Development of Chemically Amplified EUV resist for 22 nm half pitch and beyond

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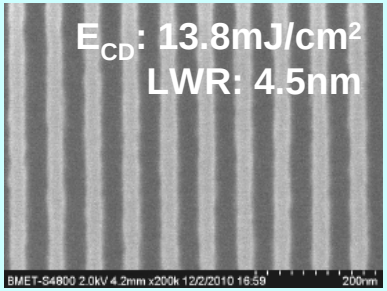
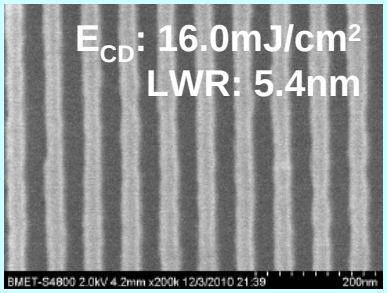
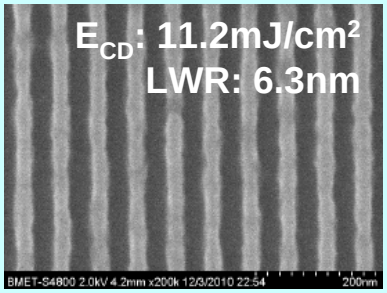
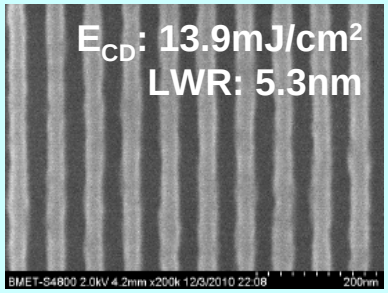
- **Summary**

Background

- ✓ Recently, OOB sensitivity has become a key metric.
- ✓ OOB can negatively impact resolution, LWR, and profile.
- ✓ Therefore, new materials may be required to alleviate OOB impact.

	JSR STD EUV PR 1	***JSR STD EUV PR 2***
	PHS/Methacryl Hybrid	***PHS/Methacryl Hybrid***
EUV		
EUV + OOB		
	ΔE_{CD}: 18.8%	**ΔE_{CD}: 13.1%**

OOB : 181-205nm, 10% dose of EUV E_{CD}

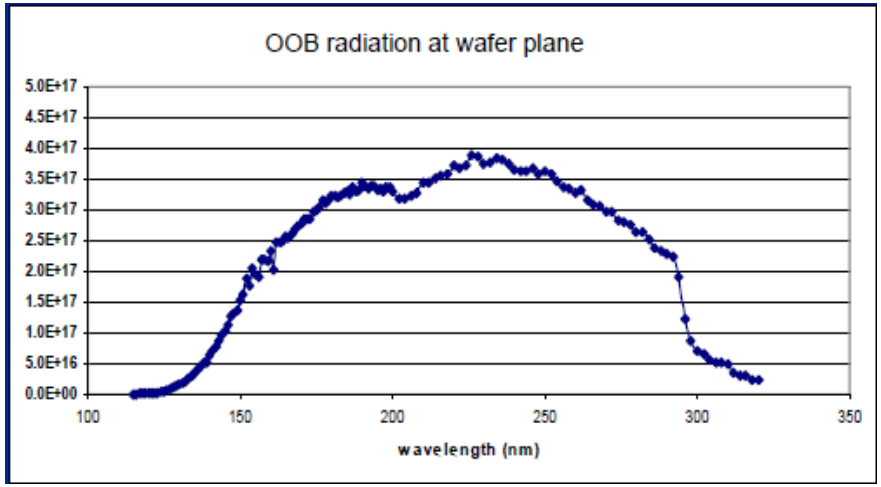
OOB exposure and EUV imaging performed at LBNL

