# Self Assembly of Electronically-Active Materials and Devices

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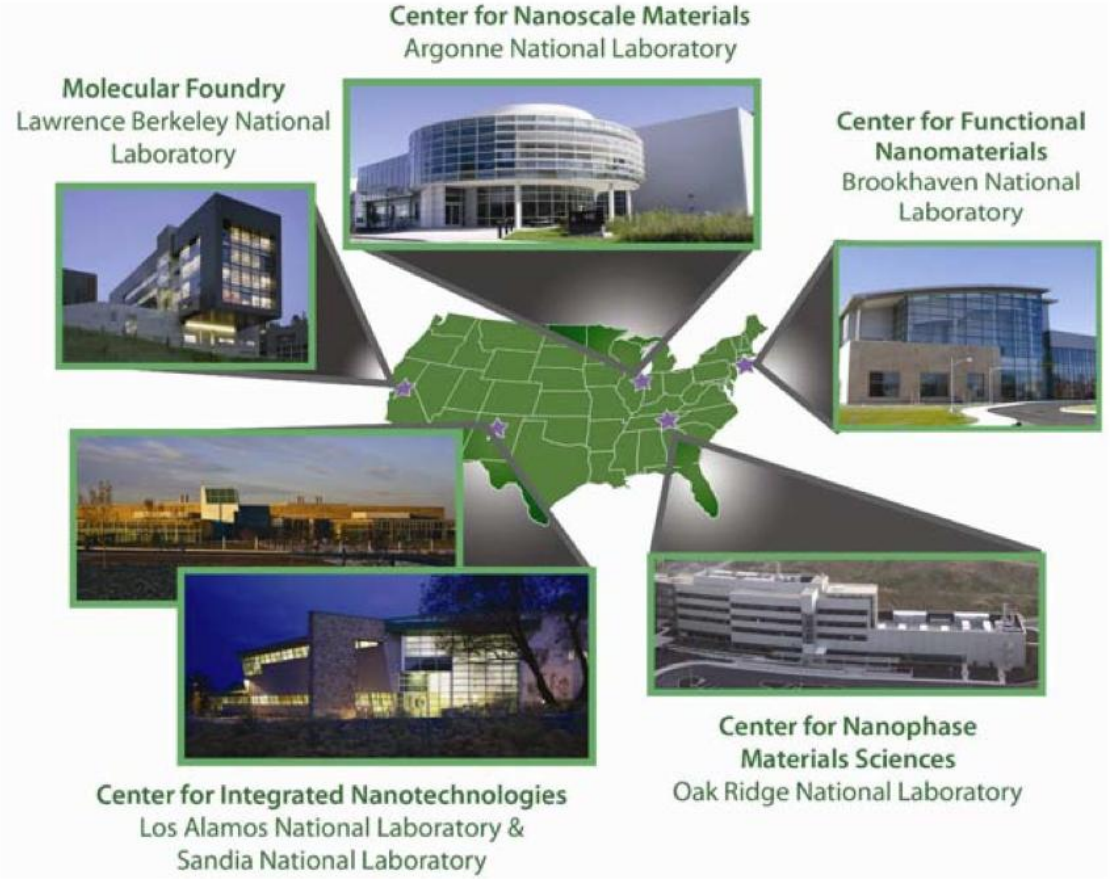
# Nanoscale Science Research Centers (NSRC)

- Funded by the US Department of Energy **Office of Science**

- 5 Centers constructed between 2004- 2008
- User-oriented research centers
- Advanced scientific instrumentation for research
- All aspects (facilities and staff) available to external research community ***for free***



# Center for Functional Nanomaterials (CFN)

**Nanofabrication**
- Aaron Stein (stein@bnl.gov)

**Electron Microscopy**
- Eric Stach (estach@bnl.gov)

**Synchrotron X-Ray Scattering (NSLS)**
- Kevin Yager (kyager@bnl.gov)

**Ultrafast Spectroscopy**
- Matt Sfeir (msfeir@bnl.gov)

**Theory/Computation**
- Mark Hybertsen (mhyberts@bnl.gov)

**Surface Science**
- Peter Sutter (psutter@bnl.gov)

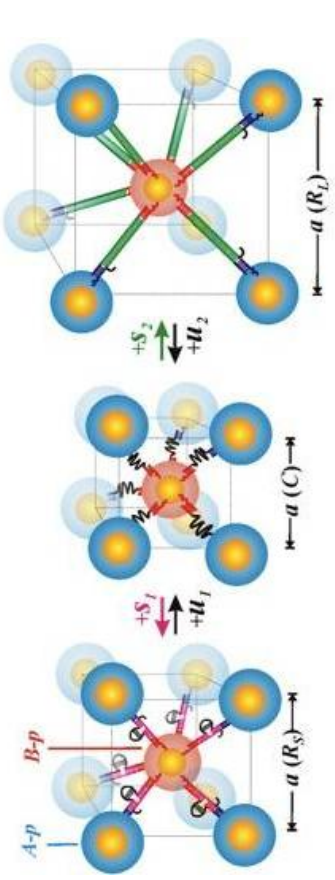
**Organic/Inorganic Synthesis**
- Weiqiang Han (whan@bnl.gov)
- Barney Grubbs (rgrubbs@bnl.gov)

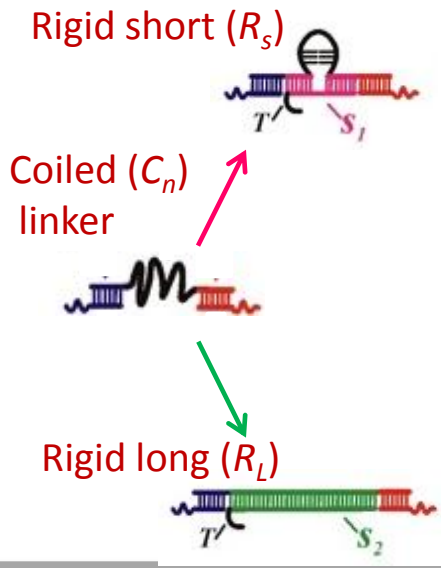
~300 Users/year from academia, government laboratories, and industries

