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***Self Assembly of Electronically-Active Materials and
Devices***

C.T. Black

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Center for Functional Nanomaterials
Brookhaven National Laboratory

U.S. Department of Energy
DOE - OFFICE OF SCIENCE

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Self Assembly of Electronically-Active Materials and Devices

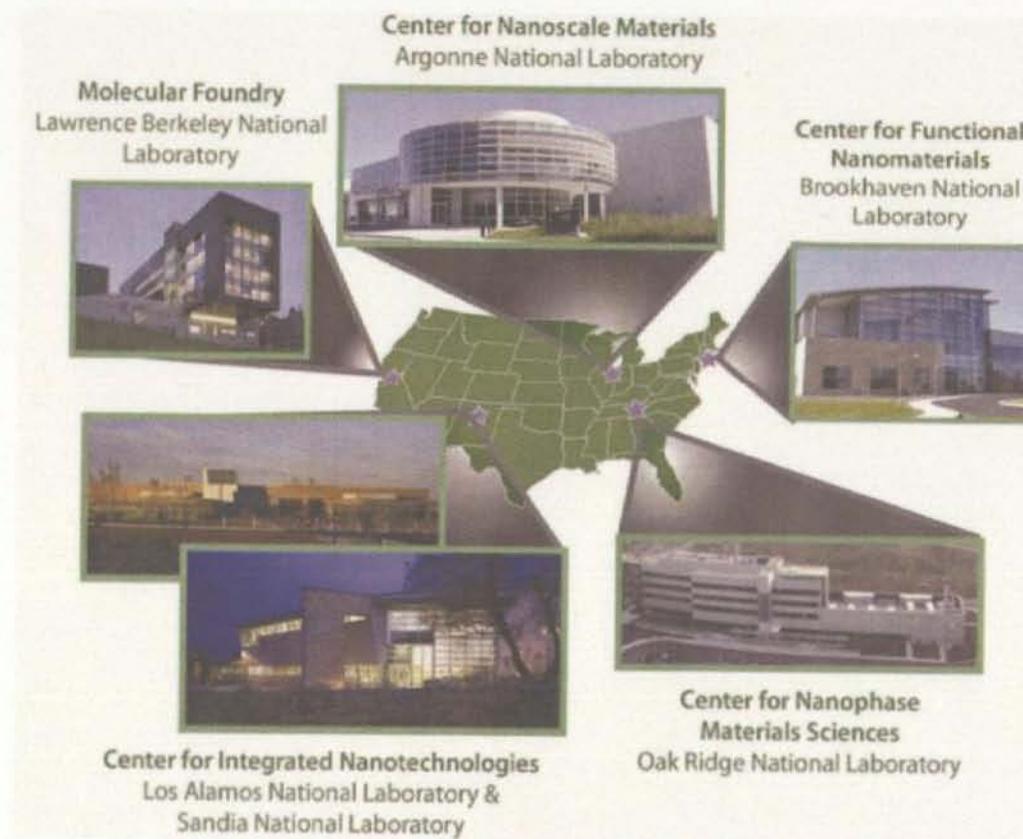
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Nanoscale Science Research Centers (NSRC)



