Novel resist System for EUV

- Small LER resist development -

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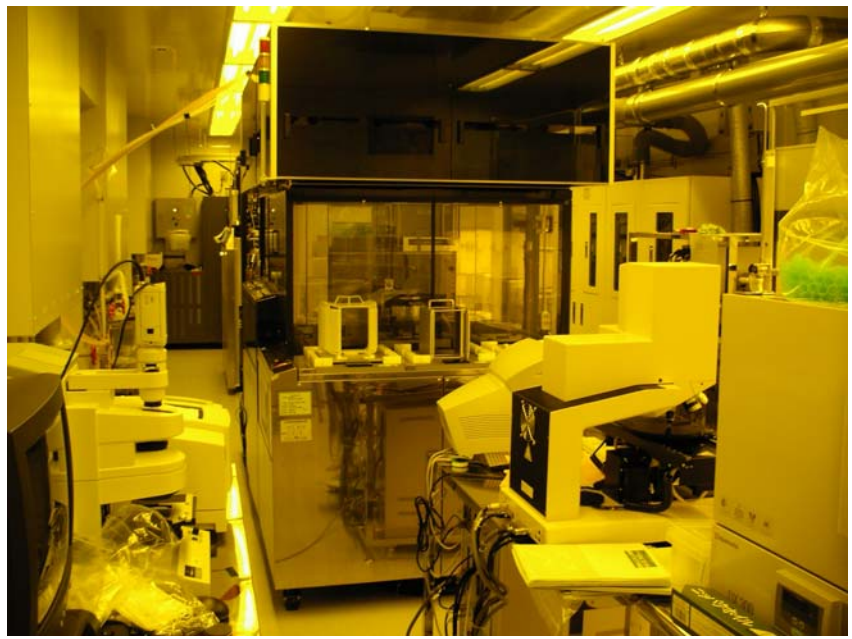
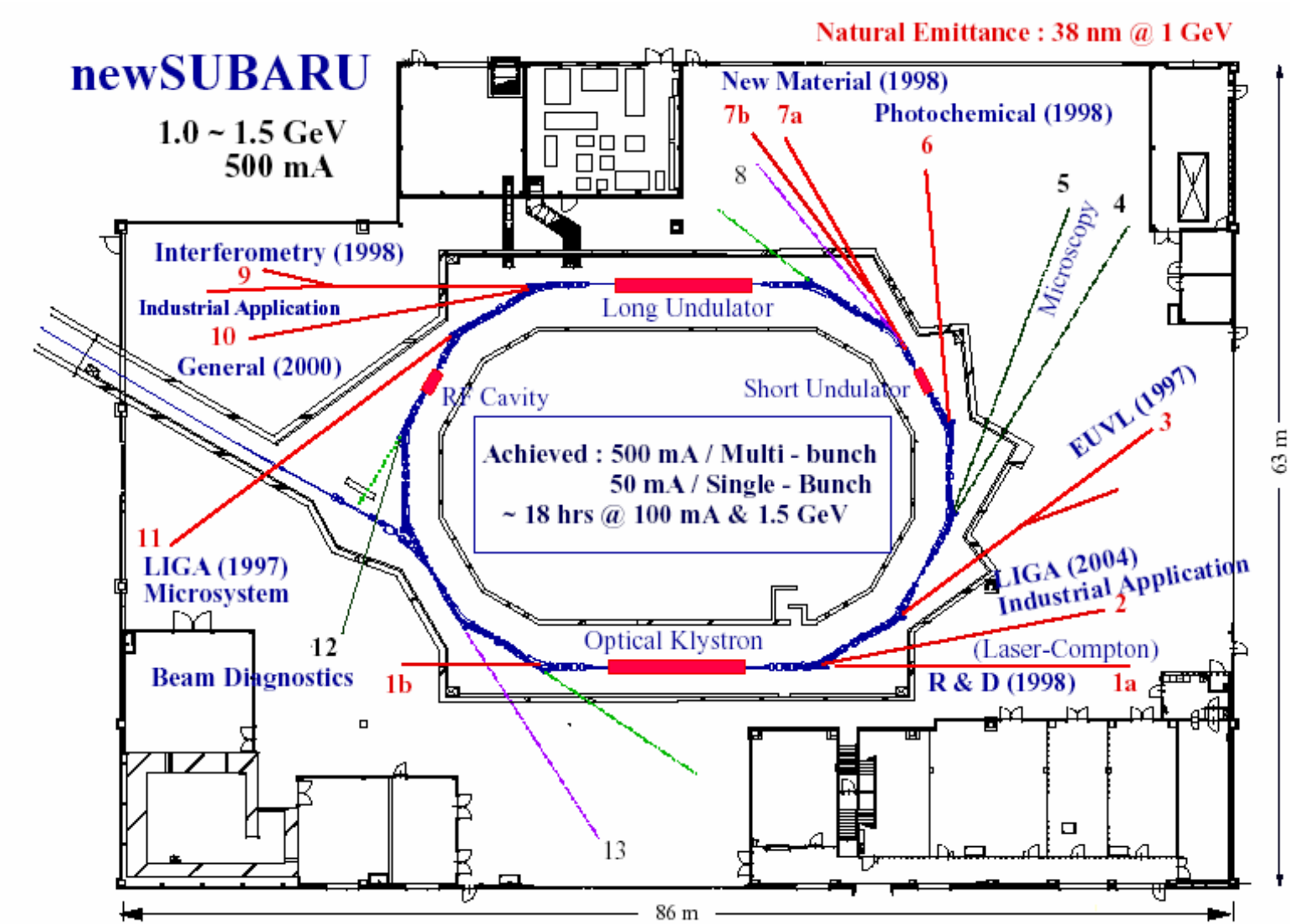
NewSUBARU Synchrotron Readiation Facility



