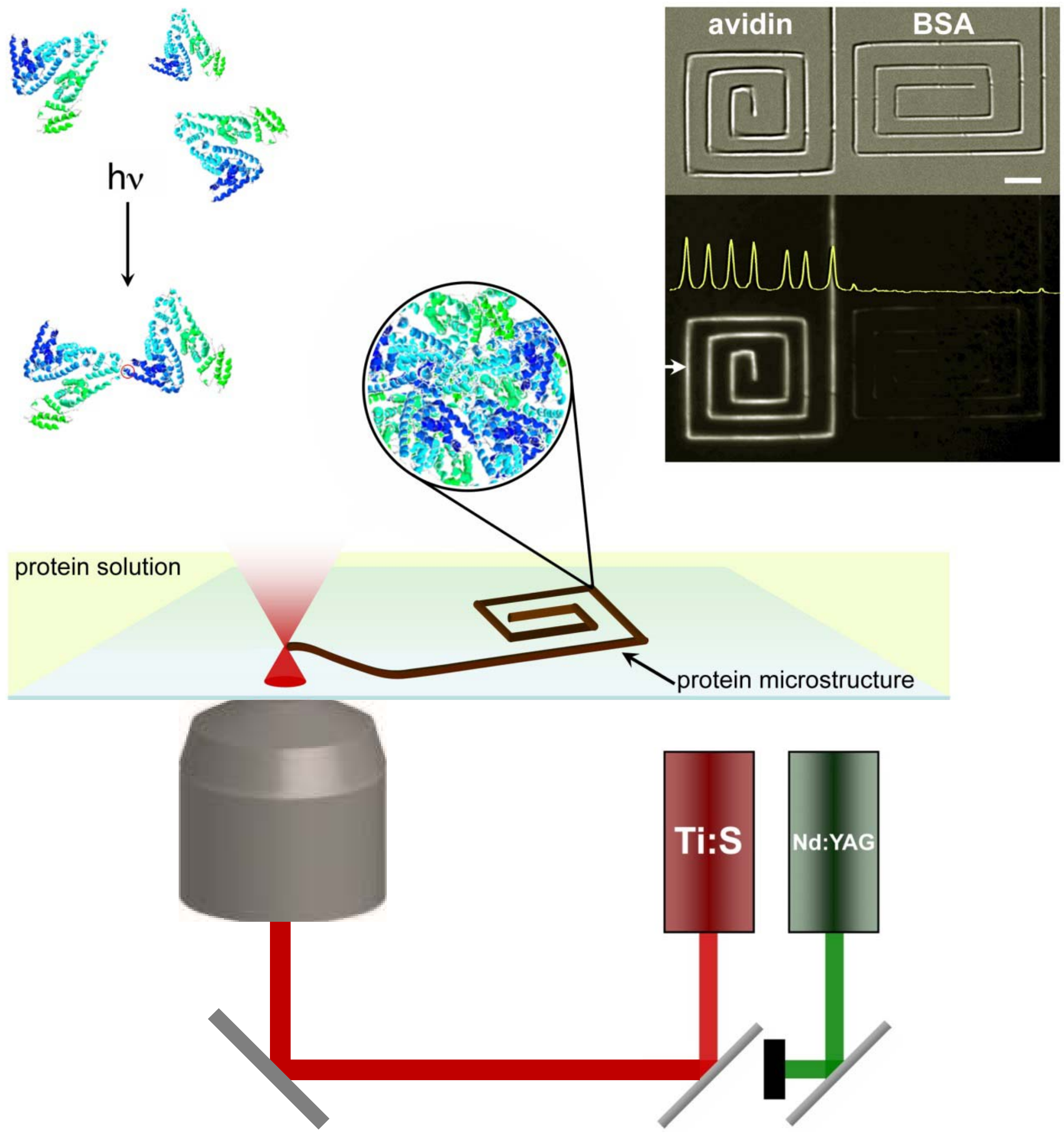
Sandia National Laboratories
Albuquerque NM
June 9, 2014

Key Themes

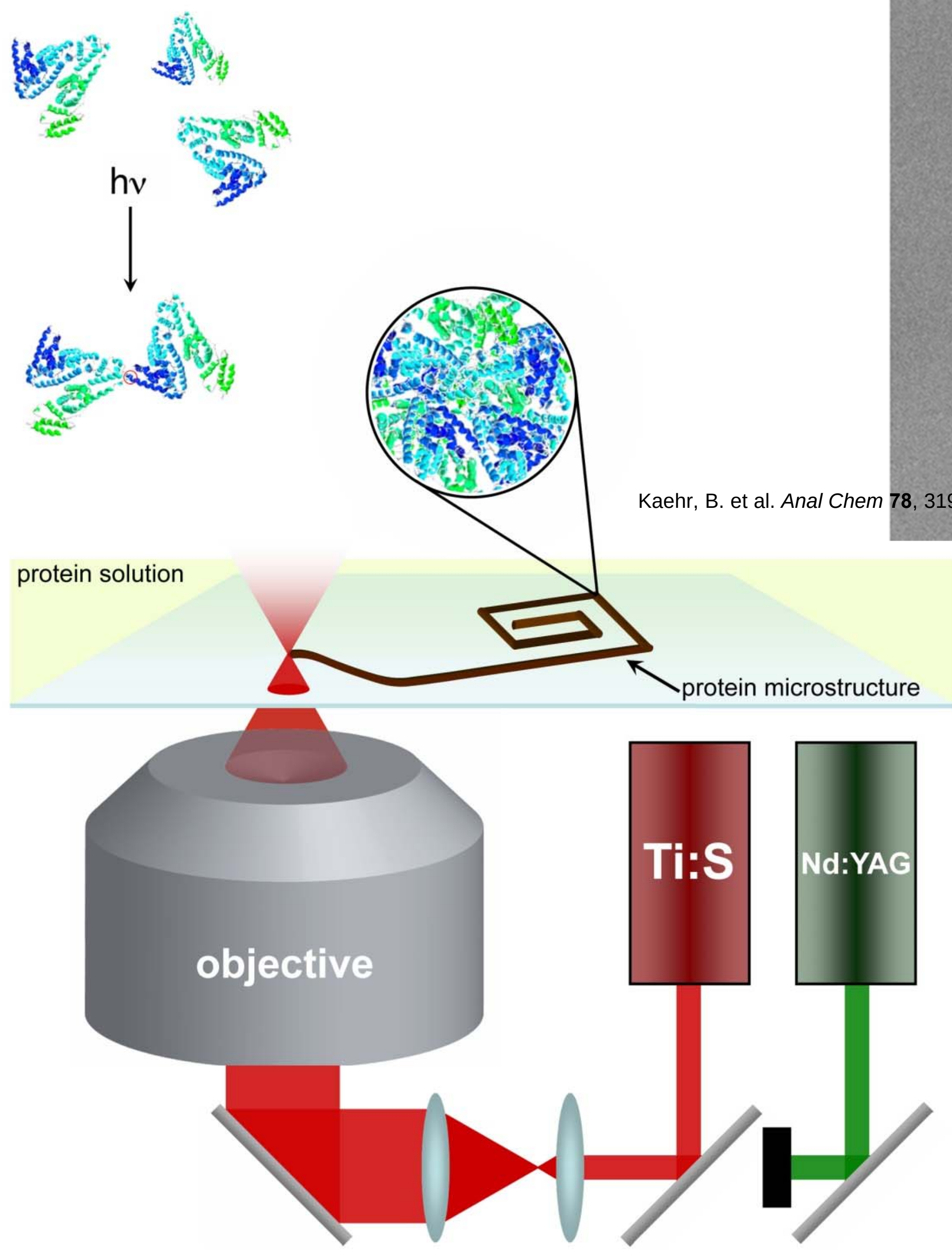
- Techniques/materials to study biology
- Biology to enable materials science

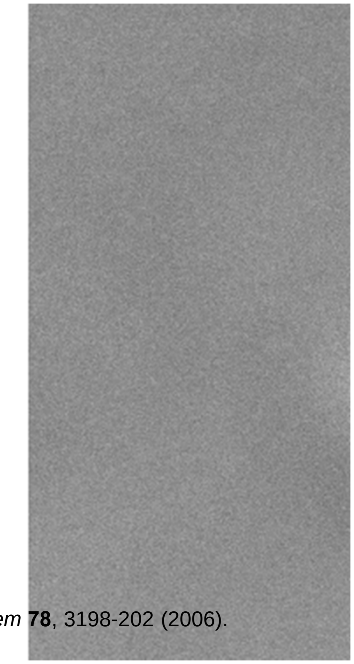


Multiphoton Lithography (MPL) using protein 'resists'



MPE Protein Photocrosslinking

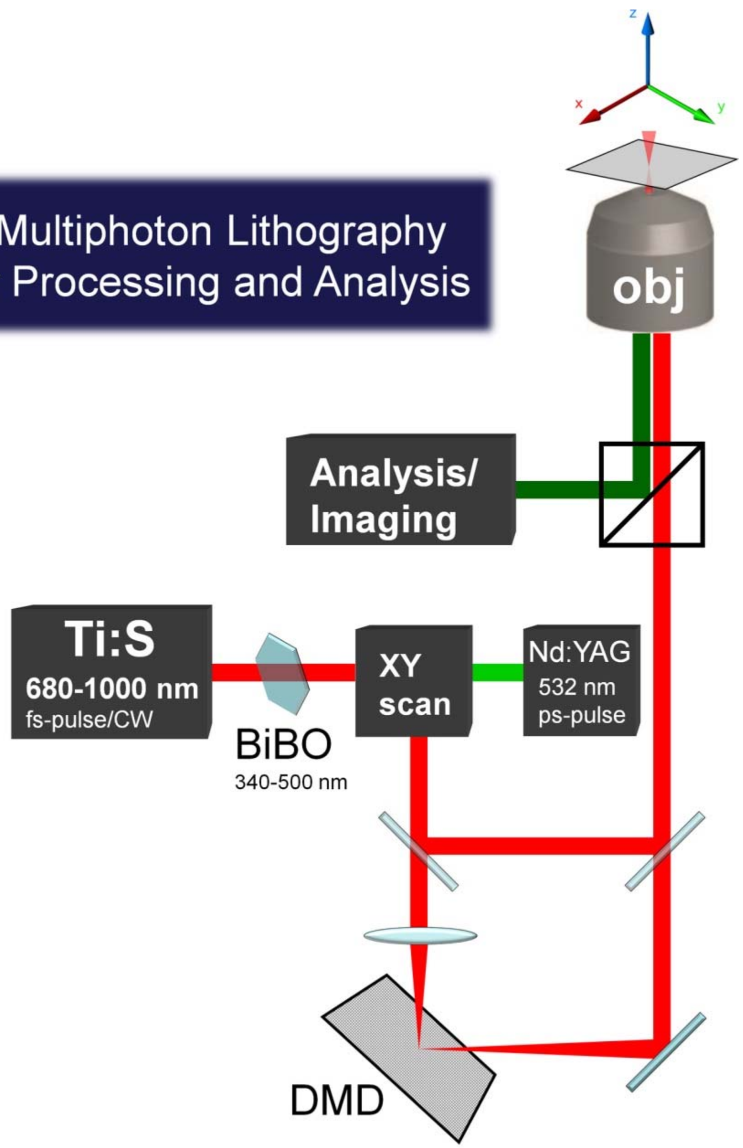




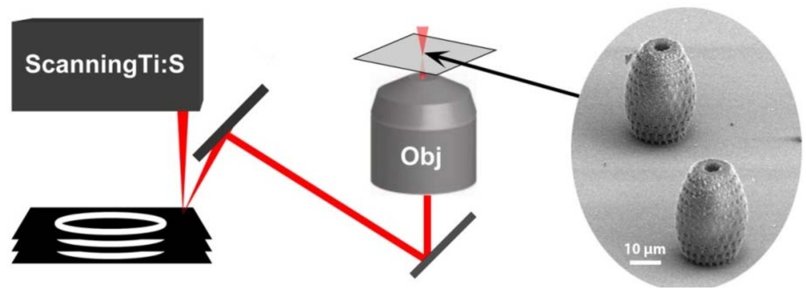
Kaehr, B. et al. *Anal Chem* **78**, 3198-202 (2006).