- 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

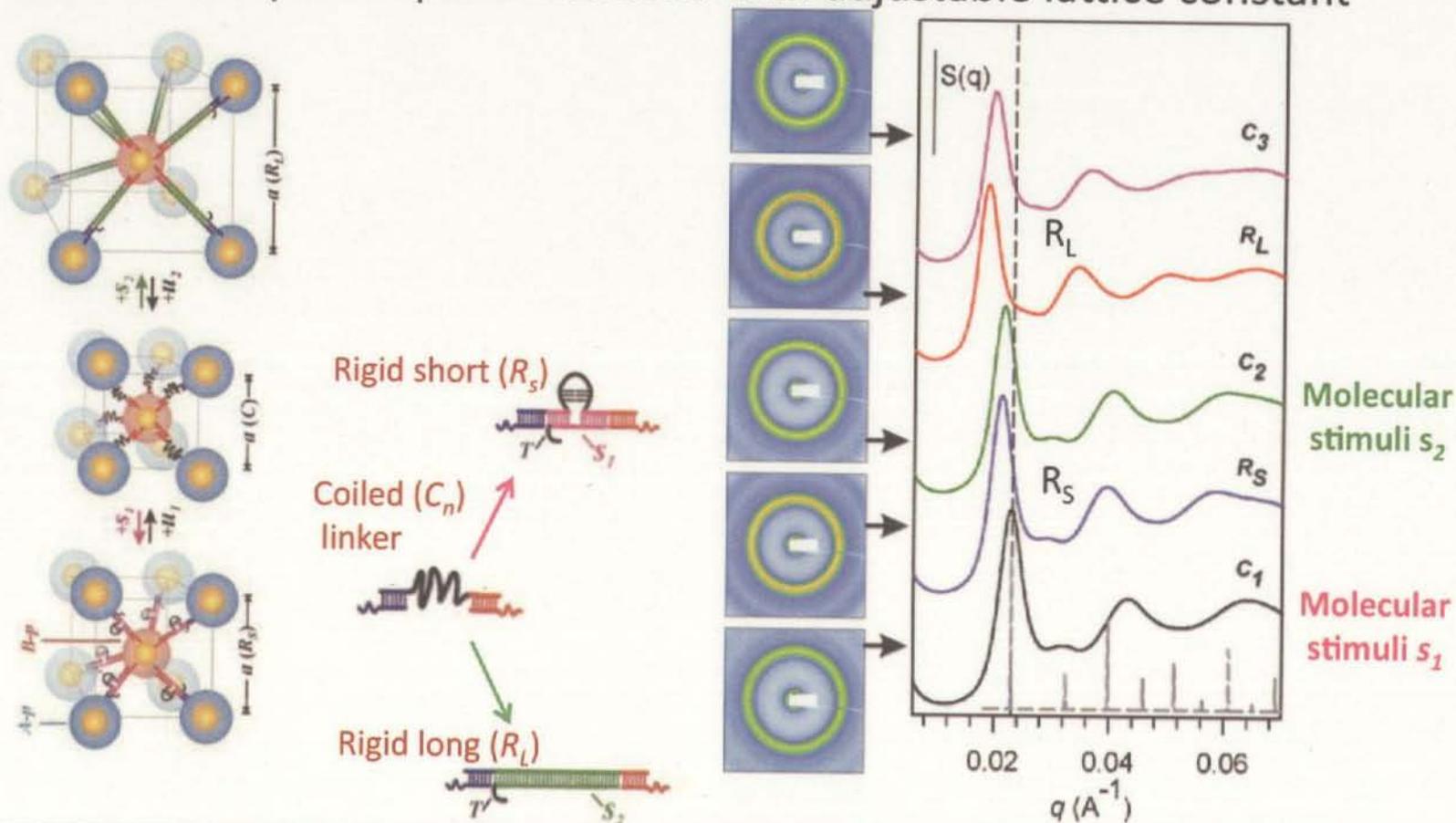


Molecularly stimulated switchable nanosystems



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

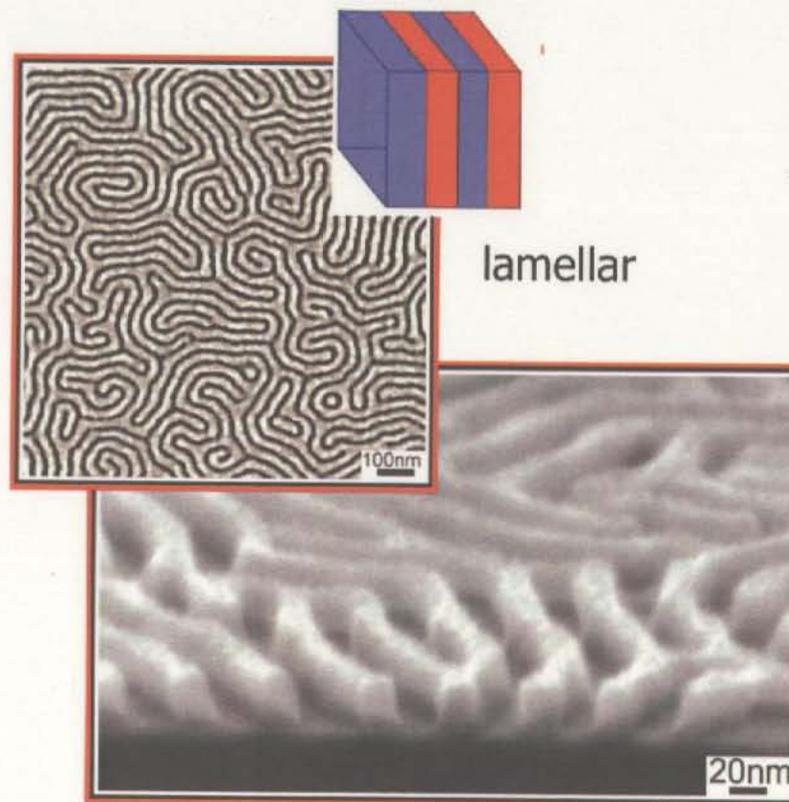
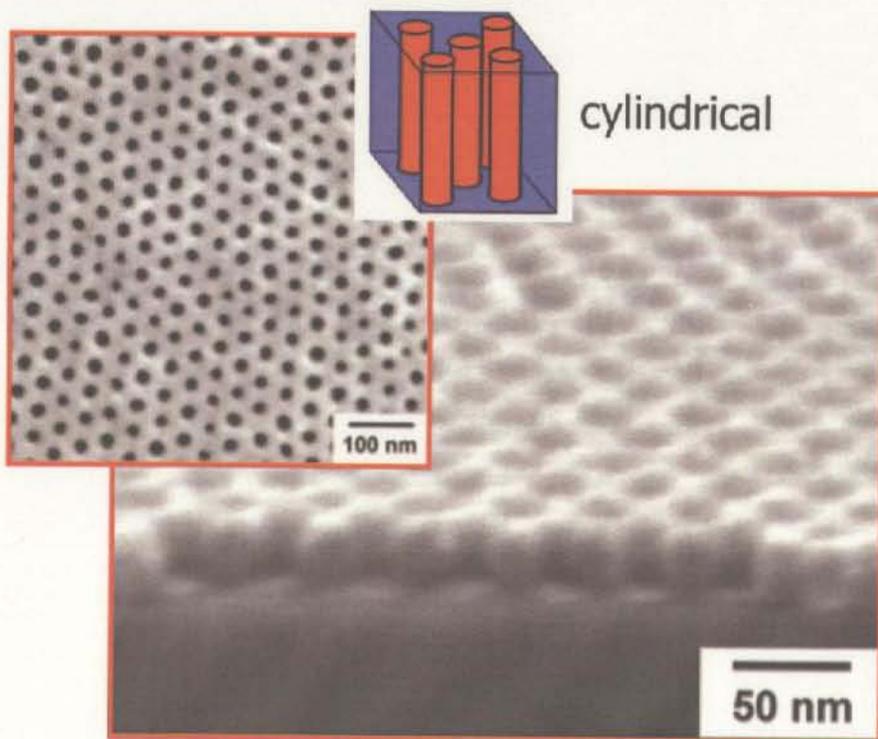