NewSUBARU Synchrotron Facility



EUVL technology development at NewSUBARU

1) EUV Resist Development

High sensitivity resist and small LER resist for 32-nm node

2) EUV mask defect inspection

At wavelength EUV microscope

3) Contamination

Outline

1. Introduction

2. Development of PAG bonded CA resist

3. Exposure characteristics under EUV and EB exposures

4. Conclusions

2005 ITRS Goals for EUV Resist and Current Best Performance

Specification	2005 ITRS Pre-production for 2011	Current Best Performance*
Resolution 1:1 (nm)	32	35
Resolution isolated lines (nm)	21	N/A
Low frequency LWR (nm, 3 σ)	1.7	6.4
Photospeed, EUV (mJ/cm^2)	5–15	11
Ougassing rate for 2 minutes under the lens (molecules/cm^2-sec)	< 5E+13	N/A

*Data courtesy of AMD/Lawrence Berkeley National Labs (LBNL) exposed on the SEMATECH 0.3 numerical aperture microexposure tool at LBNL. The wafers were exposed using Y-monopole illumination.

ITRS: *International Technology Roadmap for Semiconductors*

By Kim Dean, SEMATECH

Advantage of high sensitivity EUV Resist

Required power of EUV light source is affected by a resist sensitivity.

Resist sensitivity	EUV Power@IF
10 mJ/cm^2	180 W
5 mJ/cm^2	115 W
2 mJ/cm^2	36 W

Status of EUV light source

< Specification > 115 W @IF, Rep Freq. > 7kHz

< Current status >

1) Discharge Produced Plasma (DPP)

DPP Power 30W ~ 80W@IF

(XTREME, Philips Extreme UV)

2) Laser Produced Plasma (LPP)

LPP Power 10W@IF

Cymer developed a novel Debris reduction method

< Current issues >

- Power, stability
- High efficient collector mirror and increasing lifetime
- Debris reduction

High sensitivity resist for EUVL

Required power of EUV light source is affected by a resist sensitivity.

Resist sensitivity	Power@IF
10 mJ/cm^2	180 W
5 mJ/cm^2	115 W
2 mJ/cm^2	36 W

Beneficial PAG for EUV resist → **Increase acid generation quantum efficiency**

High sensitivity ⟷ **Outgassing**

Trade off

EUV Resist Issues

Specification of 32 nm node

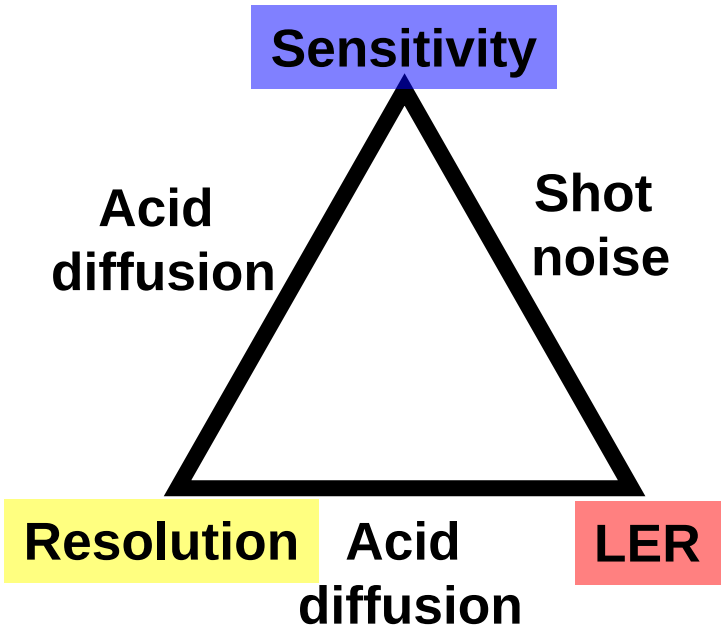
Resolution (Gate) 15 nm

Dense pattern 50 nm HP

Sensitivity ≦ 2 ~ 5 mJ/cm^2

LER ≦ 1.2 nm (3σ)
LWR ≦ 1.7 nm (3s)

Total Outgas ≦ 5×10^{13} molecules/cm^2/s



Development of LER reduction and high sensitive resist is most significant issue.

