Applications of DSA for lithography

Yoshi Hishiro, Takehiko Naruoka,
JSR Micro Inc.
Yuusuke Anno
JSR Micro NV.
Hayato Namai, Fumihiro Toyokawa, Shinya Minegishi, Yuuji Namie, Tomoki Nagai, Kentaro Goto, Masayuki Motonari, Yoshikazu Yamaguchi
JSR Corp.

19th Annual SOKUDO Lithography Breakfast Forum

Lithography Roadmap

First Year of IC Production	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
DRAM ½ pitch (nm) (contacted)	36	32	28	25	23	20.0	17.9	15.9	14.2	12.6	11.3	10.0	8.9	8.0	7.1	6.3
MPU/ASIC Metal 1 1/2 pitch (nm)	38	32	27	24	21	18.9	16.9	15.0	13.4	11.9	10.6	9.5	8.4	7.5	7.5	7.5

45 193nm Imm

32 193 nm DP

22 EUV
193nm MP
ML2 (MPU)
Imprint (DRAM)

16 EUV
193nm MP
ML2
Imprint
DSA + litho platform

11 EUV / EUV + MP
EUV (6.Xnm)
ML2
Imprint
Litho + DSA
Innovation

Narrow Options

MPU / DRAM time line

http://www.itrs.net/Links/2011ITRS/2011Chapters/2011Lithography.pdf

- **DSA has been the candidate for next generation lithography since DSA appeared on ITRS lithography roadmap from 2007.**
- **DSA attracts increasing attention because of the delay of EUV development.**

Block Copolymers VS Polymer Blends

	Block copolymer	Polymer blend
1. Phase-separated polymer domains	➢Intrinsic dimension and pre-determined morphology	➢No specific dimension, morphology, or periodicity
2. Phase separation in pre-pattern	DSA ➢Pitch multiplication ✓Block copolymer keeps intrinsic periodicity and morphology	DSA ➢Sidewall image transfer ✓Morphology and dimension are determined by pre-pattern and blend composition
3. Material/Process flexibility	✓Specialty polymers ✓High bake temperature (-250C) ✓Difficult to perform wet development ✓Need ultra-high molecular weight to achieve large features	✓Huge material selection ✓Low bake temperature (-120C) ✓Wet- or Dry-etching can be applied to selectively remove one component ✓Can apply to large dimensions

This paper will focus mainly on DSA process using polymer blend but touch on Bolck copolymer system also.

Sidewall Image Transfer with Phase Separation of Si Containing Polymer Blend

Basic Process Flow

Pre-pattern

SOC/BARC

1st Patterning

Polymer blend coating

Baking
100~140C/60s

Silicon polymer
Organic polymer

Etching
(Wet or dry)

Pattern transfer

Polymer Blend DSA for 22nm HP Spacers

SPIE 2011 7972-28 co-work of JSR&IBM

Polymer blend coating

Baking

Silicon polymer

Organic polymer

Etching (Wet or dry)

26nmL88nmP

500nm

500nm

500nm

CD=26.3 nm
LER=2.8 nm
LWR=4.8nm

CD=19.2nm
LER(3σ)=2.9nm (Pre-pattern side)
LER(3σ)=3.3nm (Organic polymer side)
LWR(3σ)=3.5nm

✓Application of polymer blend DSA for LS patterning was demonstrated.

Applications of polymer blends DSA for CH application

- CH shrink application[1]

Polymer blend coating

Silicon Polymer

Silicon Polymer

Organic polymer

- CH repair by DSA shrink

DSA

Silicon Polymer

Resist

- Pattern Doubling process

Resist

DSA

Resist

Silicon Polymer

Silicon polymer

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1. DSA shrink process with block copolymer was reported by IBM. J. Cheng et al. 2010 SPIE 7637-18.