Objectives

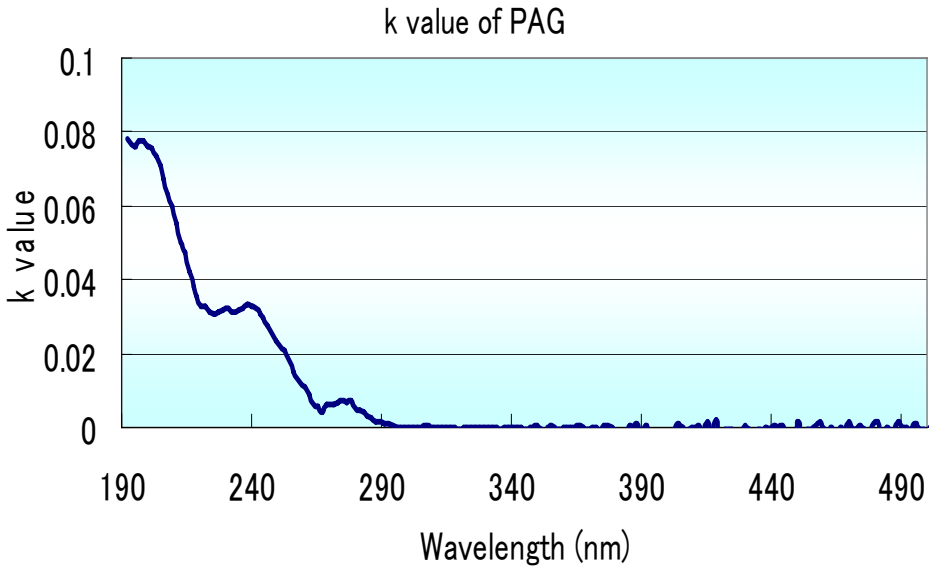
- To investigate the relationship between resist materials and OOB sensitivity.

- To develop EUV chemically amplified resists that show less OOB sensitivity and develop new processes for further OOB sensitivity reduction.

OOB Spectra: Absorption of Resist Materials



EUVL Symposium, Nov. 1- 4, 2004

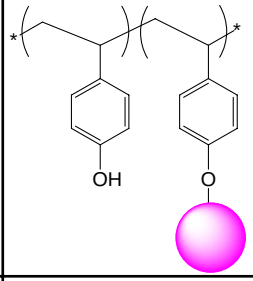
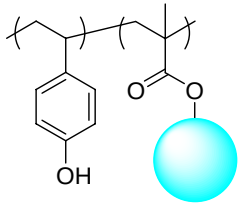
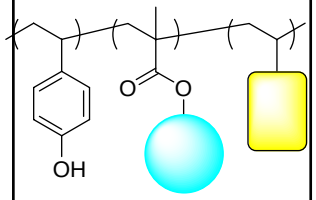
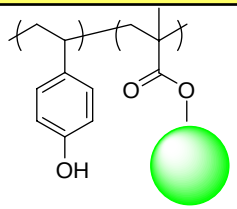
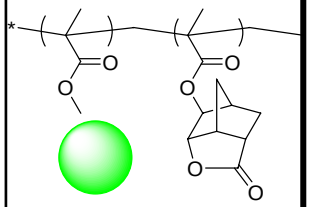
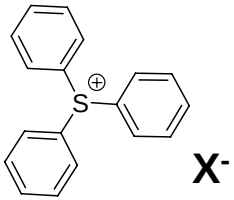


Absorption spectra of Triphenylsulfonium PAG

EUV standard PAG is sensitive to OOB, therefore, EUV resist design should include:

- ❑ PAG with insensitivity to OOB
- ❑ Modified polymer dissolution contrast properties w/ reduced OOB sensitivity
- ❑ Develop an absorber material to cut OOB

