The Art of Research... in Nanophotonic Materials

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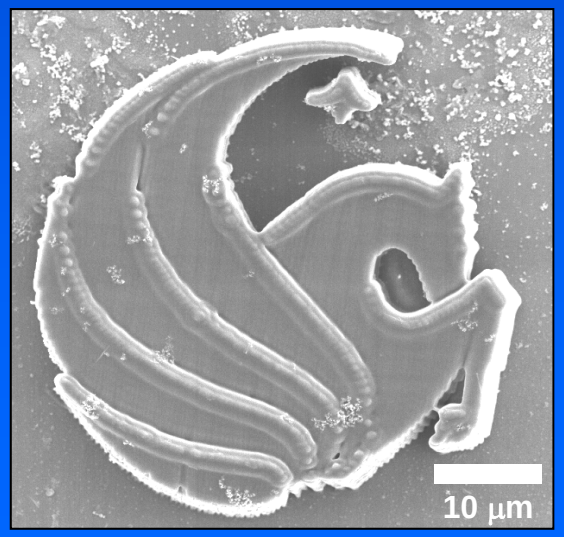
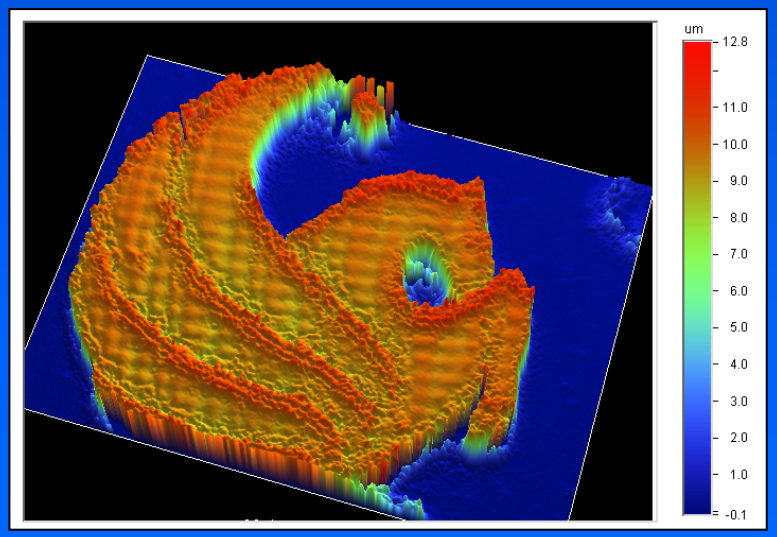


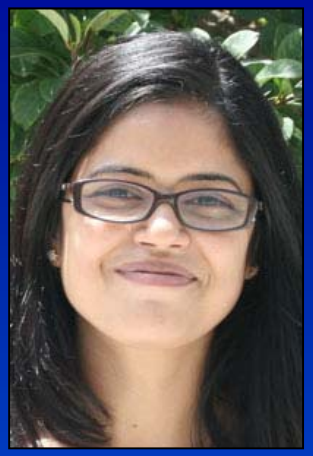


Greetings from the Kuebler Group !!

Henry Williams
Chem PhD

Chris Grabill
Chem PhD

Ping Digaum
Optics PhD



Rashi Sharma
Chem PhD

Gabe Padilla
Chem BS

Ali Ozcan
Chem MS

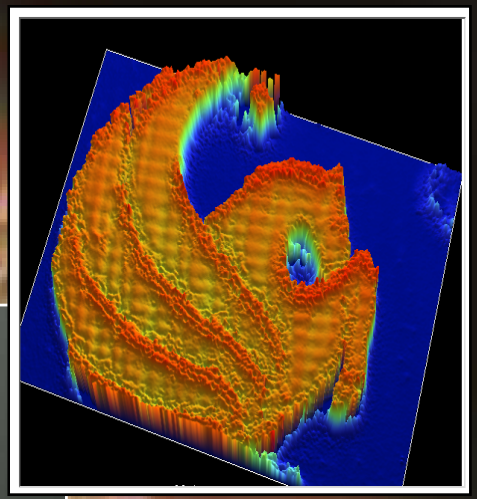
Tatiana Rios
Chem MS

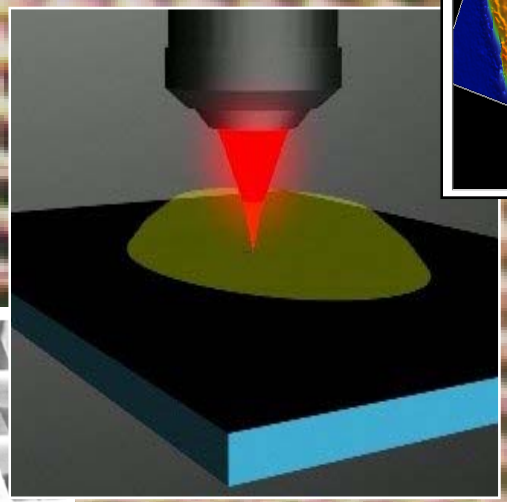
Drew Hansen
Chem BS

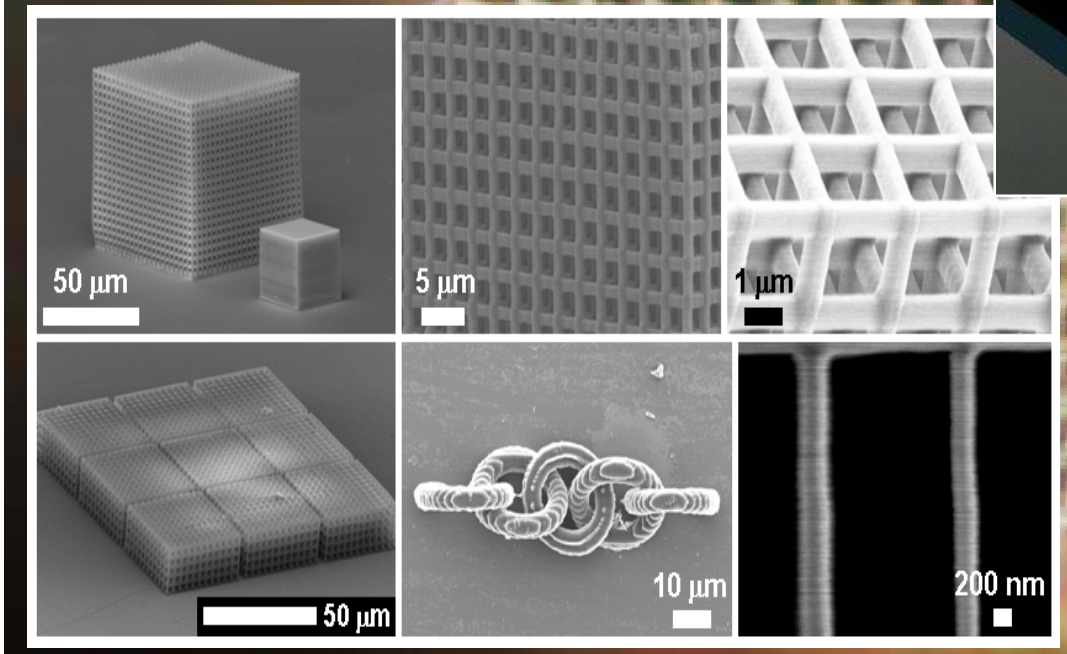
Danny Freppon
Chem BS

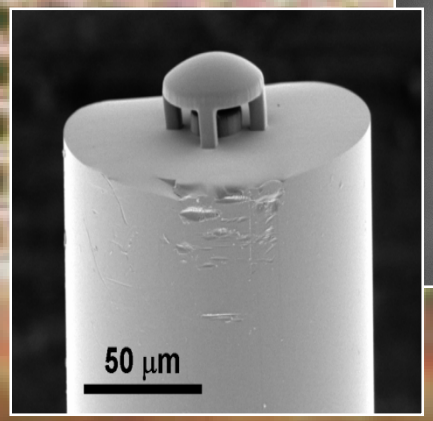
Kuebler Group: Nano-scale 3D Fabrication

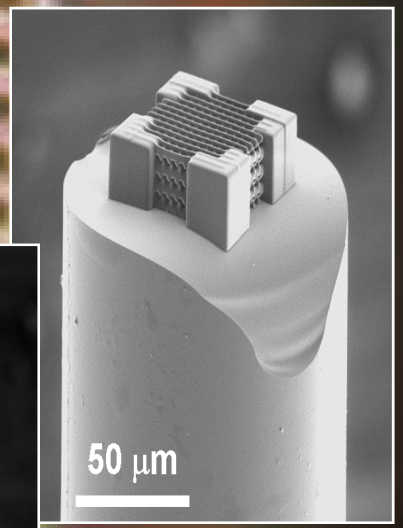
- New material systems
  - Polymers
  - Metallized structures
  - Semiconductors
- Functional devices
- Integrated sensors