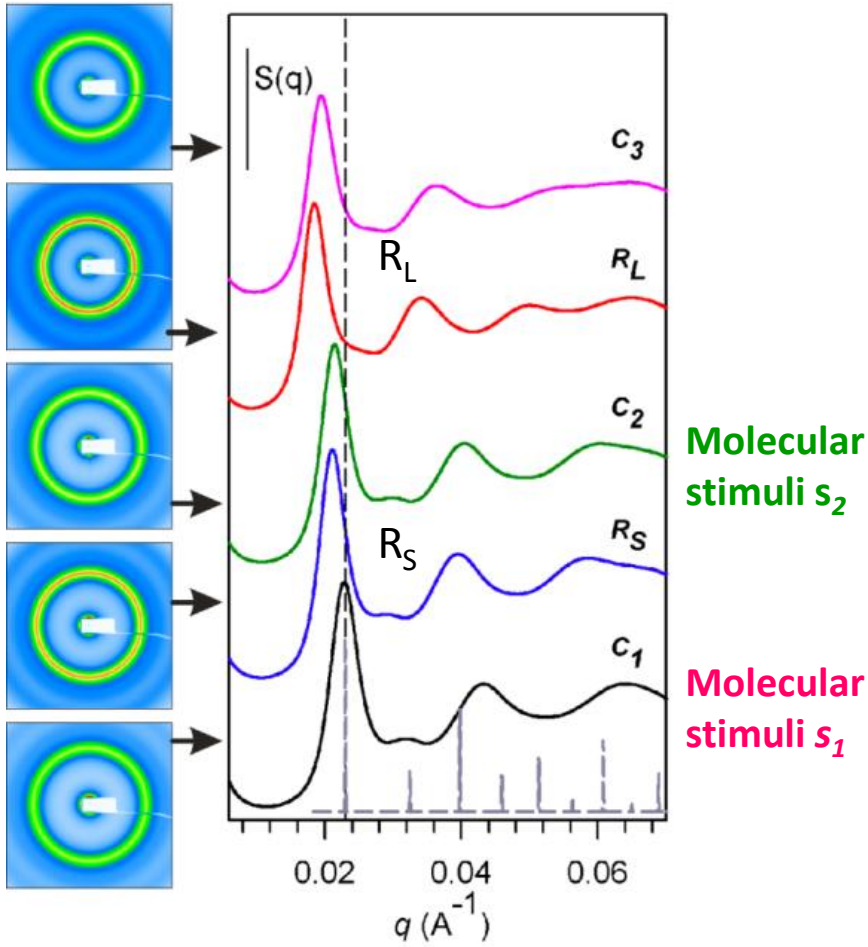
# Molecularly stimulated switchable nanosystems

