Ultrathin EUV Underlayer Materials: Stability, Coating Uniformity, Defect, and Resist Performance

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Abstract

Bottom anti-reflective coatings are widely used to control reflectivity driven pattern fidelity in i-line, DUV exposures. While no such reflectivity control is required at EUV wavelengths, it has been demonstrated that use of EUV underlayer (EBL) coatings with high EUV photon absorption (EPA) unit can improve resist performance such as sensitivity, resist-substrate poisoning thereby improving resolution and process window[1-2]. They can also control out-of-band (OoB) irradiation. AZ® EBL materials provide among others good storage stability, capability to coat ultra thin (5nm) films with low or no coating defects yet maintain same or better resist performance. In this paper we discuss coating uniformity, defects, lithographic performance of AZ® EBL105 coating at 5nm film thickness using SOKUDO coating tools and ASML NXE:3100 exposure tool targeting 27nm HP.

1. H. Yao, S. Mullen, Z. Bogusz, J. Cho, M. Padmanaban, *J. Photopolym. Sci. Tech. Vol.25, No. 2 pp647-654 (2012).*

2. H. Yao, Z. Bogusz, J. Shan, J. Cho, S. Mullen, G. Lin, M. Neisser *Proc. SPIE 7972* (2011) 7672-38.

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Contents

- **Introduction to EUV photon absorption (EPA) underlayer materials**
- **EUV underlayer development based on organic BARC platform**
- **AZ® EBL105A coating uniformity & stability studies**
- **AZ® EBL105A lithography performances on NXE:3100 Exposure Tool**
- **Recent Development of AZ® EBL materials**
  - ✓ Reduction of LWR by suppression of OOB radiation and using PAG additives
  - ✓ New Metallic EUV underlayer with high etch selectivity

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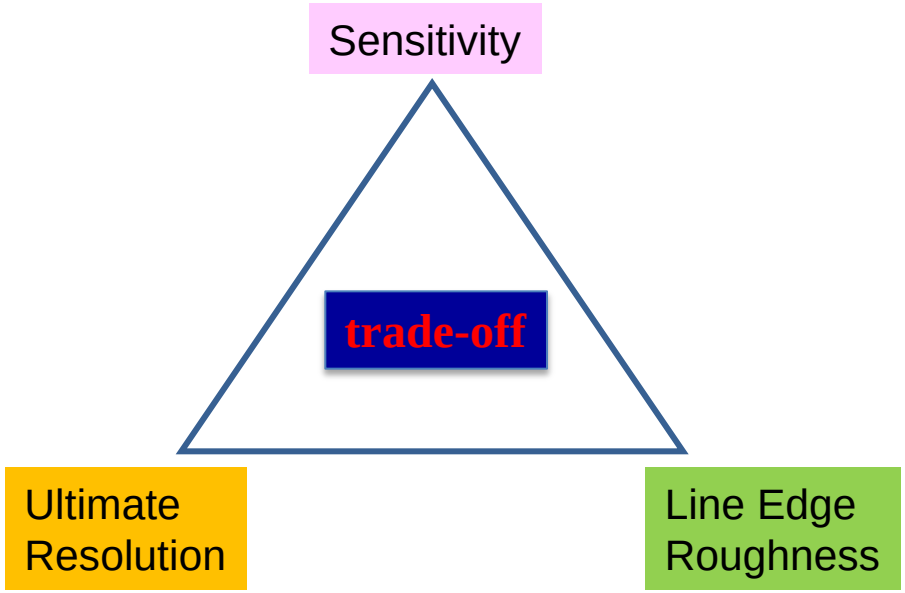
EUV Resist Challenges



Target Performances

Resolution < 22 nm HP
LWR < 3 nm
Sensitivity ~ 10mJ/cm^2

Aspect ratio < 2 (FT < 50 nm)

It is difficult to fulfill all of requirements for EUV litho performances simultaneously. Multilayer materials coupled with post-processing techniques will offer solutions likely.