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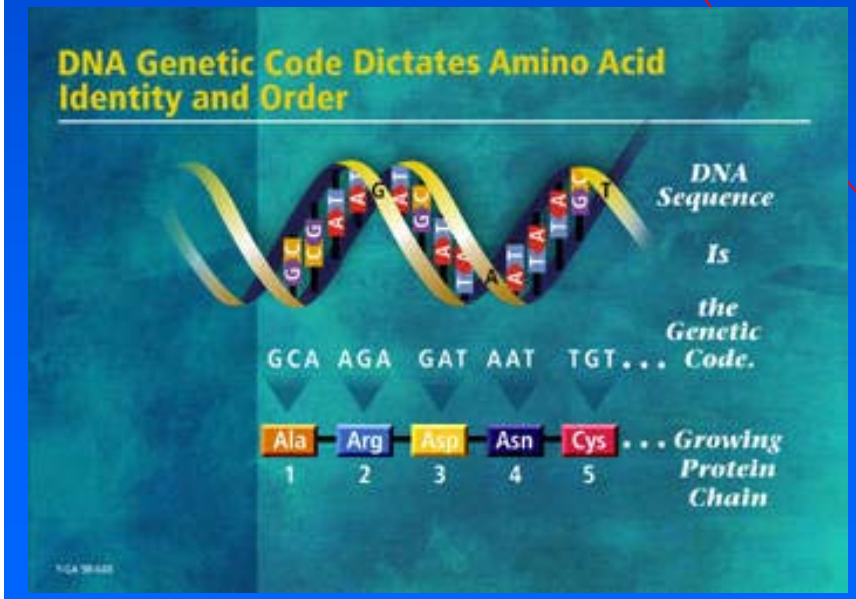
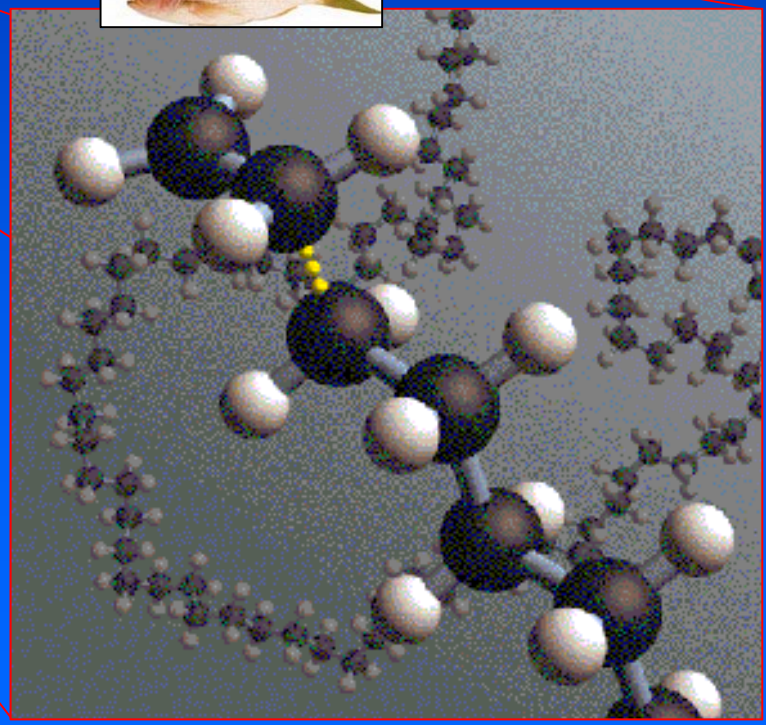
What are polymers?

Ren Ren



Wikipedia



chem.ufl.edu

How do chemistry and optics overlap?

Let's see one example from nature…

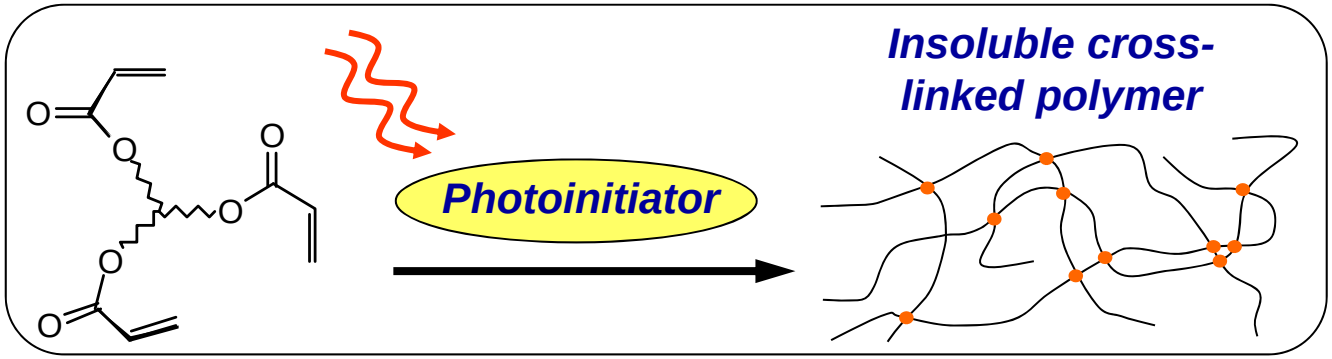
A glass
Transparent

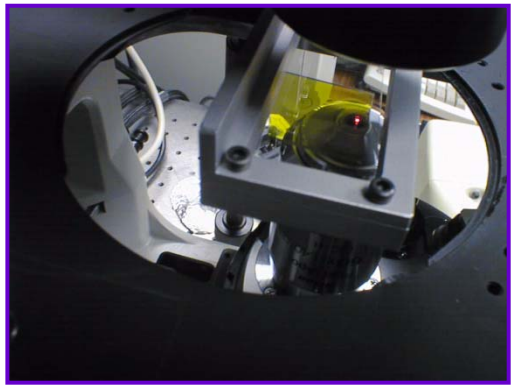
Natural opal
Multi-colored, changes with angle!

- **Glass and a natural opal share the same chemical nature: SiO_2**
- **Then why are their optical properties so different?...**