OOB sensitivity Measurement (1)
- Material-

	PHS	Hybrid 1	Hybrid 1 + Fluorinated	Hybrid 2	Methacryl
Polymer					
PAG					

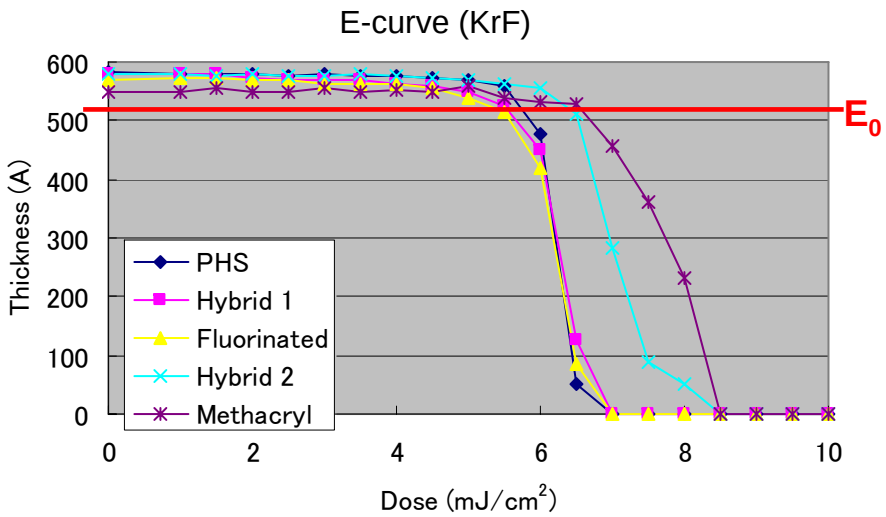
Several resist formulations based on different types of polymer platforms were prepared and investigated for sensitivity to OOB

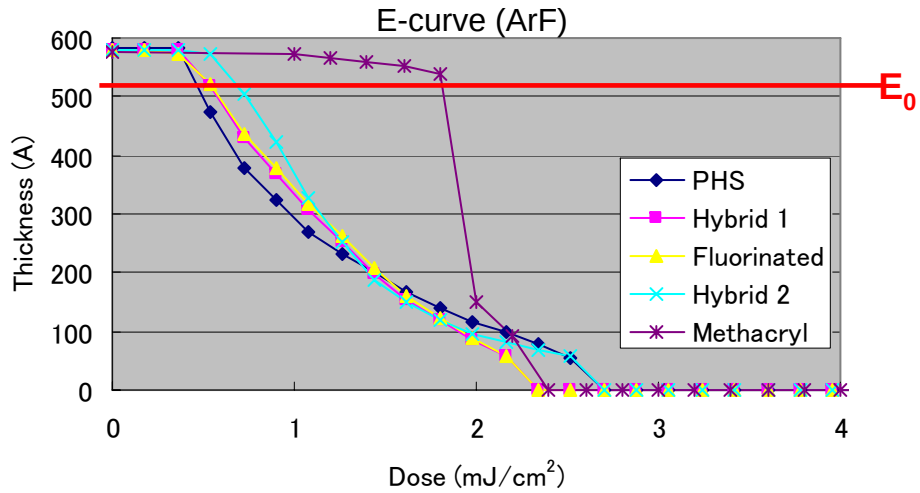
OOB sensitivity Measurement (2)
- Evaluation Condition -