Approach

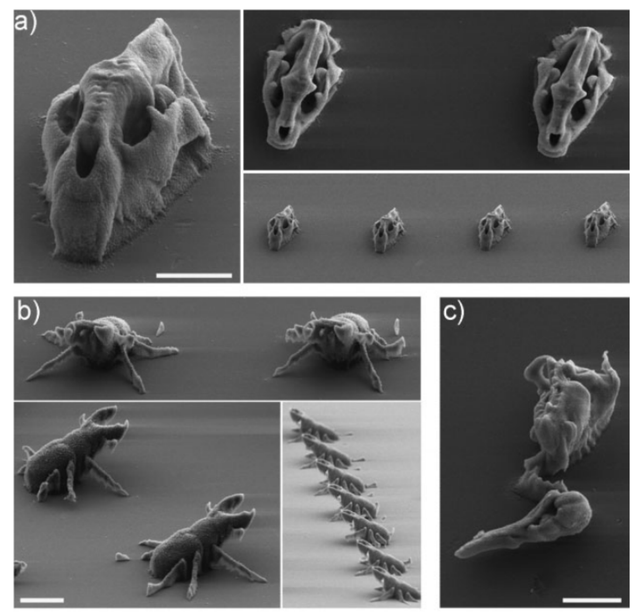
AML-Multiphoton Lithography
Laser Processing and Analysis

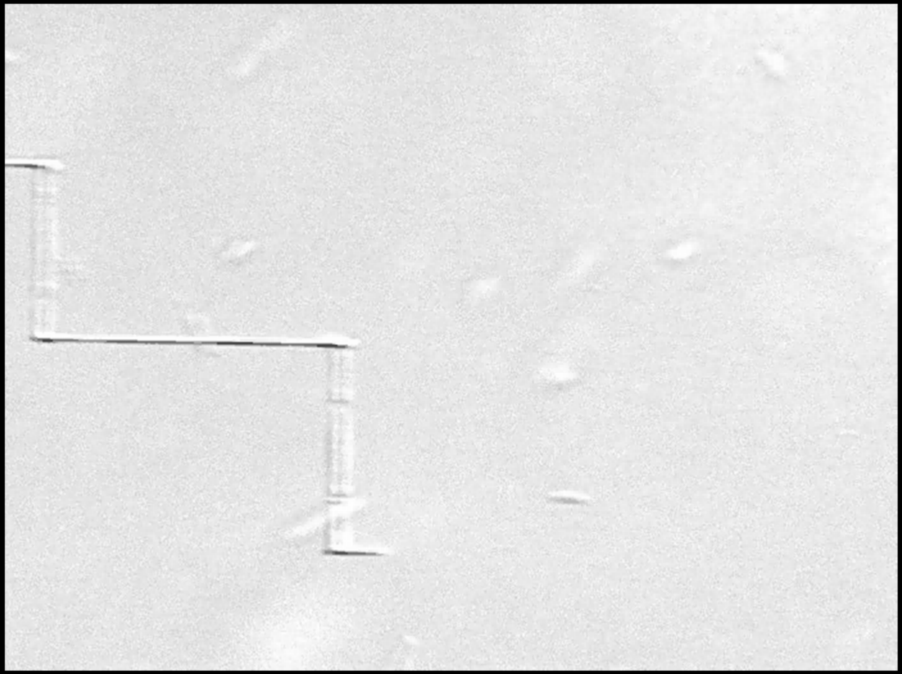


Mask-Directed Multiphoton Lithography



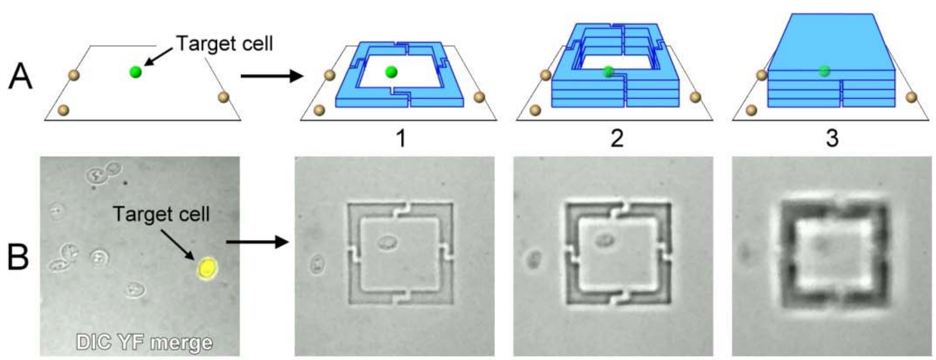
Kaehr and Shear, *JACS* 2007 129 (7),1904-1905.
Nielson, Kaehr and Shear, *Small*, 2009, 5, 120-125