Multi-photon 3D direct laser writing process

Multi-photon polymerization

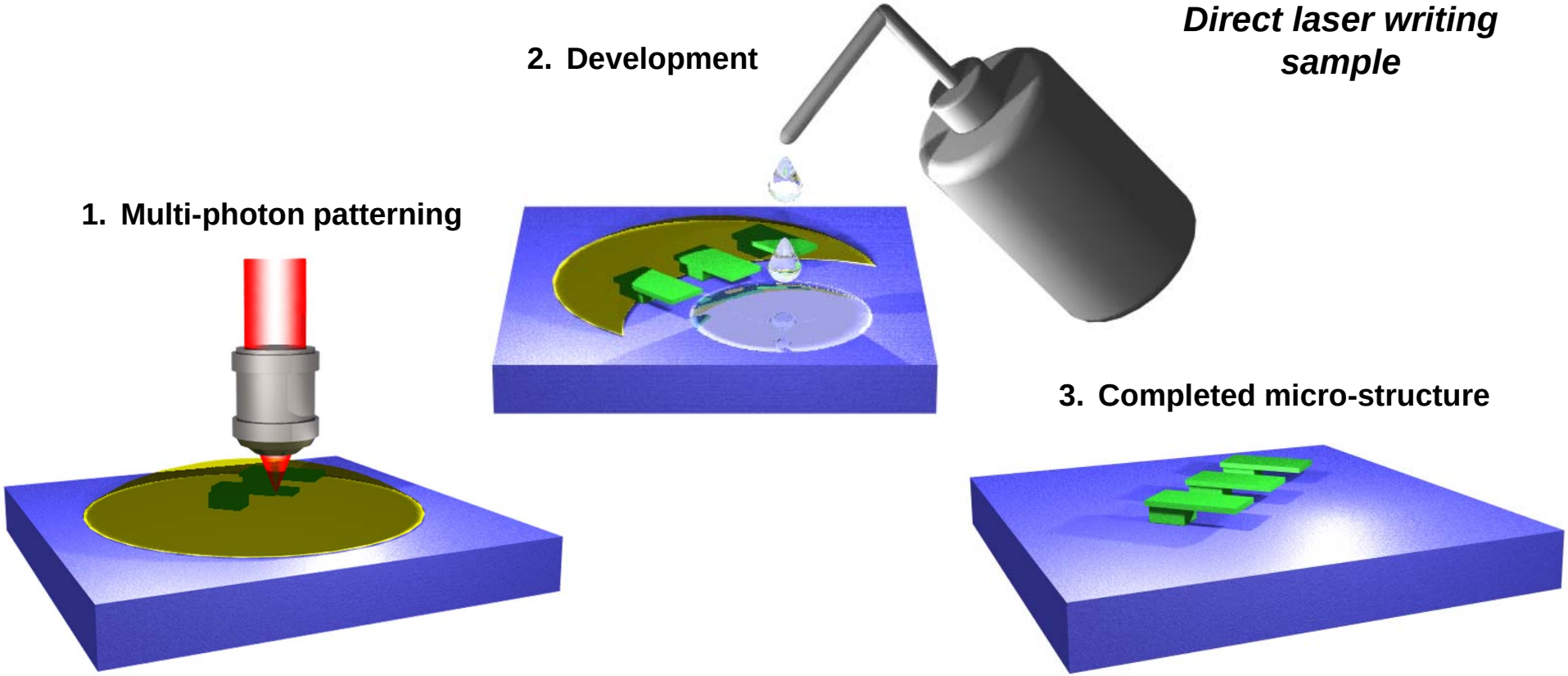




Direct laser writing sample

2. Development

1. Multi-photon patterning



3. Completed micro-structure

How we make photonics crystals

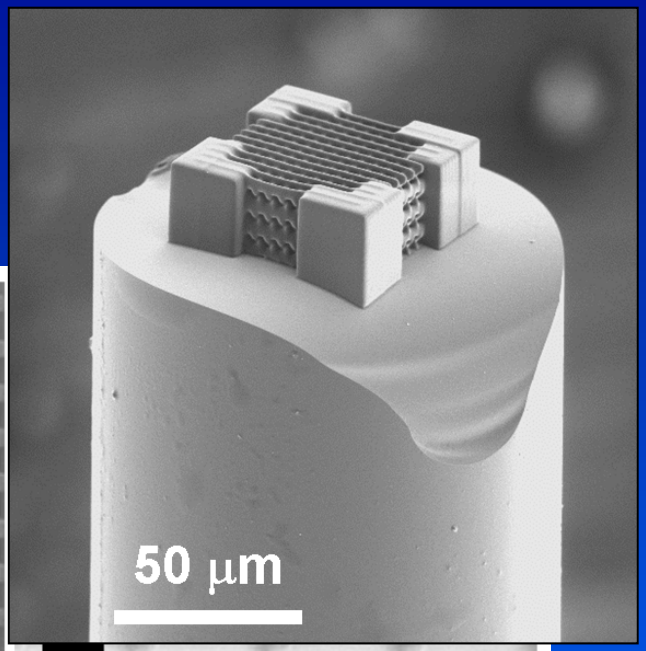
Multi-Photon 3D
Direct Laser Writing

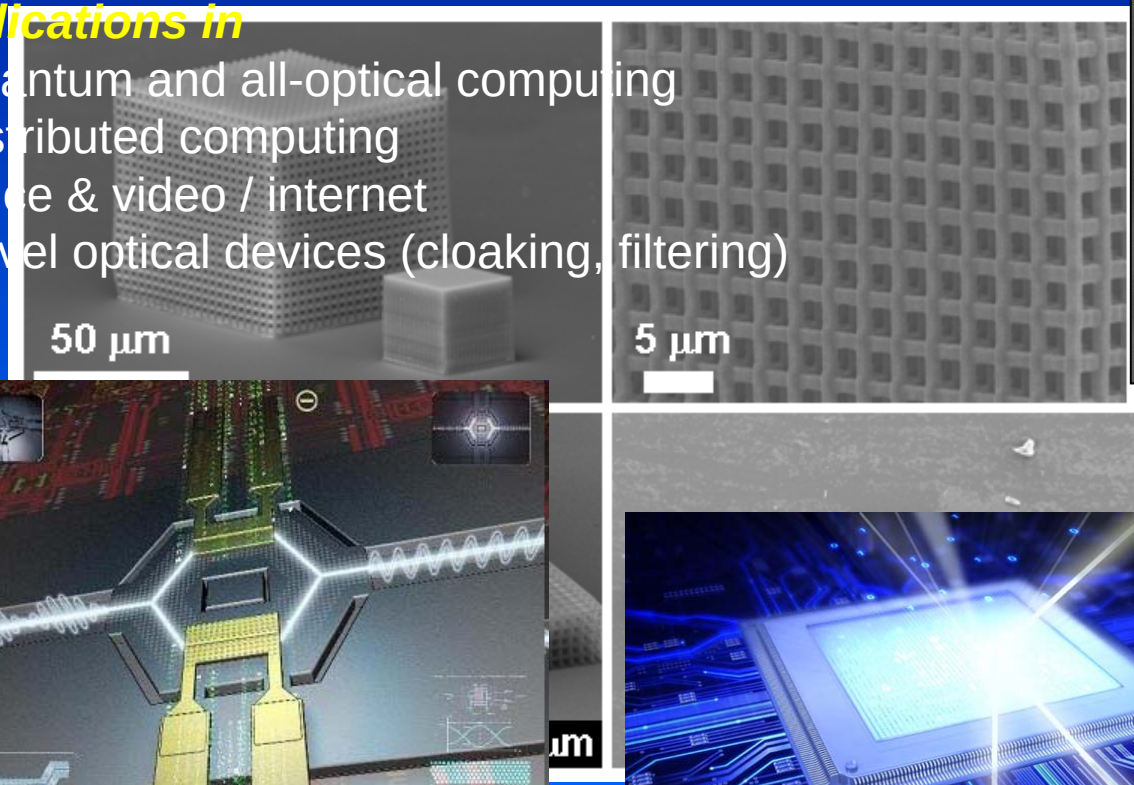
What we produce: Fundamental advances in photonics

- New materials and devices for controlling light
- x20,000 faster information processing

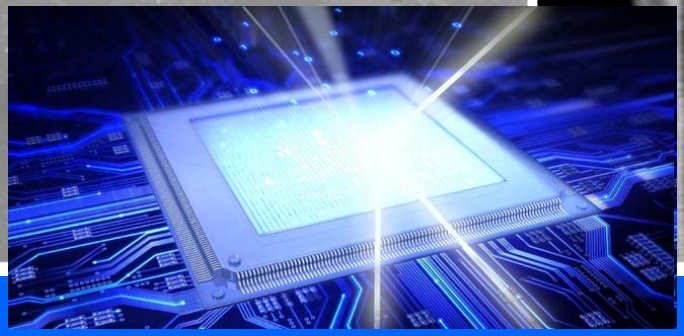
Applications in

- Quantum and all-optical computing
- Distributed computing
- Voice & video / internet
- Novel optical devices (cloaking, filtering)