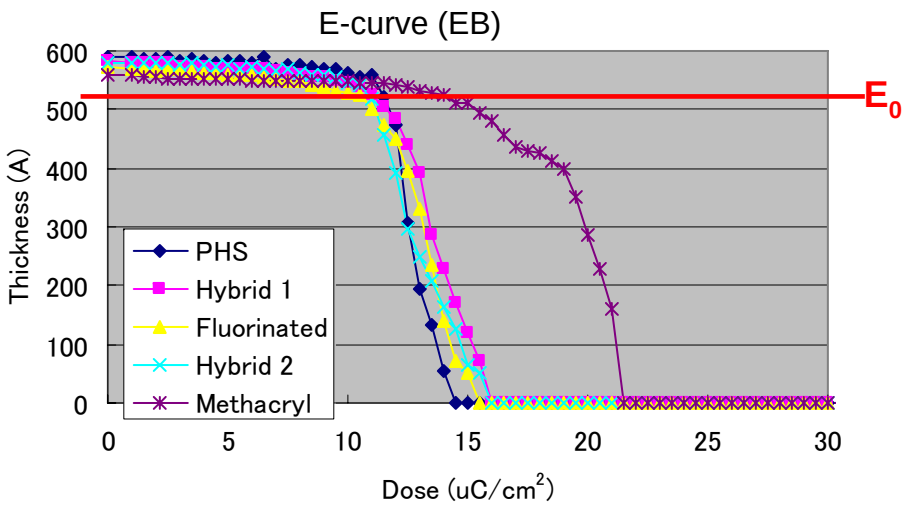
- Substrate: Org. BARC (60 nm, 205ºC / 60s)
- PR FT: 60 nm
- PR Soft Bake 130ºC / 60s
- Exposure: Nikon S203B (KrF)
  Nikon S306C (ArF)
  Hitachi HL800D (EB)
- PEB: 120ºC / 60s
- Dev.: 2.38wt%TMAH / 60s, DIW-Rinse / 15s
- E_0: Dose at 10% film thickness loss

E_0 was defined at 10% film thickness reduction because several test samples showed scumming due to high absorption – rendering difficulty in determining dose to clear.

OOB sensitivity Measurement (3)
- E-curve -



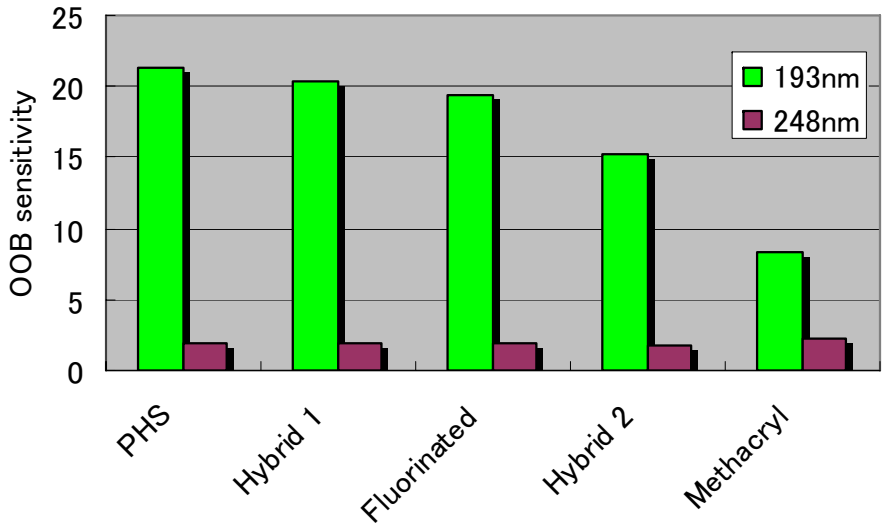




OOB Sensitivity Measurement (4)

- OOB Sensitivity -

Sample	E_0 (ArF) mJ/cm^2	E_0 (KrF) mJ/cm^2	E_0 (EB) uC/cm^2	OOB (193)	OOB (248)	OOB (DUV)	k(193)	k(248)
PHS	0.54	6	11.5	21.3	1.9	3.5	0.168	0.006
Hybrid 1	0.54	5.5	11	20.4	2.0	3.6	0.773	0.008
Fluorinated	0.54	5.5	10.5	19.4	1.9	3.5	0.717	0.008
Hybrid 2	0.72	6.5	11	15.3	1.7	3.0	0.136	0.004
Methacryl	1.8	6.5	15	8.3	2.3	3.6	0.002	0.0004