M. Maye, K. Mulige, D. Nykypanchuk, W. Sherman, and **Oleg Gang**; Nature Nanotechnology 6, 116, (2010)

**Idea**: Nanocrystal superlattice solid with adjustable lattice constant

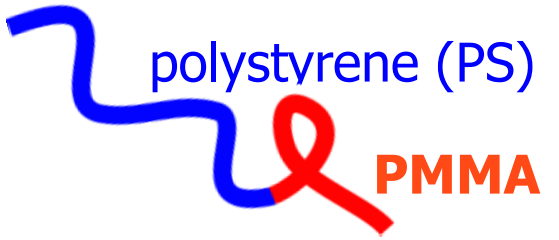


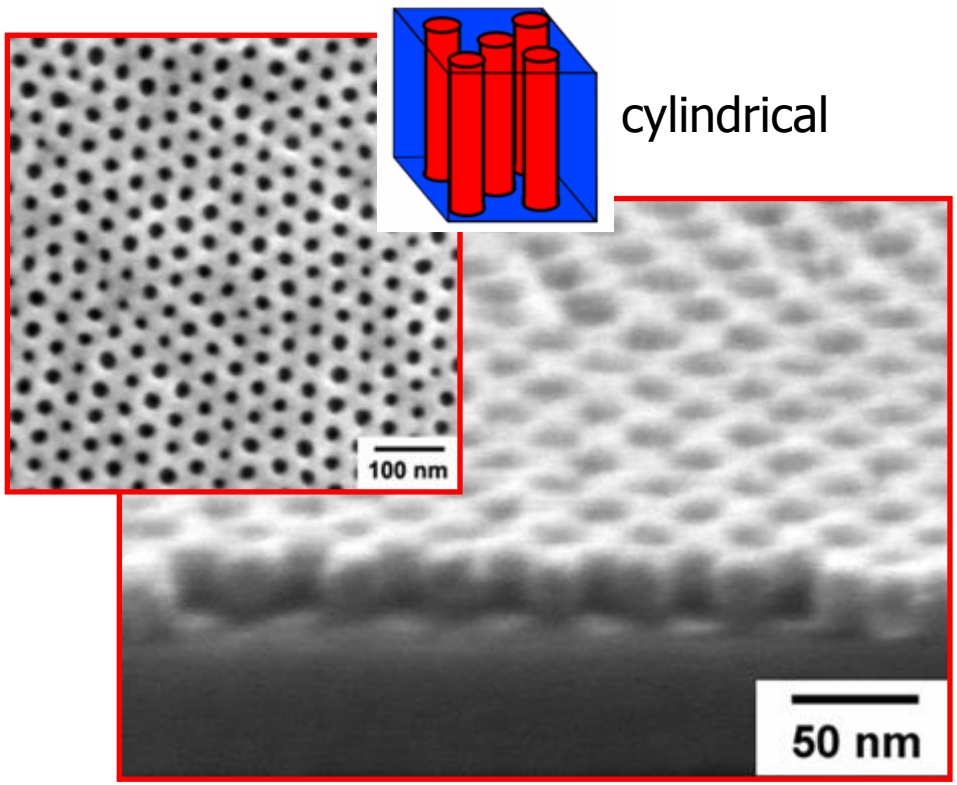



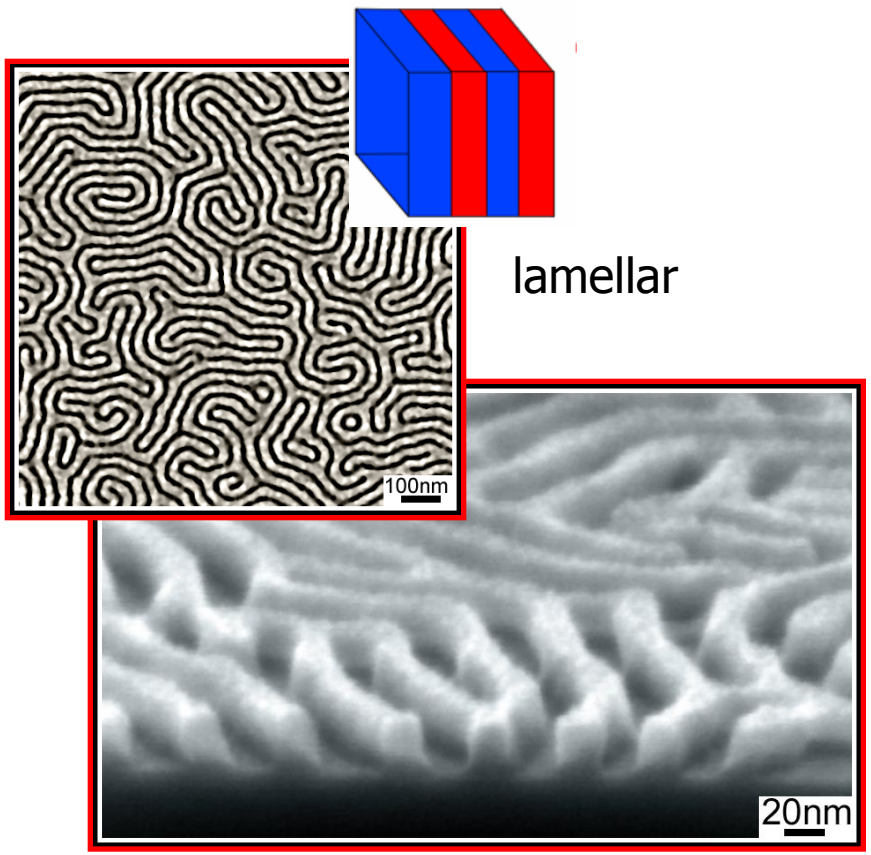



# Self-assembled block copolymer films

T.P. Russell, M. T. Tuominen (UMass Amherst), C.J. Hawker (IBM) *Adv. Mat.*, **12**, 787 (2000).



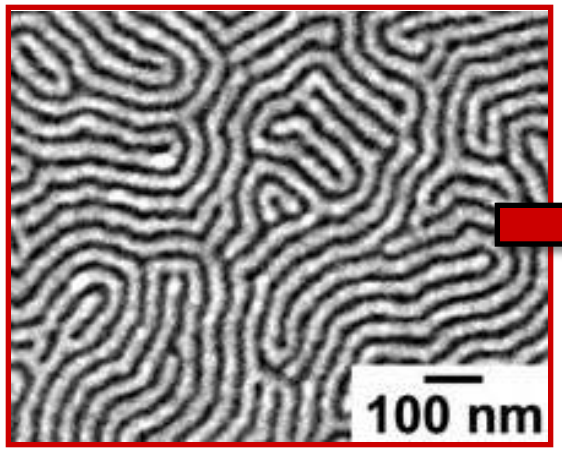



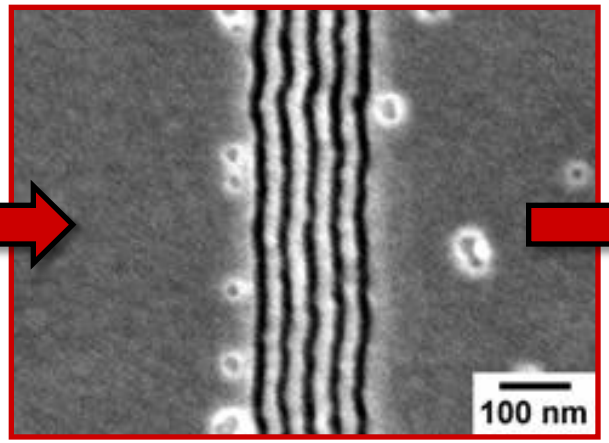
# Nanowire array field-effect transistor

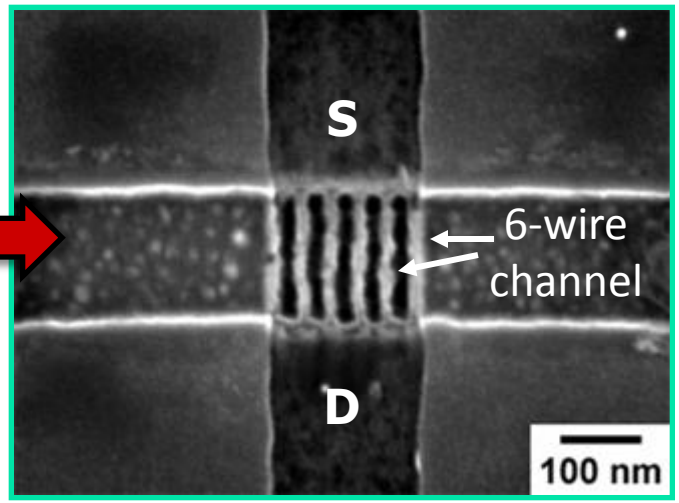
IBM Research

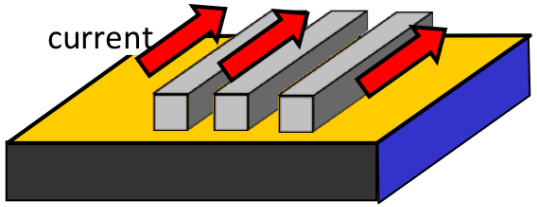
Appl. Phys. Lett. 87, 163116 (2005).