Univ. of Glasgow

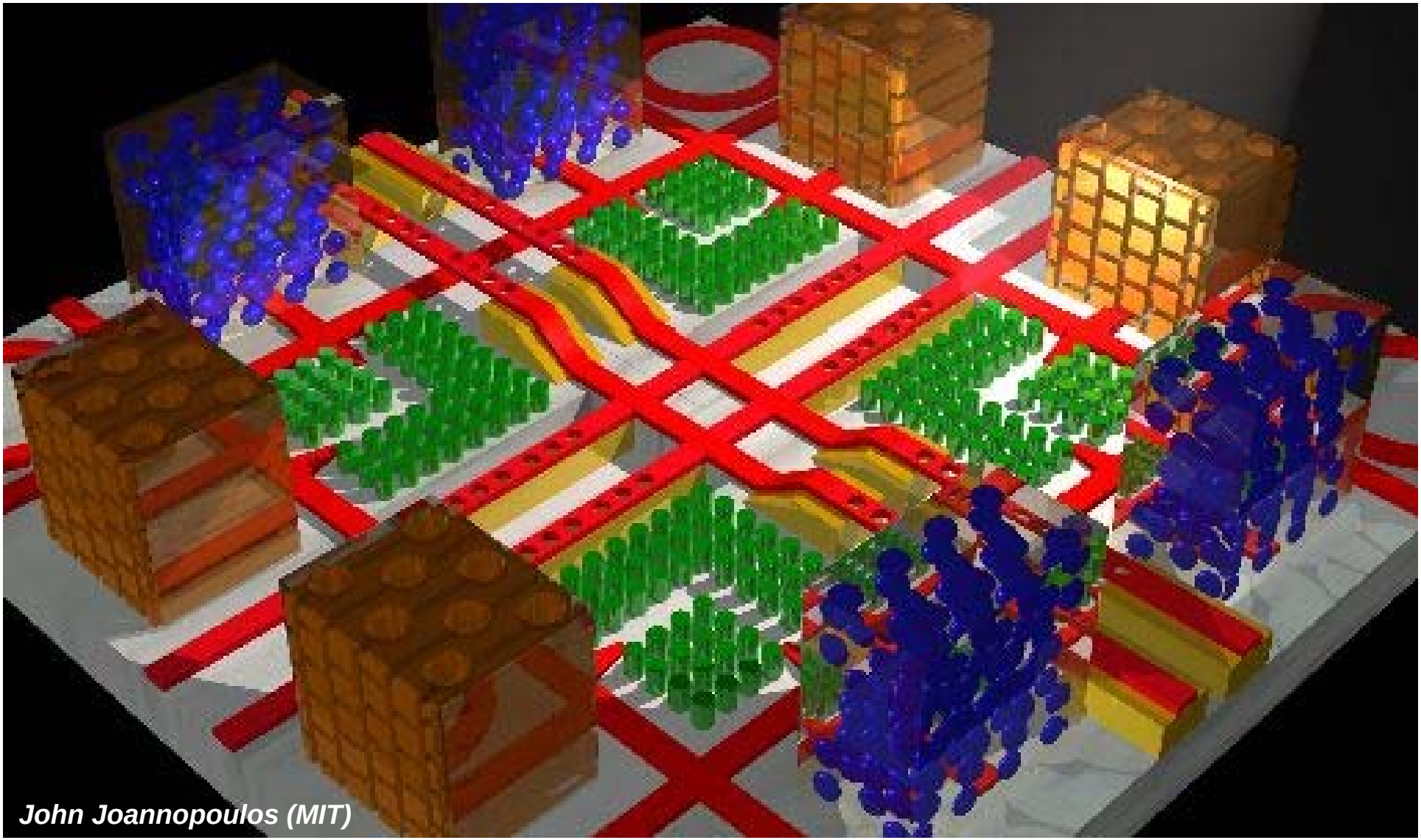


Wired

Corning

We are learning to control photons as well as we control electrons.

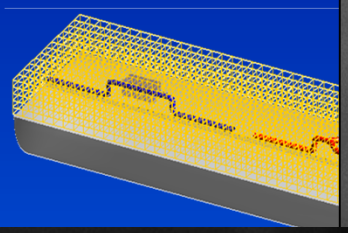
Towards Functional Devices

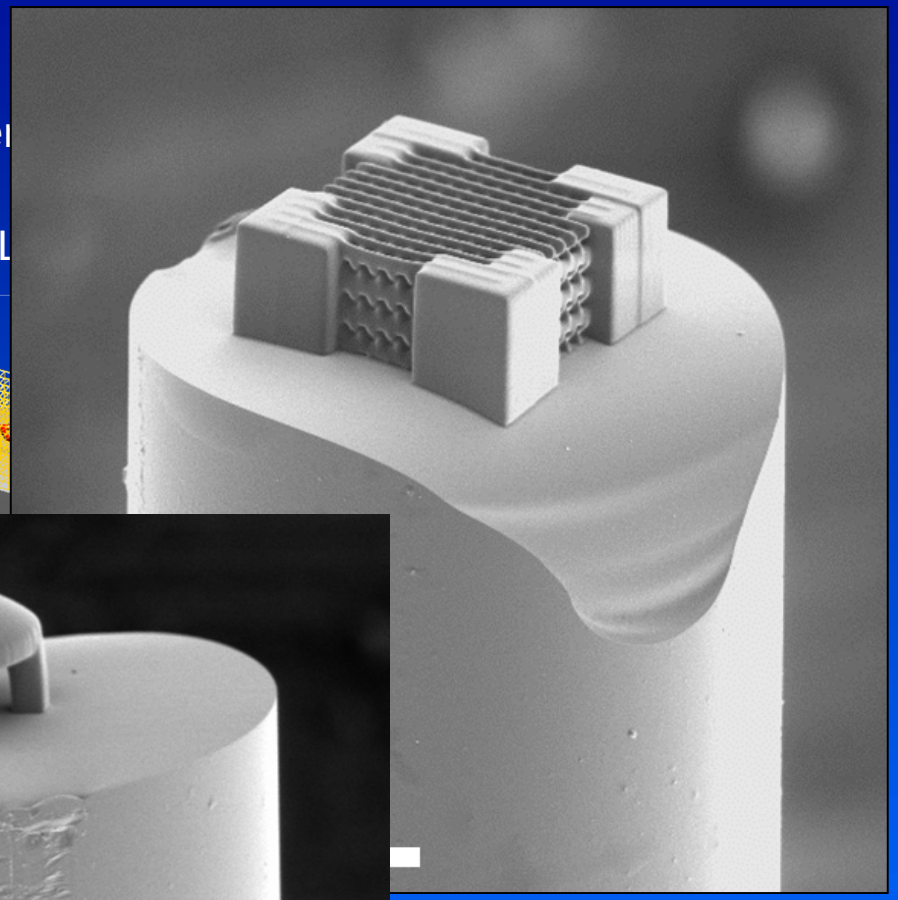


Development of new nano-photonic sensors

Objectives

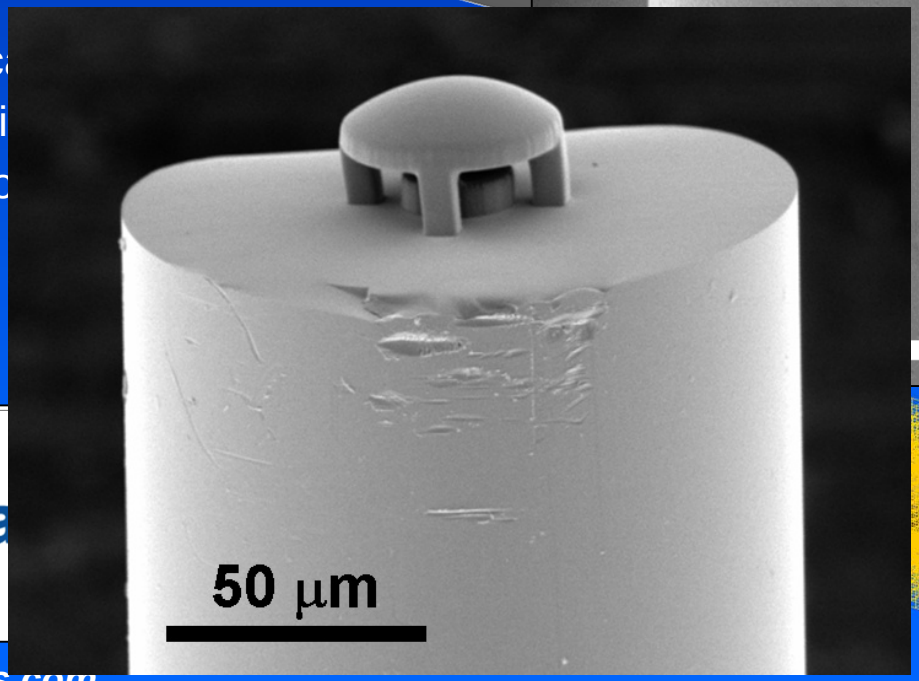
- Optimize DLW for fabricating nanophotonic elemen
  optical fibers
- Fabricate optical sensing elements on fibers by DL
  - Mach-Zehnder interferometer
  - Waveguide coupler
  - Photonic crystal reflector





Advantages

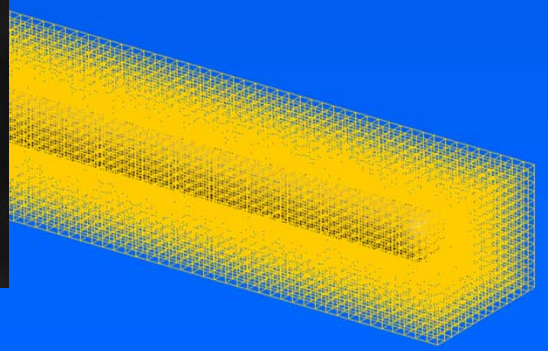
- Immunity from electric
- Useful in extreme envi
- High sensitivity (ppm c
- Remote operation