CH Shrink Application

Guide-pattern

Si polymer

Organic polymer

Polymer blend coating

SiARC

Organic Hard Mask

Annealing (100-140C/60s-90s)

Silicon polymer

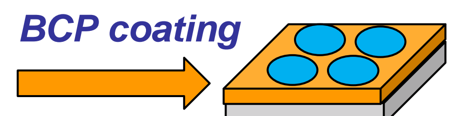
Organic polymer

Remove Organic Polymer (wet developmant)

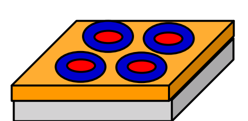
➢ *Simple process (low DSA bake temperature, existing SiARC) could be applied in polymer blend DSA shrink process.*

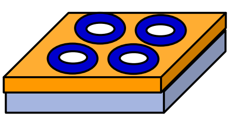
Shrink process with Block Copolymer *J. Cheng et al. 2010 SPIE 7637-18*

Guide-pattern



Annealing (>200C)





Neutral Layer

Results of CH Shrink Application (Top-Down)

Guide-pattern (110nmP) — **After DSA shrink**

55.6nm — 33.2nm

100K — 500nm

70K — 500nm

- Over 20nm shrink amounts was observed in DSA shrink process.

Full-Field CDU Evaluation

DSA material; JSR DS003X
Bake; 120C/90s

Guide Pattern: 55nmH110nmP		After DSA Shrink	
		DS003X	
3σ (local); 4.6nm		3σ (local); 4.0nm	
Avg.CD: 55.8nm	CD(nm) 58.5-59.5 / 57.5-58.5 / 56.5-57.5 / 55.5-56.5 / 54.5-55.5 / 53.5-54.5 / 52.5-53.5 / 51.5-52.5 / 50.5-51.5	Avg.CD: 28.6nm	CD(nm) 30.5-31.5 / 29.5-30.5 / 28.5-29.5 / 27.5-28.5 / 26.5-27.5 / 25.5-26.5 / 24.5-25.5 / 23.5-24.5 / 22.5-23.5
3σ (in wafer): 4.9nm		3σ (in wafer): 4.0nm	
Max CD: 59.5nm		Max CD: 32.1nm	
Min CD: 50.7nm		Min CD: 25.7nm	