Idea: Nanocrystal superlattice solid with adjustable lattice constant



Self-assembled block copolymer films



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



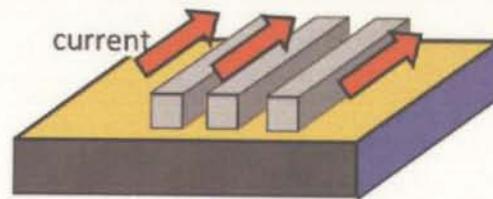
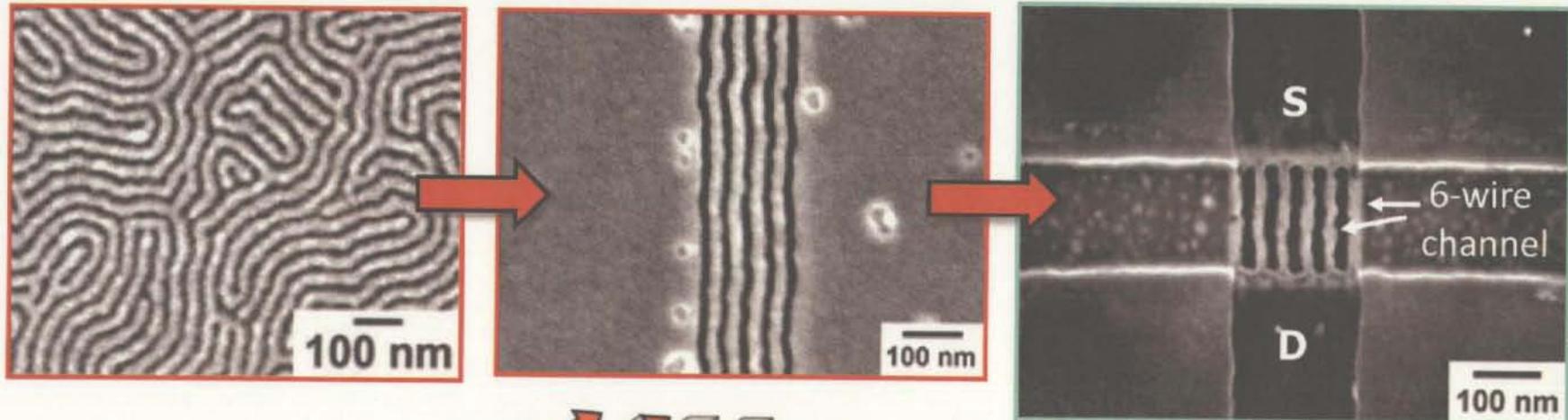
Nanowire array field-effect transistor