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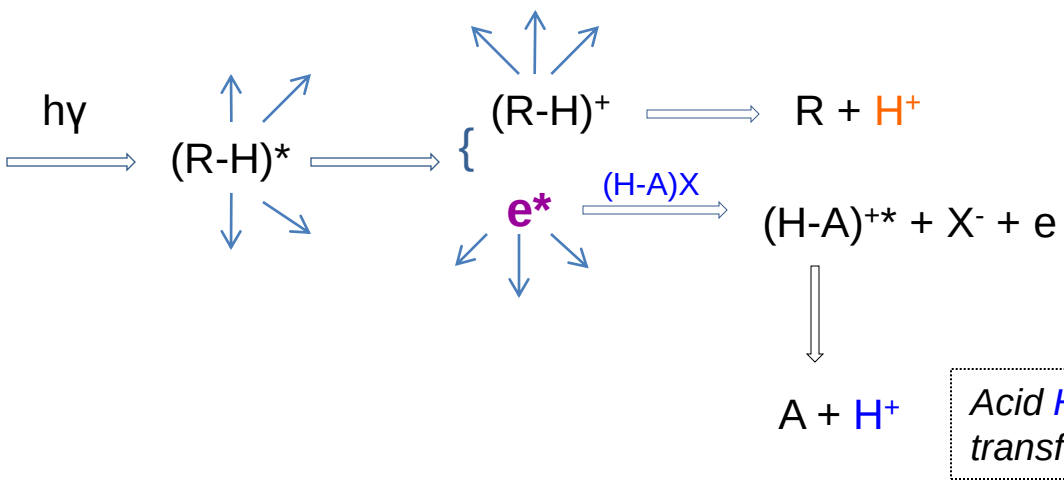
Photo acid generation during EUV exposure (simplified)

R-H = resist molecule (H-A)X = PAG

⇒ Path leading to acid formation



EUV absorption increases acid H^+ from ionization and amount of e (secondary electron)*

Acid H^+ generation via energy transfer from e to PAG*

High EUV absorption is required in resist and especially at the resist/substrate interface.

(R. Gronheid et.al. "EUV resist requirements: absorbance and acid yield" *Proc. SPIE 7273 7273-167*, **2009**)

High EUV absorption underlayer improves acid generation through energy and electron transfer from underlayer to resist.

