DSA and 193 immersion lithography

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Where the industry wants to go
Where we are now

193i

e-beam

EUV
193i optical lithography: pushing the limit

![Graph showing the decrease in CD (nm) over the years with labels for Rayleigh limit, Working limit, and k₁ gap.](image)

**Year of Introduction**

- 1990
- 1995
- 2000
- 2005
- 2010
- 2015

**CD (nm)**

- 500
- 400
- 300
- 200
- 150
- 100
- 70
- 50
- 40
- 30
- 20

Sokudo breakfast 2012
DSA: Who ordered *that*?
Block copolymers, or magic spaghetti

Stringlike molecules with A and B segments that repel each other

\[ f = \text{length of A portion} \]
\[ 1 - f = \text{length of B portion} \]

\[ \chi = \text{Strength of repulsion between A and B monomers} \]
\[ N = \# \text{ monomer units} \]

Bates, Fredrickson
Physics Today 1999

Courtesy of G. Gallatin, NIST
Self Assembly

Cylindrical phase oriented parallel to the wafer surface

Directed

“Straight” Edge

Undirected

Different annealing schedules

“Straight” Edge

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

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

1. Expose guide
2. Coat
3. Anneal
4. Etch

### Chemoepitaxy: painting chemical stripes

1. Expose/etch guide
2. Coat
3. Anneal
4. Etch
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

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

Rathsack et al., AdvLitho 2012, Proc SPIE 8323
Resolution cont’d (contacts)

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

The guide structure resolution is well within 193i capability

Rathsack et al., AdvLitho 2012, Proc SPIE 8323
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)
Existing focus and dose control

- **Focus control:**
  - 12.2 nm $3\sigma$ across a wafer
  - About 10 nm full range drift over several days

- **Dose control:**
  - Typically ±1% or less.

... but the scanner is already designed for sensitive processes
Process tuning capability already exists

- CDU Master compensates for process-induced errors

... 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:

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

- Immersion-induced defects have been steadily reduced

Defectivity should continue to drop with DSA.

*Dynamic receding contact angle
- 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.