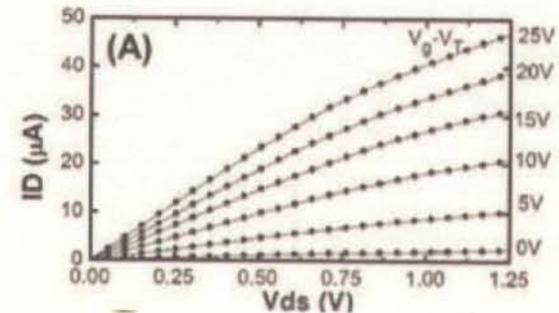
IBM Research

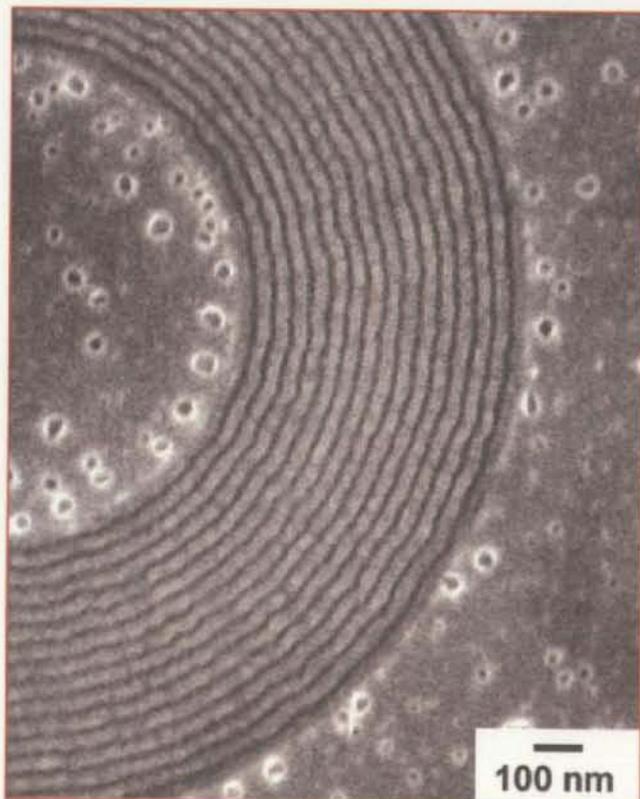
Appl. Phys. Lett. 87, 163116 (2005).

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



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





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



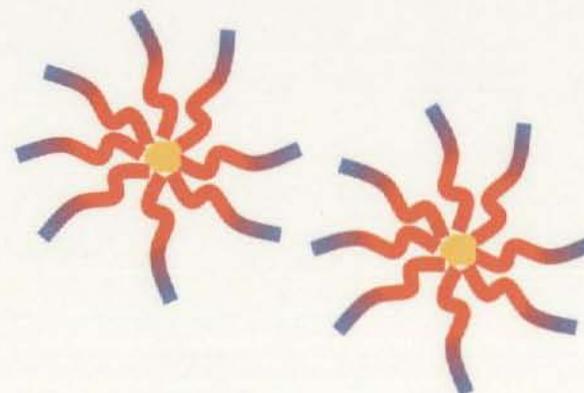
J. Spatz *et al.*, Adv. Mat. 11, 149 (1999).