➢ ***CDU improvement in DSA shrink process was observed.***

CH Repair by DSA Shrink

Concept

Silicon-Organic Blend Polymer

Si polymer

Organic polymer

Organic Polymer

Silicon Polymer

Polymer blend coating

DSA Annealing

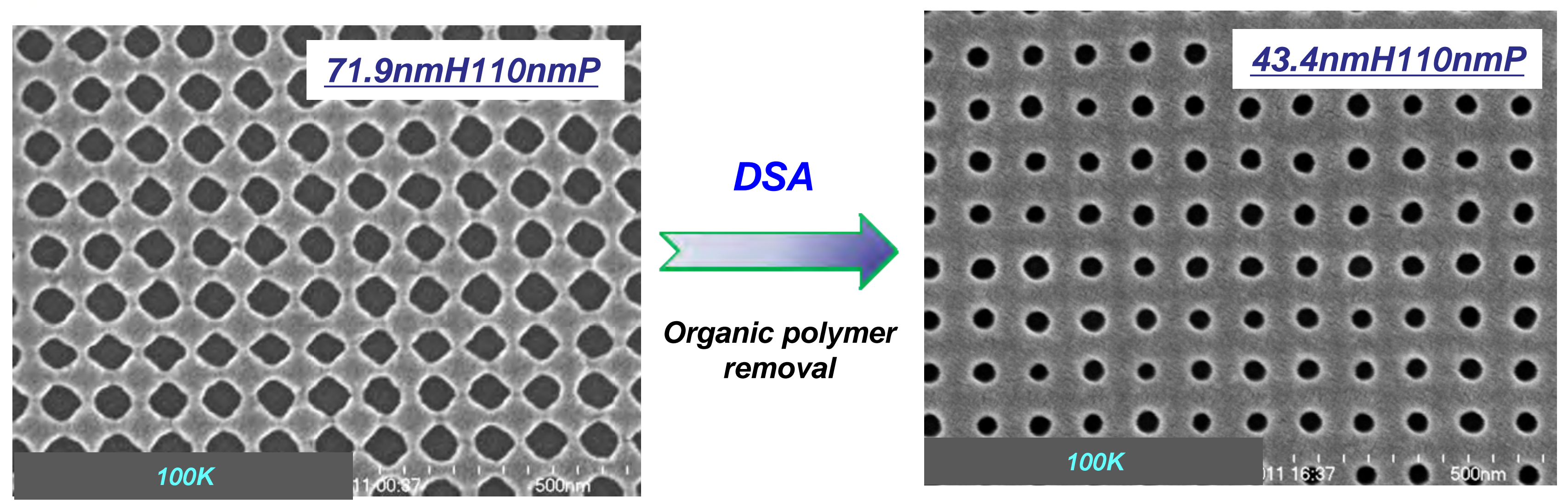
Remove Organic layer

Diamond shape

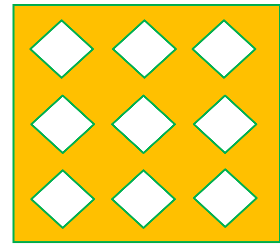
Normal Hole

Hole Repair by DSA shrink

CH Repair by DSA Shrink (1)

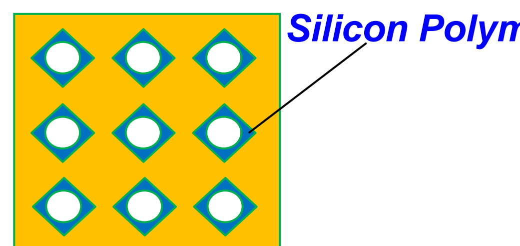


Before Shrink



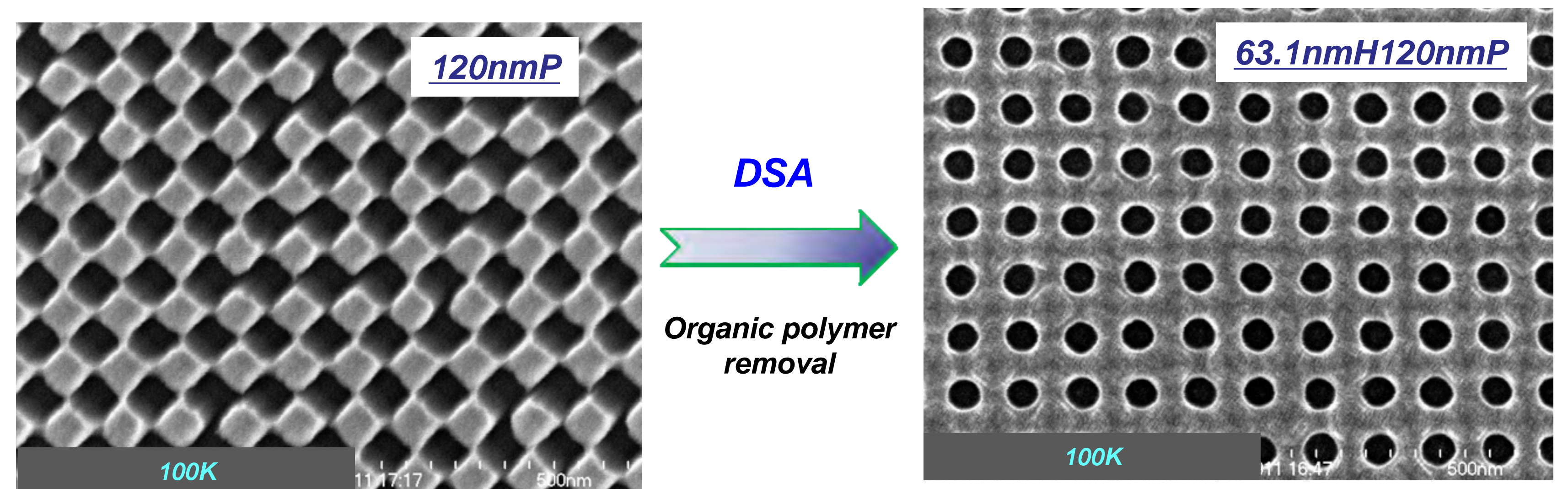
Profile Repair (Circularity improvement)

