NIKON RESEARCH CORP. OF AMERICA

DSA and 193 immersion lithography

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Imaging Sol'ns Technology Development

Where the industry wants to go

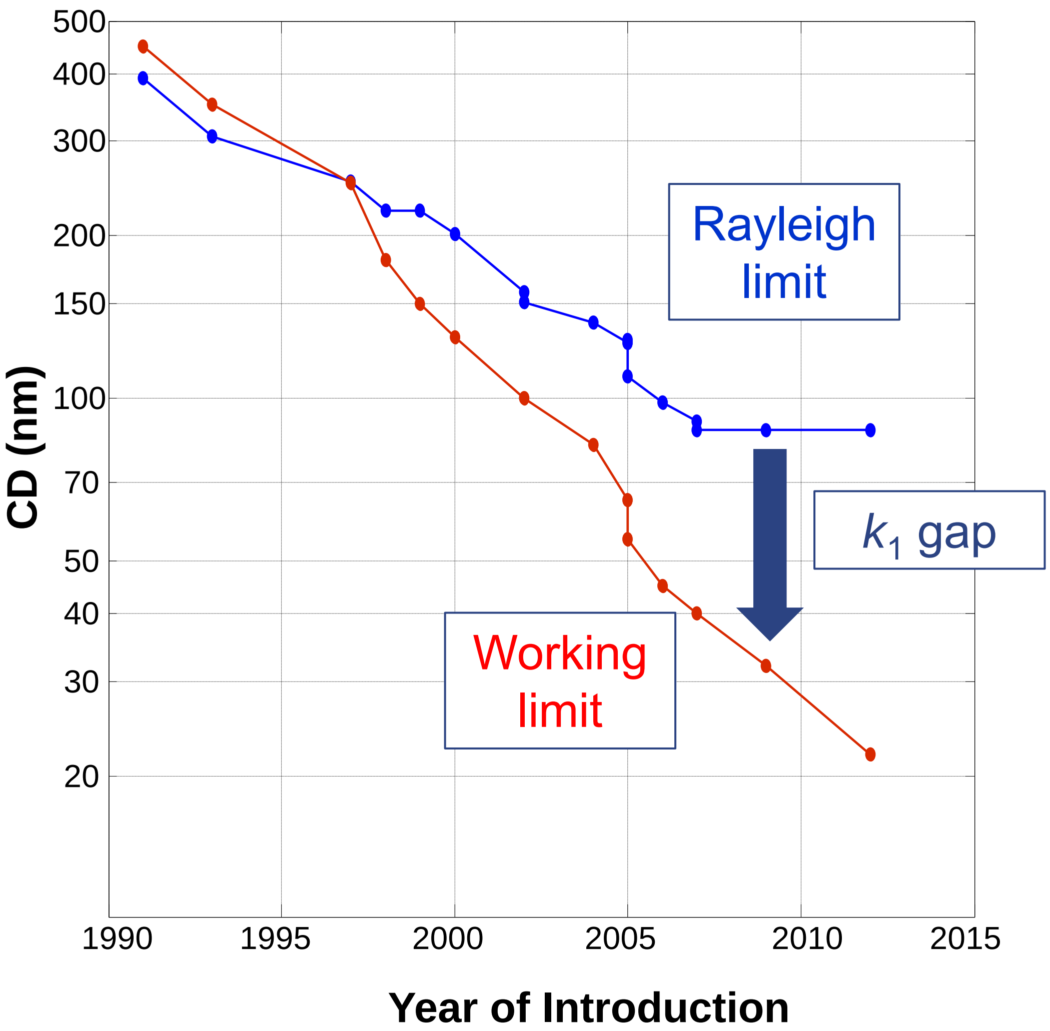
Where we are now

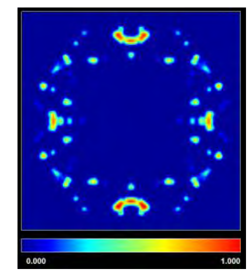
193i

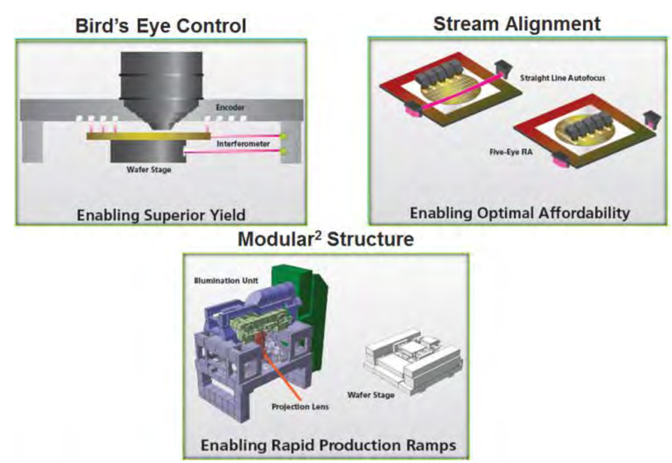
e-beam

EUV

193i optical lithography: pushing the limit



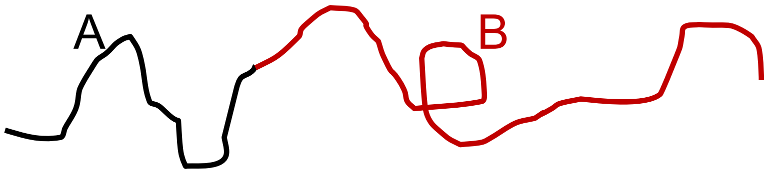




DSA: Who ordered *that?*