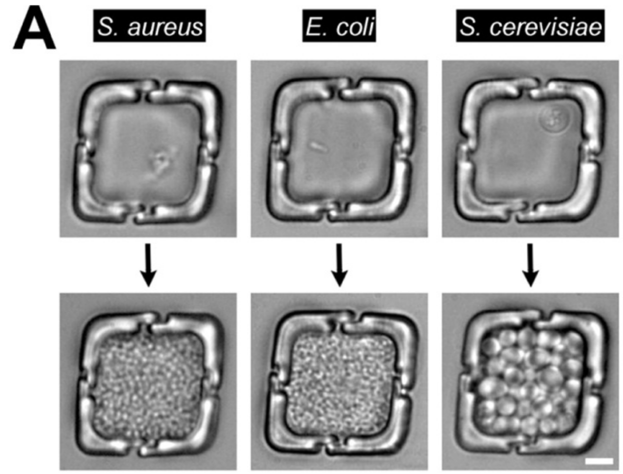


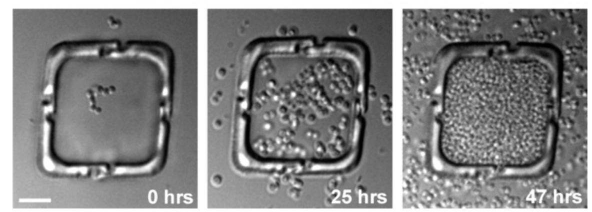


Kaehr & Shear (2009) *Lab on a Chip,* 9, 2632-2637

Targeted cell confinement using biocompatible microfabrication



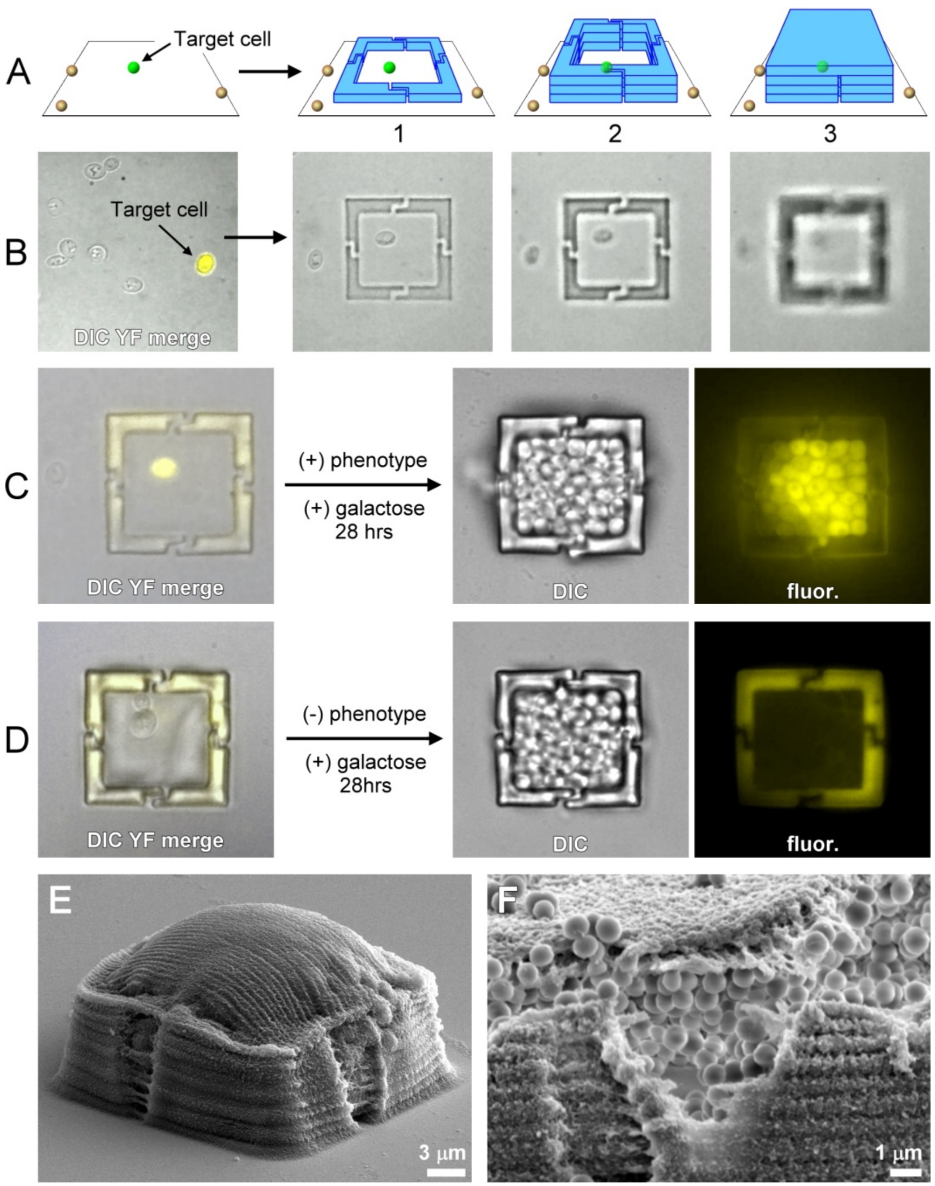




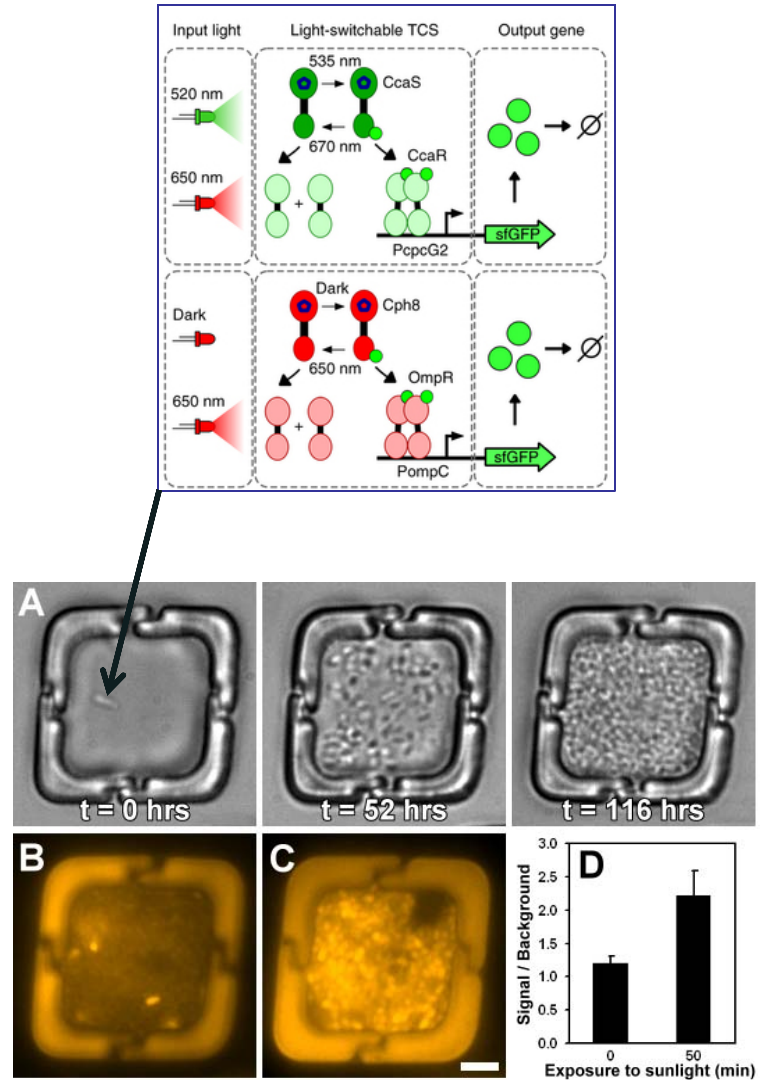
mammary carcinoma 4T1

Harper, Brozik, Brinker, Kaehr (2012), *Analytical Chemistry*

Targeted cell confinement using biocompatible microfabrication



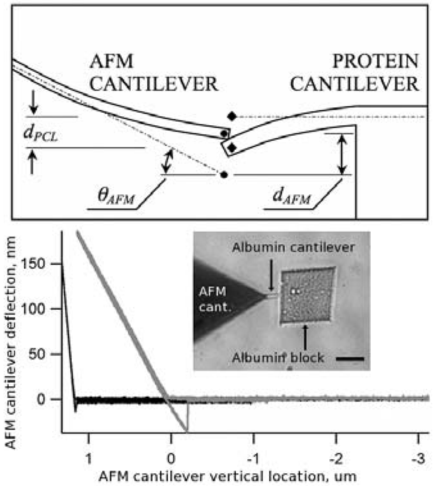
Jeff Tabor (Rice)

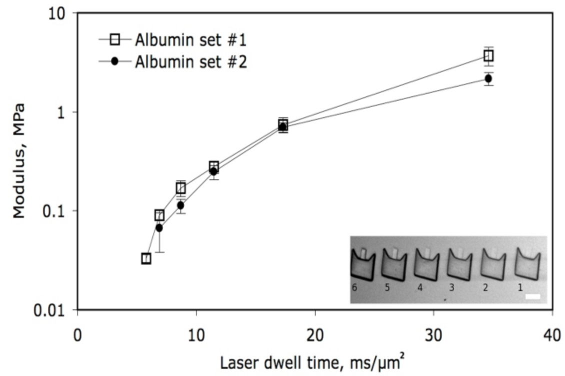


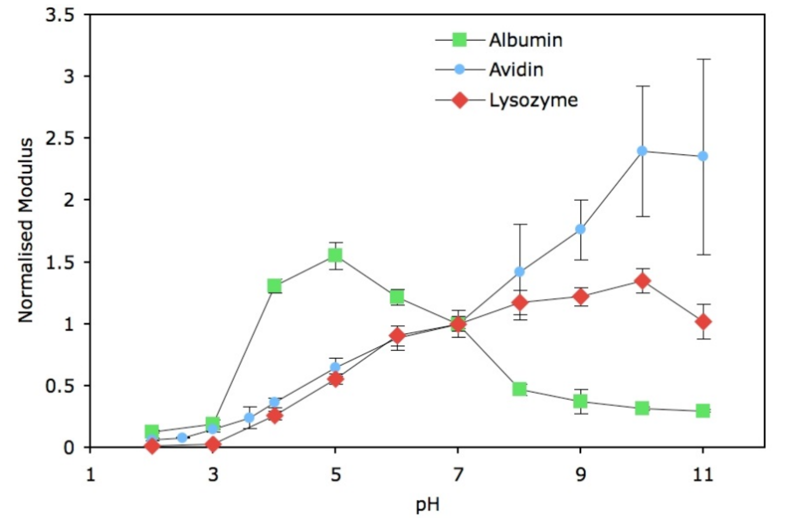
Harper, Brozik, Brinker, Kaehr (2012), *Analytical Chemistry*

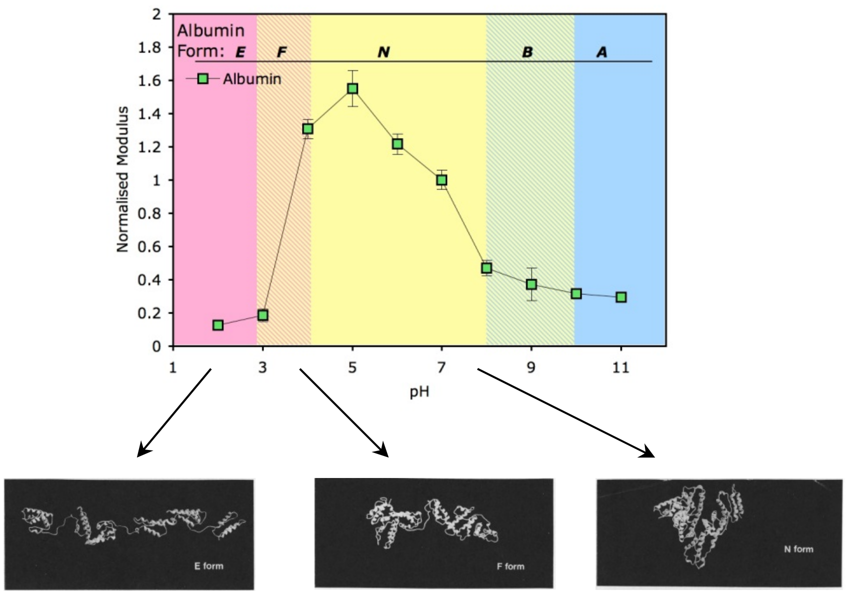
Mechanical properties of MPL protein structures

Depend on protein identity

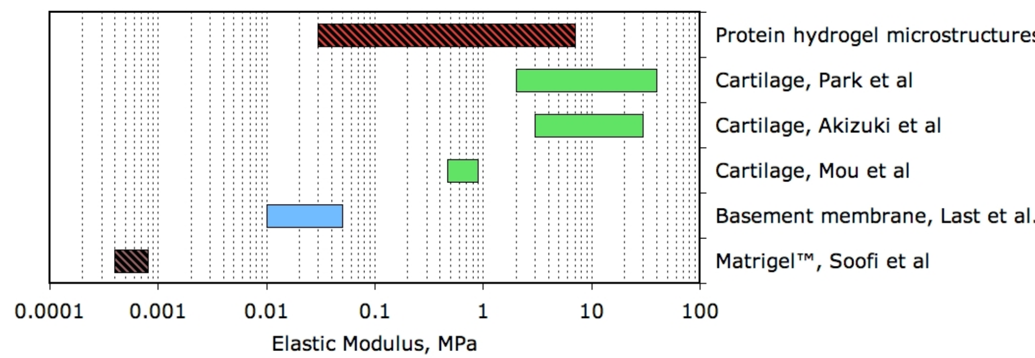






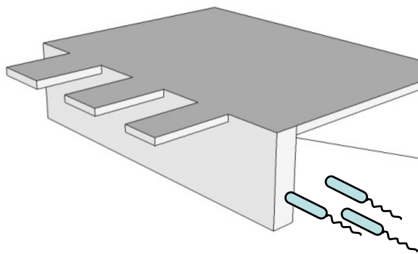


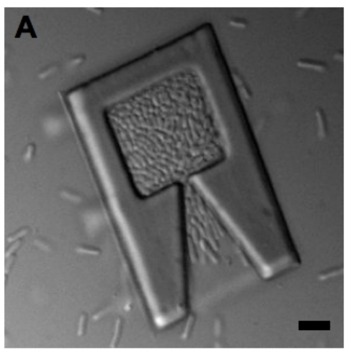
Images from Carter et al *Adv Prot Chem* 1994



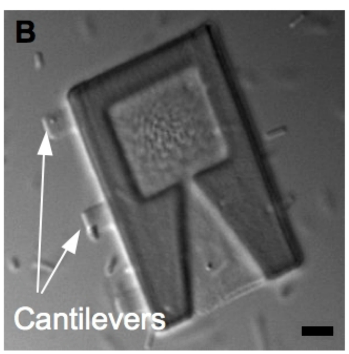
Khripin, Brinker , Kaehr, Soft Matter, 2010, 6, 2842-2848