After Shrink

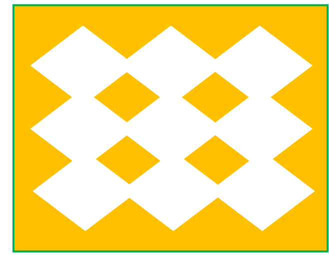


➢ ***Hole profile was effectively repaired by DSA shrink process.***

CH Repair by DSA Shrink

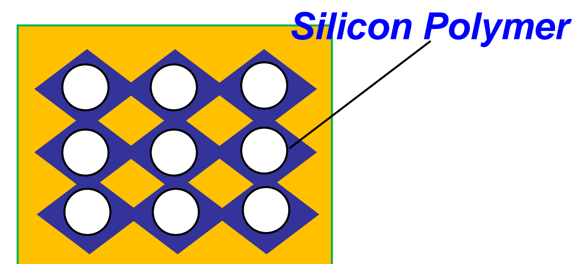


Before Shrink



Profile Repair
(CH Reassembly)

After Shrink

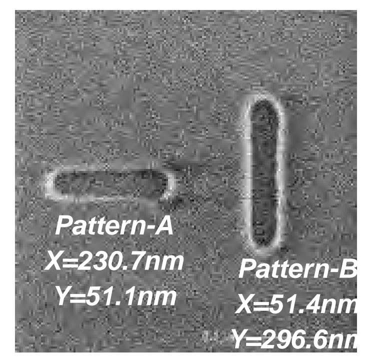


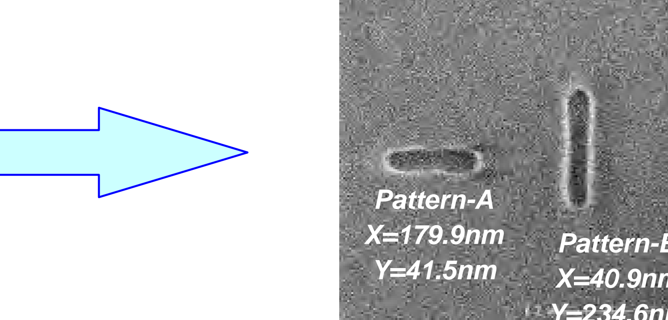
➢ ***Hole profile was effectively repaired by DSA shrink process.***

Blend DSA Shrink and Repair for Various Patterns

- Blend DSA reduce hole size with maintaining the shape of guide pattern.
- Blend DSA also work for pattern repair as well as size shrink.