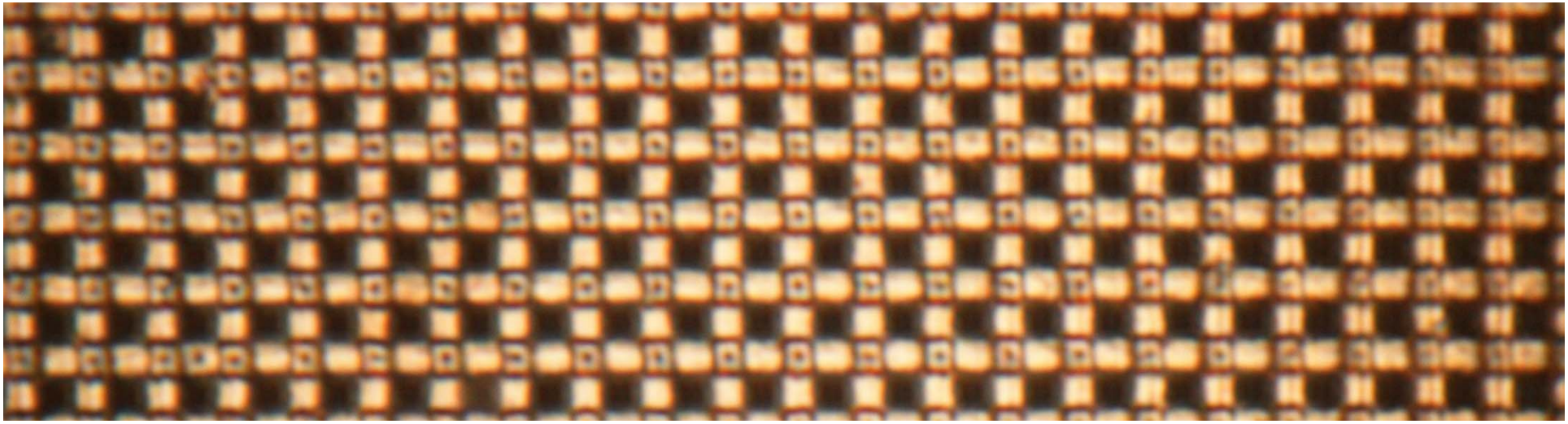


Industrial partner

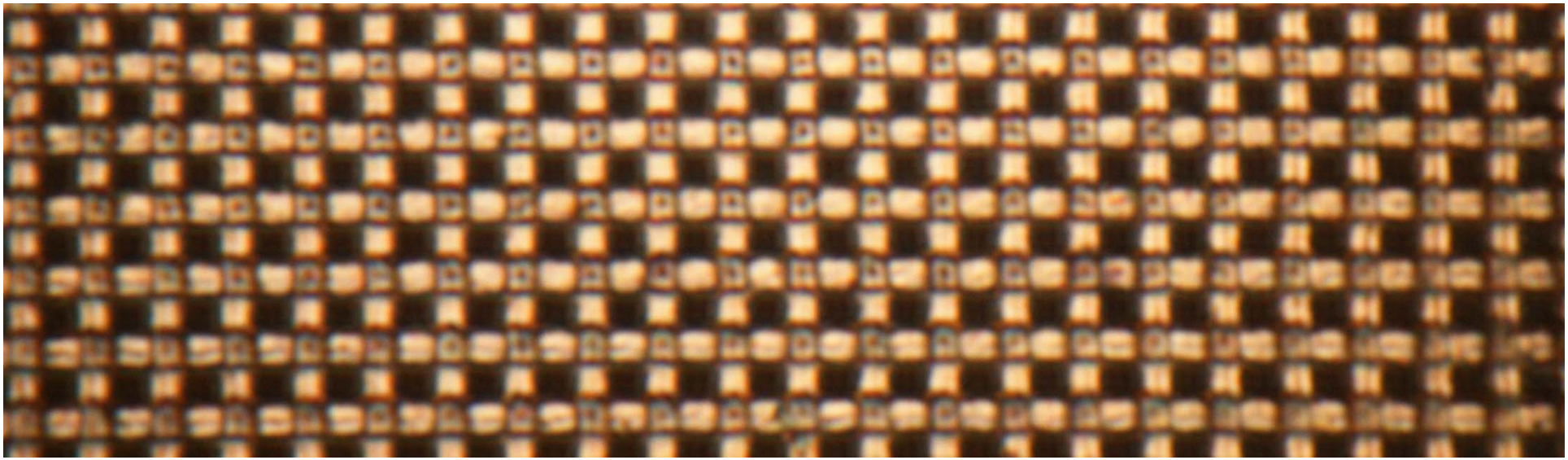
prime resea

www.primephotonics.com

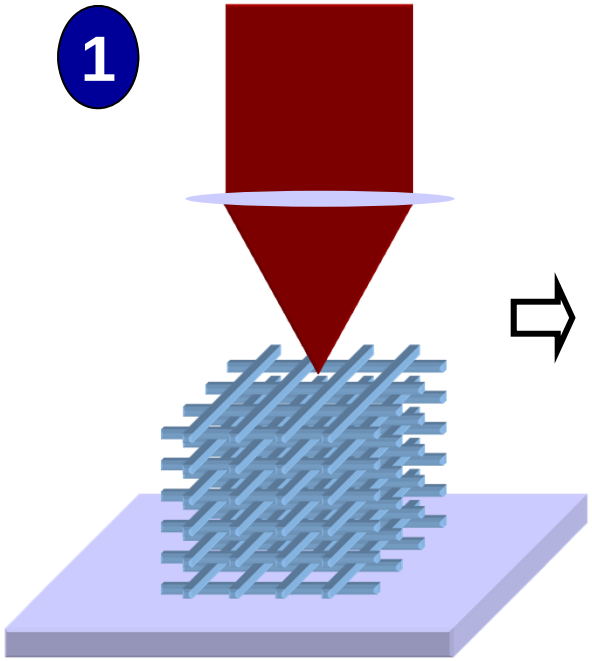




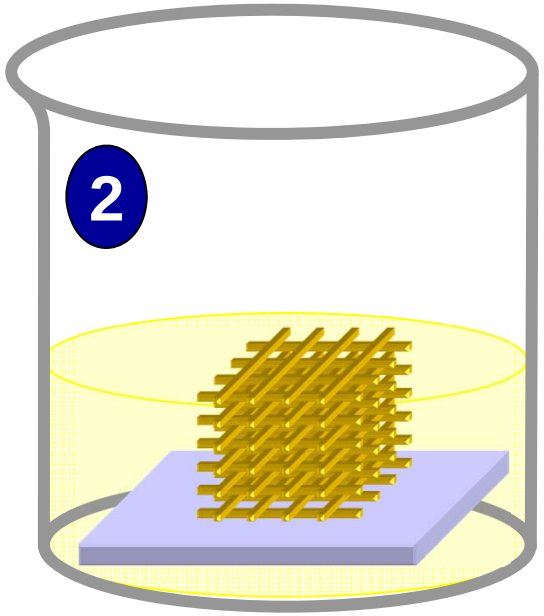
Metallic Photonic Crystals



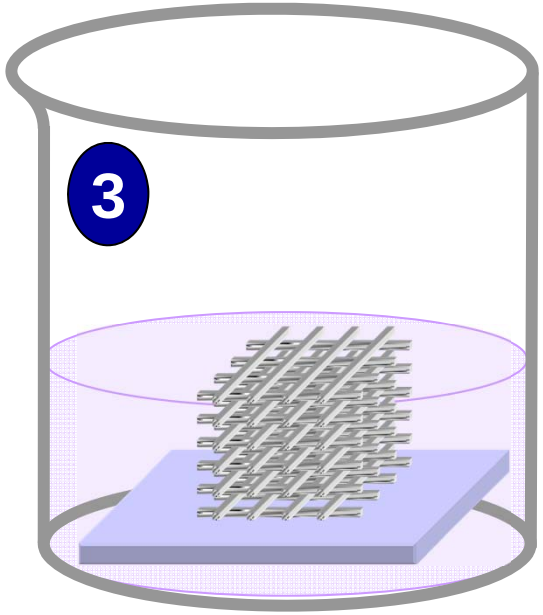
Route to 3D metallo-dielectric PCs



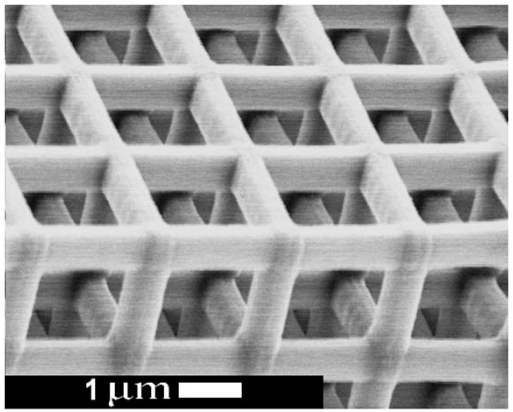
Create polymeric template by multi-photon 3D direct laser writing