Measuring cell/materials interactions in situ

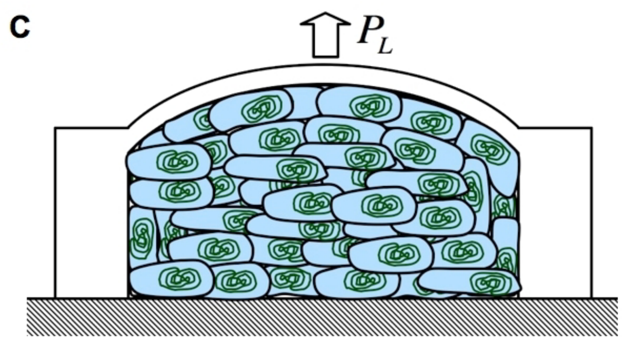


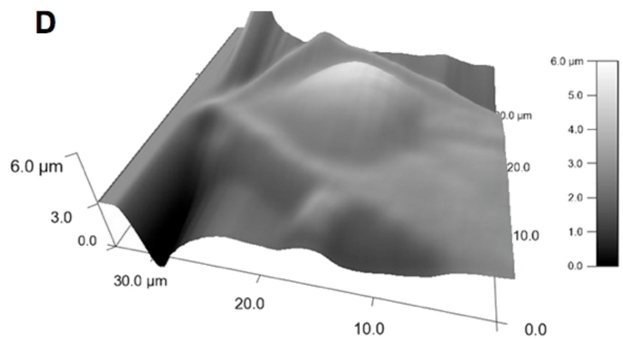


focus low

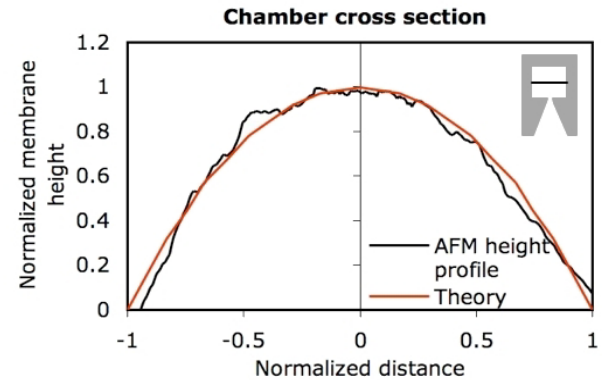


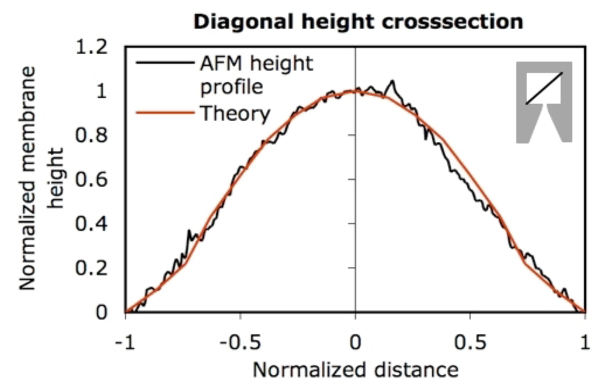
focus high





AFM image of chamber

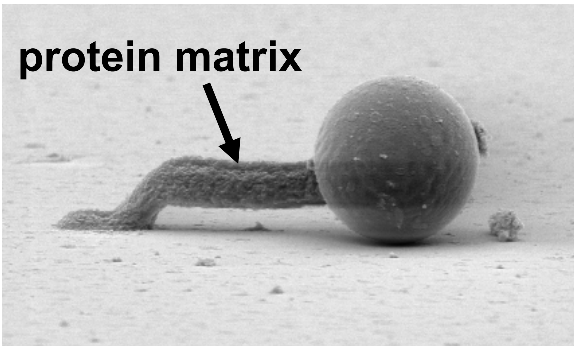


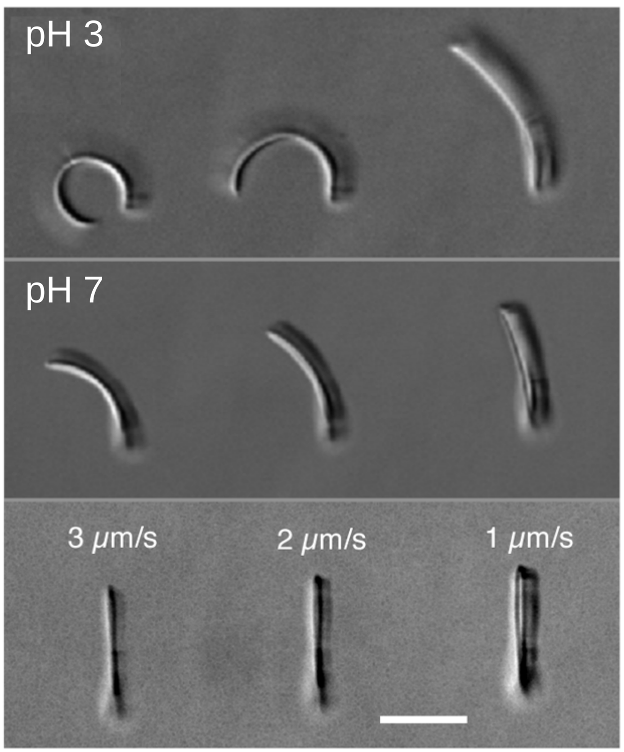


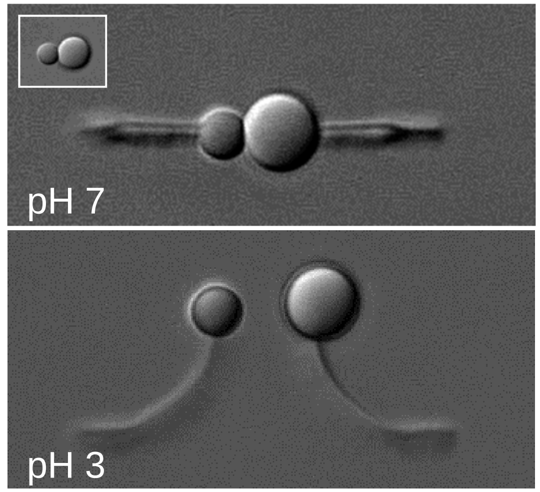
The pressure exerted by this colony of *E. coli* was 2.1 ± 1 kPa. This is comparable to pressures measured in tumors[2]

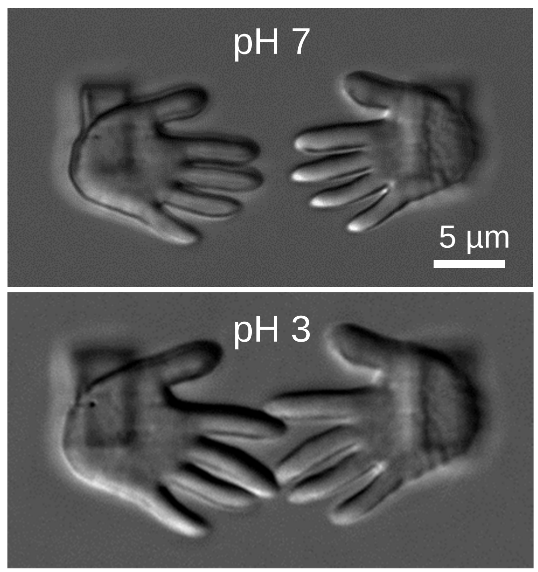
C. Y. Khripin, C. J. Brinker and B. Kaehr*, Soft Matter, 2010, 6, 2842-2848

