CHE323/CHE384
Chemical Processes for Micro- and Nanofabrication
www.lithoguru.com/scientist/CHE323

Lecture 69
Directed Self Assembly, part 2

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Directed Self-Assembly (DSA)

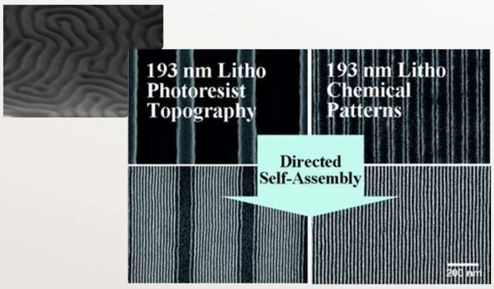
- DSA is a bridge between top-down and bottom-up patterning
  - Can leverage existing patterning methods
- Two possible goals for DSA:
  - Create long-range order in the self-assembled structures
  - Align structures to existing patterns on the substrate
- Two approaches to DSA
  - Field-guided self-assembly
    - Can create long-range order, but not alignment
  - Template-guided self-assembly
    - Can accomplish both DSA goals

Directed Self-Assembly

- Types of fields
  - Electric and magnetic
  - Flow gradients
  - Temperature gradients (zone annealing)
  - Mechanical shear stress
- Types of templates
  - Physical (topographical)
  - Chemical
  - Biological (e.g., DNA)

I will focus on these two

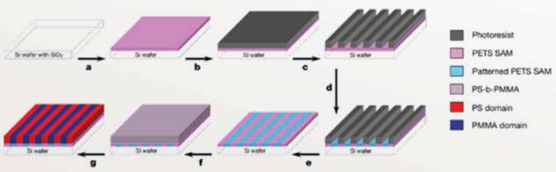
Topographical vs. Chemical Guides



ACS Nano, **2010**, *4* (8), pp4815–4823

Note the period division: Lo = template period/M, M ~ 4

DSA through chemical modification of substrate using lithography

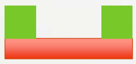
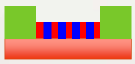
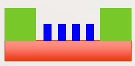


PETS = phenylethyltrichlorosilane
SAM = self-assembled monolayer

Epitaxial self-assembly of block copolymers on lithographically defined nanopatterned substrates, Sang Ouk Kim, Harun H. Solak, Mark P. Stoykovich, Nicola J. Ferrier, Juan J. de Pablo & Paul F. Nealey, *Nature* **424**, 411-414(24 July 2003).

DSA through Topographic Guiding

- Print topographic pattern using conventional lithography at a multiple of the natural period of the block copolymer
  - Wetting properties of the top, bottom, and sidewalls is very important
- Fill in topography with block copolymer at its natural period (vertically oriented lamellae)
- Etch the pattern (remove one of the co-polymer blocks, e.g., plasma removal of PMMA leaving PS)
- Big Questions: Defects and termination

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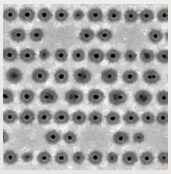
Topographically Guided Contacts

- Print contact holes larger than needed
- Use DSA to fill holes, then etch out the middle material
- Result – smaller holes of very uniform size



H.-S. Philip Wong, et al., "Block copolymer directed self-assembly enables sublithographic patterning for device fabrication", *Proc. SPIE* 8323, Alternative Lithographic Technologies IV, 832303 (2012).

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DSA Resolution

- Natural Period: $L_0 \approx a\chi^{1/6}N^{2/3}$
- Microphase separation occurs when $\chi N > 11$
- It is hard to make *a* (monomer size) small
- Thus, keeping χN fixed, we want high χ and small *N*: $L_0 \sim 1.5a\sqrt{N}$

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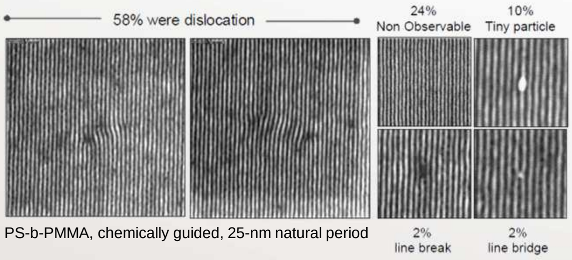
DSA Defects – The Biggest Problem



PS-b-PMMA, chemically guided, 25-nm natural period

Chris Bencher, et al., "Self-assembly patterning for sub-15nm half-pitch: a transition from lab to fab", Proc. SPIE 7970, 79700F (2011).

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Potential Future DSA Lithography

- Using 193i, print ~80-nm pitch patterns over large area
- Using DSA, create ~20-nm pitch patterns over large area
- Using cut-mask lithography, cut up patterns as needed by circuit design
  - Requires restricted design rules: all features one size, on regular grid, in one orientation
  - This is the hard lithography step! 193i? E-beam? EUV?

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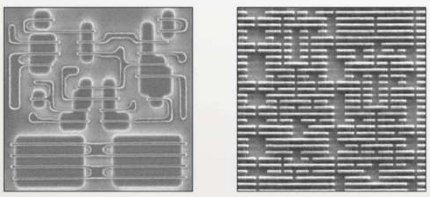
Restricted Design Rules

65 nm Layout Style | **32 nm Layout Style**



65 nm Layout Style:
- Bi-directional features
- Varied gate dimensions
- Varied pitches

32 nm Layout Style:
- Uni-directional features
- Uniform gate dimension
- Gridded layout

Source: Intel

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Lecture 69: What have we learned?

- What are the two common ways to create guide patterns for DSA in lithography?
- How is DSA likely to be used first in semiconductor manufacturing?
- How can DSA resolution be improved?
- What is the biggest problem for DSA in semiconductor manufacturing?