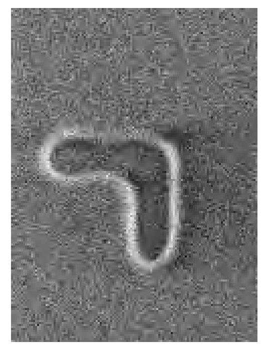
✓ Elongated CH Shrink

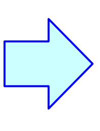




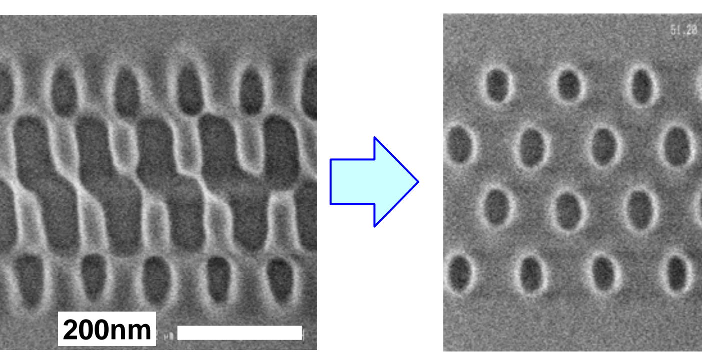
A:X/Y=4.4, B:Y/X=5.7

✓ L-plate trench



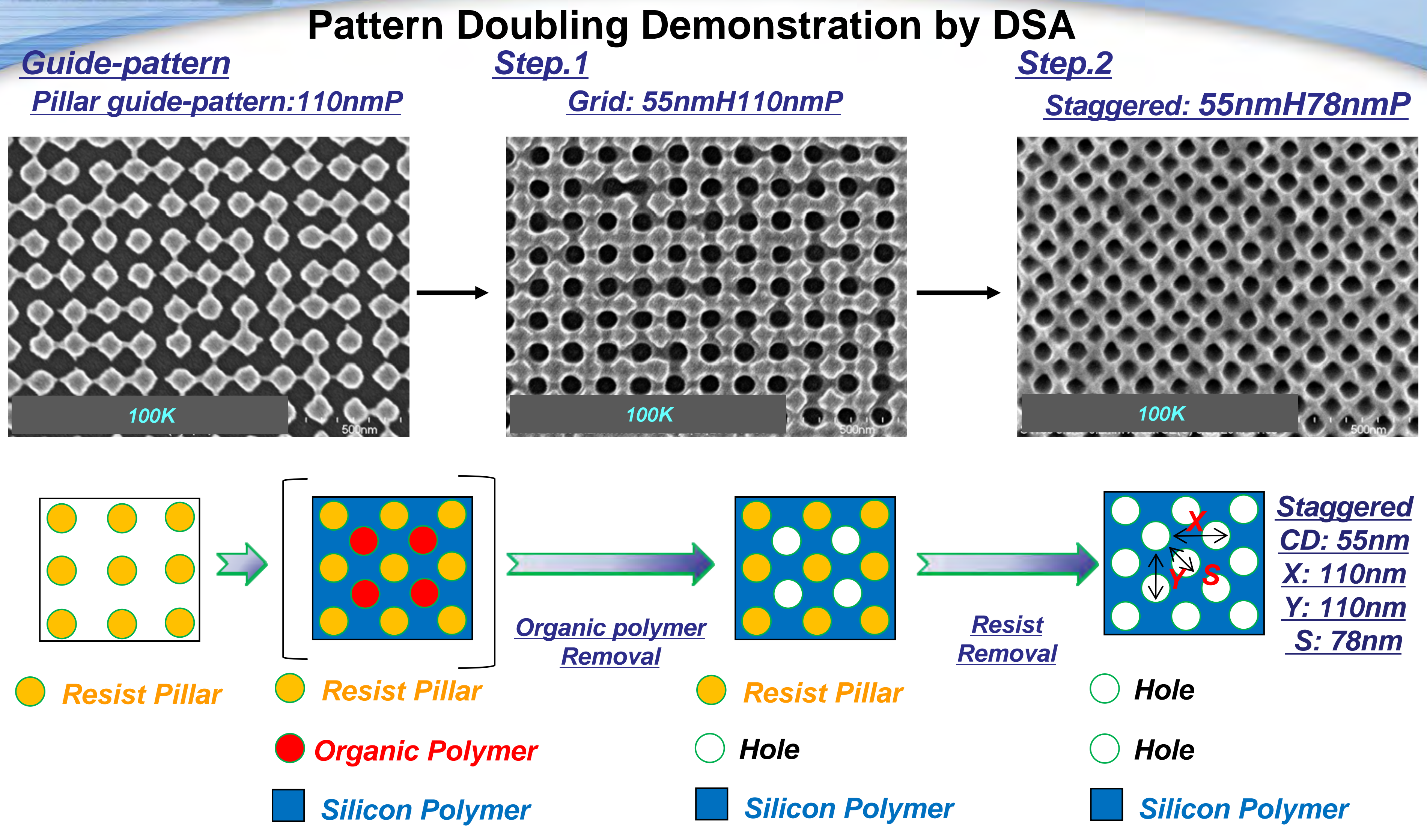


✓ Oval hole repair



Pattern Doubling Process by DSA shrink

Pattern Doubling Demonstration by DSA



➢ *Pattern doubling by polymer blend DSA was demonstrated.*