Stimuli-Responsive Behavior of Protein Matrices

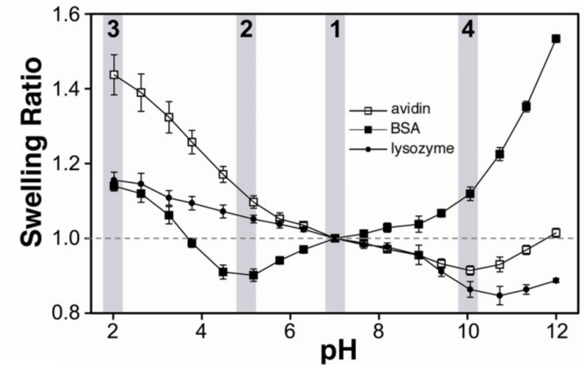




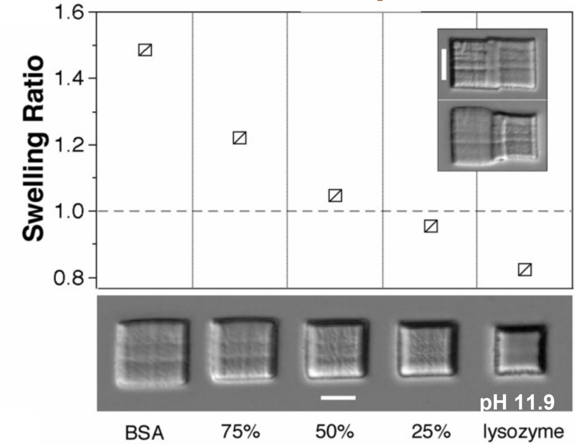




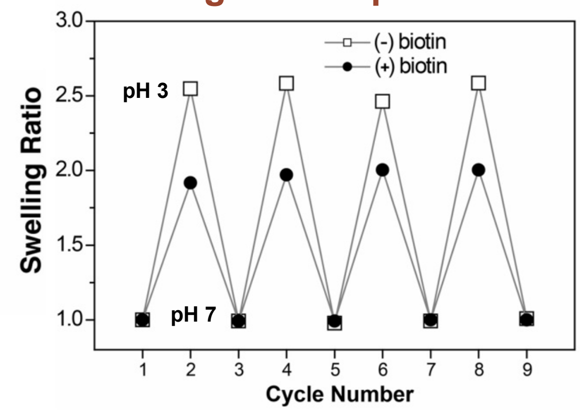
Protein Specific Response



Tunable Response

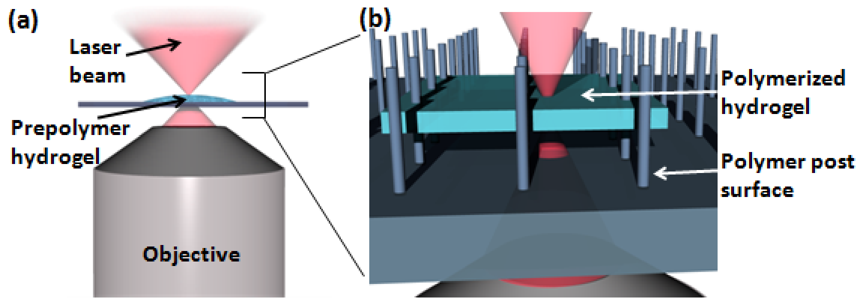


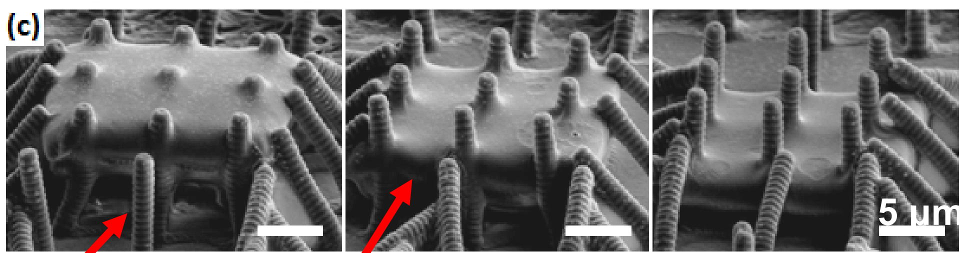
Ligand Response



B. Kaehr and J. B. Shear, *Proc Natl Acad Sci U S A*, 2008, 105, 8850-8854.

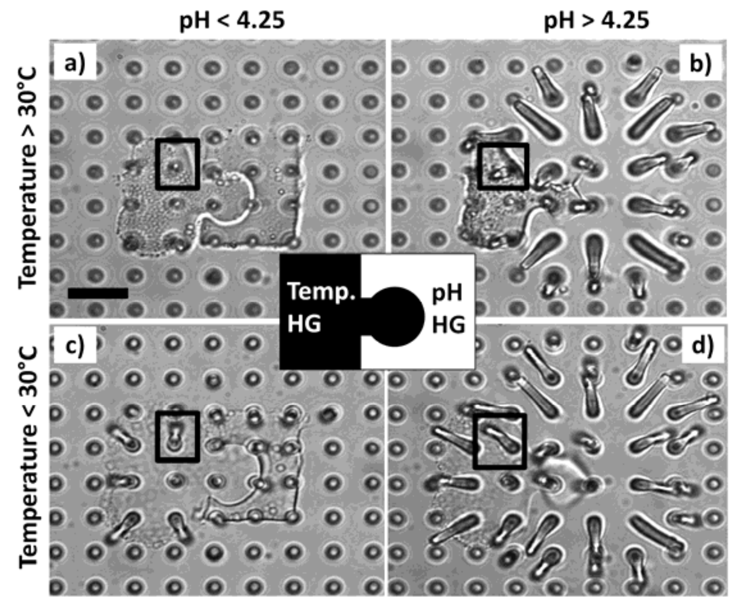
Integration of acrylamide-based MPL materials into "ciliated" surfaces

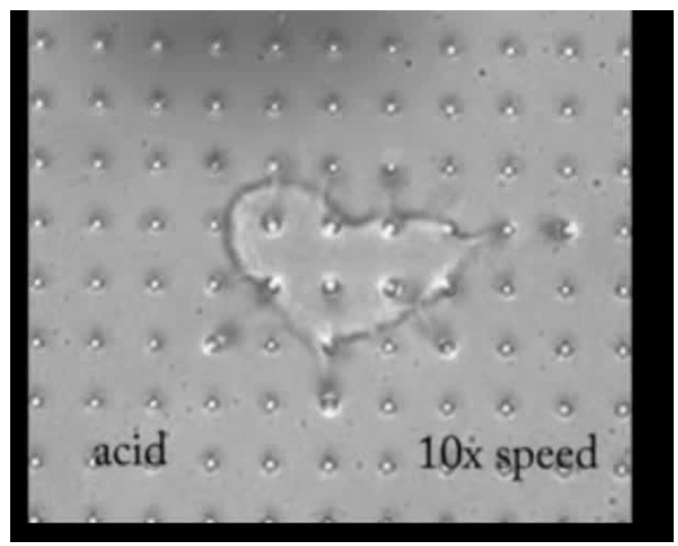




hydrogel micro-muscle

synthetic cilia



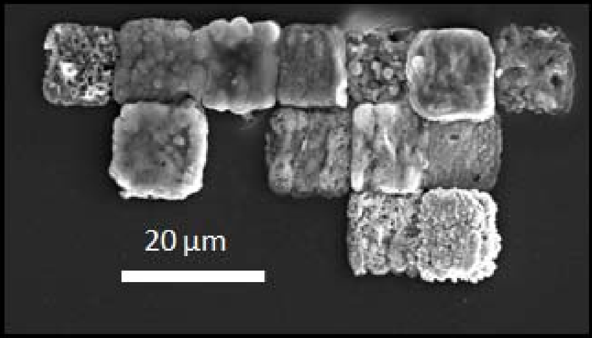


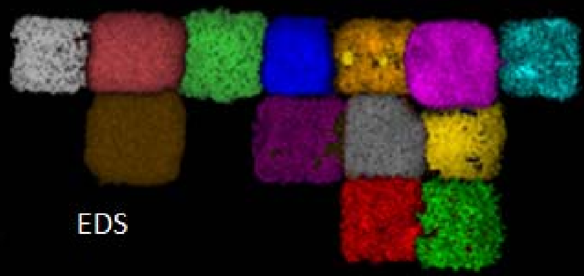
pH responsive hydrogel:
poly(acrylic acid-co-acrylamide) (poly(AAc-co-AAm).
20% AAm, 20% AAc, 2% bis-AAm, 1% Irgacure 819 in ethylene glycol

temperature-responsive hydrogel:
poly(N-isopropylacrylamide) (PNIPAM)
40% NIPAM, 2% bis-AAm, 1% Irgacure 819 in ethylene glycol (w/w)

Zarzar, Kim, Kolle, Brinker, Aizenberg, Kaehr (2011) *Angew. Chem. Int. Ed.*, 50, 9356–9360.

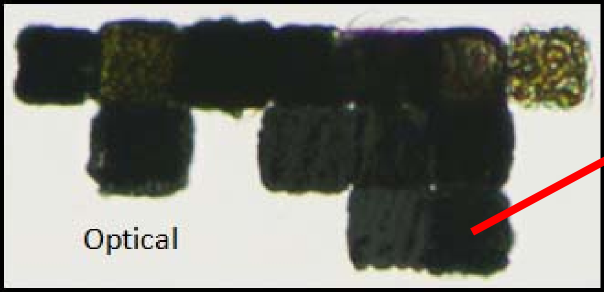
Sequential deposition of diverse materials into arbitrary patterns

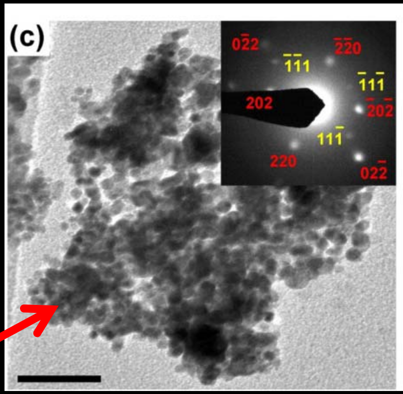


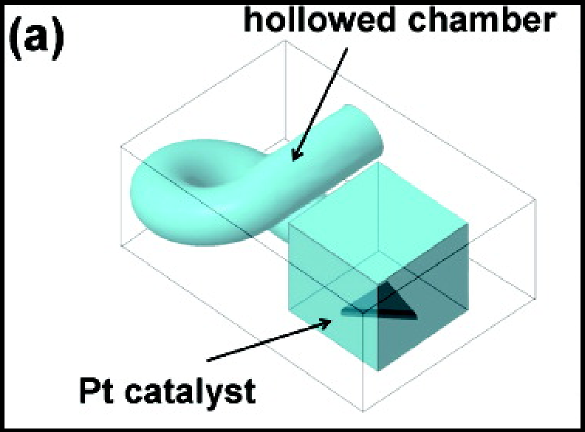


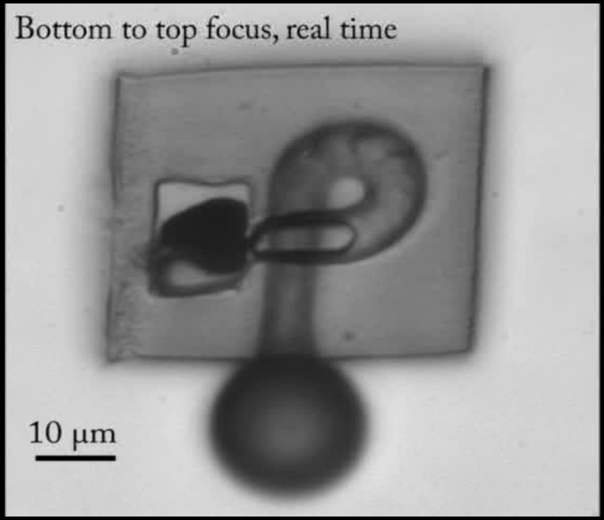
V	Cr	Mn	Fe	Co	Ni	Cu
	Mo		Ru	Rh	Pd	
				Ir	Pt	

Zarzar, Kaehr (2014)