Idea: Localize inorganic precursors within block copolymer micelles

ADVANCED MATERIALS

**Micellar Inorganic-Polymer Hybrid Systems—
A Tool for Nanolithography****

By Joachim P. Spatz, Thomas Herzog, Stefa
Paul Ziemann, and Martin Möller*



Loaded block copolymer micelles in solution

Catalyst design

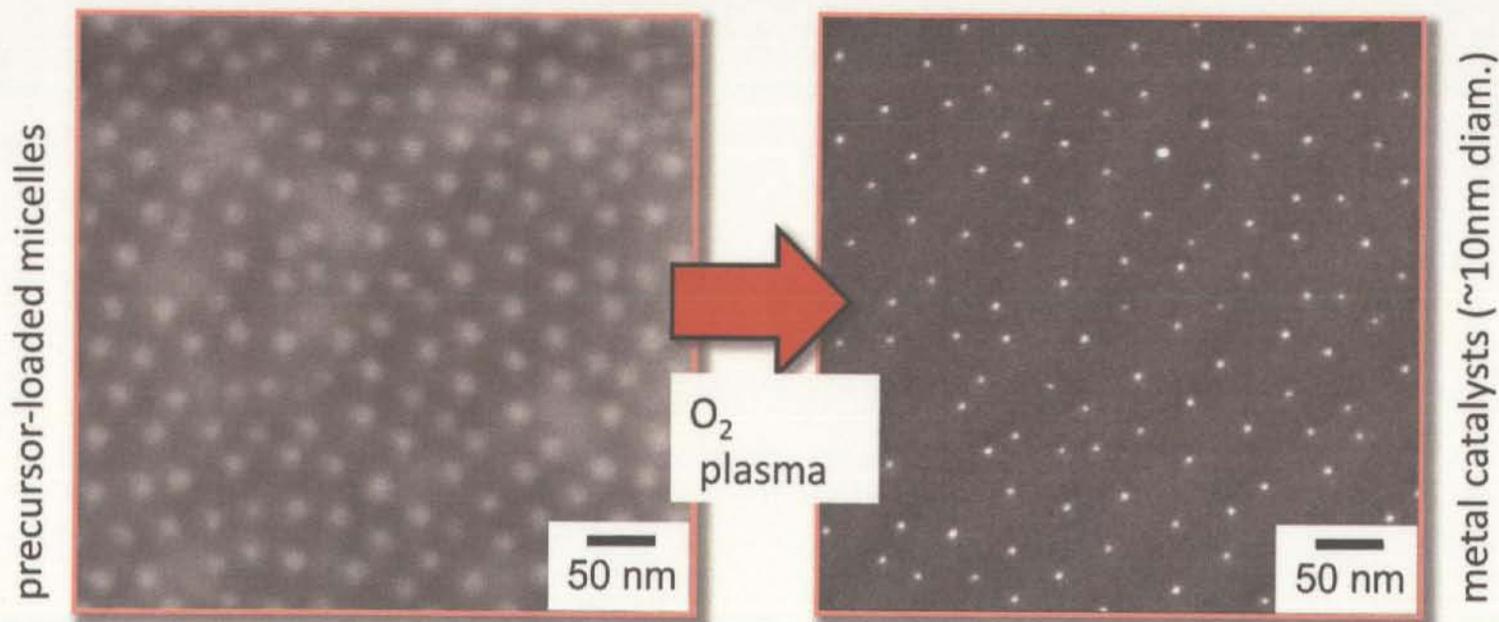


CFN Users Prof. Michael White, Robert Palomino (SUNY Stonybrook)