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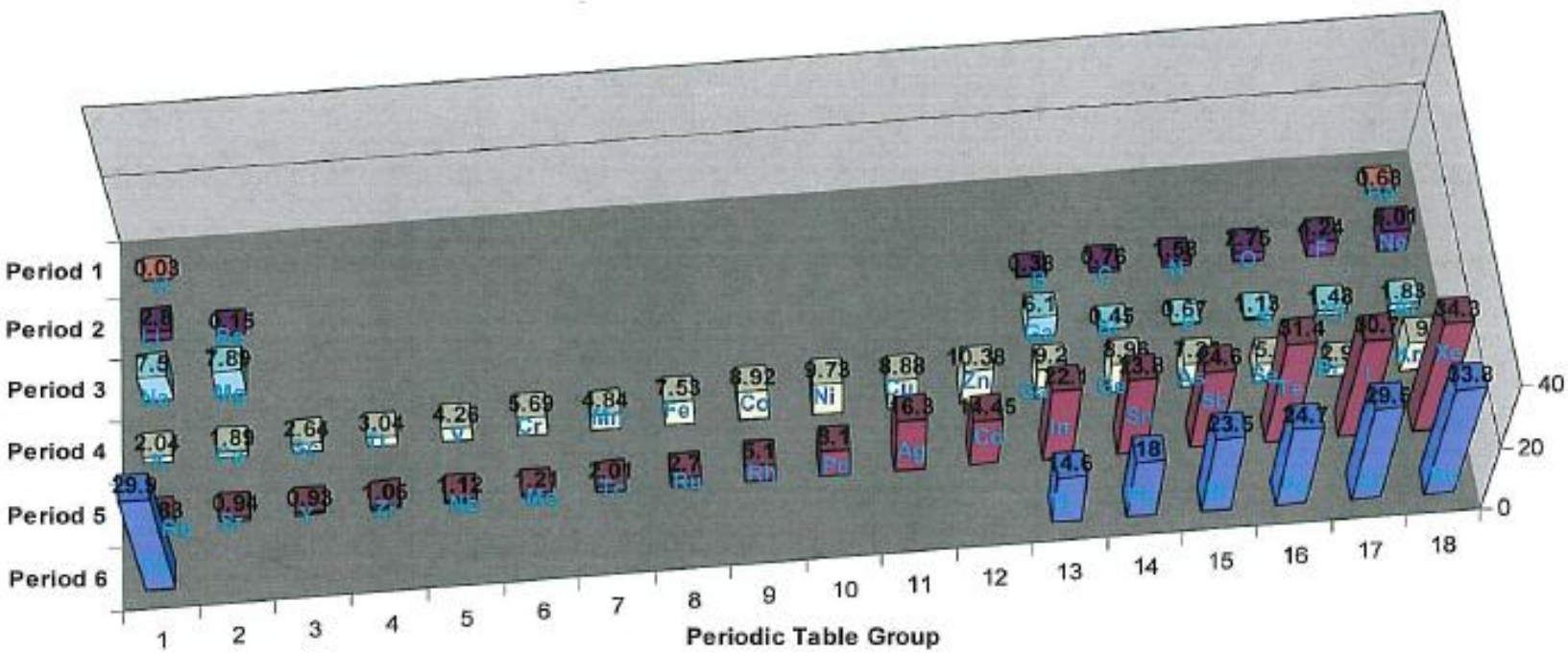
EUV Absorbance per gram of the material



Pratical choice for higher EUV absorbance are:
H/1(0.03)<C/12 (0.76) <N/14 (1.58)<O/16 (2.75) <F/19 (4.24) <Sn/118 (23.8) <I/126.9 (30.7) per gram or
H/1 (0.03) < C/12 (9.1) <N/14 (22.1) <O/16 (44.0) <F/19 (80.6) <Sn/118 (2808.4) <I/126.9 (3895.8) per mole

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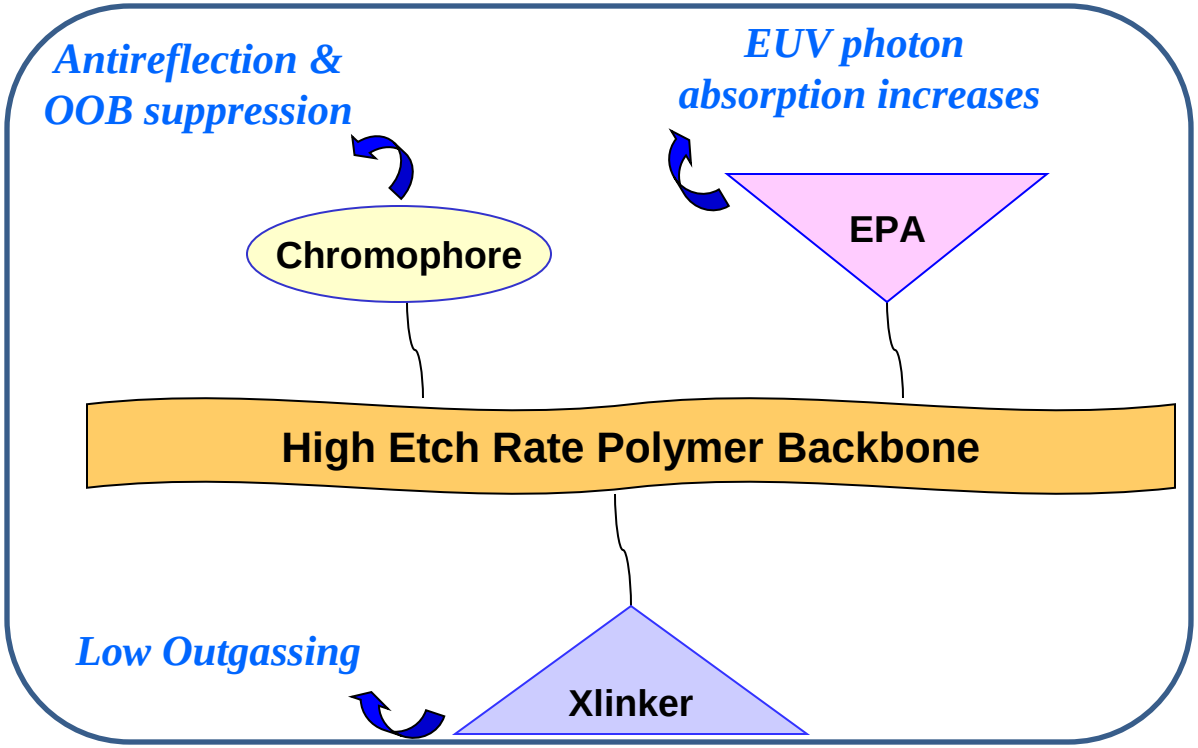
AZ®EBL aterials based on organic BARC platform