CH Shrink by Block-co-Polymer

CH Shrink by PS-b-PMMA

- 80nmCH was shrunk to CD=20nm hole with PS-b-PMMA.
- Metal contents of DSA solution: less than 2ppb.
  - Li, Na, Mg, Al, K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, Zr, Pb

Resist

NL

SiARC

Organic Hard Mask

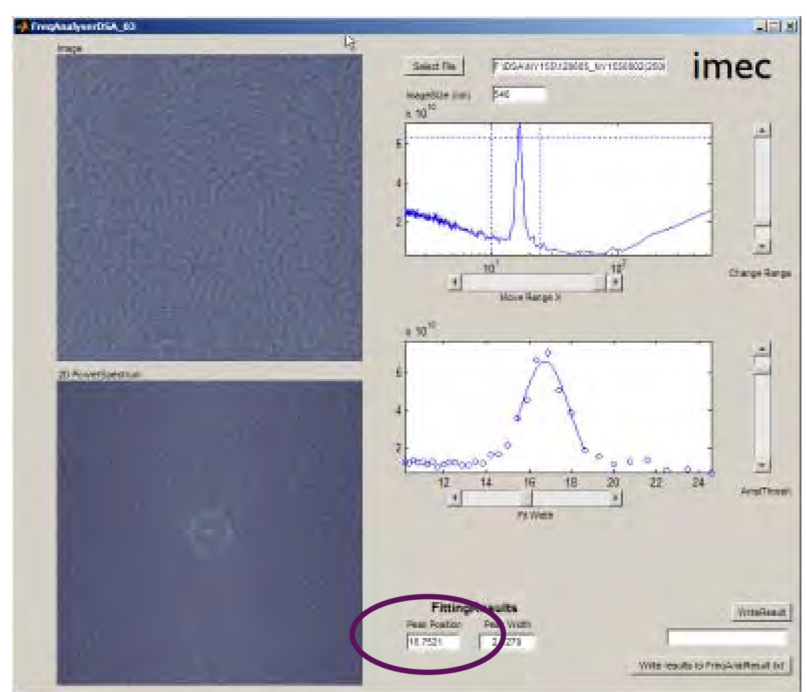
Polymer Coating /Annealing (250C/300s)