**Idea**: Use block copolymer self assembly to substitute for high-resolution lithography

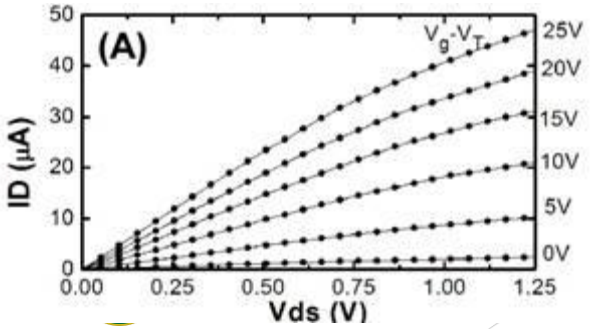



nanowire, nanotube, tri-gate, fin- FET
(current ~ # of wires)



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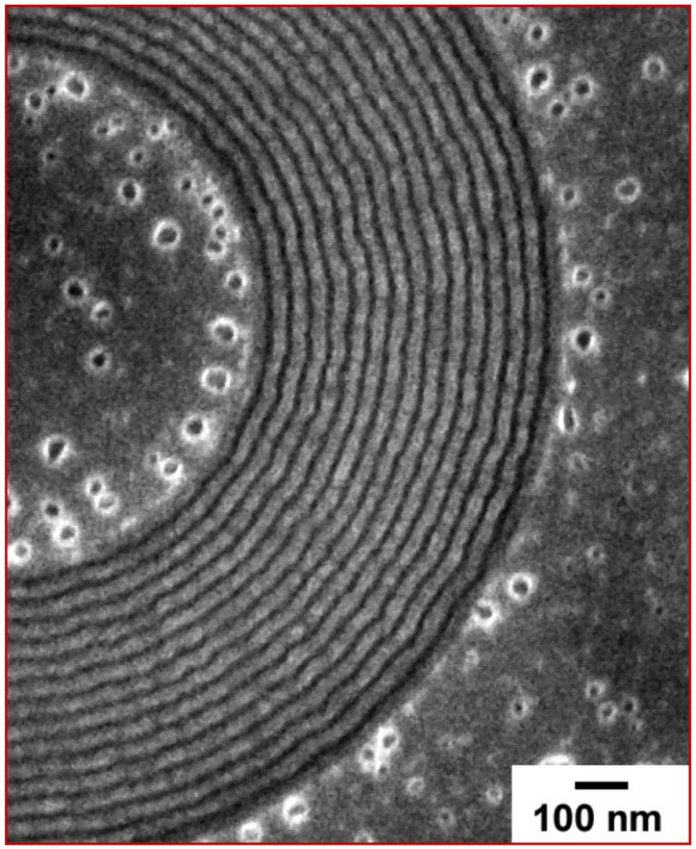



## Good

Lithography by self assembly:

Use self-assembled material to template the final active structure

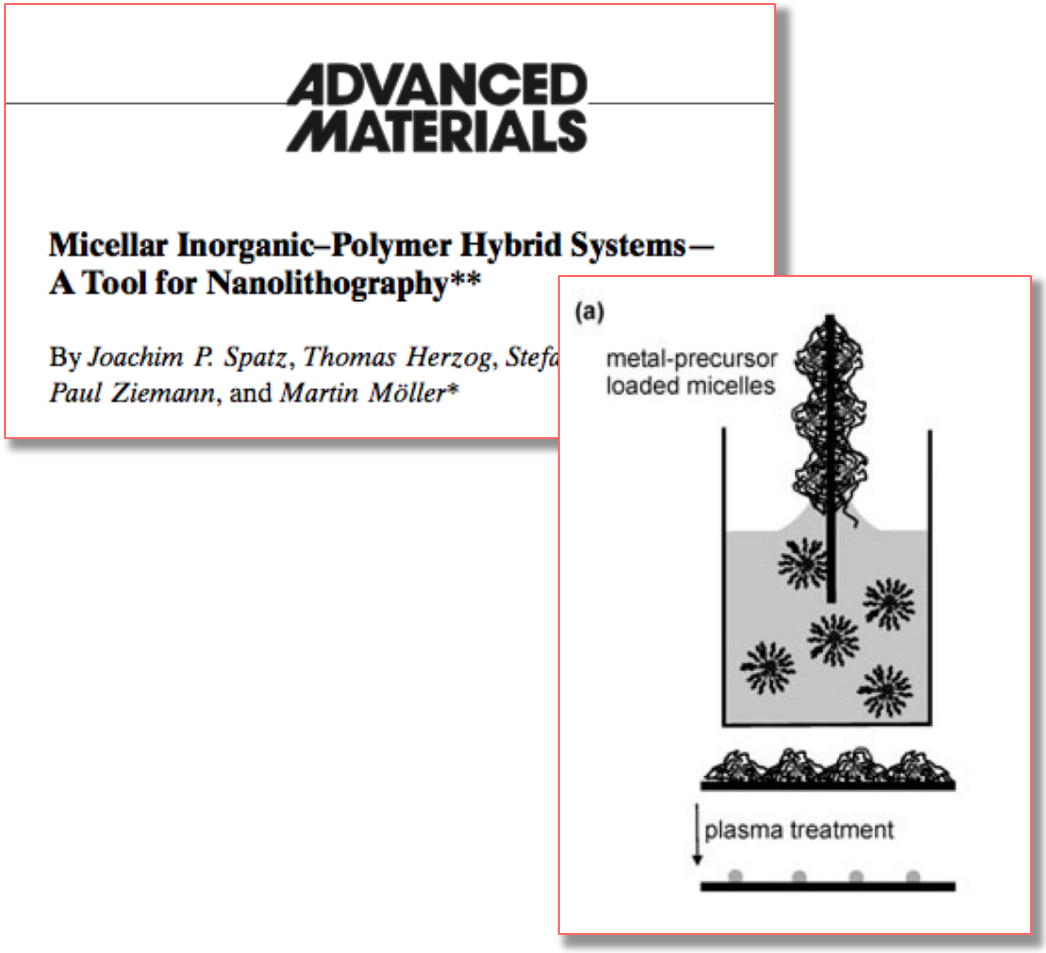
## Better?