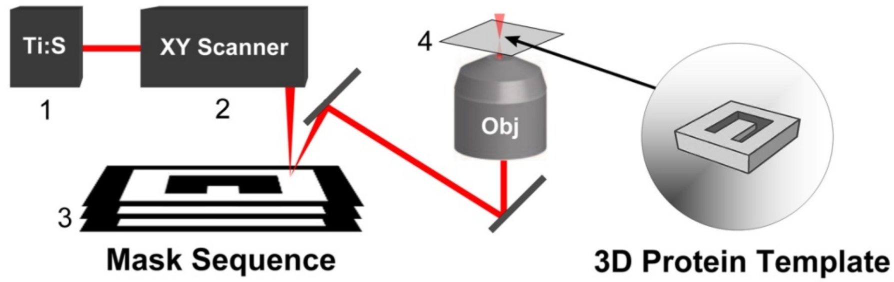


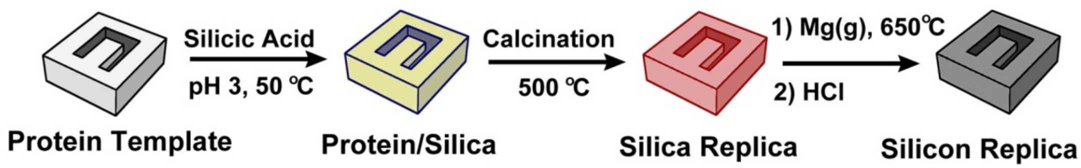


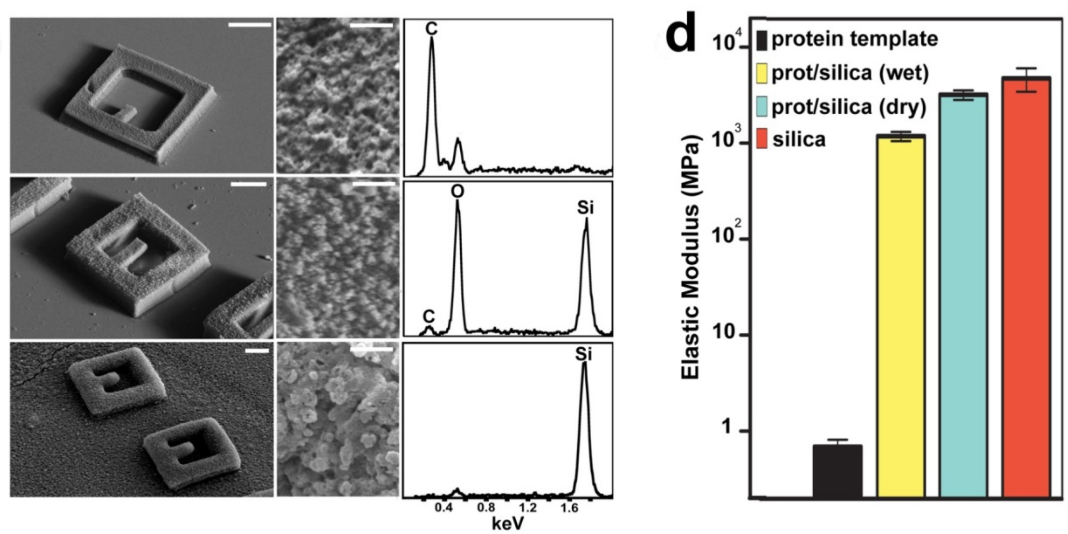


Zarzar, et al Kaehr (2012) *JACS*

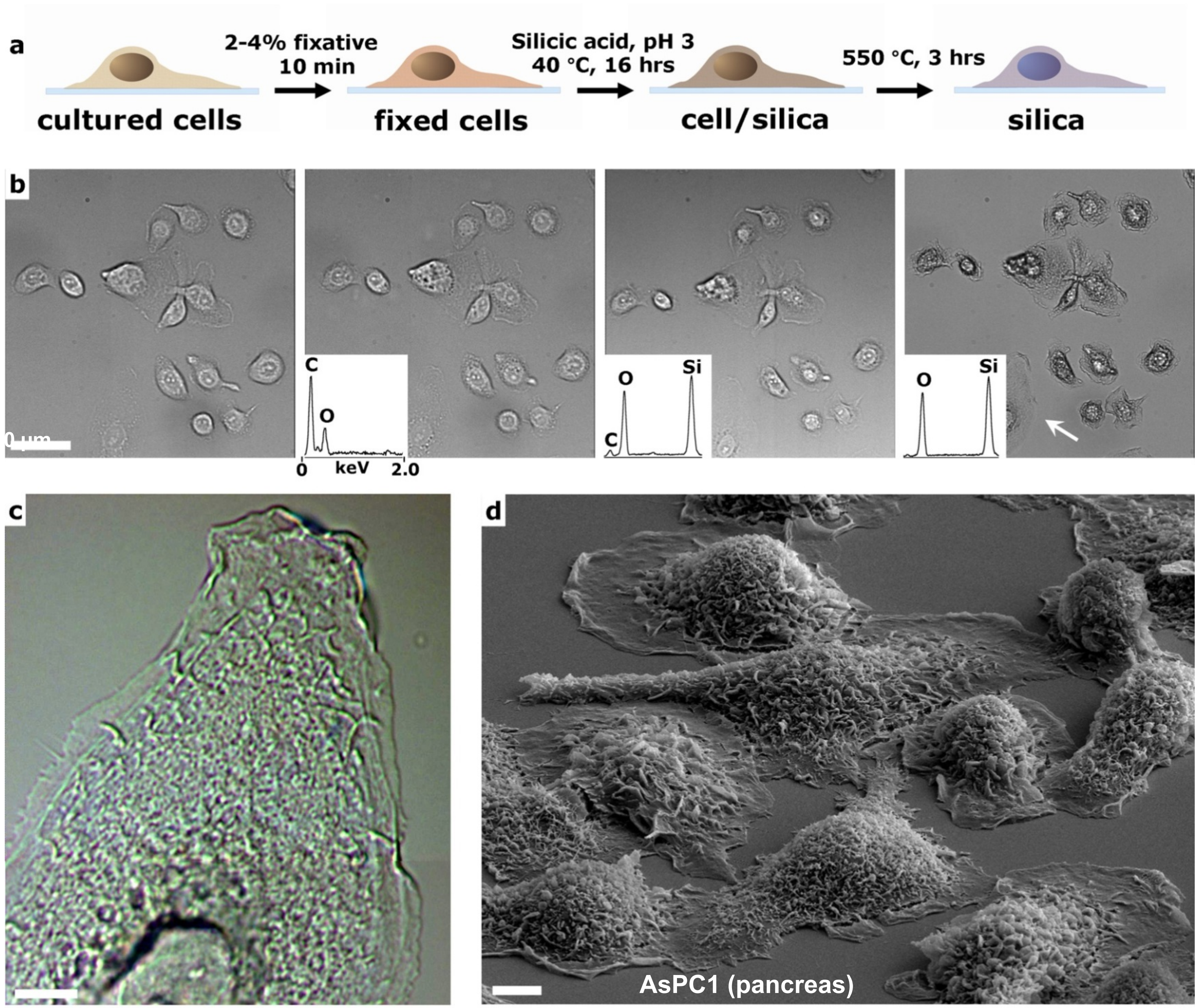
Shape-preserving transformation of protein structures into inorganic replicas







Khripin, C.Y., Pristinski, D., Dunphy, D.R., Brinker C. J., Kaehr, B. (2011) ACS Nano, 5, 1401-1409.

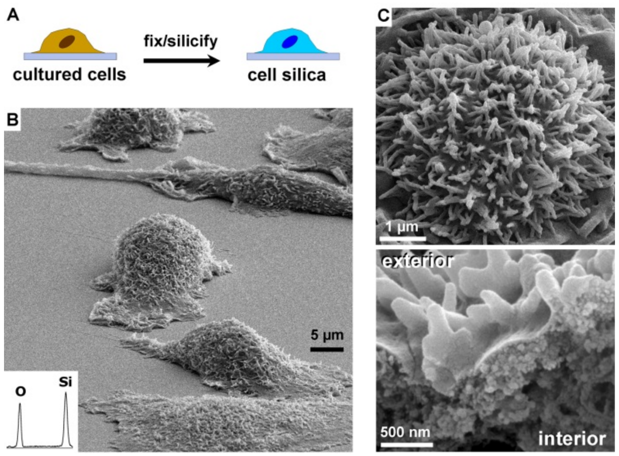


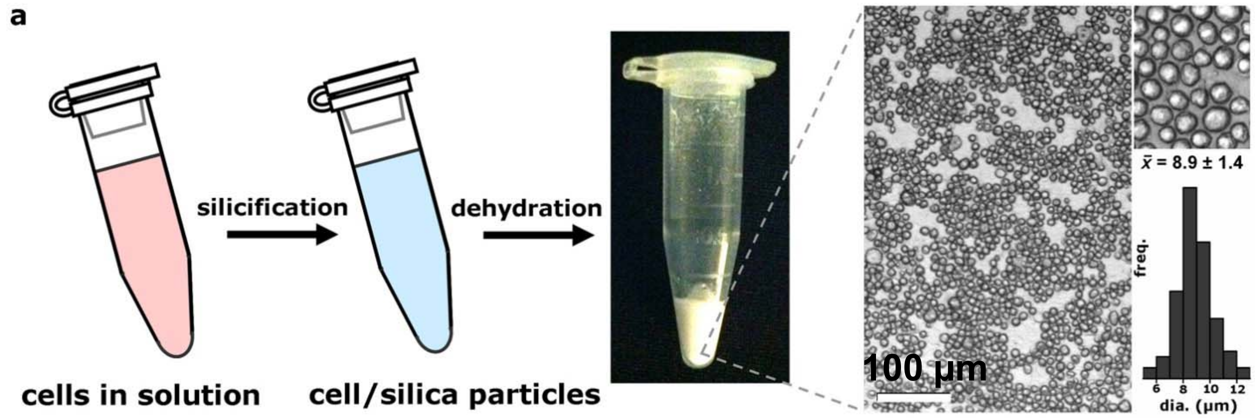
Proc Natl Acad Sci U S A. 2012 23;109(43):17336-41.

Silica Bioreplication (SBR)