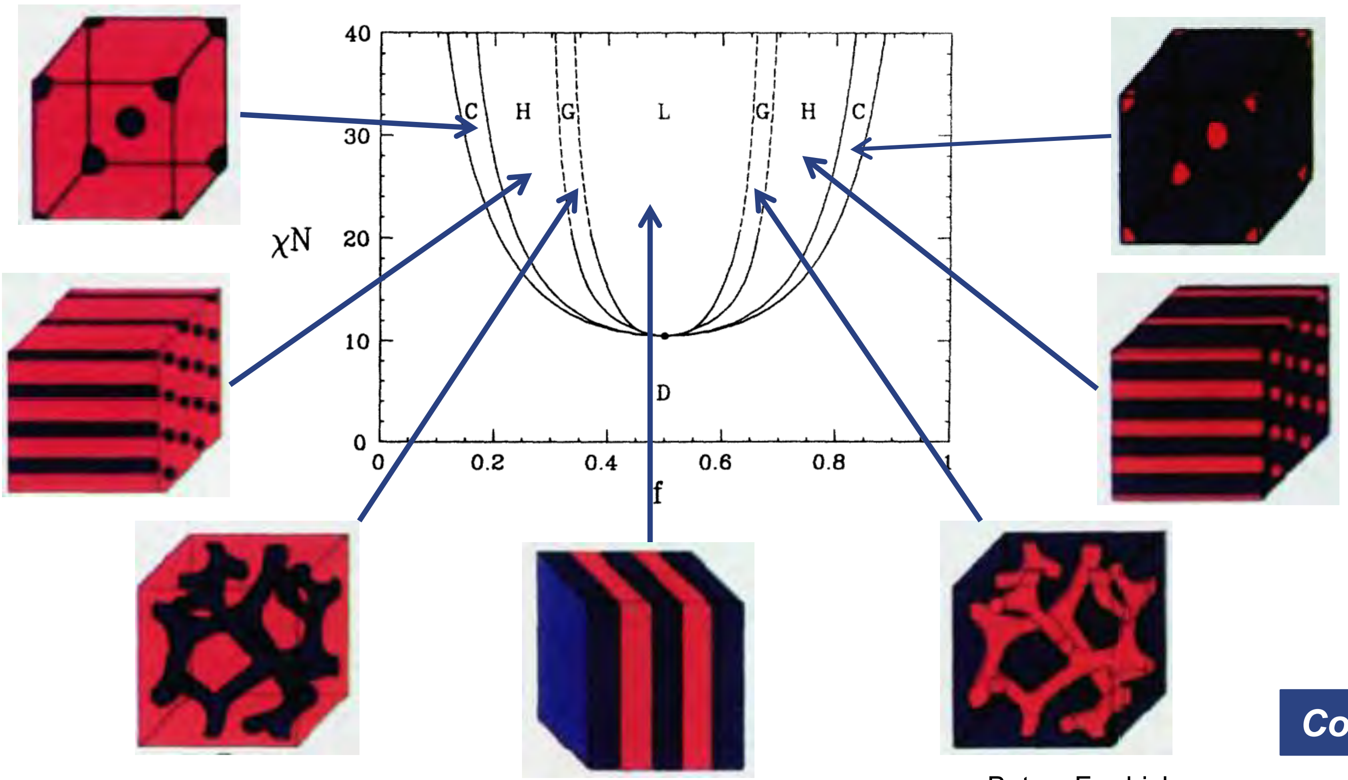
Block copolymers, or magic spaghetti

Stringlike molecules with A and B segments that repel each other



f = length of A portion

1– f = length of B portion



χ = Strength of repulsion between A and B monomers

N = # monomer units

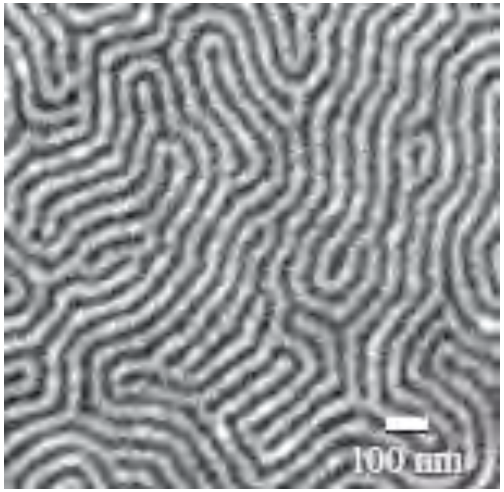
Courtesy of G. Gallatin, NIST

Bates, Fredrickson
Physics Today 1999

Self Assembly

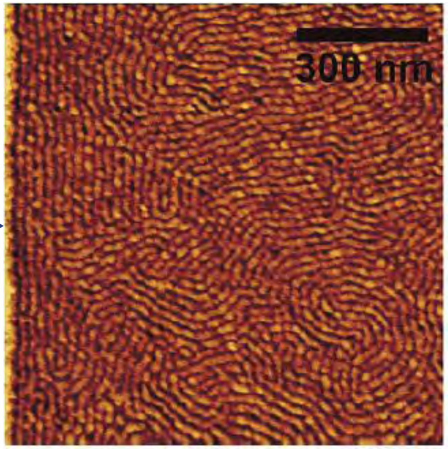
Cylindrical phase oriented parallel to the wafer surface