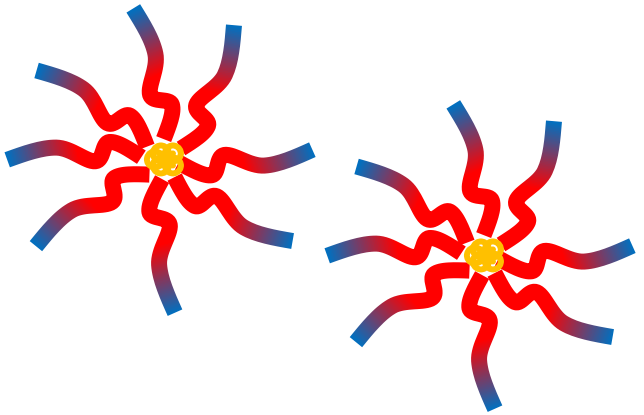
Self assembly of the active structure itself

# Block copolymer micelle lithography

J. Spatz *et al.*, Adv. Mat. 11, 149 (1999).

**Idea**: Localize inorganic precursors within block copolymer micelles



Loaded block copolymer micelles in solution

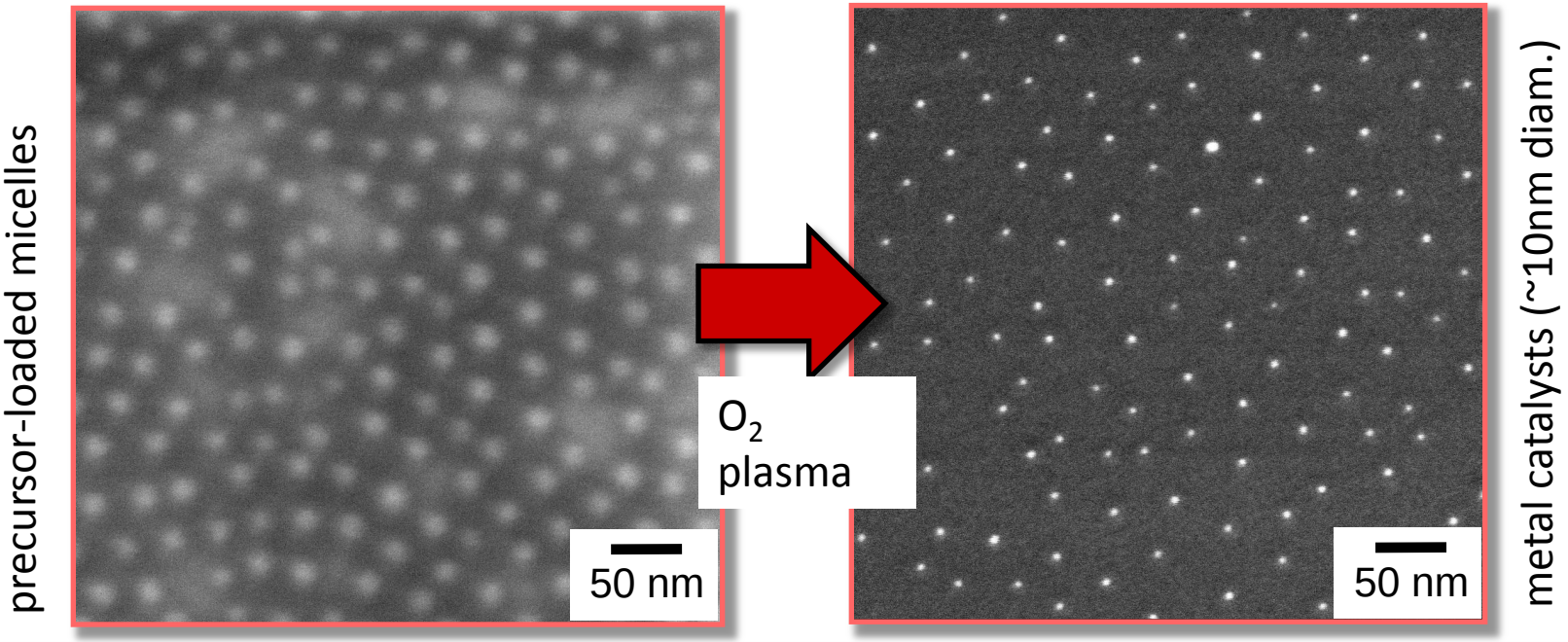
# Catalyst design

**CFN Users** Prof. Michael White, Robert Palomino (SUNY Stonybrook)

**Idea**: Use block copolymer micelle approach to design catalysts, heterogeneous catalysts for solar water splitting, liquid fuel synthesis

e.g., Rhodium; Rhodium-iron; Copper oxide ($Cu_2O$)