EPA unit has been incorporated in polymer structure



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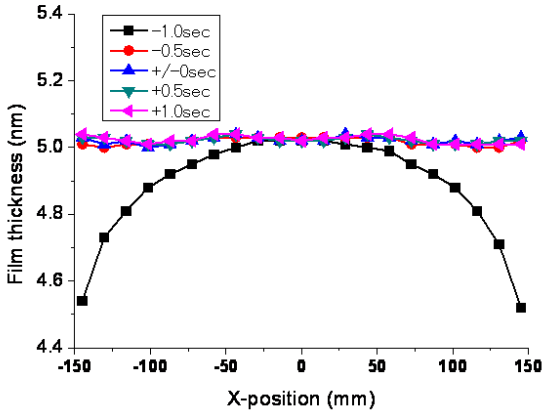
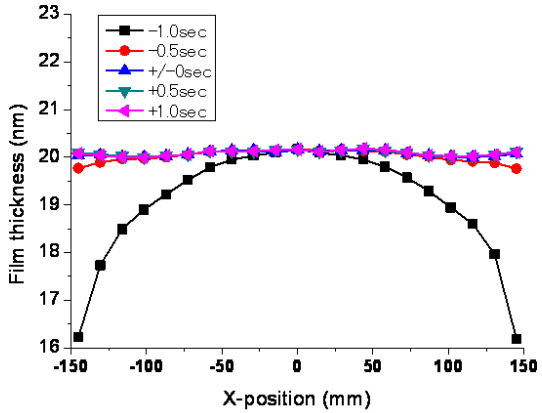
Minimum Dispense Volume

EBL105A Coating 5nm



Dispense Volume	FT mean (nm)	Range (nm)	3sigma (nm)
-1.0sec (0.3g)	4.89	0.489 (10.1%)	0.455
-0.5sec (0.5g)	5.02	0.033 (0.66%)	0.033
+/- 0sec (0.7g)	5.02	0.033 (0.66%)	0.026
+0.5sec (0.9g)	5.02	0.027 (0.54%)	0.026
+1.0sec (1.1g)	5.01	0.038 (0.76%)	0.036

EBL105A Coating 20nm



Dispense Volume	FT mean (nm)	Range (nm)	3sigma (nm)
-1.0sec (0.3g)	19.07	3.99 (20.9%)	3.58
-0.5sec (0.5g)	20.02	0.42 (2.10%)	0.38
+/- 0sec (0.7g)	20.08	0.15 (0.76%)	0.17
+0.5sec (0.9g)	20.09	0.18 (0.91%)	0.16
+1.0sec (1.1g)	20.09	0.19 (0.94%)	0.18