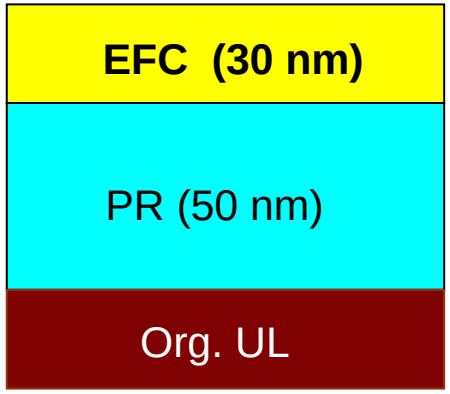


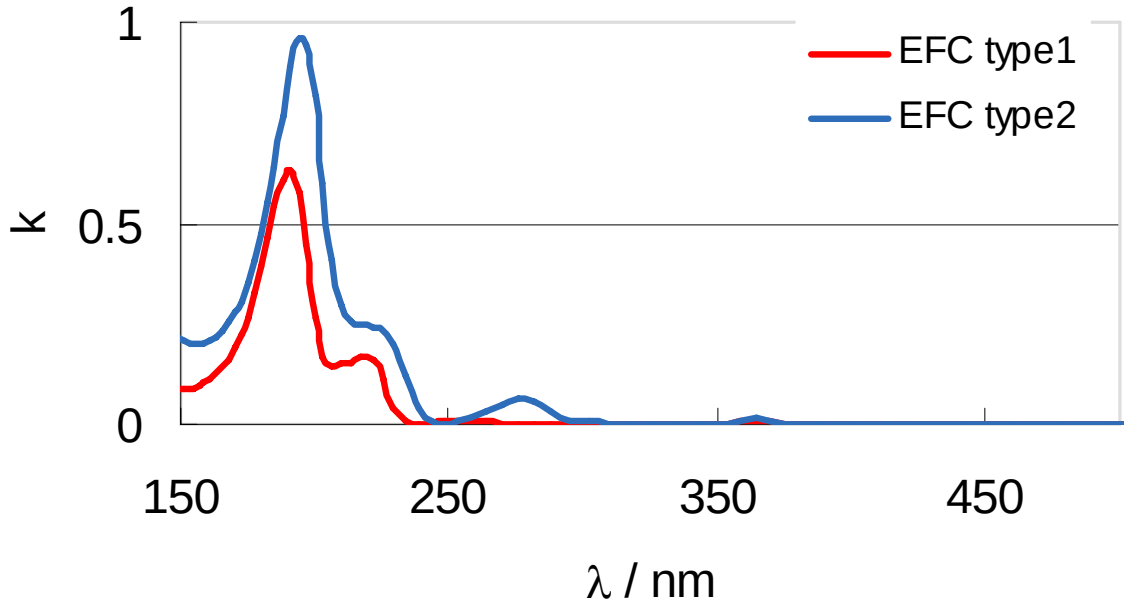
OOB(193) = E_0(EB) / E_0(ArF)
OOB(248) = E_0(EB / E_0(KrF)
OOB(DUV) = E_0(EB) / (E_0(ArF)+E_0(KrF)/2)

- EUV resists are more sensitive to ArF light than KrF.
- Methacryl platform is less sensitive against ArF exposure

EFC (EUV Filter Coating) (1)

JSR is now developing EFC (Top Coat type material) to reduce OOB sensitivity





Calculated EUV transmittance (30nmFT) is 90% (Type1), 83% (Type2), respectively.