**Goals**: Control size, shape, heterogeneous composition, core-shell vs. alloy, ….



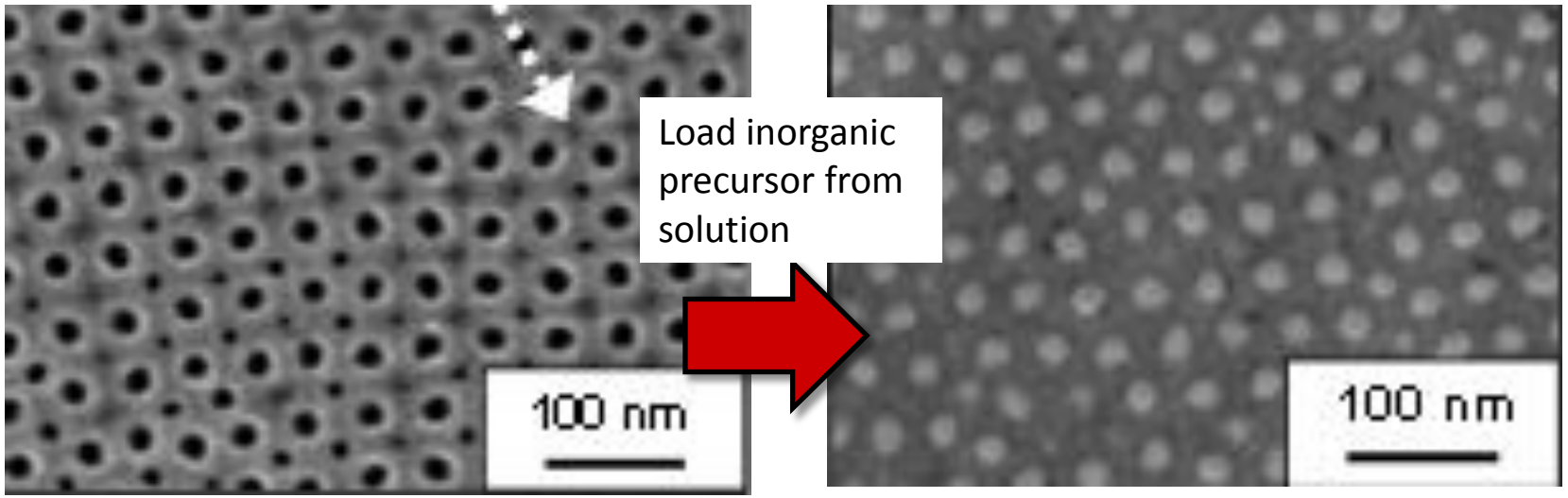
# Selective precursor deposition

**CFN User** Prof. Chris Ober, Dr. K. Bosworth (Cornell Univ.)

**Idea**: Load inorganic precursor after self-assembled pattern formation

**Goals**: Different pattern geometries, improved pattern order

Self-assembled PS-P2VP polymer film




GeOx dot array

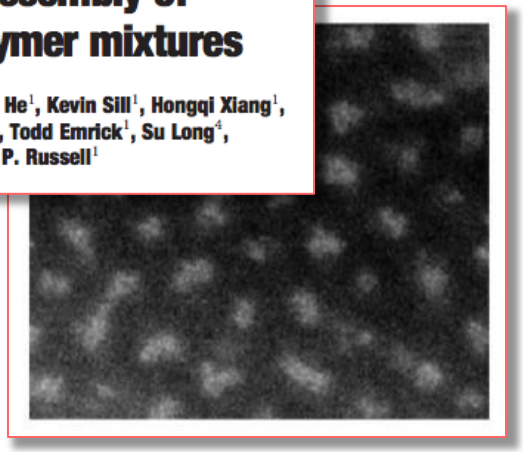
# Block copolymer/nanocrystal composites

**Idea**: Control surfactant/polymer block interactions to localize solution-phase materials

Y. Lin et al., Nature 434, 55 (2005).
J. Chiu et al., JACS 127, 5036 (2005).
B. Sohn et al., JACS 125, 6368 (2003).

**Self-directed self-assembly of nanoparticle/copolymer mixtures**

Yao Lin[1]*, Alexander Böker[1]*†, Jinbo He[1], Kevin Sill[1], Hongqi Xiang[1], Clarissa Abetz[2], Xuefa Li[3], Jin Wang[3], Todd Emrick[1], Su Long[4], Qian Wang[4], Anna Balazs[5] & Thomas P. Russell[1]



J|A|C|S COMMUNICATIONS

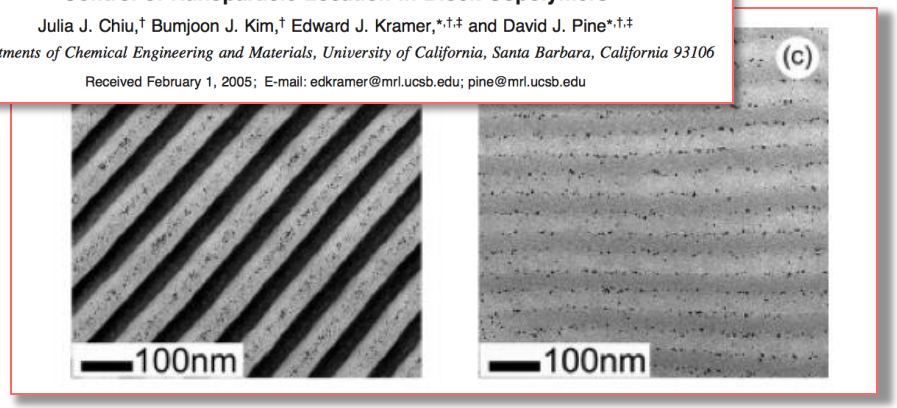
Published on Web 03/19/2005

**Control of Nanoparticle Location in Block Copolymers**

Julia J. Chiu,† Bumjoon J. Kim,† Edward J. Kramer,*,†,‡ and David J. Pine*,†,‡

*Departments of Chemical Engineering and Materials, University of California, Santa Barbara, California 93106*

Received February 1, 2005; E-mail: edkramer@mrl.ucsb.edu; pine@mrl.ucsb.edu

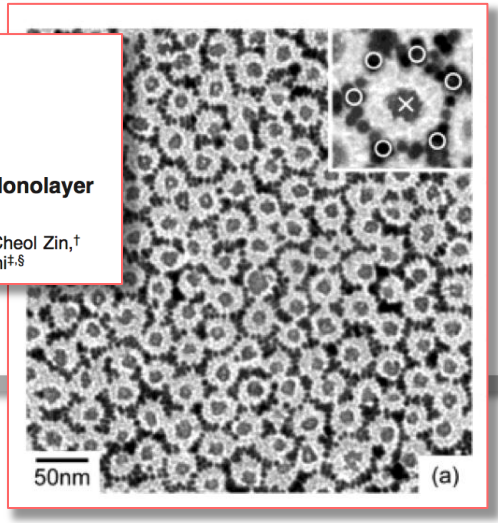



J|A|C|S COMMUNICATIONS

Published on Web 05/01/2003

**Directed Self-Assembly of Two Kinds of Nanoparticles Utilizing Monolayer Films of Diblock Copolymer Micelles**

Byeong-Hyeok Sohn,*,† Jeong-Min Choi,† Seong Il Yoo,† Sang-Hyun Yun,† Wang-Cheol Zin,† Jin Chul Jung,† Masayuki Kanehara,‡ Takuji Hirata,‡ and Toshiharu Teranishi‡,§