Advantage of EUV resist material selection

- Do not have limitation of the material selections
- It’s a chemist’s wonderful time to go on stage to develop an EUV resist
- Wide material selectivities
  Novolak, PHS, Methacrylate
- Etching selectivity
  Benzyl group

Mitigation to develop high sensitivity and small LER EUV CA resist

For 32 nm node, chemically amplified (CA) resist is necessary.

a) Polymer

・ Low outgassing

T. Watanabe, et al., *J. Vac. Sci. Technol.* B**19**, 736 (2001) 742.

T. Watanabe, et al., *J. Photopolym. Sci. and Technol.* **14** (2001) 550

・ Main chain decomposition type - methacrylate type -

T. Watanabe, et al., *J. Photopolym. Sci. Technol.* **17** (2004)362.

b) Solvent - low outgassing material -

T. Watanabe, et al., *Jpn. J. Appl. Phys.* **43** (2004)3713.

c) Photoacid generator (PAG)

・ Increasing acid generation efficiency → small LER, high sensitive

Multiple acid generation

T. Watanabe, et al., *Jpn. J. Appl. Phys.* **44** (2005) 5866.

・ Uniform PAG density

T. Watanabe, et al., *J. Photopolym. Sci. Technol.* **19** (2006) 521.

Increasing Sensitivity and Reduction Method of LER

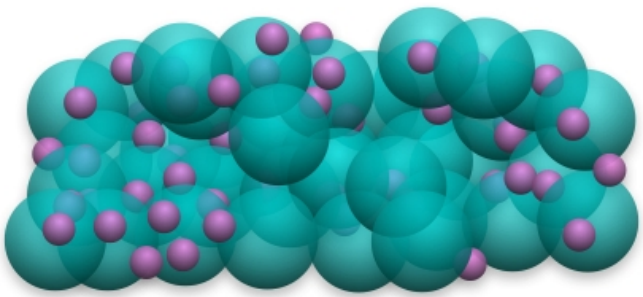
Increasing sensitivity

- optimization of absorption of PAG
- increasing acid production efficiency
- increasing deprotection reaction efficiency

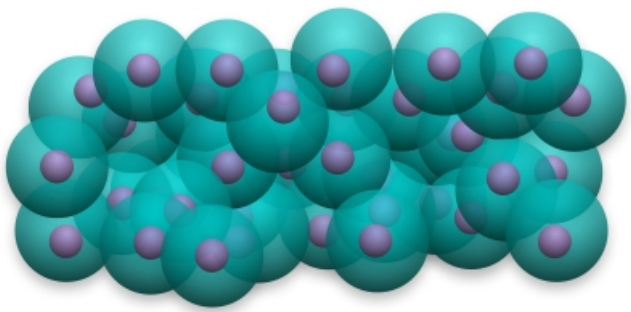
Reduction method of LER

- low molecular weight
- narrow dispersion polymer
- uniform PAG density

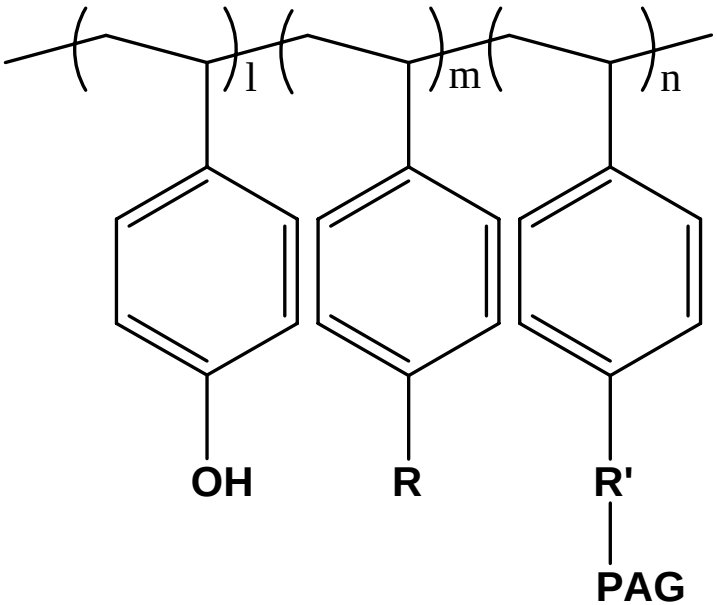
PAG blended polymer



PAG bonded polymer

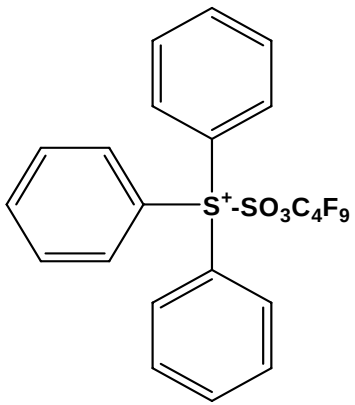


Structure of PAG Bonded Polymer



R;protection group

PAG;



	Protection group	PAG
Resist A	30.6mol%	1.63mol%
Resist B	30.8mol%	0.6mol%
Resist C	Conventional CA resist	

Mw=16400
Mw/Mn=1.085

Resist Process Conditions

Substrate	Si wafer
Solvent	PGMEA
Resist thickness	100 nm
Prebake	90 ~ 130℃ 90 s
PEB	90℃ 60 s (resist A and B)
	110℃ 90 s (resist C)
Development	TMAH 2.38% 23℃ 30 s
Rinse	De-ionized water 23℃ 30 s