Undirected



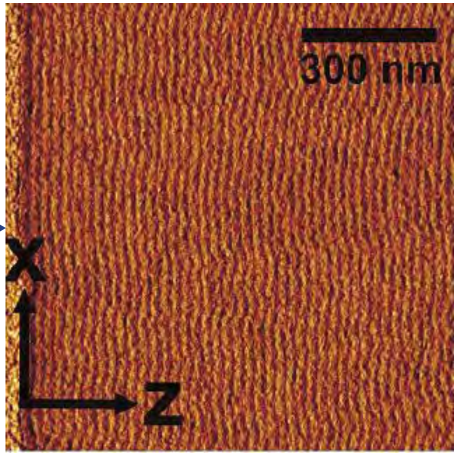
Black, et. al.,
IBM J. Res. & Dev.
2007

Directed



"Straight" Edge →

Different annealing schedules



"Straight" Edge →

Hammond, Kramer
Macromolecules 2006

It "*wants*" to form structures that we like.

Photos courtesy of G. Gallatin, NIST

DSA and 193i litho: a new team

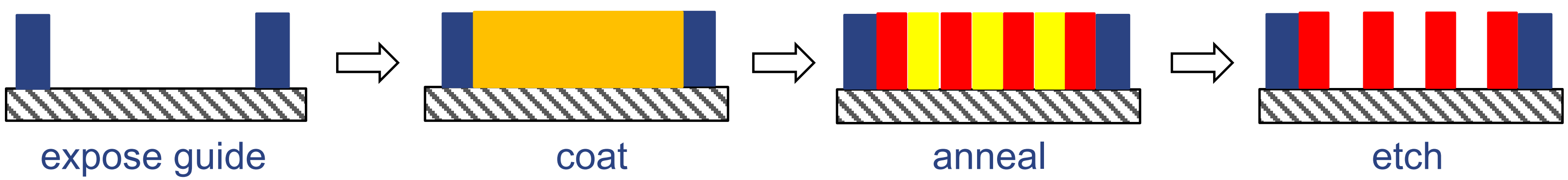
- The scanner provides the support:
  - CD Control
  - Flexible focus and dose control
  - Overlay
  - Fast wafer handling

- *Through the magic of chemistry ...*
  DSA provides the small size.

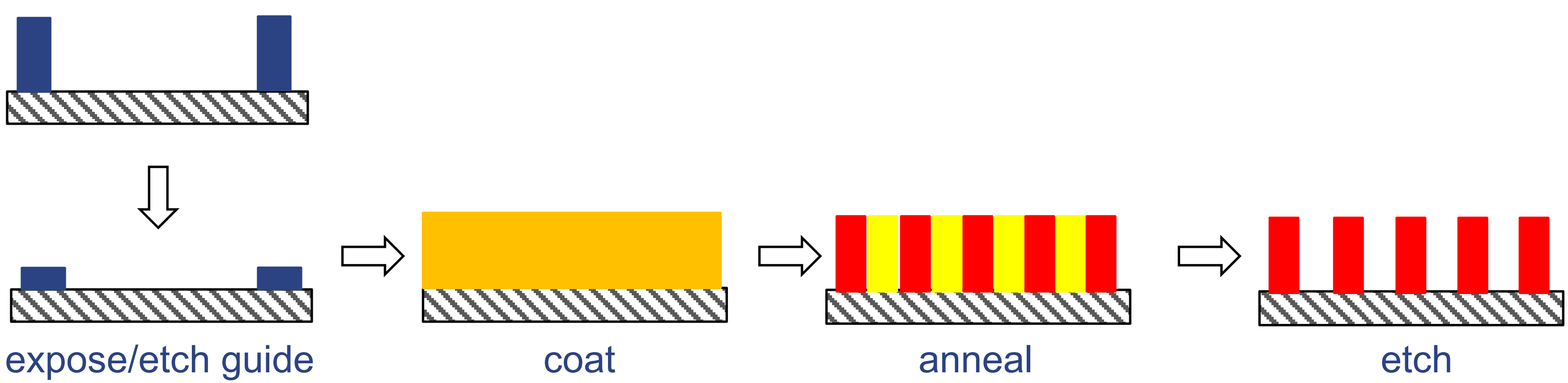
Directing the self-assembly

- In each case, a guide structure is printed with 193i litho.
- The rest is chemistry ...

- Graphoepitaxy: building a physical fence

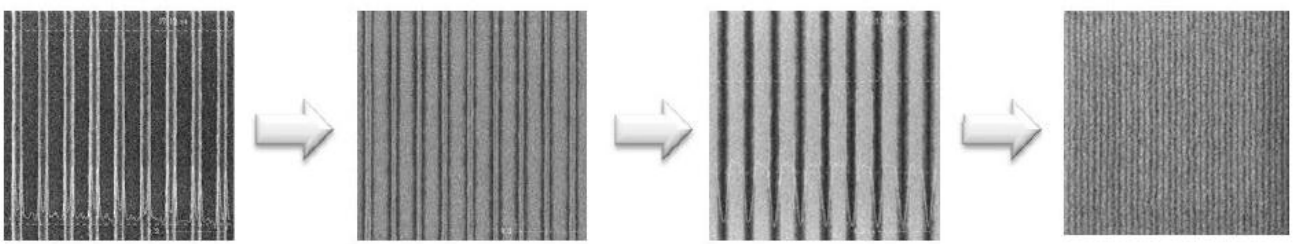


- Chemoepitaxy: painting chemical stripes



Resolution (L/S)

- Univ. Wisconsin, chemoepitaxy approach:
  - Positive-tone resist used to expose guide patterns.
  - Coating and etching to produce stripes used for directing the polymers.
- 12.5 nm L/S
- 200 nm DoF and 40% EL