SBR: interior, exterior, solution processing

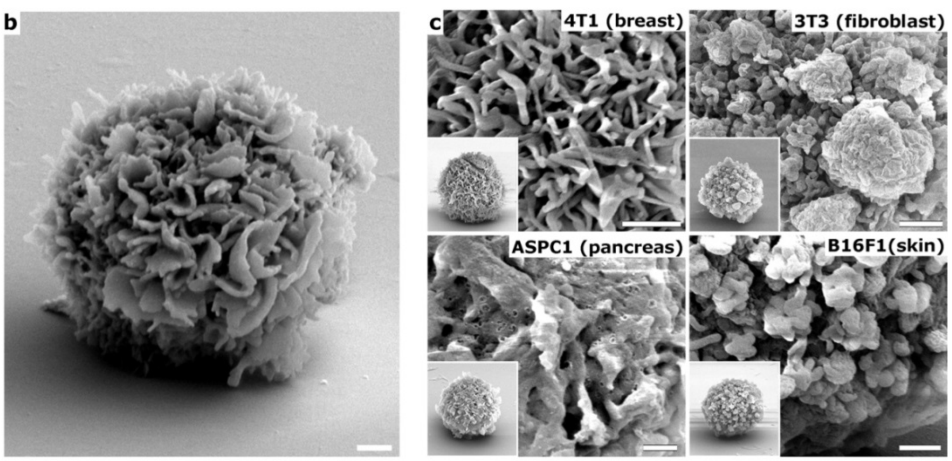
- High throughput
- Monodisperse



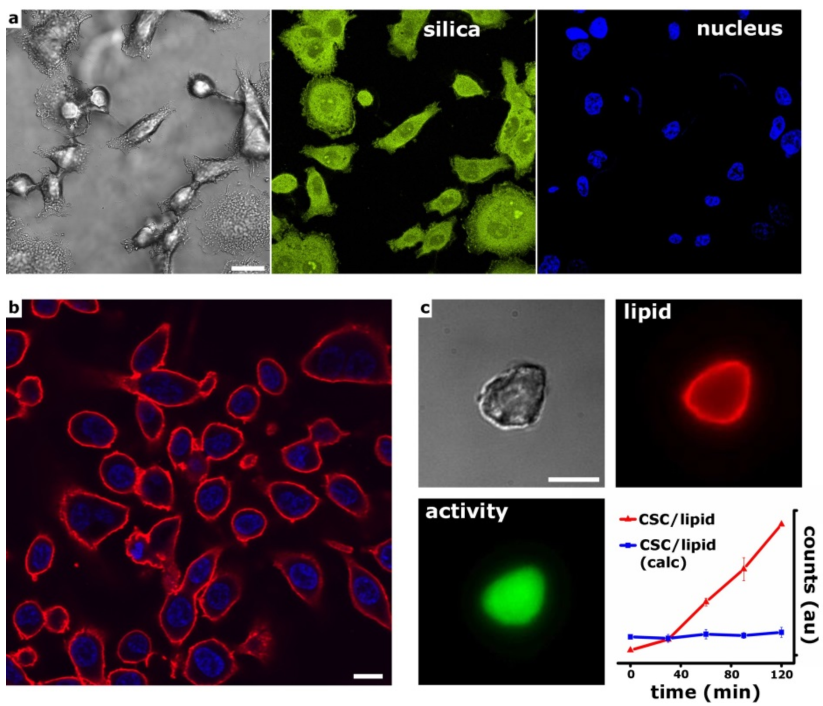


- Accessibility
- Retain/reconstitute function

- Generalizable across cell types
- Varying surface morphology

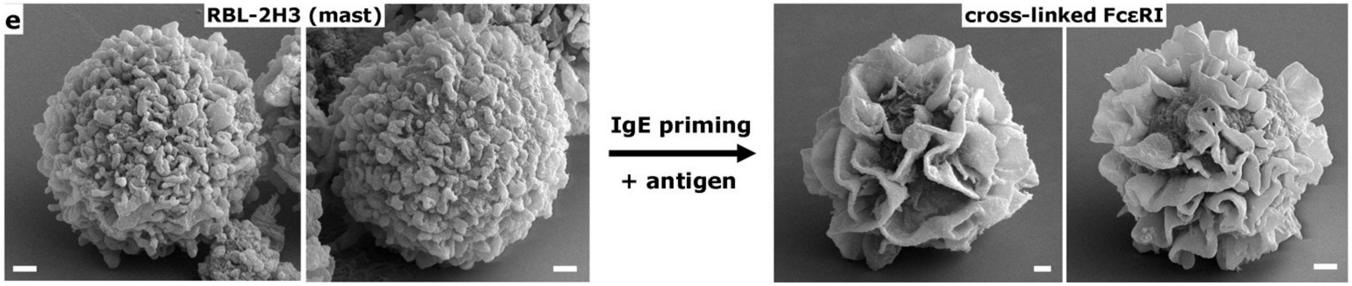


scale bars = 1 µm



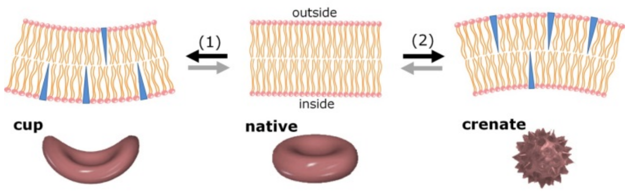
Proc Natl Acad Sci U S A. 2012 23;109(43):17336-41.

Using cellular response to tune material properties

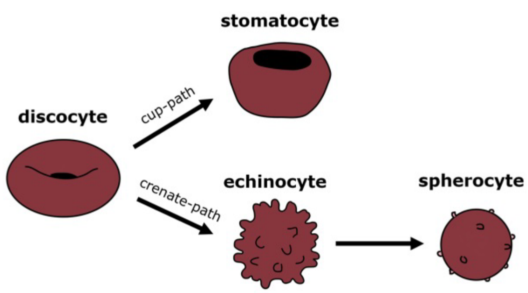


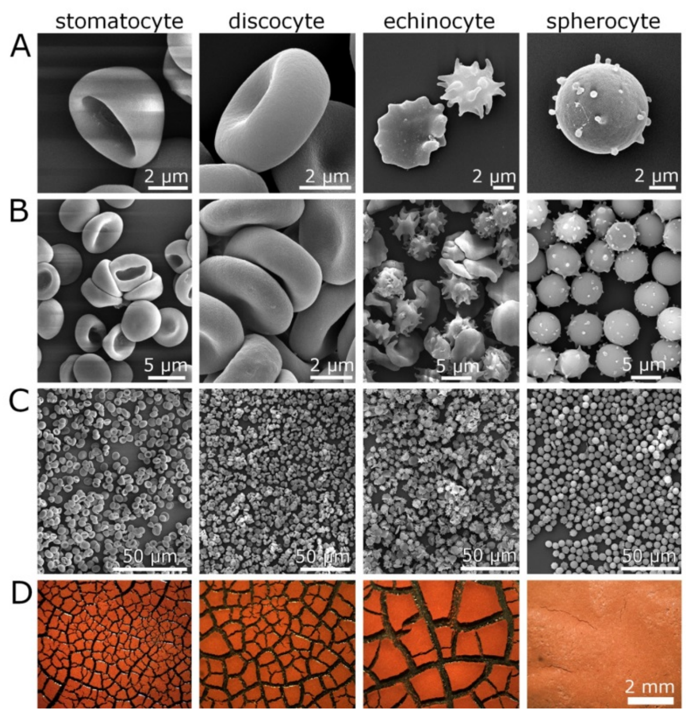
Proc Natl Acad Sci U S A. 2012 23;109(43):17336-41.

Bilayer couple….

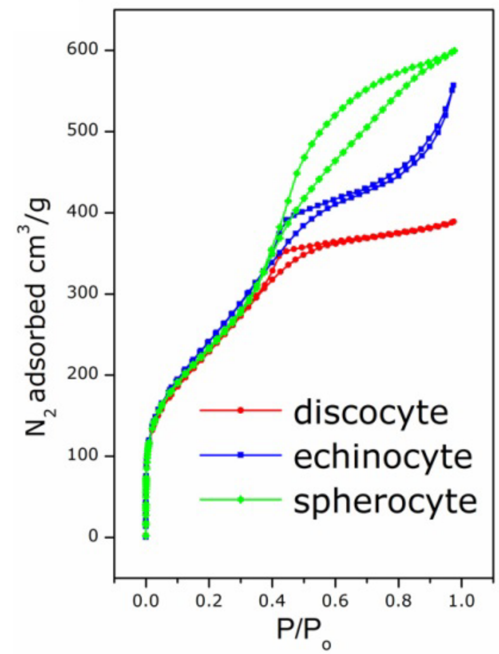


to direct shape.



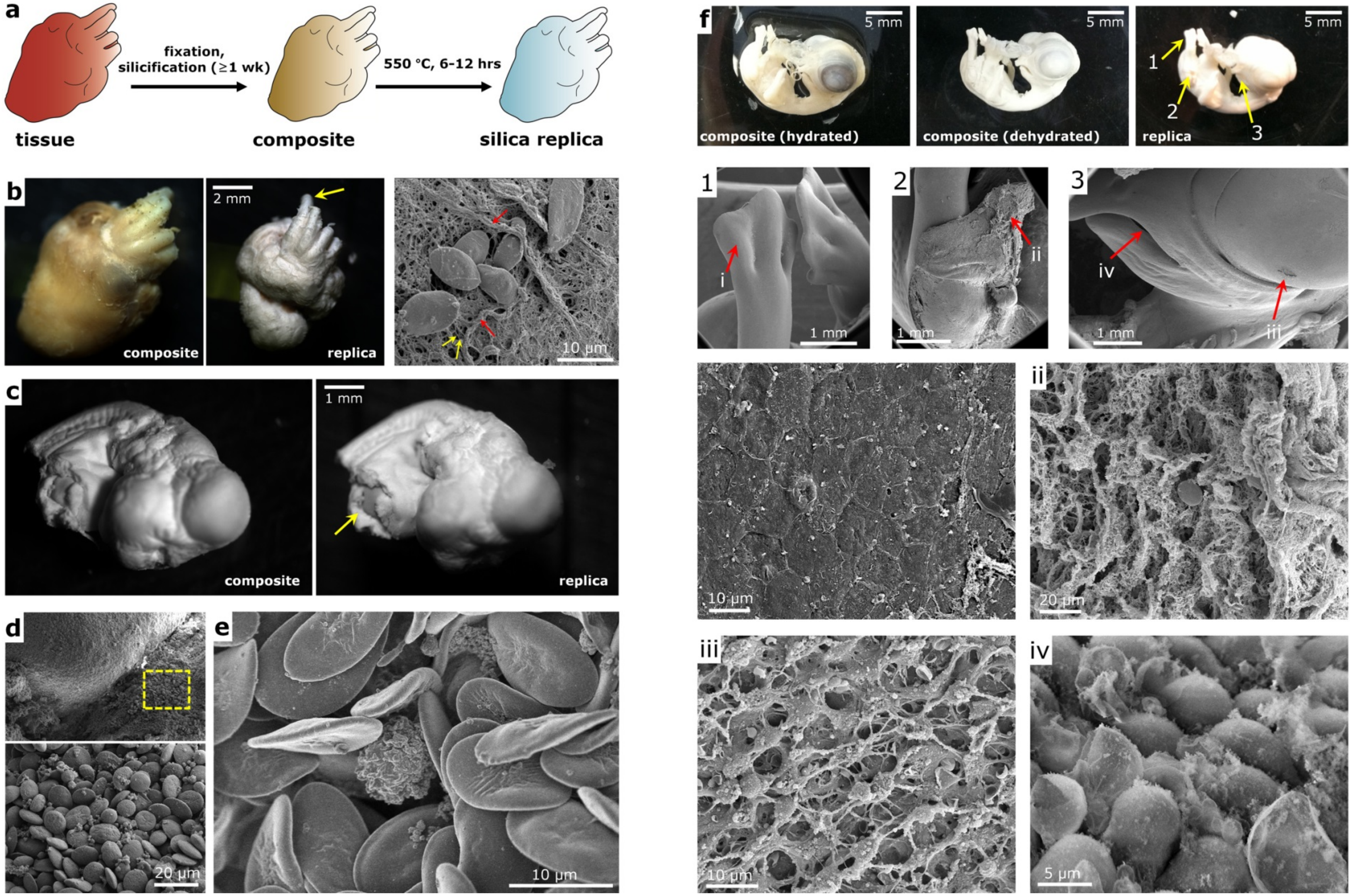


Mesopore structure directing



Myers, Coker, Bolintineanu, Kaehr (2014)