Evaluation of resist characteristics under EUV and EB exposures

1) EUV exposure
   - Sensitivity
   - Outgasssing

     Resist evaluation system in NewSUBARU BL3

2) Electron beam exposure
   - LER

     EB direct writing system

     Acceleration voltage 30 kV

     EB direct writing system

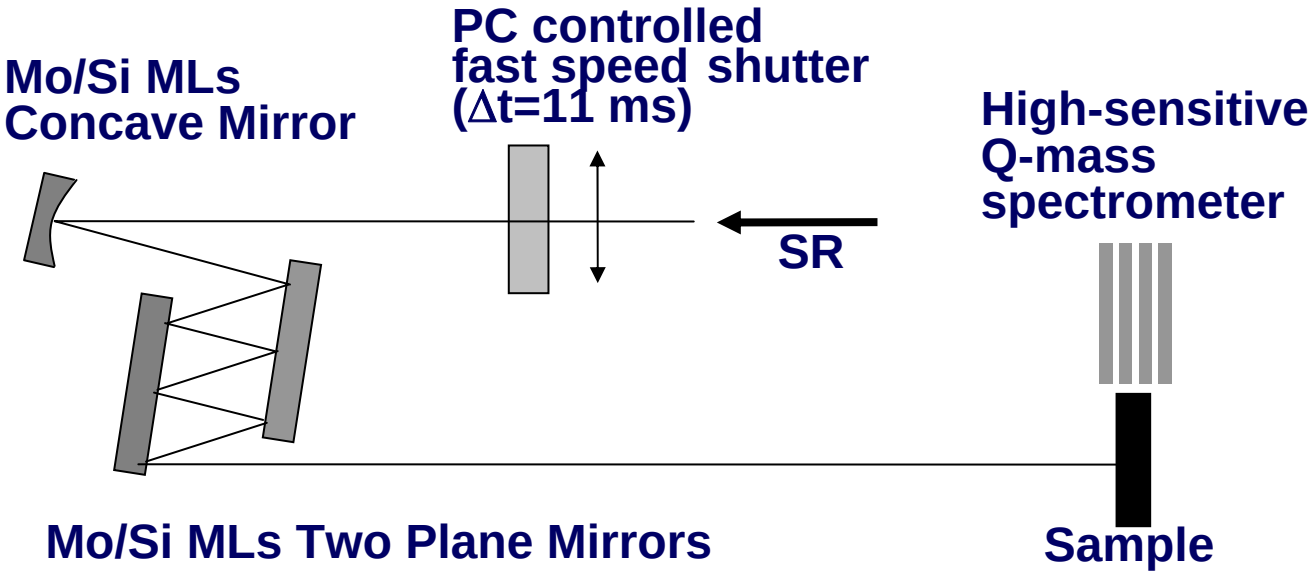