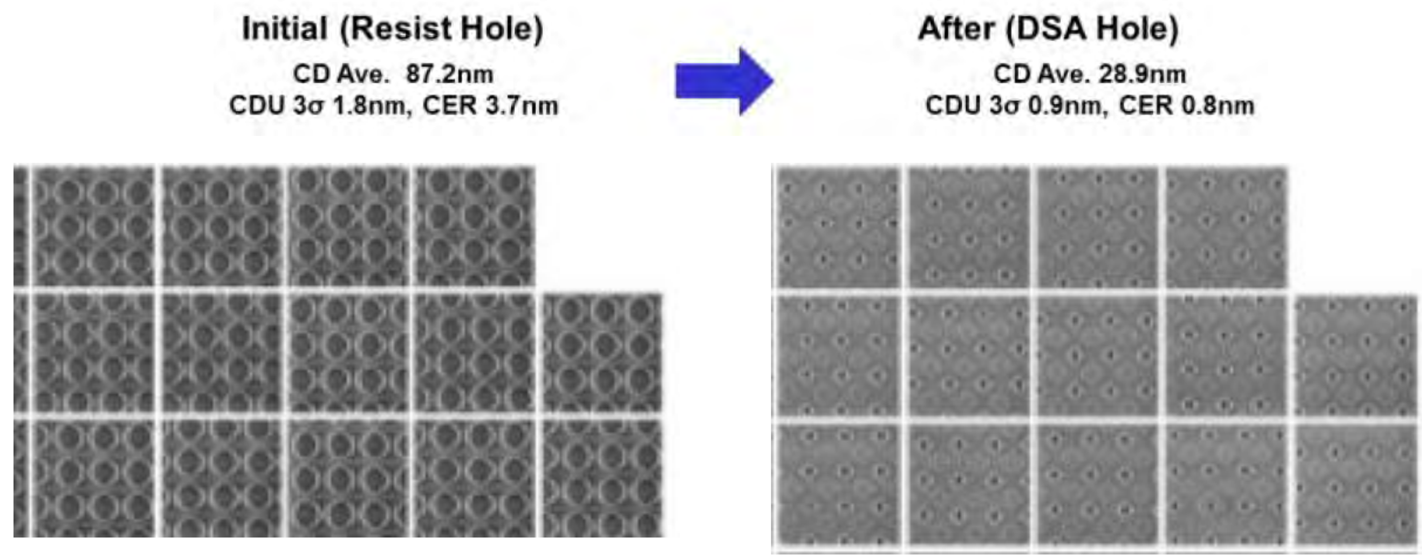
DSA Pre-pattern ~35 nm LN/ 100 nm pitch | Trim etch ~15 nm | Wet resist strip | After 4x DSA process **12.5 nm line/spaces**

Rathsack *et al.*, AdvLitho 2012, *Proc SPIE* **8323**

Chemical process teamed with 193i litho produces 12.5 nm L/S with excellent process latitude

Resolution cont'd (contacts)

- TEL Japan on a Nikon S610 scanner:
  - Negative-tone prepatterning
  - 87 nm guide patterns minimized missing-hole effect
  - Note the "healing effect:" CDU and CER were *reduced*.



Rathsack *et al.*, AdvLitho 2012, *Proc SPIE* **8323**

The guide structure resolution is well within 193i capability

Process control ⇒ Focus & dose control

- Does the DSA process impose special requirements on the scanner?

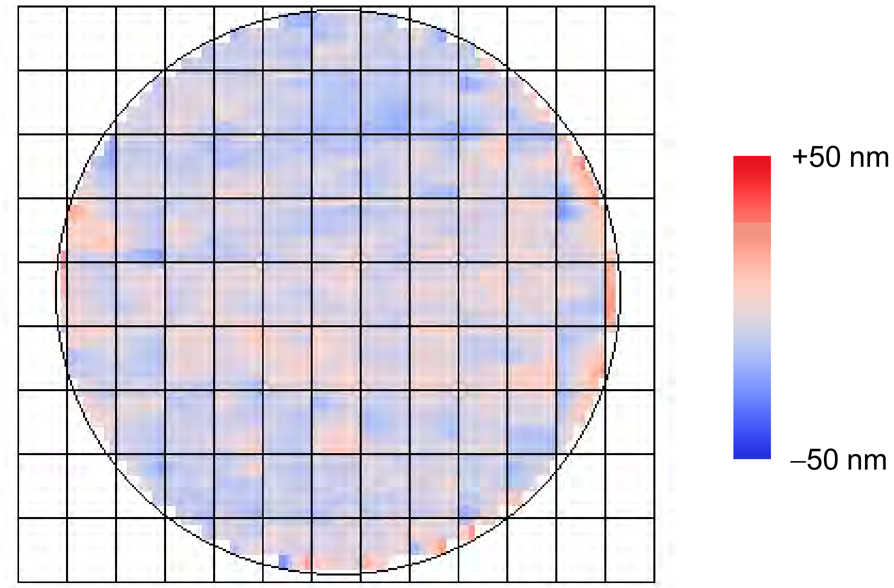
- Some processes very sensitive:
  - Graphoepitaxial process
  - 3% exposure latitude @ ~50 mJ/cm^2
- Some are not:
  - Chemoepitaxial process
  - Process window:
    - 13.5 to 16.5 mJ/cm^2 dose (25% @ best focus)
    - 140 to 270 nm focus (130 nm @ best dose)

Some sensitive DSA processes exist ...