Functionalize surface for <u>electroless</u> metallization



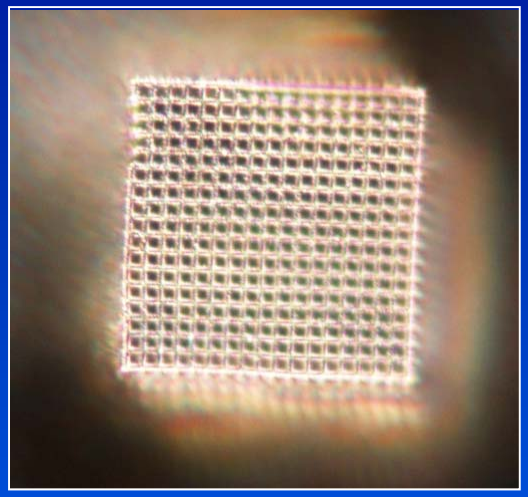
Conformally plate metal onto template

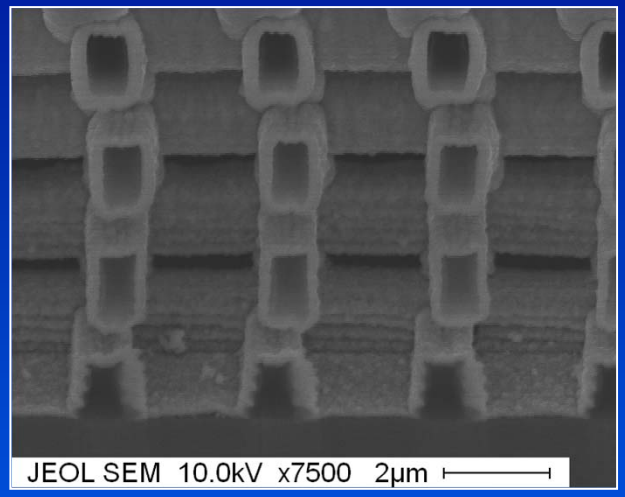


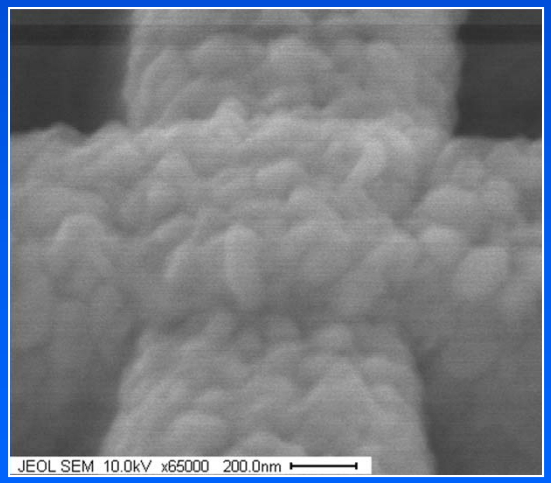
Related metallization approaches:

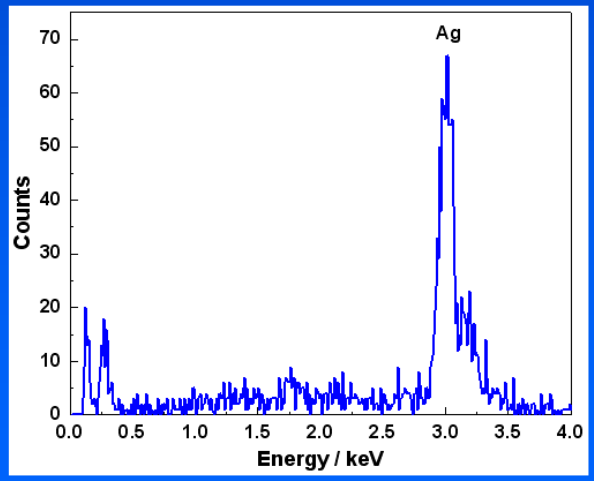
- John T. Fourkas *et al.* (2006)
  Cu & Au plated acrylate structures
- Satoshi Kawata *et al.* (2006)
  Ag-plated acrylates
- Hiroaki Misawa *et al*. (2007)
  Ni-plated SU-8 PCs

Metallo-dielectric micro-structures





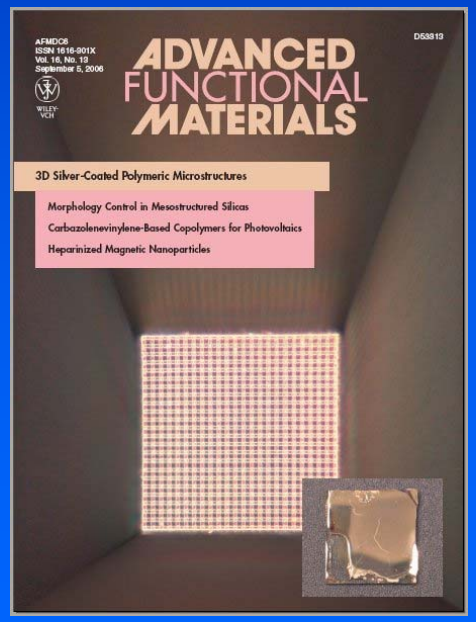




- Reflective silvered surface
- Conformally coated surface
- Silver layer:

  ~200 nm thick layer

  50-150 nm grain size



Kuebler *et al.*, *Chem. Mater.* 19, 3858 (2007)

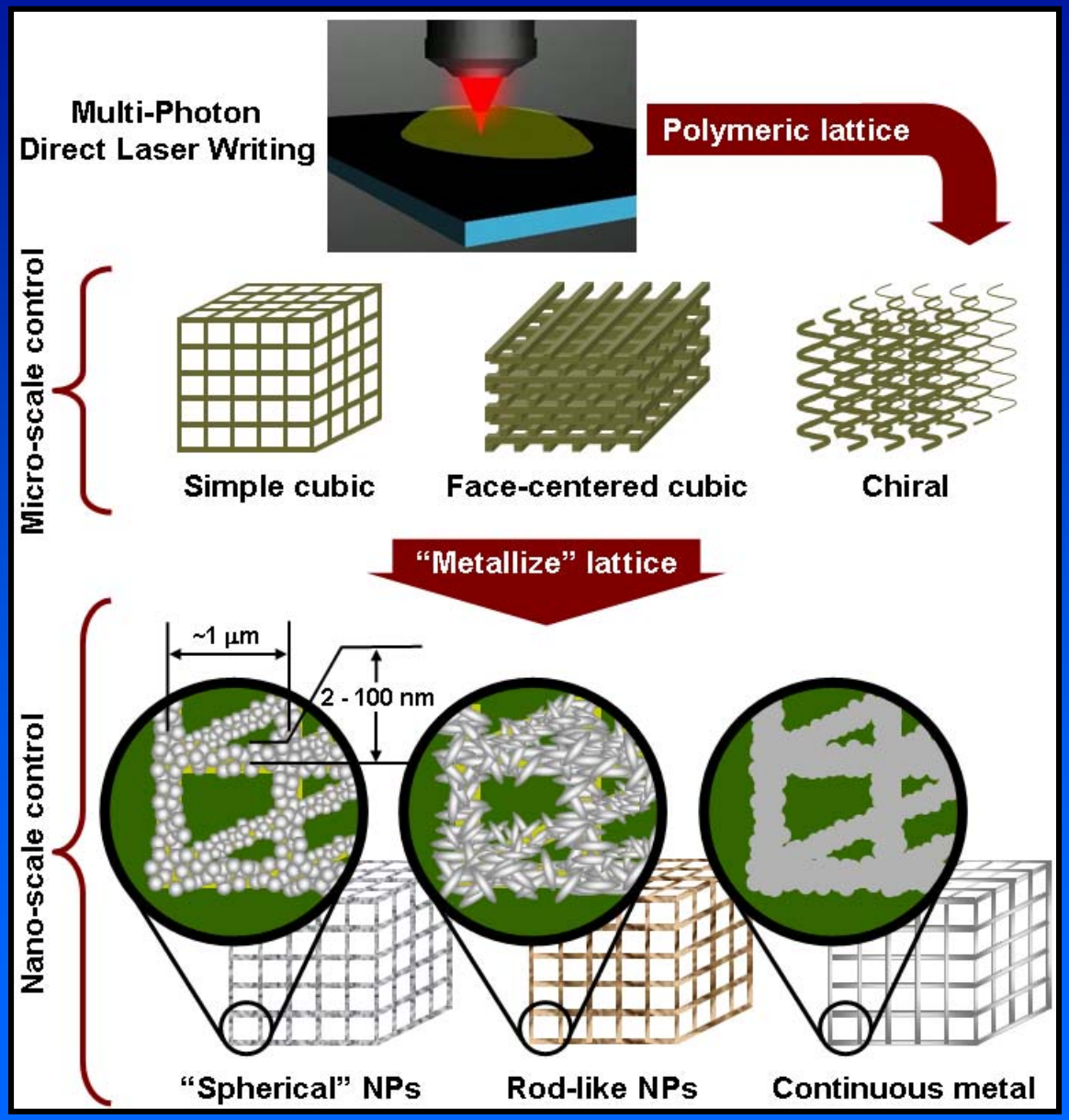
Project 2: Exploration of new metallo-dielectric photonic meta-materials