     Acceleration voltage 50 kV

Setup of resist evaluation system

Simulating six-mirror optics

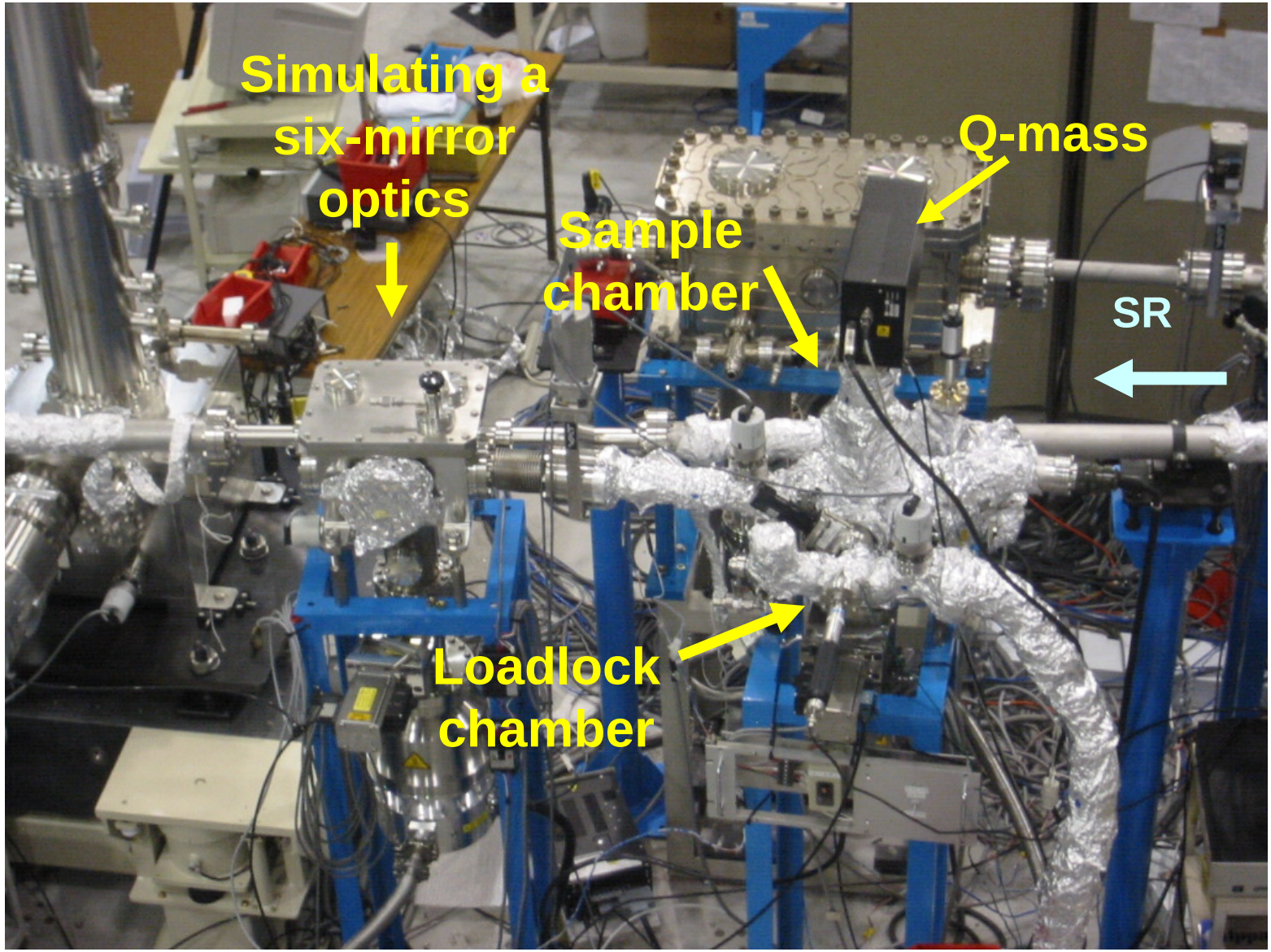
↓

Practical exposure spectrum

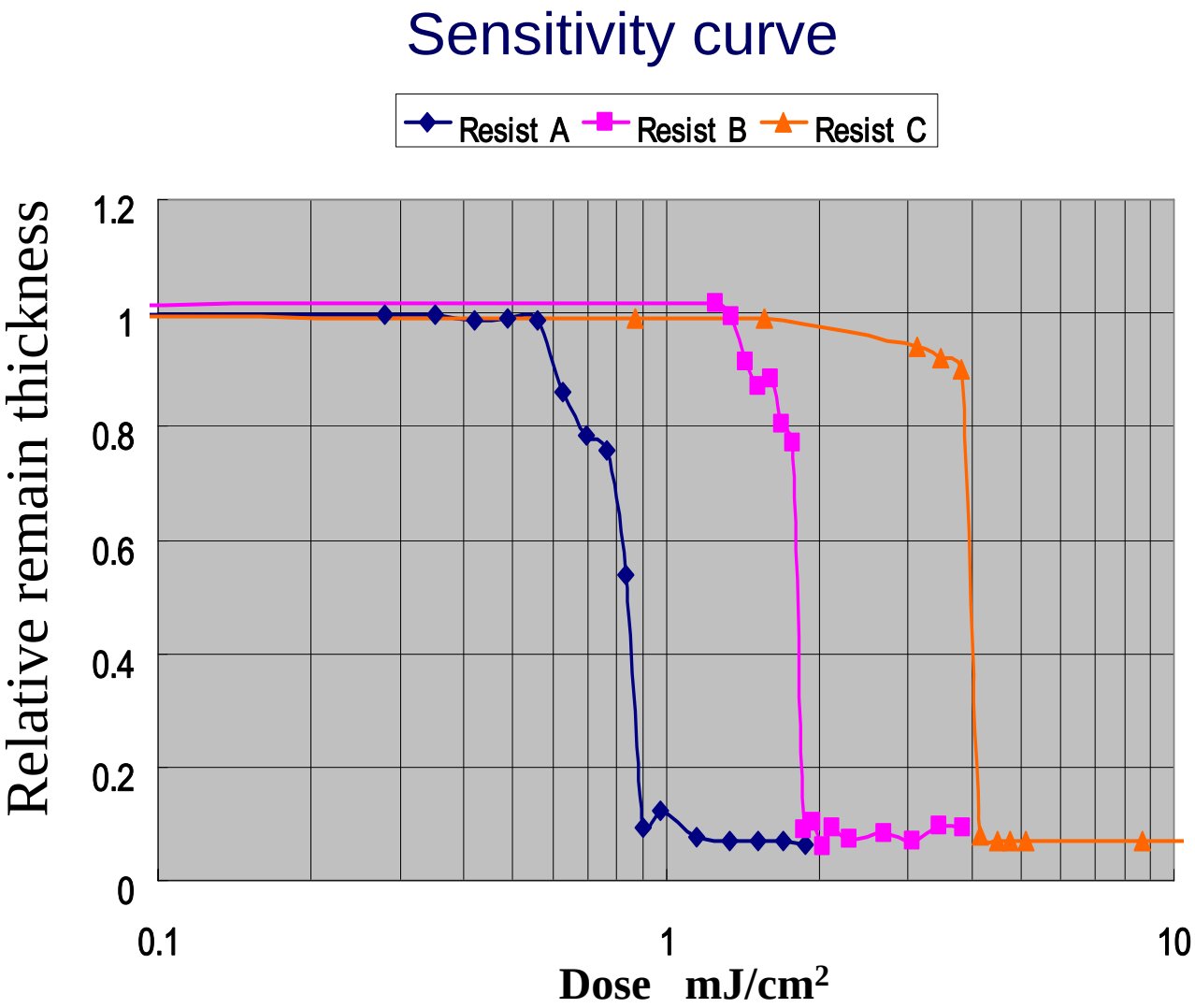


1) Measurements of sensitivity
2) Outgassing characteristics
3) Internal chemical behavior analysis