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

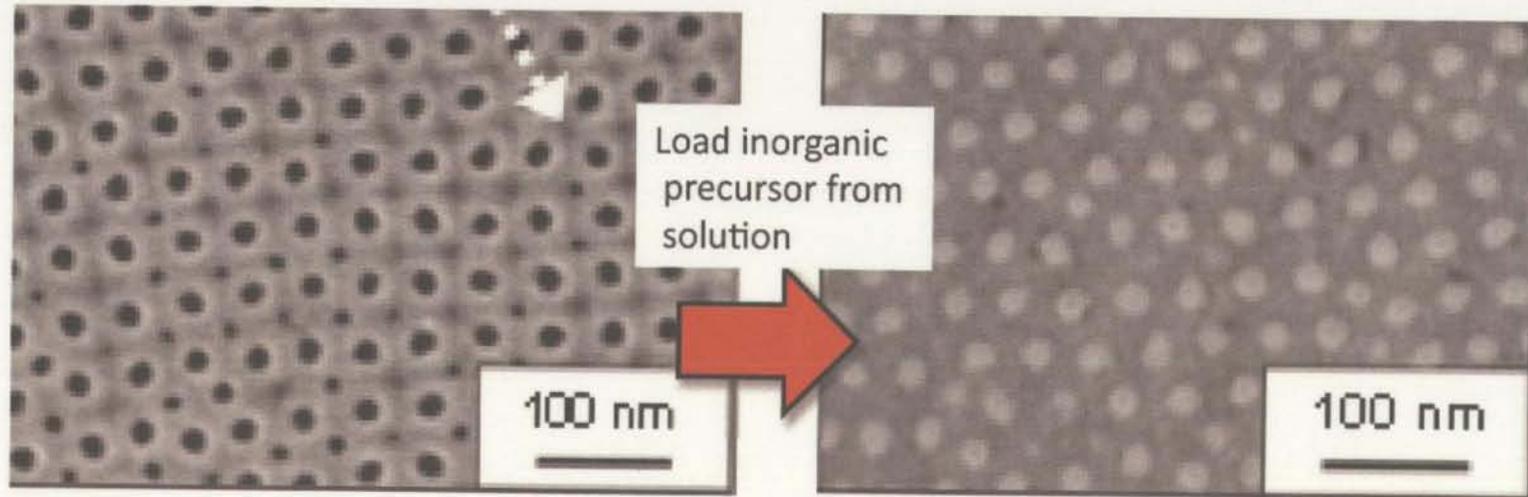


CFN User Dr. K. Bosworth (Cornell Univ.)

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 Lin¹, Alexander Böker^{1,2}, Jinbo He¹, Kevin Sill¹, Hongqi Xiang¹, Clarissa Abetz², Xuefa Li³, Jin Wang³, Todd Emrick¹, Su Long⁴, Qian Wang⁴, Anna Balazs⁵ & Thomas P. Russell¹



JACS
COMMUNICATIONS

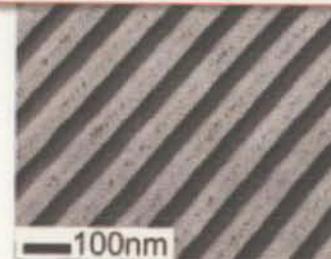
Published on Web 03/18/2005

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



100nm



100nm

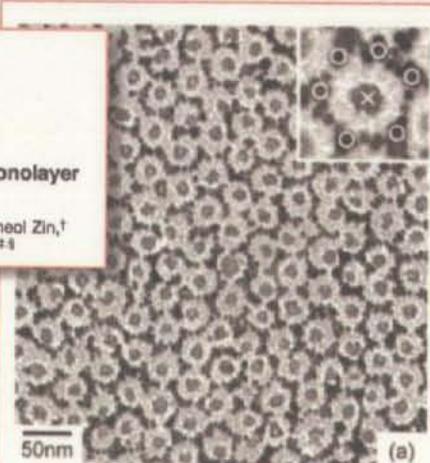
(c)

JACS
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Published on Web 05/01/2003

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

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



50nm

(a)



U.S. DEPARTMENT OF ENERGY

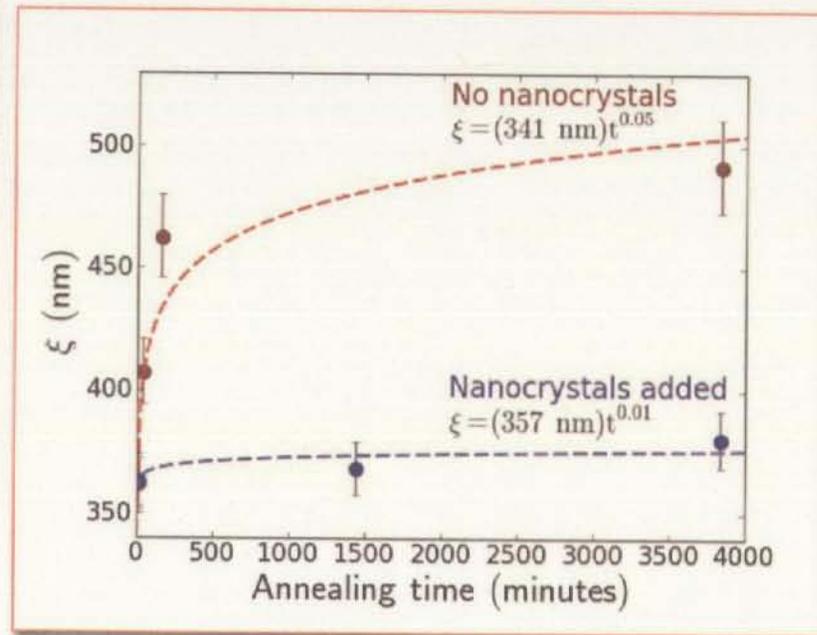
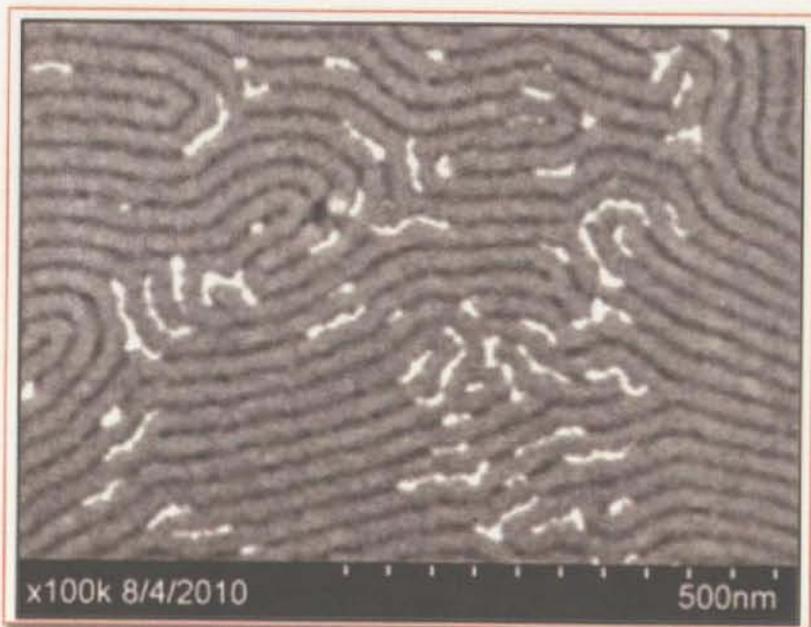
BROOKHAVEN NATIONAL LABORATORY