Possibilities

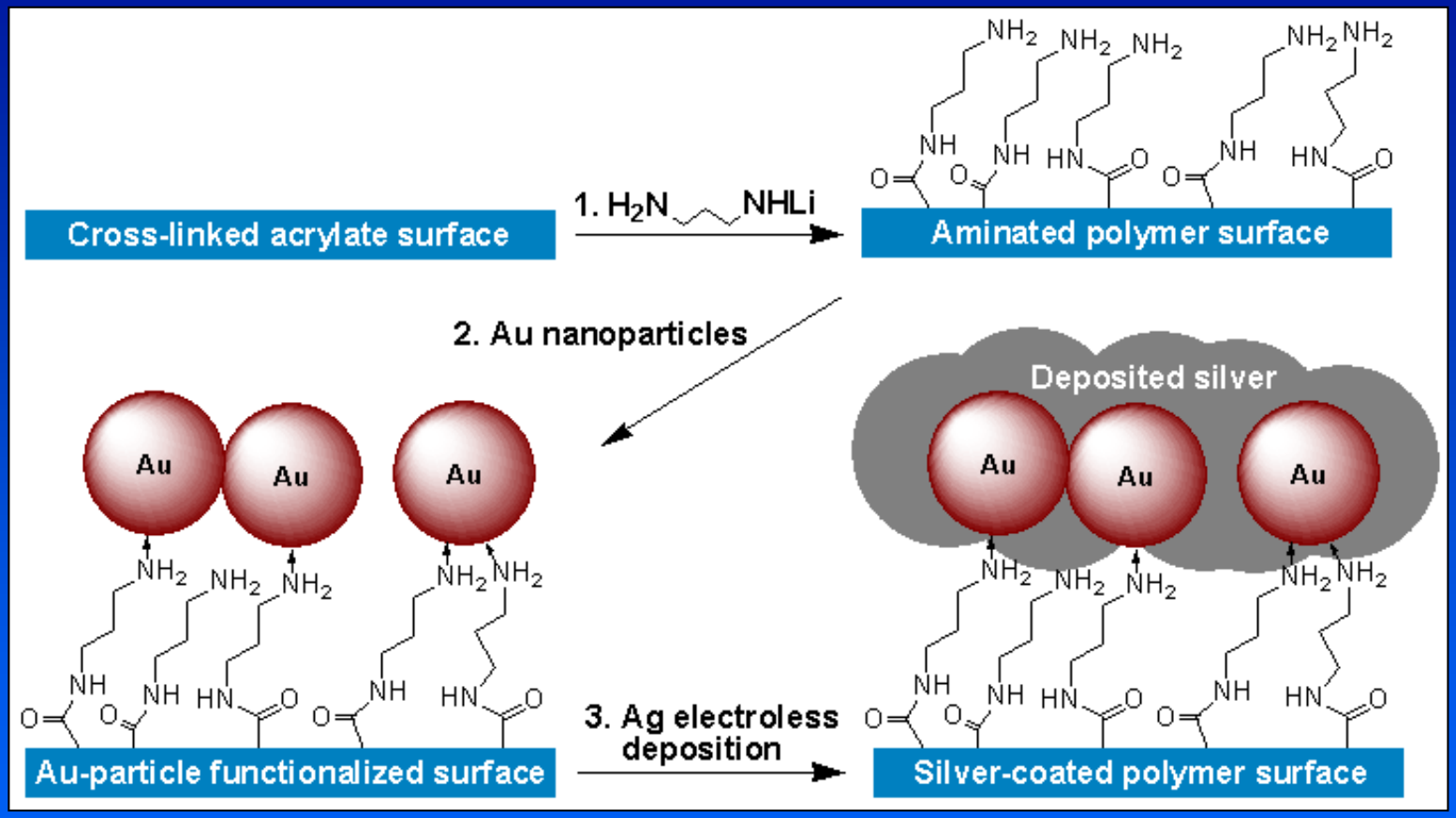
- Ultra-wide photonic band gaps
- Plasmonic coupling
- Enhanced optical nonlinearities
- Negative refractive index

Objectives

- Control micro-structure via DLW
- Control nano-structure via metallization
- Learn how micro- & nano-structure together affect the optical properties



Metallizing polymeric structures



Chen *et al.*, *Adv. Funct. Mater.*, 2006, 13, 1739

Surface- and nano-chemistry of electroless metallization

Collaboration with Drs. Heinrich and Bhattacharya (UCF physics)

Background The surface chemistry involved in electroless metallization of polymeric surfaces (**EMPS**) is not well understood, despite its widespread industrial use. EMPS has remained largely a "dark art" with applications limited to bulk-part fabrication.

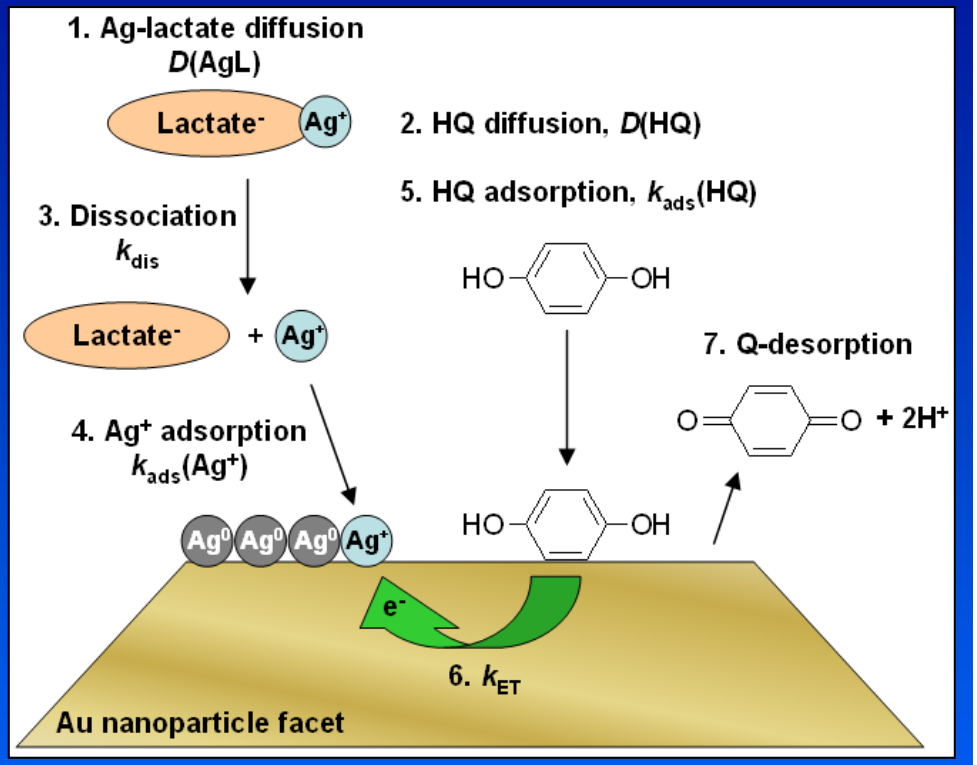


Fig. 1. Processes relevant to electroless deposition of silver nucleated by gold-nanoparticles.

