BCP’s DSA for contact hole shrink: guiding patterns requirements

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Outline

- DSA: BCP specification
- Commensurability
- Process integration
- Lithographic performances
- Contact multiplication
- Summary
Different morphologies function of weight fractions $f_A$ & $f_B$ of each BCP sequence A & B.

- Morphology $\Leftrightarrow$ concentration of each phase
- Pitch = period of the polymer = length of the chain
  - 1 polymer $\Leftrightarrow$ 1 CD $\Leftrightarrow$ 1 pitch ($L_0$)
- For constant morphology CD/pitch = ct

$$f_A = \frac{N_A}{N_A + N_B}$$
Why grapho-epitaxy preference?
A versatile process
LETI demonstration
How to find optimum guiding litho process?

=> Influence of Litho1 design rules & BCP material

To generate zero defects configuration commensurability between BCP and guiding patterns must be respected.

Design rule compatibility

N = (L + S) / a₀

Zero Defect Configuration

Before litho1 optimization

After litho1 optimization

- Defectivity measurement enables lithography and process optimization.
- This methodology may be easily scale up from laboratory environment to a large scale industrial process.
LETI’s DSA dedicated Process Implementation
DSA 300 mm process implementation

- No metallic contamination in polymers
- POR using a cylindrical polymer PS-\textit{b}-PMMA from Arkema with $L_0=38$nm
- Spin casting solvent: PGMEA
- Brush bake: 230C / 1min
- Non grafted brush removal: using PGMEA
- DSA bake: 245C / 1min
- PMMA remove wet and/or dry processes
- Pattern transfer by etching

“Pattern density multiplication by direct self-assembly of BCP: towards 300mm CMOS requirements” R. Tiron et al., SPIE2012
Two integration schemas:

1. Double hard-mask

2. NTD Resist

NTD resist approach: less process steps but resist reflow and control of CD during DSA bake still difficult
Contact shrink vs. BCP morphology

A/ Cylindrical PS-\(b\)-PMMA

B/ Lamellar PS-\(b\)-PMMA

- Contact shrink is possible using both cylindrical and lamellar morphologies

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\left( \frac{CD_{BCP}}{CD_{guide}} \right)_{\text{lamellar}} > \left( \frac{CD_{BCP}}{CD_{guide}} \right)_{\text{cylindrical}}
\]
Broad range of PS-\textit{b}-PMMA

Customizable PS-\textit{b}-PMMA platform with various pitch demonstrated

For more details see X.Chevalier et al. paper 8680-5 on February 26
BCP Etching: capabilities demonstration on small samples

Transfer of BCP into Si by using SiO2 hard mask

Transfer of BCP into 193 nm hardmask

Copolymer etching process fully compatible with CMOS requirements
DSA LETI’s 300 mm pilot line

193nm litho pattern

BCP self-assembly

BCP pattern transfer

CD ~ 120nm

CD ~ 15nm

CD ~ 15nm

For more details see R.Tiron et al. paper 8680-37 on February 28
Contact shrink process: lithographic performances
For manufacturing solution we have to manage several metrology challenges:

- High resolution patterns
- Complex morphologies (contact in contact like structures)
- Pattern placement control
- Defectivity

J. Foucher, J. Hazar, R. Thérèse
Contact hole characterization

- CD\(_1\) and CD\(_2\) by CD-SEM
- h\(_1\) and h\(_2\) by AFM3D

Need to combine different metrology tools to fully characterize patterns (hybrid metrology)

J. Foucher, J. Hazar, R. Thérèse
CD of BCP’s final contact hole depends on both initial CD and initial pitch.
Contact hole shrink by DSA

Pitch guiding = 140 nm

Contact shrink with DSA => large process latitude (> 20nm)
Contact rectification using DSA

Contact rectification is possible with DSA
…but process latitude should be established
Contact multiplication & simulation
Contact doubling by using BCP

- Contact doubling demonstrated by using DSA
- Pitch sizing is possible using contact doubling approach

Guiding template  After PMMA removal  After BCP transfer

100 nm
Exotic configurations accessible with BCP

Complex structures available for contact multiplication by DSA to address design rules
How to predict polymer structures?

- Design
- Calculated CH placement

Simulation contour

Contour variation w.r.t. dose, focus and mask CD error variations

Experimental validation

- Extracted Contour
- Calculated CH position
- CH position on wafer

R. Tiron et al.
Summary

- DSA is a complementary lithography technique that could be inserted as early as the 14nm node
  - In a first step by using PS-\(b\)-PMMA like materials (lowest CD after etching 10nm)
  - In a second step by using high \(\chi\) materials (CD < 10nm)

- A realistic application: contact hole shrink and multiplication
Thank you!