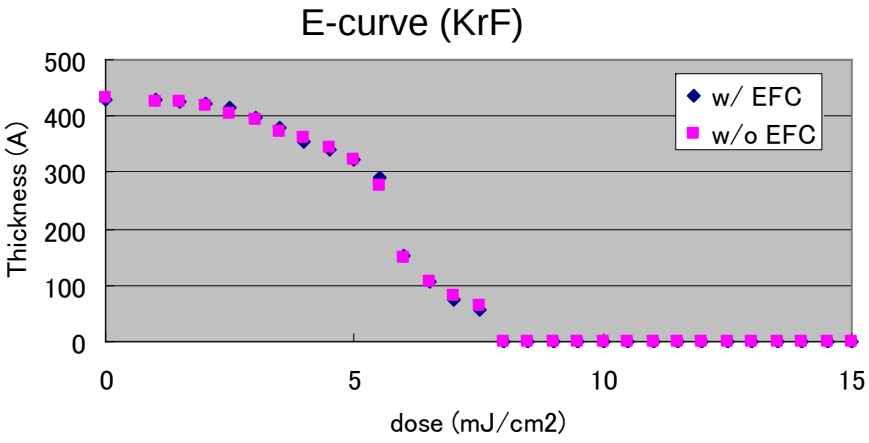
http://henke.lbl.gov/optical_constants/filter2.html

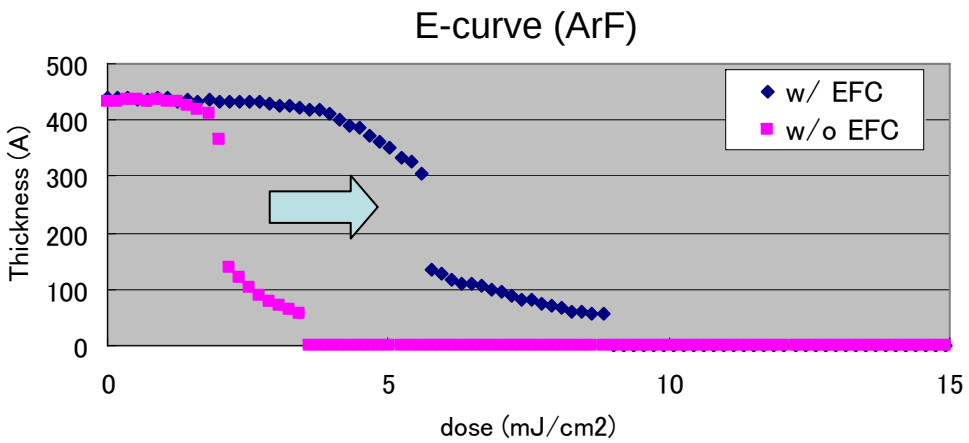
EFC (EUV Filter Coating) (2)
- Development Status -

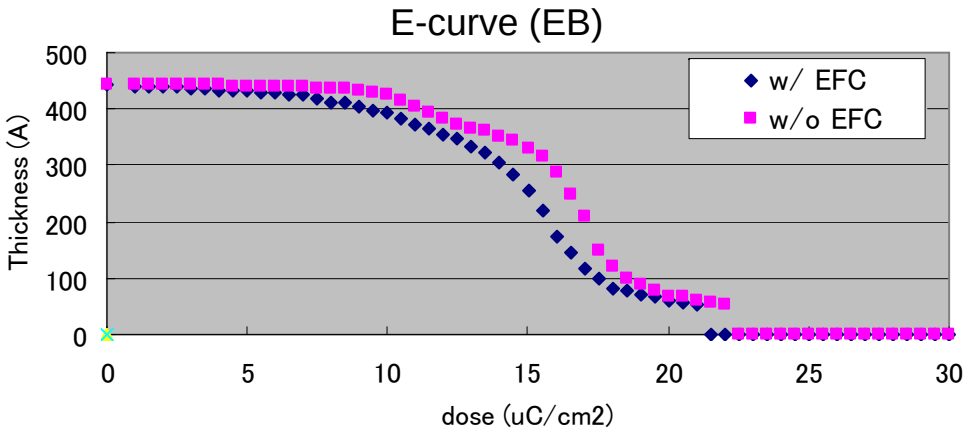
Target	EFC Type1		EFC Type2	
High transparency @ EUV	☹	83% @ 30nmFT	☺	90% @ 30nmFT
High absorbance @ OOB wavelength (150-300nm)	☺	High Abs. 150nm – 230nm	☺	Higher Abs. 150nm – 230nm
TMAH developable	☺	Good	☺	Good
Resist compatibility	☺	Both PHS and Acryl	☹	Acryl type only
No outgas		TBD		TBD
Outgas reduction		TBD	☺	1/10 less than w/o EFC