Photograph of resist evaluation system

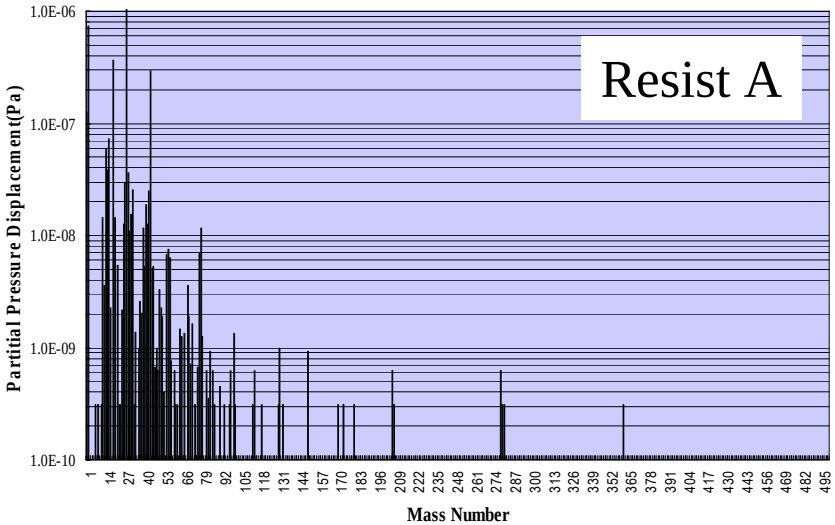


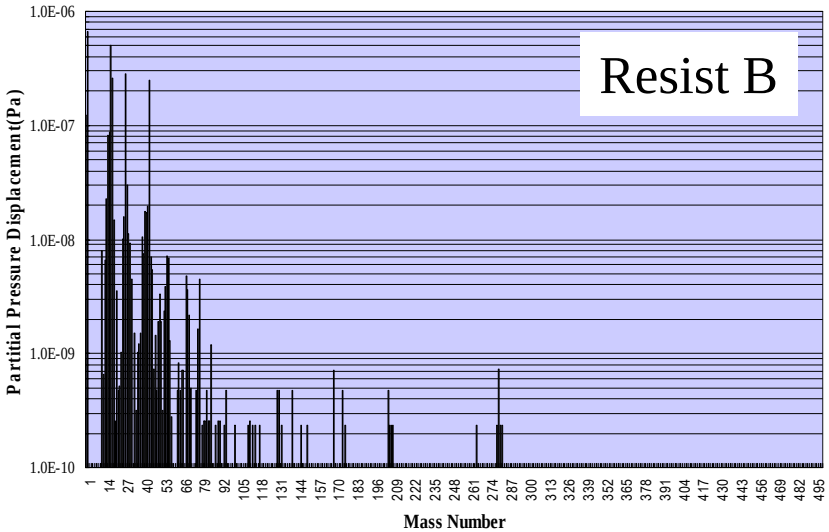
Sensitivity under EUV exposure

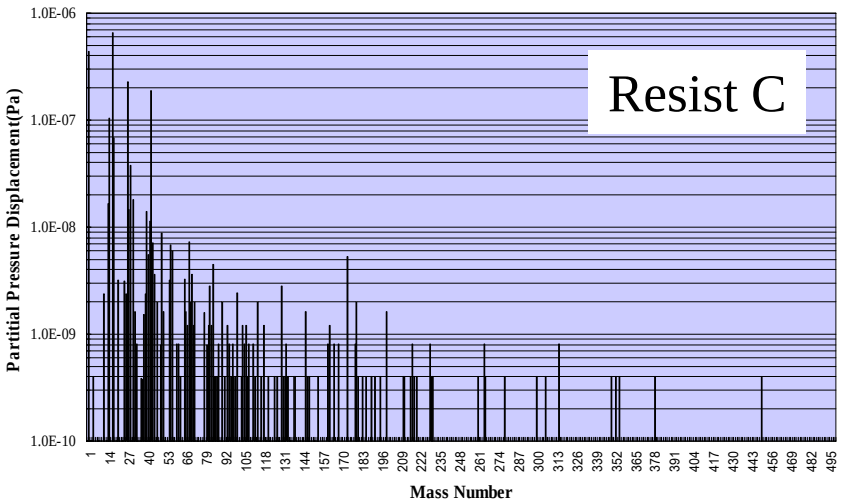


	E_0 sensitivity
Resist A	0.9mJ/cm^2
Resist B	1.9mJ/cm^2
Resist C	4.1mJ/cm^2

Outgassing measurement results under EUV exposure

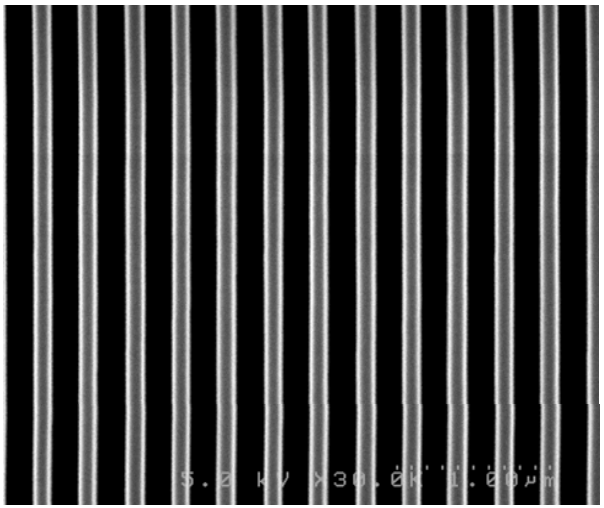


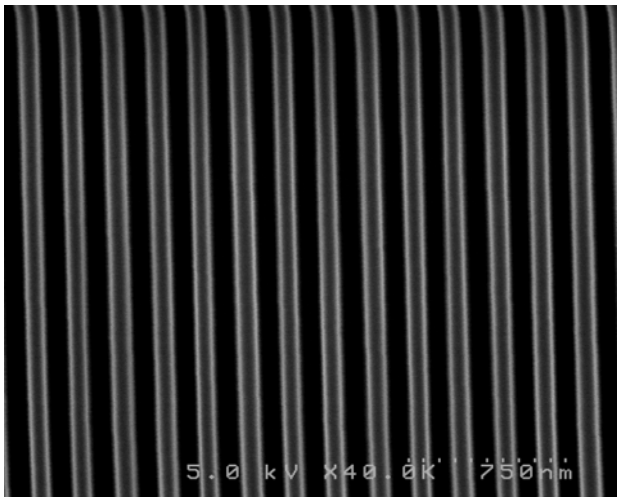


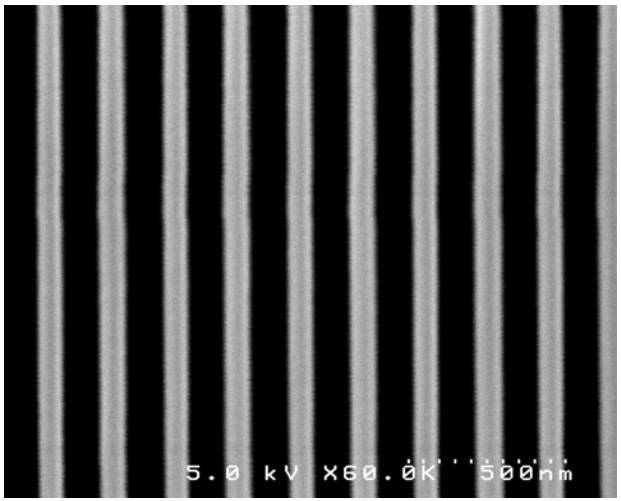


Resist A < Resist B < Resist C

EB evaluation result







Resist A

