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

Note the period division: $L_0 = \text{template period}/M$, $M \sim 4$

Directed Self-Assembly through chemical modification of substrate using lithography

- PETS = phenylethyltrichlorosilane
- SAM = self-assembled monolayer


Directed Self-Assembly 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 copolymer blocks, e.g., plasma removal of PMMA leaving PS)
- Big Questions: Defects and termination
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


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 \( \chi N \) fixed, we want high \( \chi \) and small \( N \): \( L_0 \sim 1.5a\sqrt{N} \)

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


DSA Defects – The Biggest Problem

58% were dislocation
24% Non-Observable
10% Tiny particle
2% line break
2% line bridge

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?

Restricted Design Rules

85 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

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?