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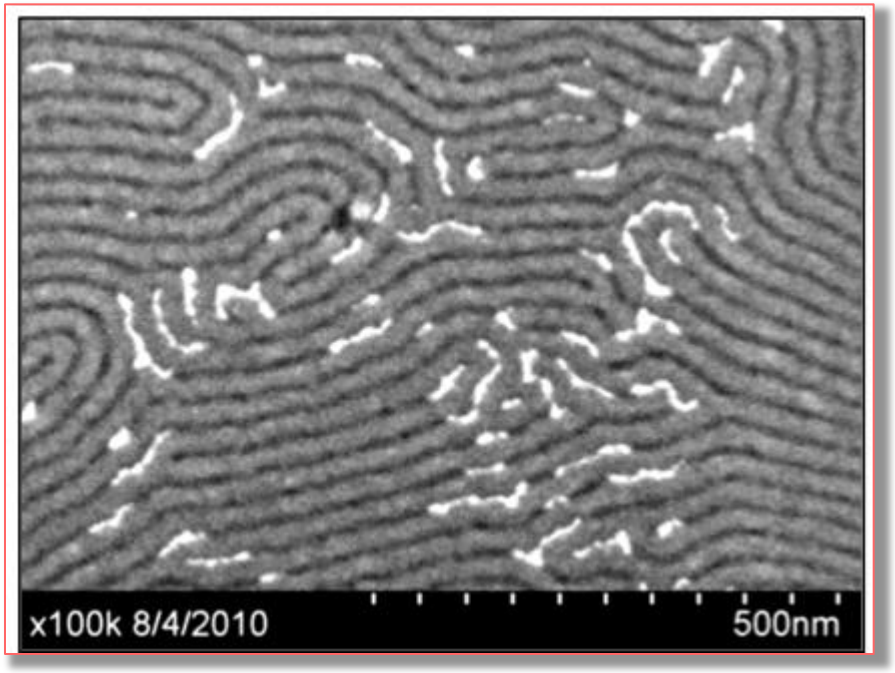
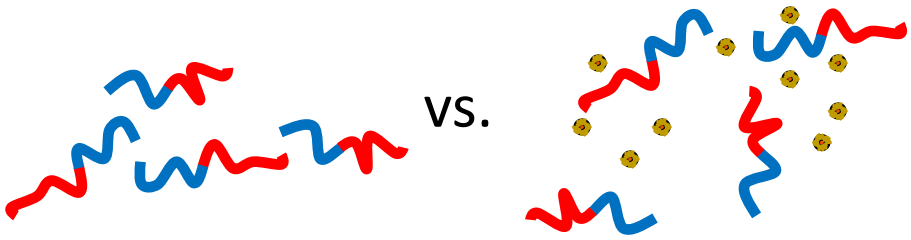
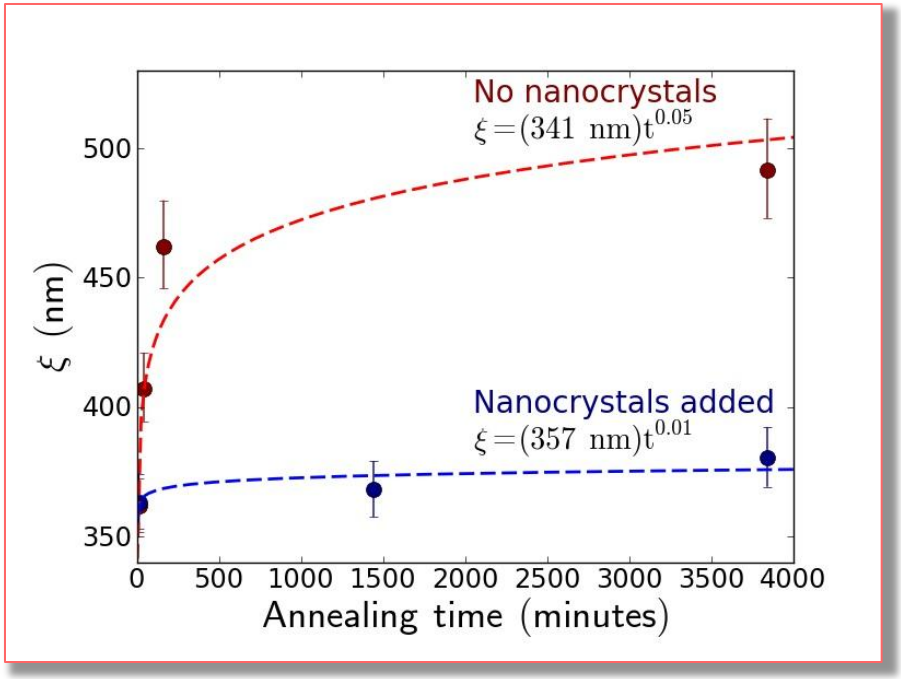
# Block copolymer/nanocrystal composites

Daniel Jacobsen (Harvard) (undergraduate summer intern), Kevin Yager (CFN)

**Idea**: Understand influence of nanocrystals on the composite self assembly process



# Selective atomic-layer deposition

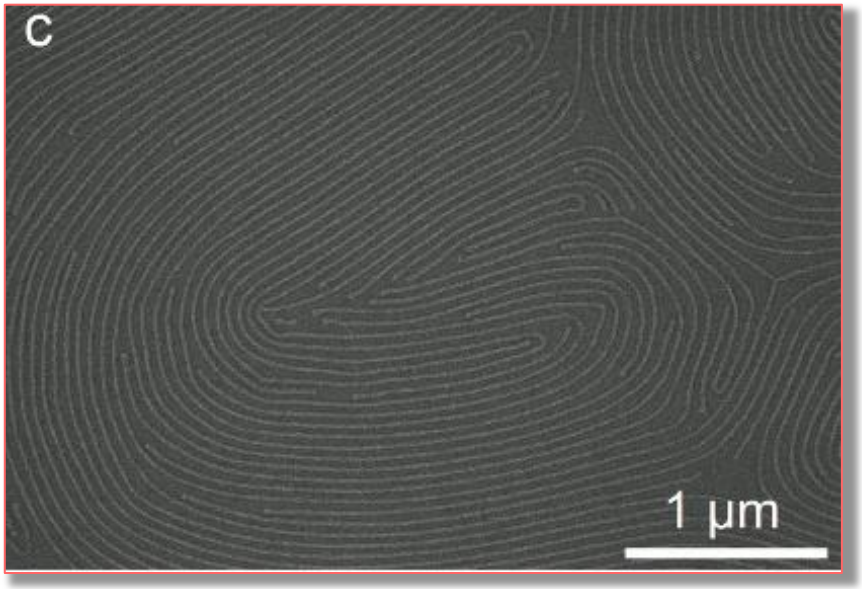
Q. Peng et al., Adv. Mat. 22, 5129 (2010).

Materials Views
www.MaterialsViews.com
ADVANCED MATERIALS
www.advmat.de

**Nanoscopic Patterned Materials with Tunable Dimensions via Atomic Layer Deposition on Block Copolymers**

By *Qing Peng, Yu-Chih Tseng, Seth B. Darling,* and Jeffrey W. Elam**

load precursor from **vapor phase**
e.g., $Al(CH_3)$, $TiCl_4$, ….