PMMA development

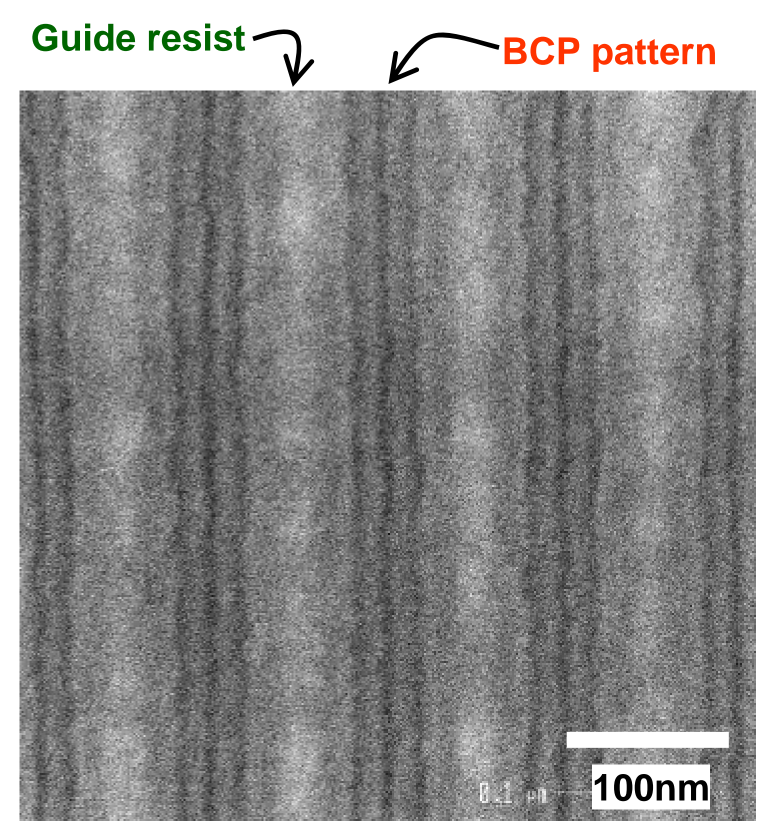
Beyond PS-b-PMMA

High χ Materials for Fine Patterning

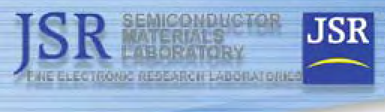
- **8.4nm line pattern was formed with high χ block-co-polymer BCP at 220C60s anneal under air.**



L_0=16.75nm



Anneal condition
Bake: 220C60s
Atmosphere: Air



Summary

- **Blend DSA was applied for sidewall L/S pitch splitting, hole pattern shrink, hole pattern repair, and hole pattern doubling process.**
- **"EUV + DSA" was examined to prove DSA can support EUV.**
- **BCP DSA is also used for CH shrink.**
- **Post PS-b-PMMA material was developed to form 8.4nmLS pattern.**

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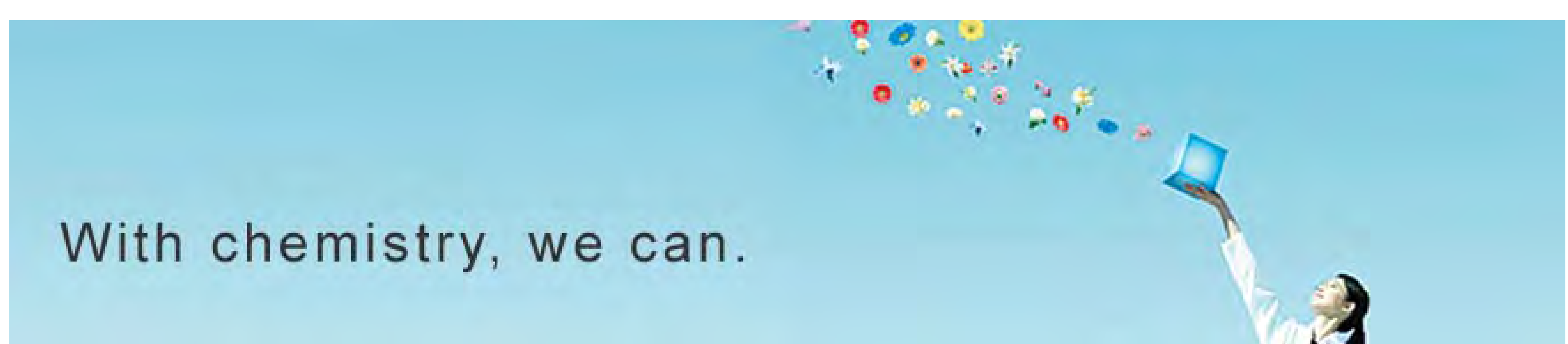
Thank you for kind attention !

We will develop materials

for expansion of industry



Thank you for your attention.