- EFC Type1 has wide resist compatibility, while EFC Type2 shows higher EUV transparency with higher absorbance at DUV
- OOB sensitivity and EUV exposure of EFC Type 1 was investigated

EFC (EUV Filter Coating) (3)
- KrF, ArF E-Curve -







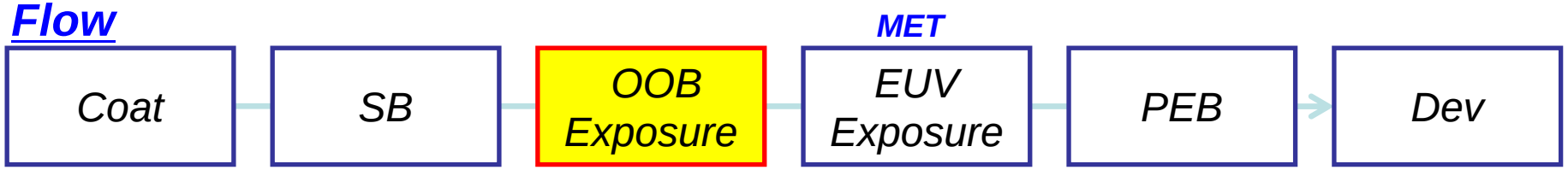
EFC : Type1 (30nm thickness)
Resist : Methacryl type (45nm thickness)

EFC type1 shows significant low ArF sensitivity due to its high Absorption at 193 nm

EFC (EUV Filter Coating) (4)
- EUV Exposure Condition -

- Substrate: org. UL (20nm, 205ºC / 60s)
- PR: Methacryl type, FT 50 nm
- PR Soft Bake: 130ºC / 60s
- EFC: EFC type1, FT 30nm
- EFC Soft Bake: 110ºC / 60s
- OOB: 10% of EUV Center Dose (Wavelength 181 nm-205 nm)
- Exposure: LBNL MET, 0.30NA, Rot. dipole
- PEB: 110ºC / 60s
- Dev.: 2.38wt%TMAH / 60s, DIW-Rinse / 15s

Flow



Wavelength: 181 - 205nm
Dose: 10% of EUV Center Dose

EFC (EUV Filter Coating) (5)