Existing focus and dose control

- Focus control:
  - 12.2 nm 3σ across a wafer
  - About 10 nm full range drift over several days
- Dose control:
  - typically ±1% or less.

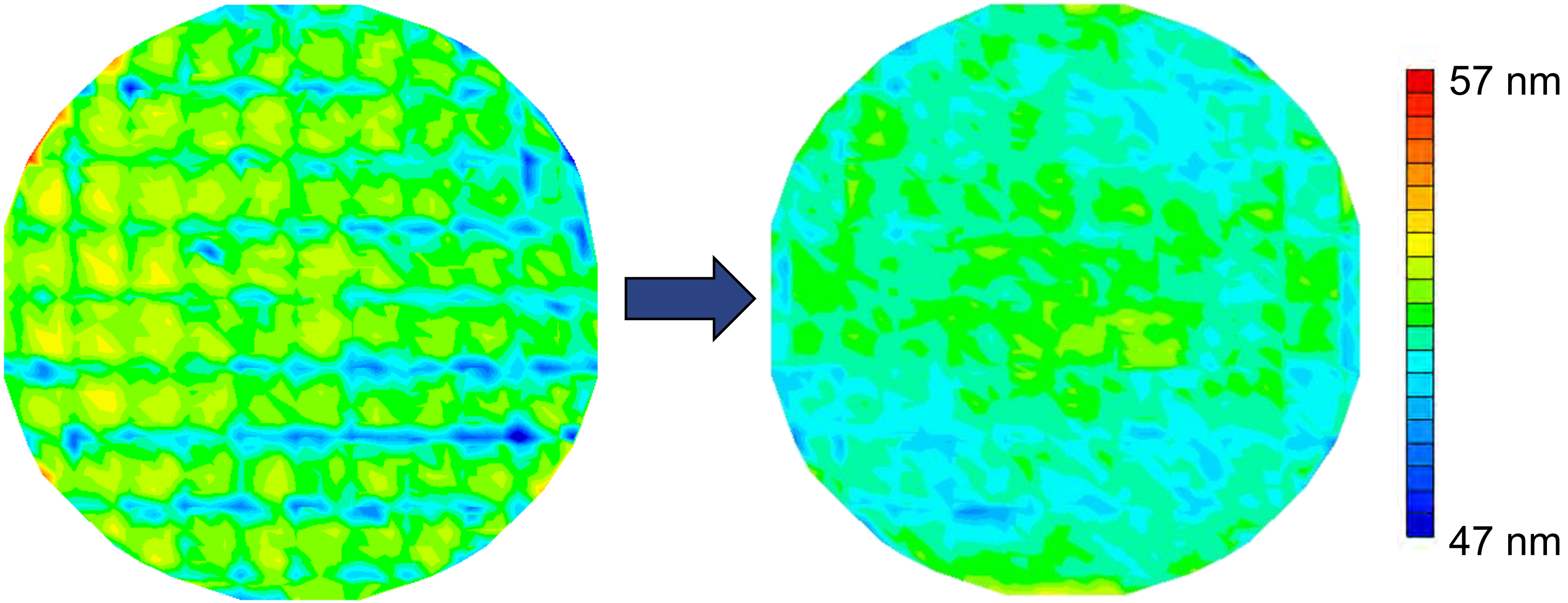
S621D focus uniformity



... but the scanner is already designed for sensitive processes

Process tuning capability already exists

- CDU Master compensates for process-induced errors



Inter field : 1.2 nm(3σ)
Intra field : 2.1 nm(3σ)

Inter field : 0.9 nm(3σ)
Intra field : 0.6 nm(3σ)

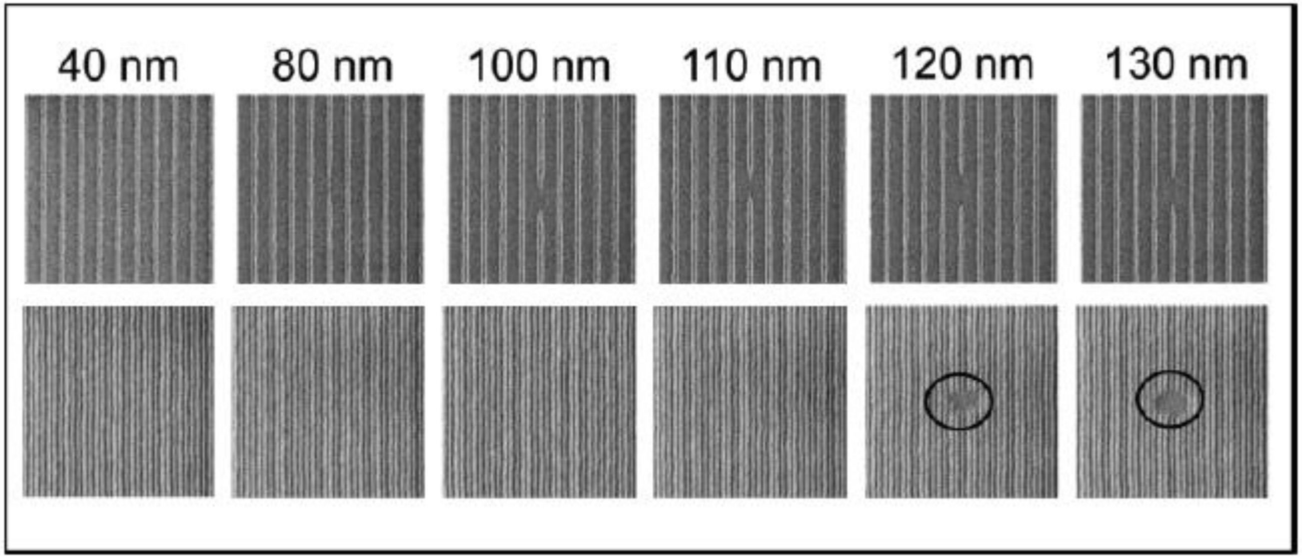
... even to the point of compensating for them.