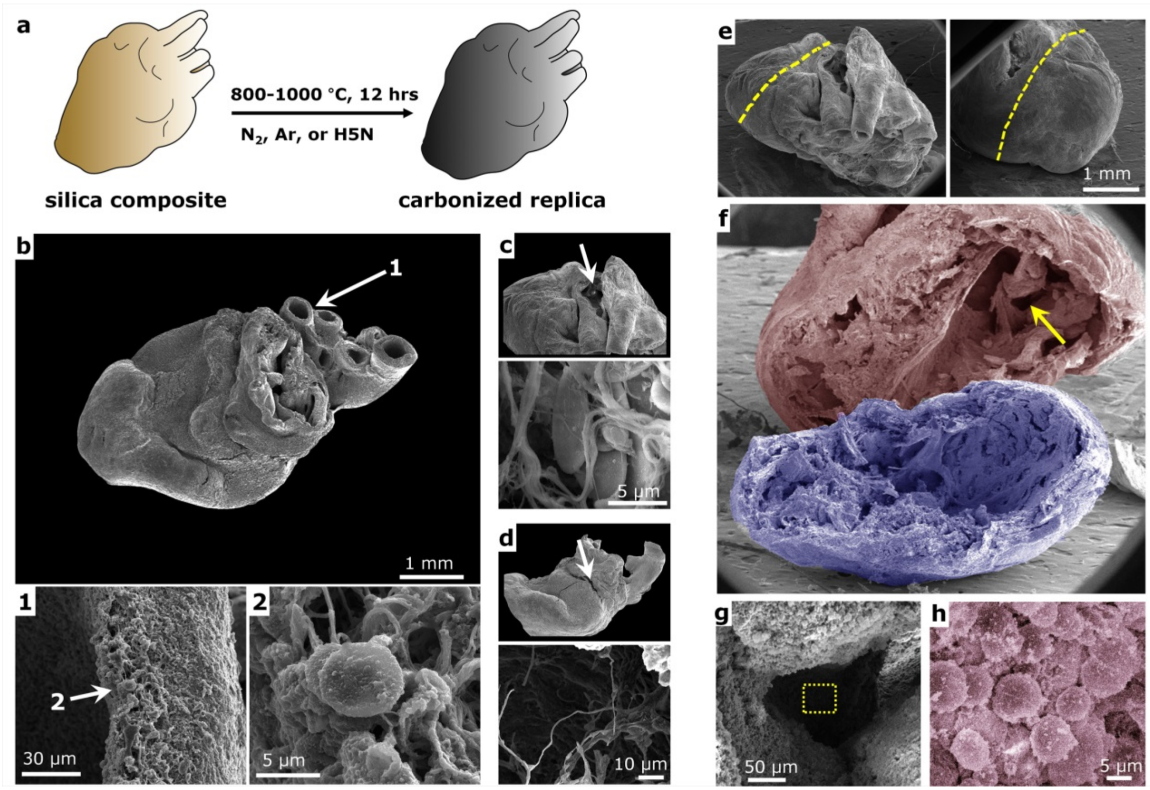
Shape-preserving transformation of tissues/organisms into inorganic and conductive specimens



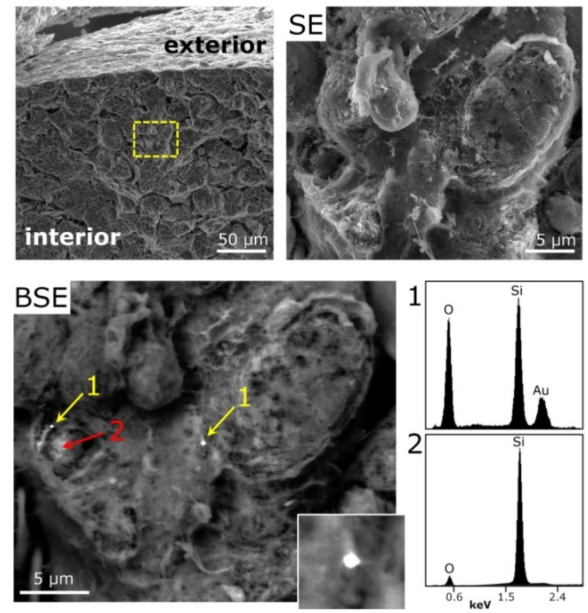
Townson, Lin, Chou, Awad, Brinker, Kaehr (2014)

Shape-preserving transformation of tissues/organisms into inorganic and conductive specimens

SEM imaging and sectioning w/o conductive coating



Detection of single ingested AuNPs



Townson, Lin, Chou, Awad, Brinker, Kaehr (2014)

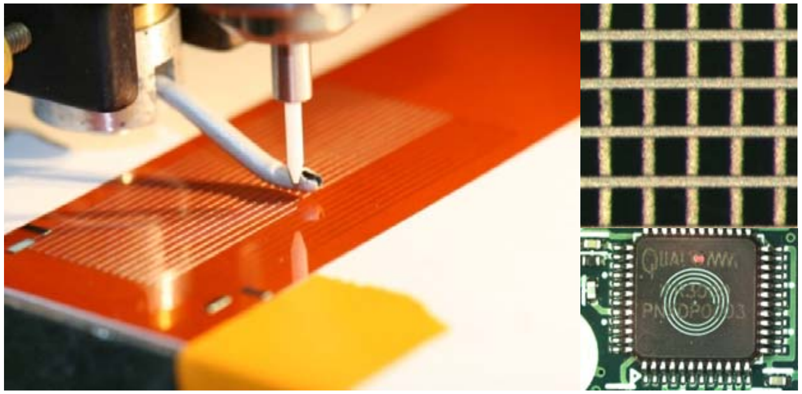
Direct Write Technologies

Applications for Printed Electronics

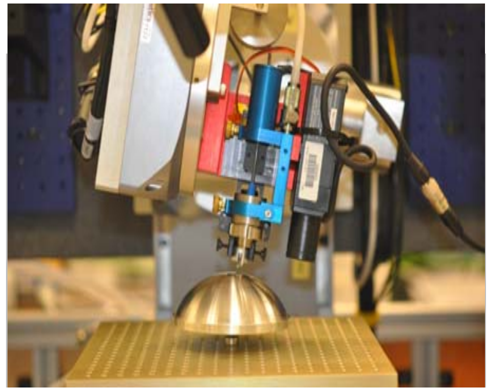
Exceptional service in the national interest

Sandia National Laboratories

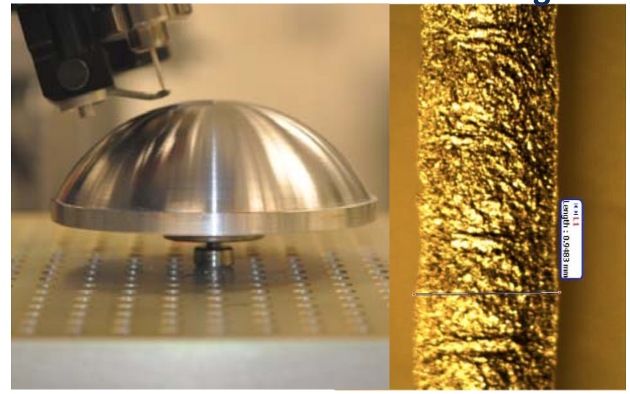
Aerosol Jet Printing to 10 µm



6-Axis Machine Center



Conformal Additive Manufacturing



DC and RF pathways for interconnect and antenna applications on planar or arbitrary surfaces

Strain and crack sensors for structural health monitoring, resistance temperature devices (RTD)

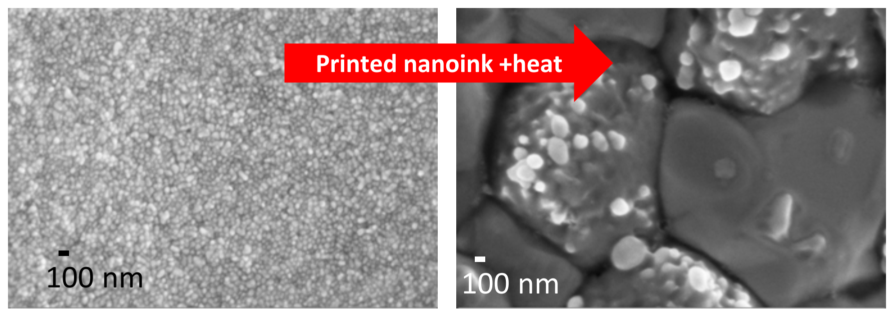
Integration of packaged components with external sensing networks for value added functionality

Printable materials include metallic nanoinks, organic polymer inks, ceramic slurries, dielectrics, epoxies, UV curable materials, novel research compounds

Extensive substrate compatibility including :

PLASTICS	CERAMICS	POLYIMMIDE	METALS
FR4	GLASS	PAPER	ENCAPSULANTS

Low temperature post processing requirements enable maskless direct write printing of nanomaterial based conductors on temperature sensitive substrates. Sintering of intricate metallized nanoink patterns can be achieved through thermal, photonic or electrical mechanisms to achieve near bulk conductivity for electronics grade metallic conductors. Electrical resistivity as low as 1.5x bulk (silver).



Sintering of silver nanoinks to form conductive pathways (170 C)

U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

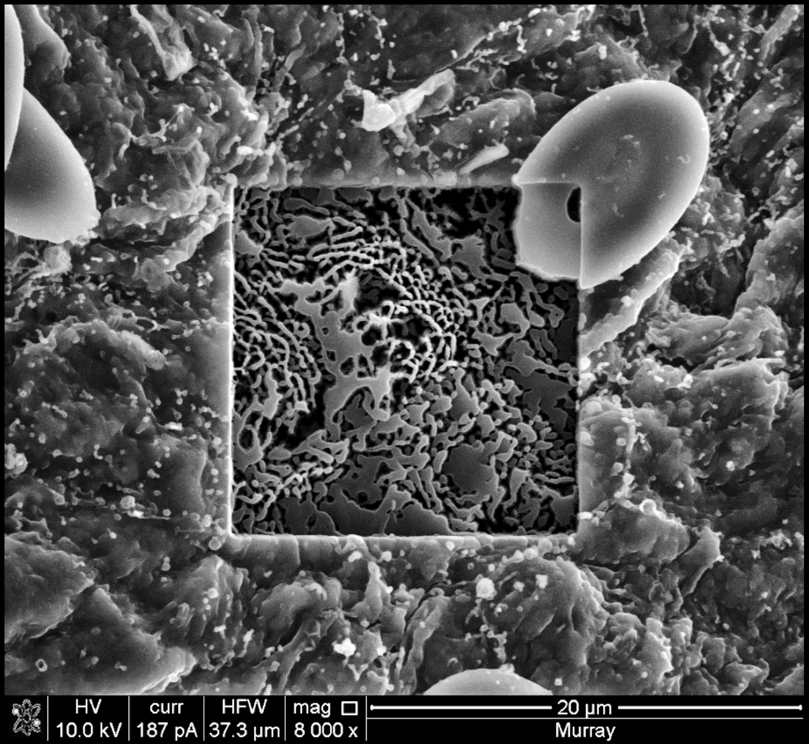
Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

AEROSOL & INK JET PRINTING   EXTRUSION CASTING   SPRAY COATINGS   DC & RF CHARACTERZATION   MATERIALS & PROCESS DEVELOPEMENT

Adam W. Cook
acook@sandia.gov

Acknowledgments

- Kristin Meyer
- Jason Townson
- Constantine Khripin
- Jeff Brinker
- Dan S. Bolintineanu
- Yu-Shen Lin
- Yasmine Awad
- Darren Dunphy
- Robin Kalinich
- Eric Coker
- Stan Chou
- Jason Harper
- Susan Brozik
- Jason Shear
- Rex Neilson
- Lauren Zarzar
- Joanna Aizenberg
- Brian Swartzentruber



FIB SBR specimen

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