Block copolymer/nanocrystal composites



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

Idea: Understand influence of nanocrystals on self assembly process



Selective atomic-layer deposition



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

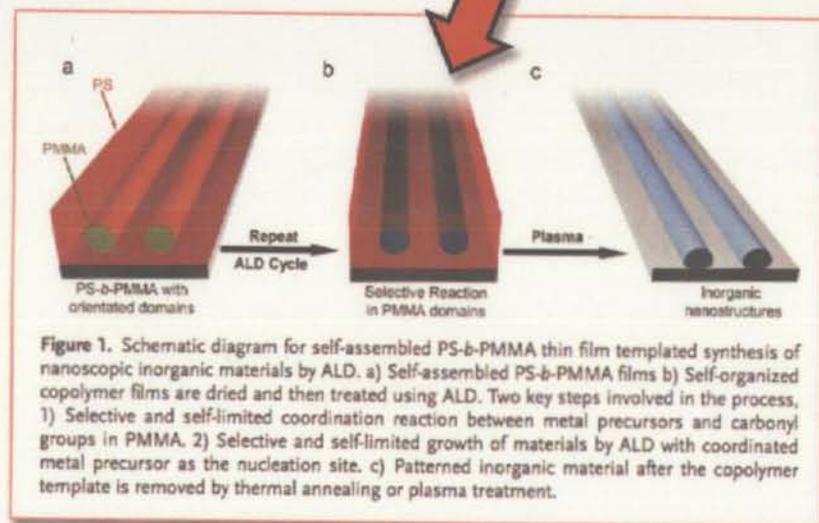
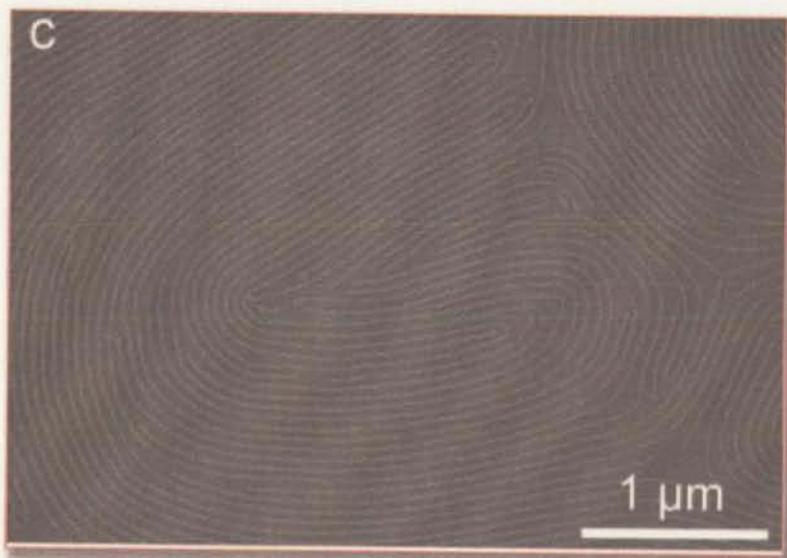
Materials Views
www.MaterialsViews.com