LER=2.0 nm
CD=120 nm
6.4 $\mu C/cm^2$

Resist B

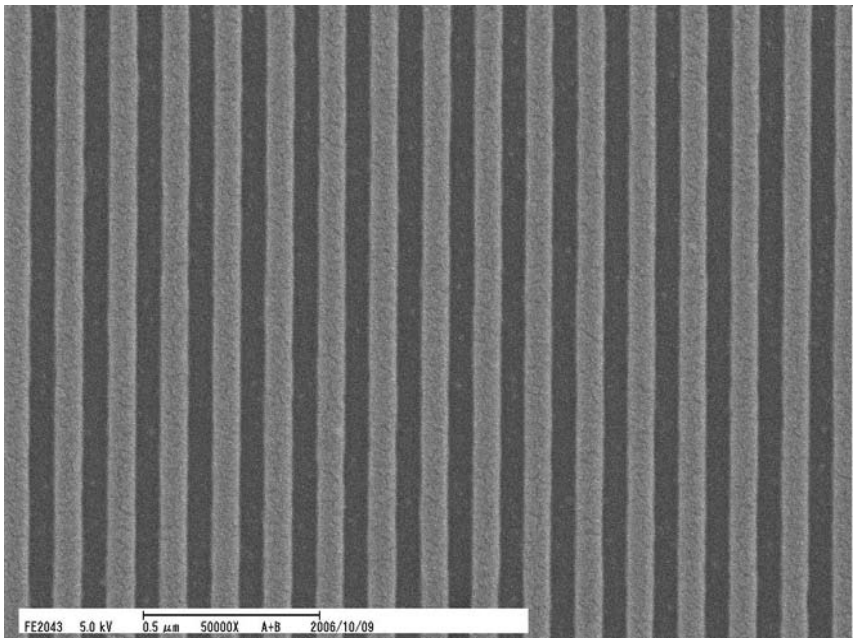
LER=2.1 nm
CD=100 nm
14.4 $\mu C/cm^2$

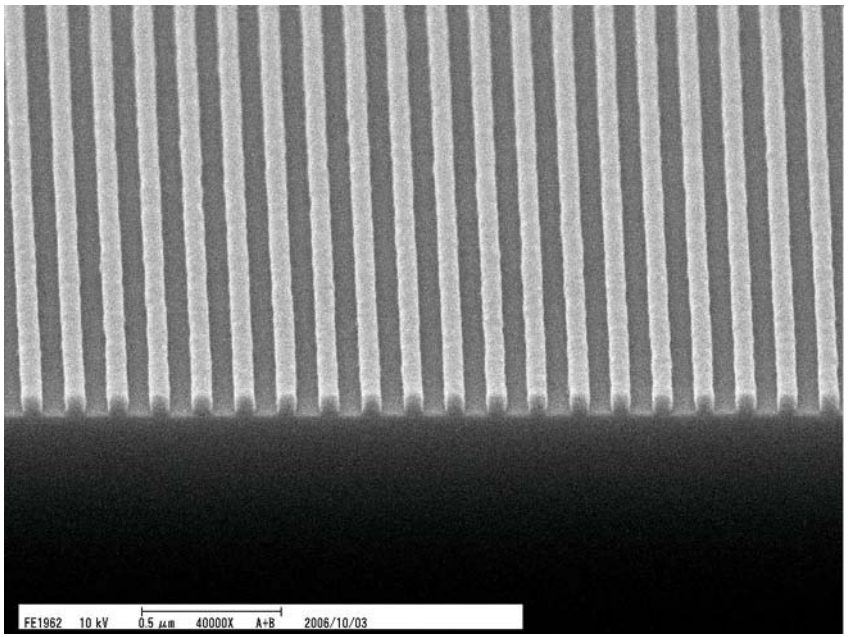
ZEP520A

LER=5.0 nm
CD=100 nm
184 $\mu C/cm^2$

Exposure characteristics (1/2) Resist D

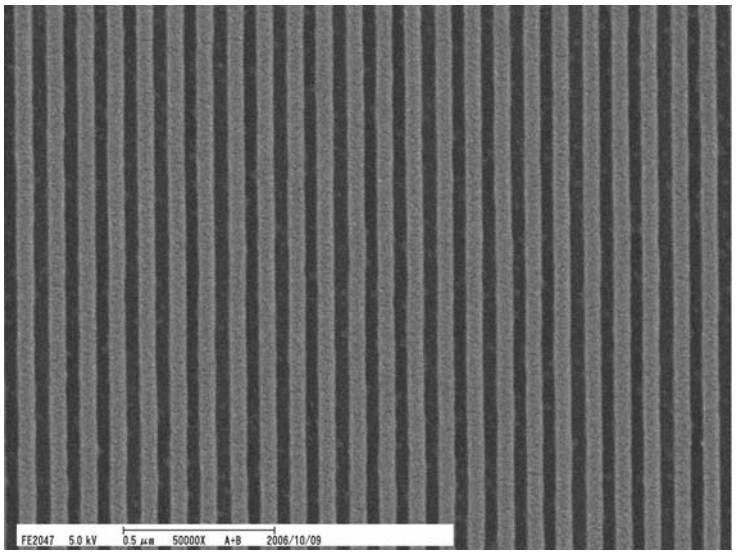
75 nm L/S pattern



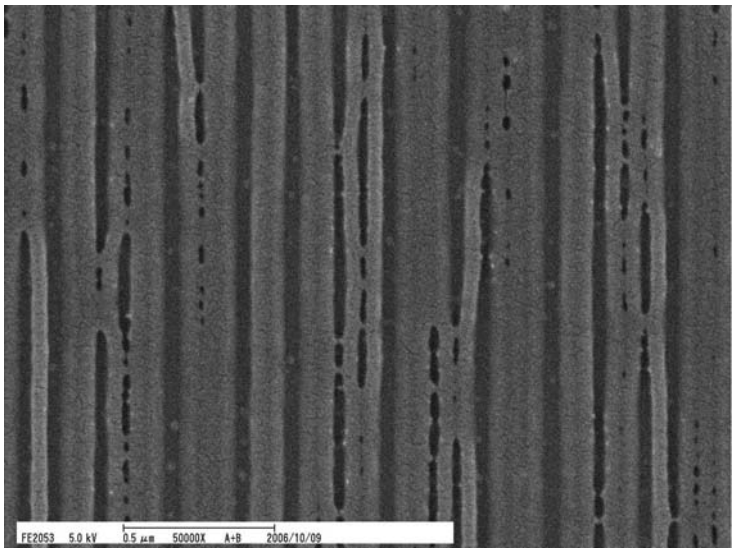


100 nm^{t}

Exposure characteristics (2/2) Resist D



50 nm L/S



30 nm L/S

100 nm^{t}

Conclusions

- CA resist with side chain PAG polymer system was designed to reduce line edge roughness and increase sensitivity for a resist in extreme ultraviolet lithography.

- CA resist with side chain PAG polymer system has good advantage for a low LER resist.

- Since efficiency of deprotection reaction in PAG bonded polymer is higher than that in PAG blended polymer, sensitivity of PAG bonded resist is higher than that of PAG blended resist.

We have to make a big effort in the individual field and part to meet the schedule !!

Resist
Source
Mask

Thank you for your attention !!