Defectivity

- Immersion-induced defects have been a challenge for the industry. Will that happen again?
- Studies with deliberate defects show that the DSA process is self-healing to a point:

Guide pattern

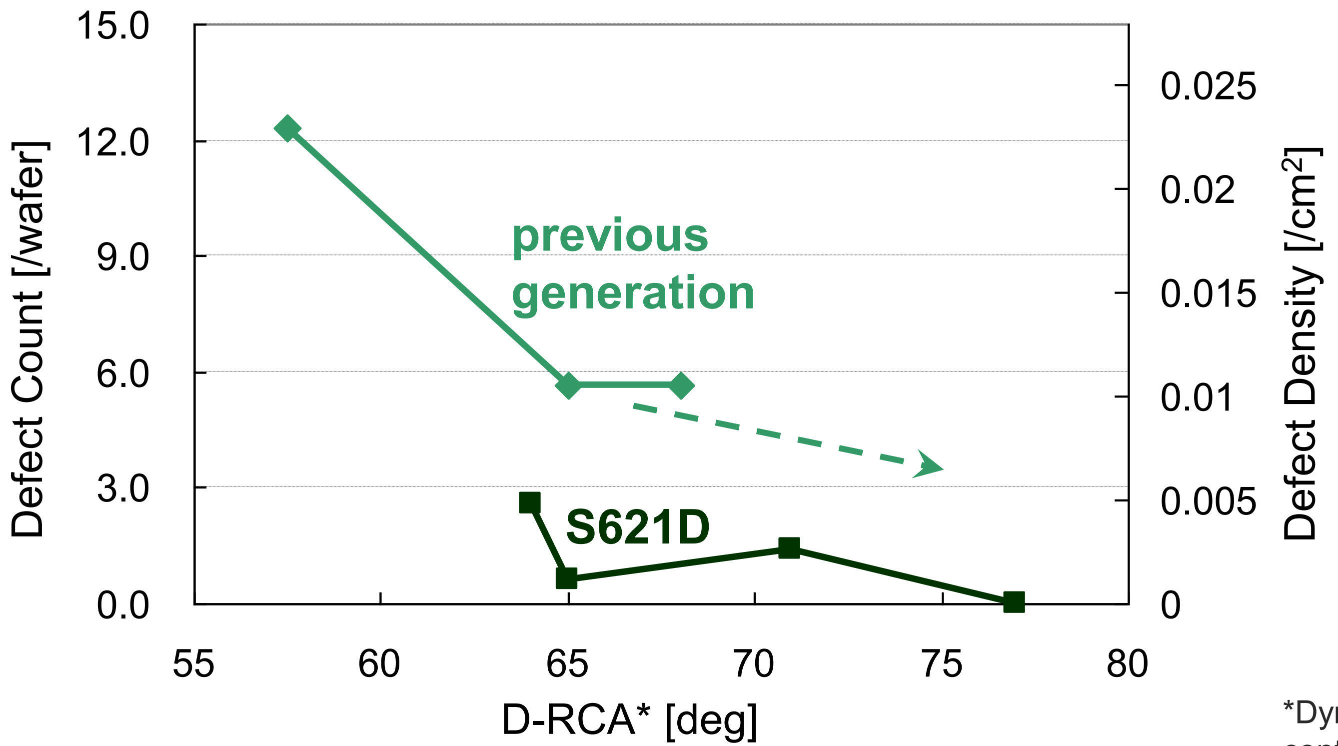
Guide pattern



Somervell *et al.*, Advances in Resist 2012, *Proc SPIE* **8325**

Existing defectivity

- Immersion-induced defects have been steadily reduced