ADVANCED MATERIALS
www.admat.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*

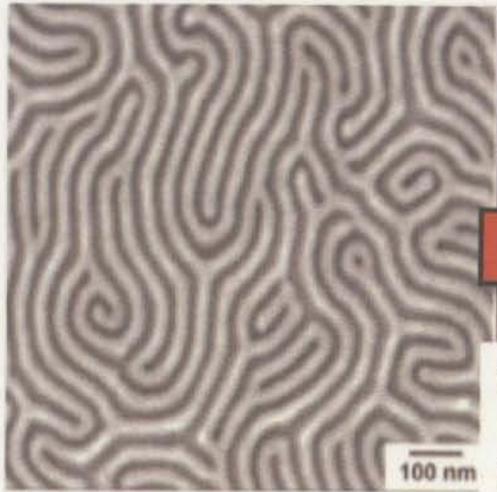
load precursor from **vapor phase**
e.g., $\text{Al}(\text{CH}_3)_3$, TiCl_4 ,



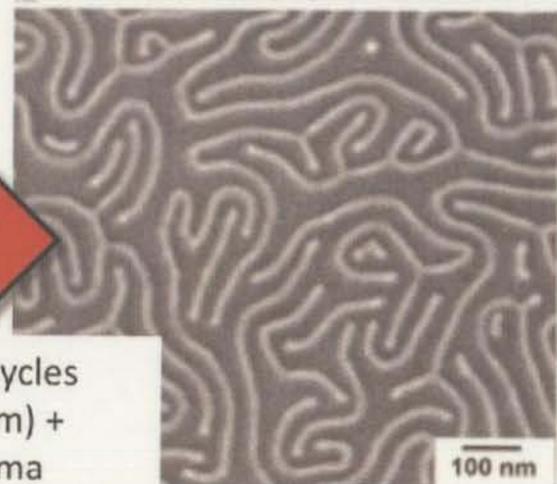
Selective atomic-layer deposition



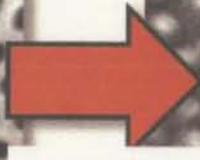
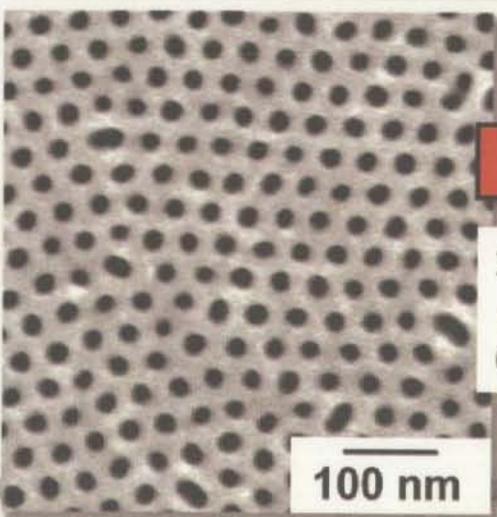
lamellar block copolymer



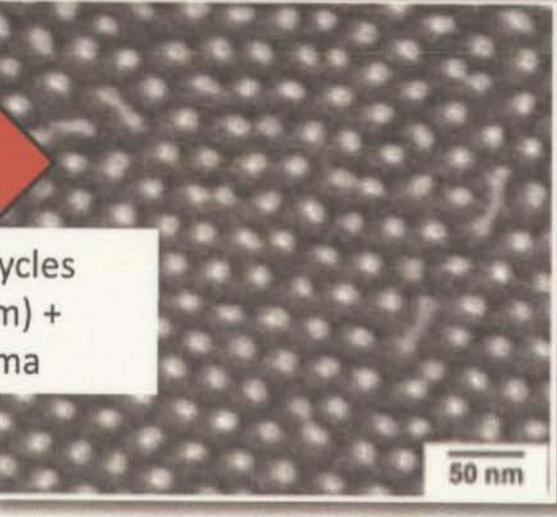
3 ALD cycles
(~0.3nm) +
O₂ plasma



cylindrical block copolymer



3 ALD cycles
(~0.3nm) +
O₂ plasma



~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*