Sample Sen.@36nmLS

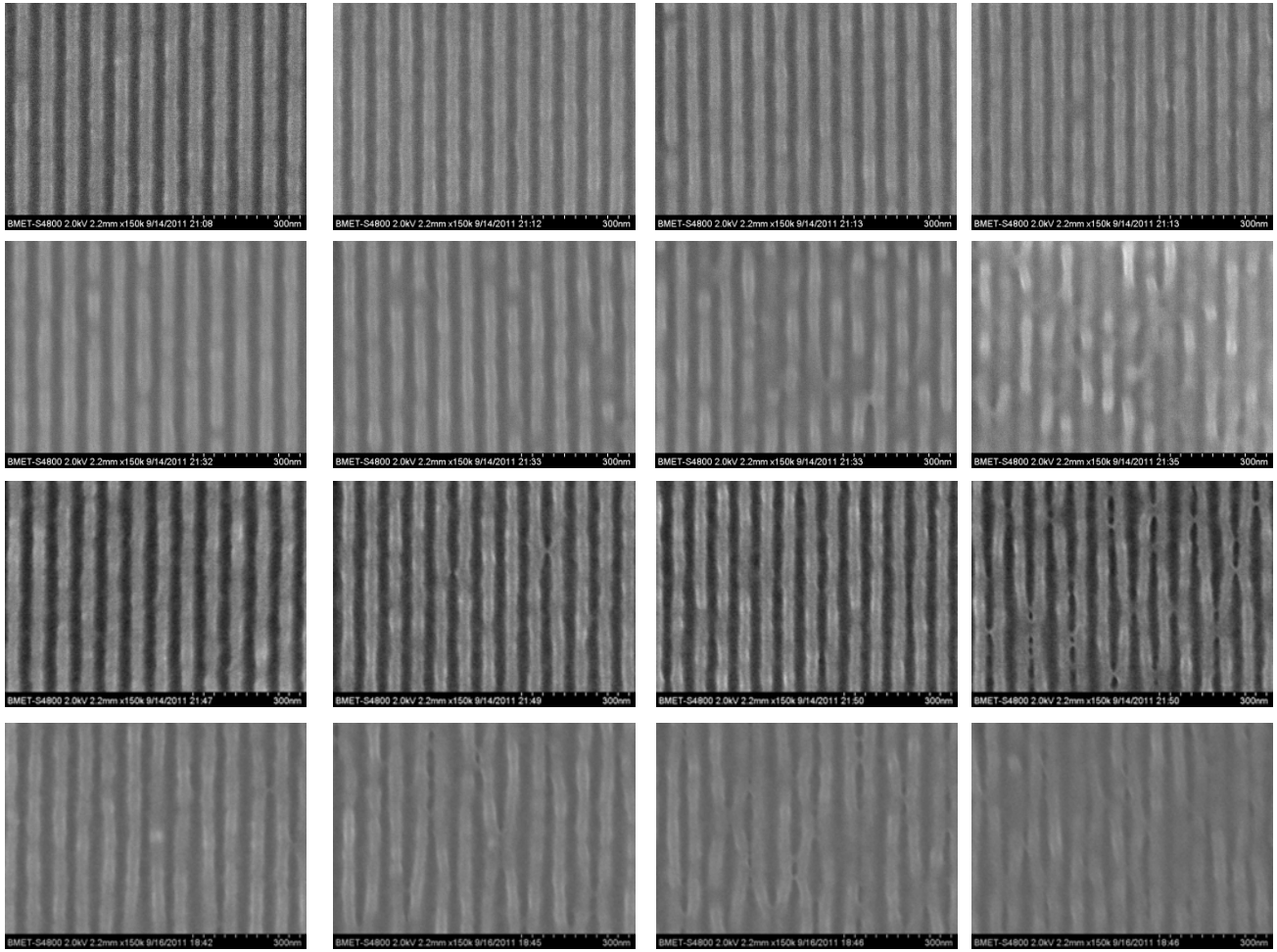
36nmLS **34nmLS** **32nmLS** **30nmLS**

w/o EFC
w/o OOB
9.78mJ/cm²

w/o EFC
w/ OOB
8.10mJ/cm²

w/ EFC Type1
w/o OOB
7.82mJ/cm²

w/ EFC Type1
w/ OOB
8.10mJ/cm²



Resist with EFC shows insignificant sensitivity shift by irradiation of OOB demonstrates the effectiveness of EFC coat for blocking OOB

Summary

- **OOB sensitivity of various types of resist platforms were measured. Methacryl platforms show less OOB sensitivity over PHS types.**

- **Newly developed Top Coat material, EFC has several good performance related properties:**
  - **High transparency to EUV light**
  - **High absorption to OOB light**
  - **Compatibility to various resist types**

- **OOB exposure and EUV imaging experiments performed at LBNL confirmed the effectiveness of EFC for blocking OOB radiation. Further evaluation of EFC will be continued to understand how OOB affects the EUV resist lithographic performance.**

Acknowledgement

- Advanced Light Source (LBNL)

- Sematech Resist and Materials Development Center (RMDC)