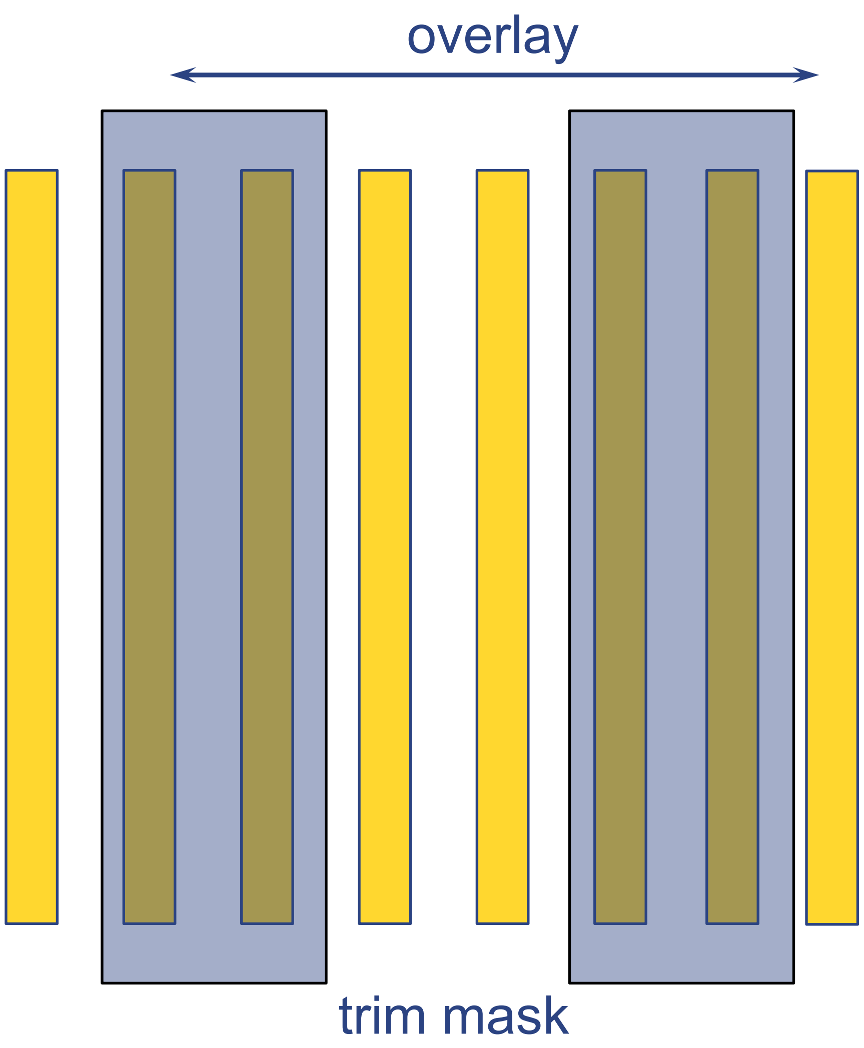


*Dynamic receding contact angle

Defectivity should continue to drop with DSA.

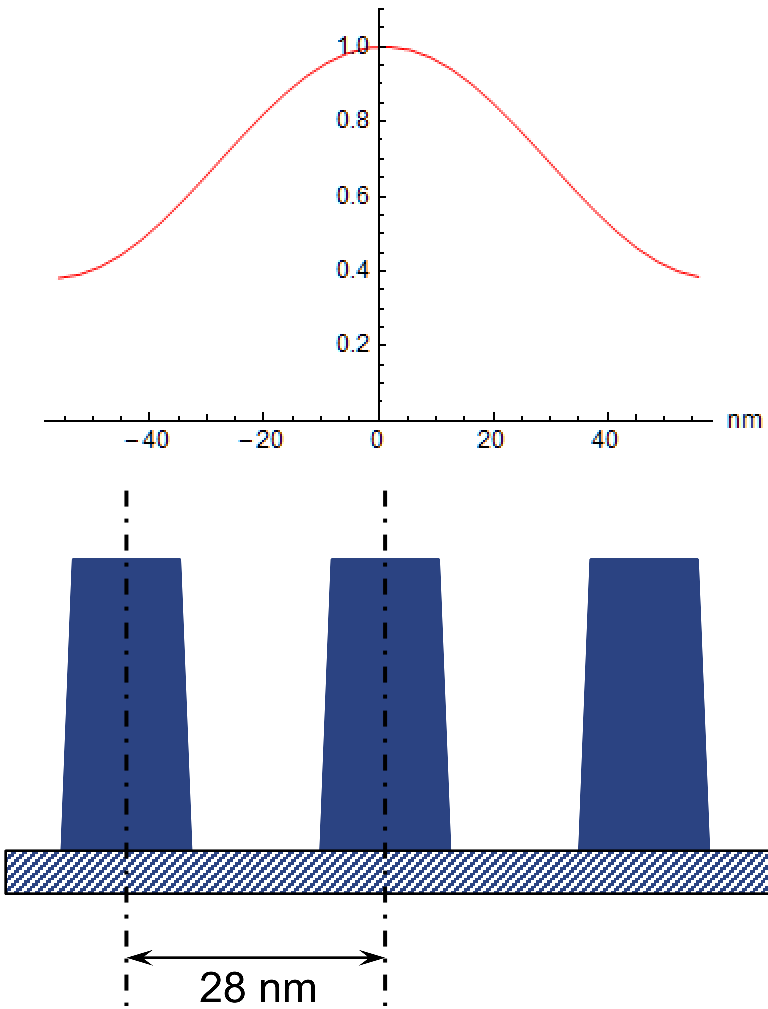
Overlay

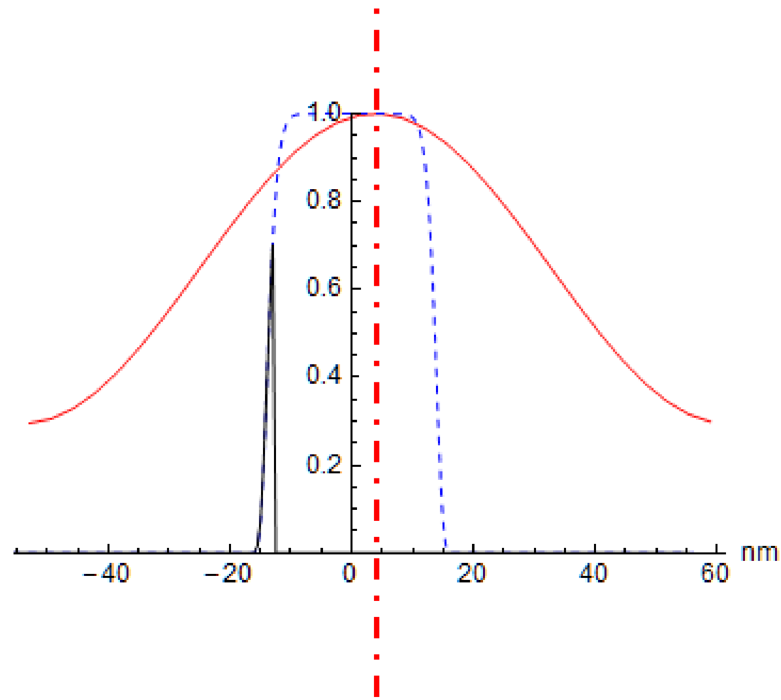
- DSA can only print:
  - Contact holes
  - Equal L/S gratings.
- What if you want something else?
- DSA processes will need associated trim masks.
- Additional overlay requirements.