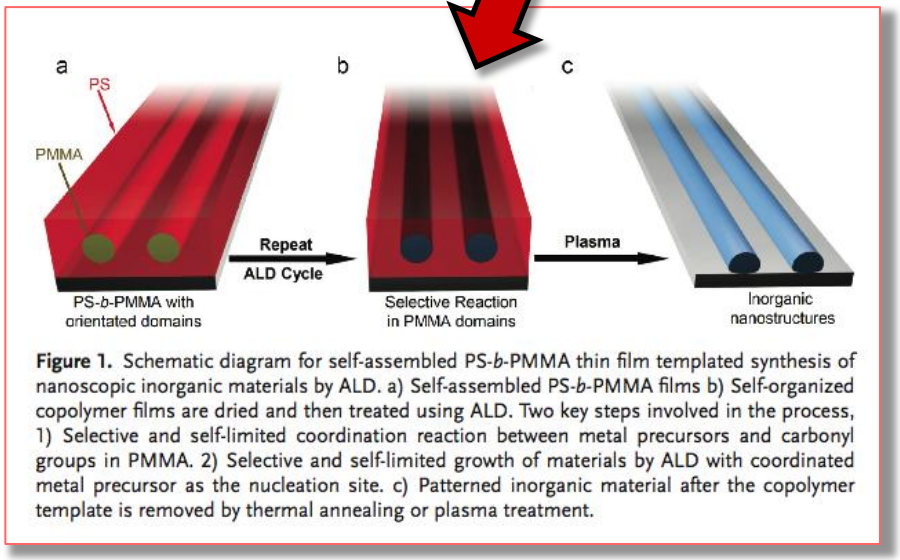
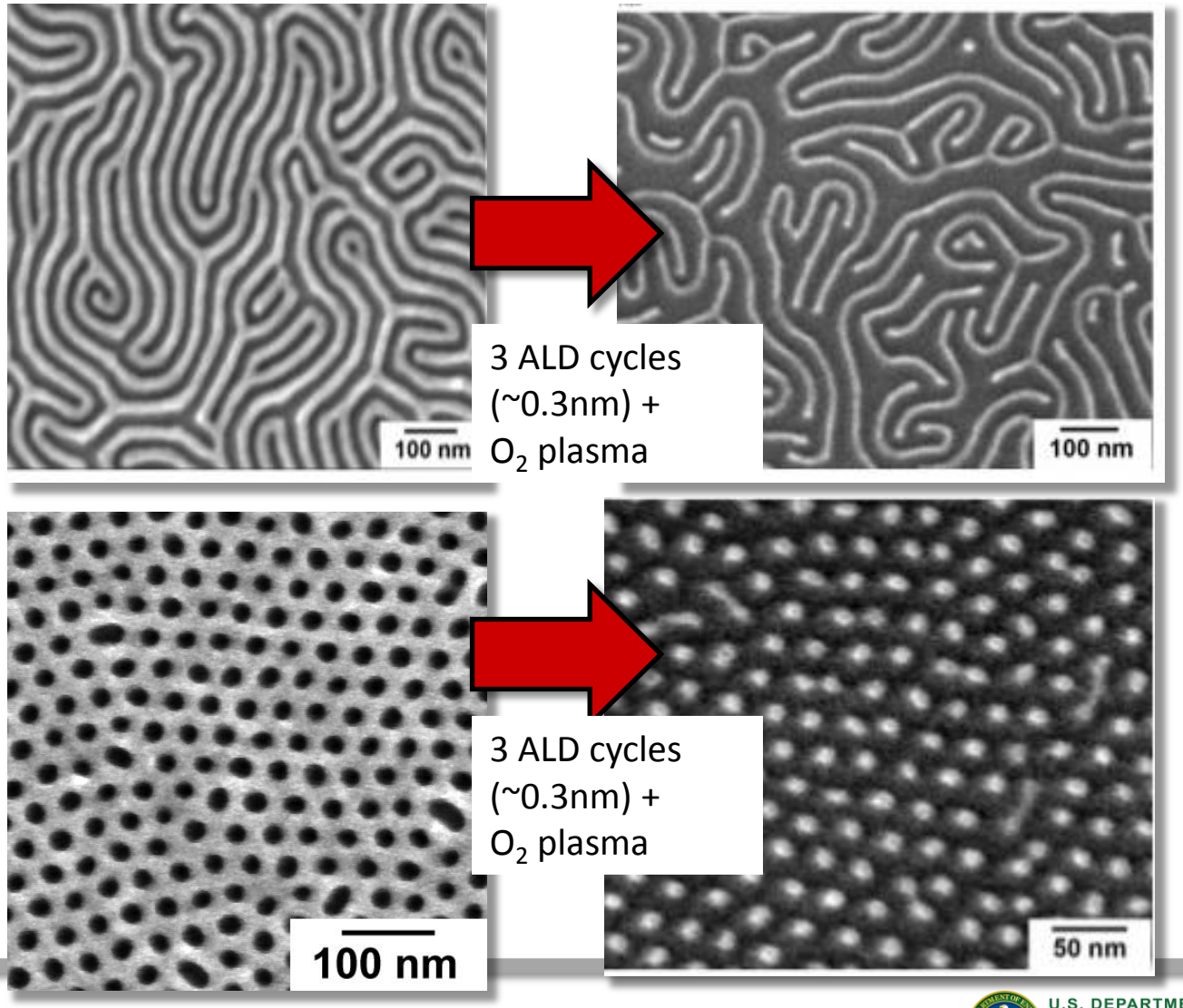




**Figure 1.** Schematic diagram for self-assembled PS-*b*-PMMA thin film templated synthesis of nanoscopic inorganic materials by ALD. a) Self-assembled PS-*b*-PMMA films b) Self-organized copolymer films are dried and then treated using ALD. Two key steps involved in the process, 1) Selective and self-limited coordination reaction between metal precursors and carbonyl groups in PMMA. 2) Selective and self-limited growth of materials by ALD with coordinated metal precursor as the nucleation site. c) Patterned inorganic material after the copolymer template is removed by thermal annealing or plasma treatment.

# Selective atomic-layer deposition




~8nm tall inorganic structures

# Message

**The Center for Functional Nanomaterials:**

- Is one of five NSRCs funded/overseen by DOE Office of Science
- Is a User-oriented research center
- Has internal research programs in nanoscience
- Makes all facilities/expertise available to external research community
- (Come visit!)

**Polymer self assembly**:

- Provides access to sub-lithographic scales
- Can be a lithography substitute for device fabrication
- *Provides a means to direct assembly of electrically-active materials, without need for traditional thin-film fabrication approaches*