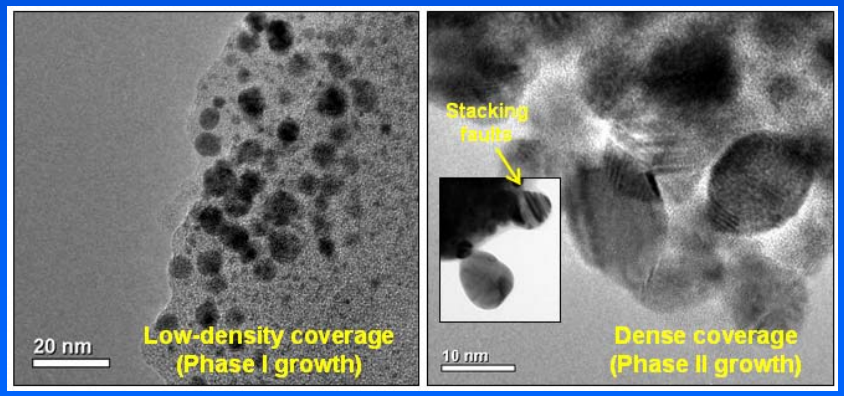
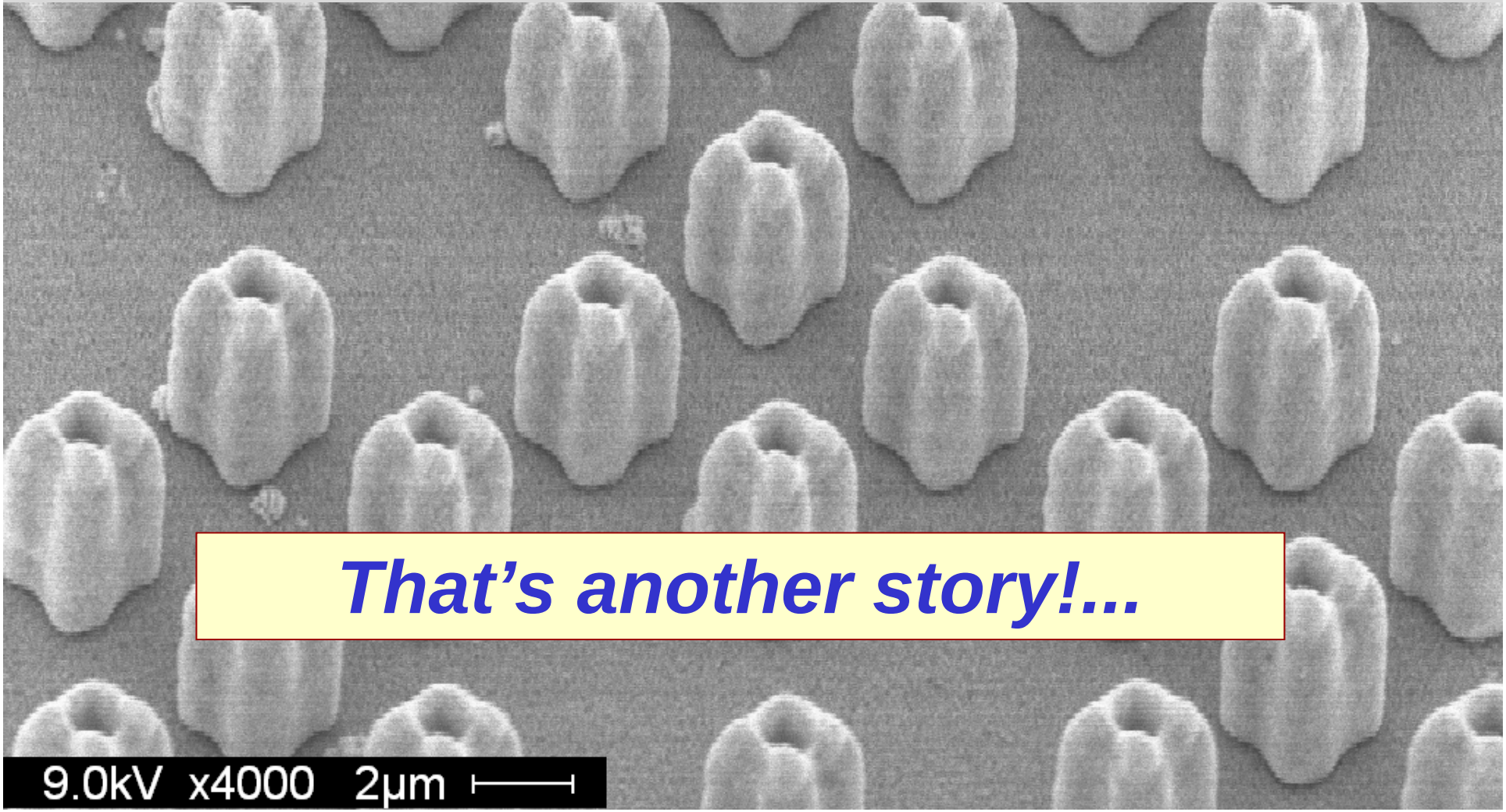


Fig. 2. High-resolution transmission electron micrographs of Ag-EMPS samples in early- and late-stage growth.

Goal Obtain fundamental understanding of EMPS so the method can be developed into an enabling process for emerging micro-\nano-scale technologies with a high level of predictability and control.

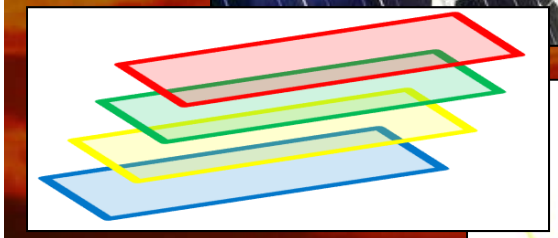
How small can we go?

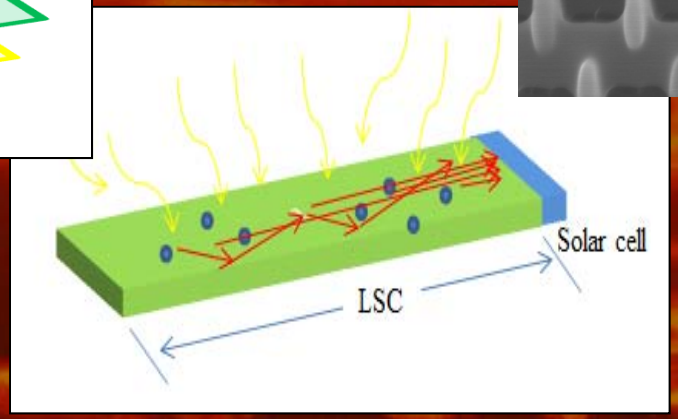


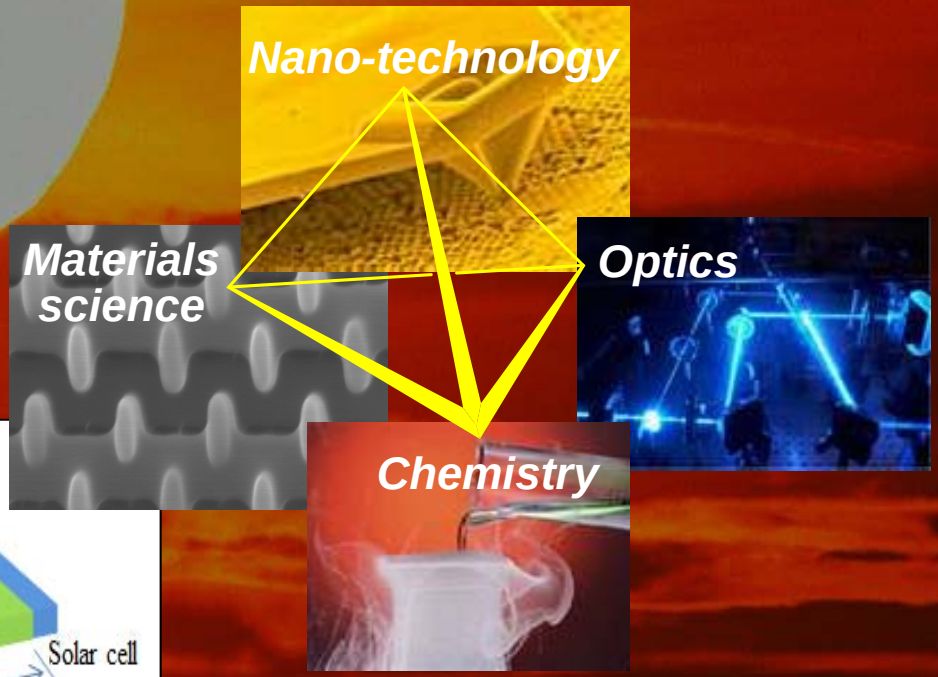
That's another story!...

Kuebler Group: Solar Energy Harvesting

- **Luminescent Solar Concentators (LSCs)**
- **Materials for LSCs**
- **New LSC devices**







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