Back-of-the-envelope analysis

Use an aerial image to “burn off” a resist feature...

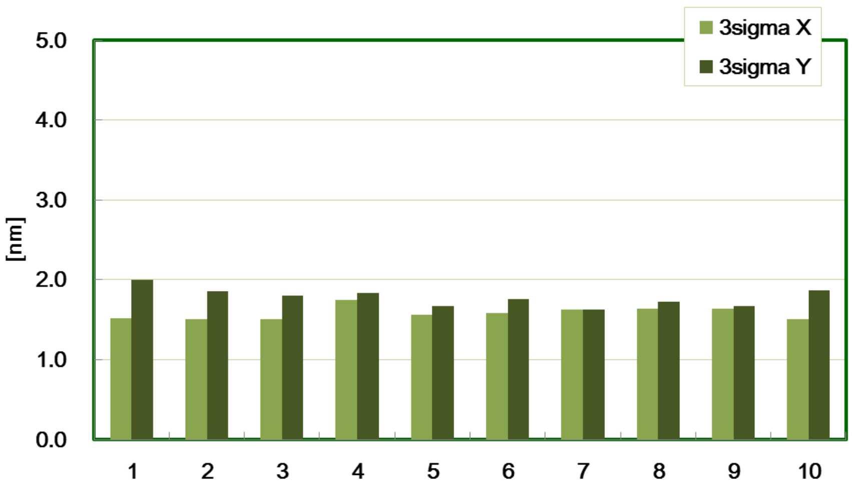




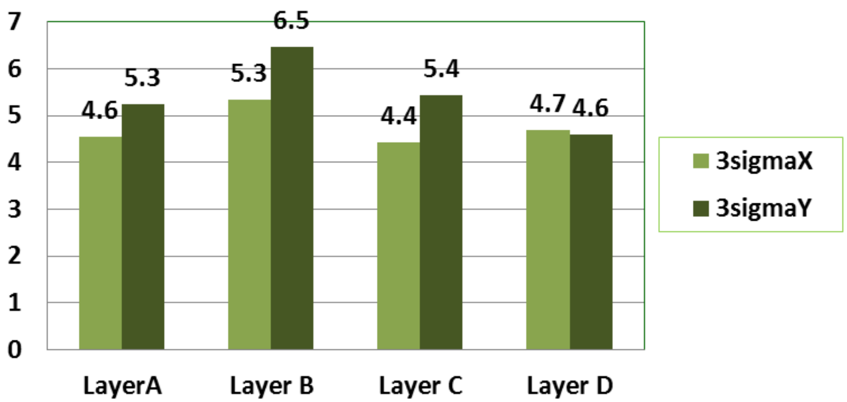
allowed overlay error 2-3 nm

Existing overlay

- The *Streamlign* platform is already meant for double patterning.



Single-machine OL < 2 nm



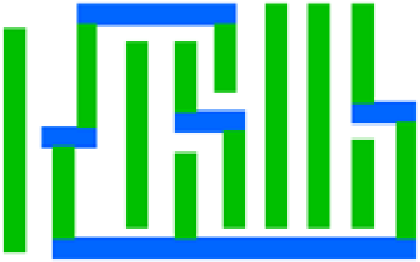
Tool-tool product overlay 4.5 - 6.5 nm

- Champion data: 0.74 nm SMO.

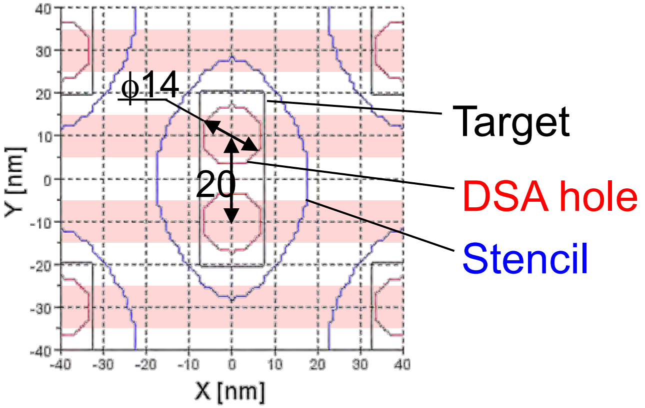
Existing scanner platforms should meet DSA requirements

Potential ways to employ DSA

- Careful trim-mask schemes.
  - employ existing knowledge from double patterning.



- Cutting lithography



- "Alphabet" methods for constructing arbitrary contact patterns
  - Stanford University work

Much of the challenge will be in the EDA area.

Will it fly? Conclusions

- Scanner requirements are largely met already:
  - Resolution
  - Dose and focus control
  - Overlay (ongoing improvements)
  - 200 wph throughput

- Challenges remain for processing, integration, and mask design.

We expect DSA to be employed as an adjunct to 193i lithography.

Nikon

Nikon. Evolution in Action.