- **0.5g/wf is minimum based on Film thickness uniformity.**

***Final condition :0.7g/wf.**

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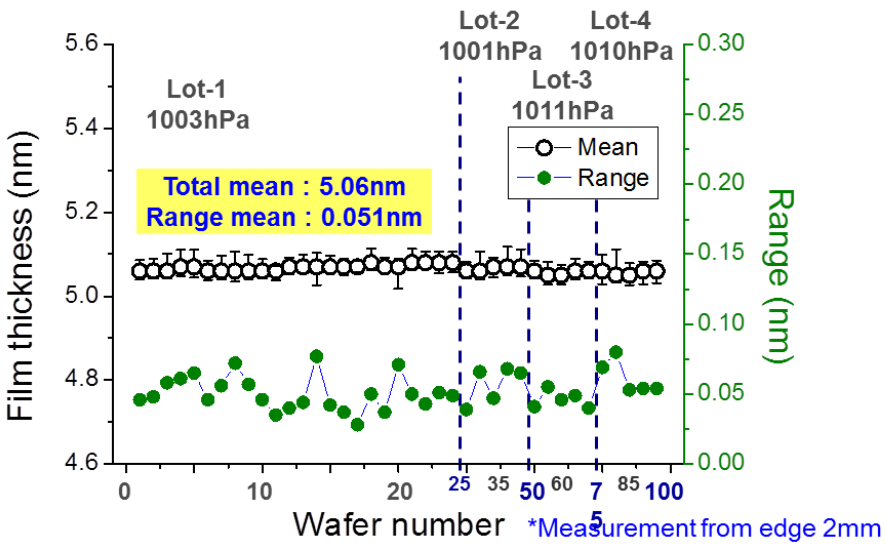
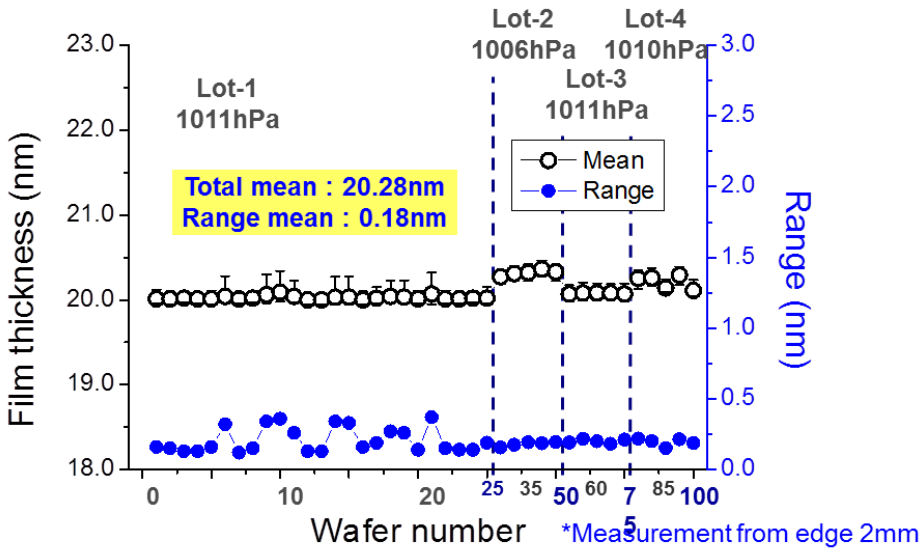
Long term stability (Film thickness)

EBL105A Coating 5nm



EBL105A Coating 20nm



- **Excellent long term stability of film thickness at each FT.**

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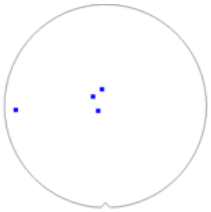
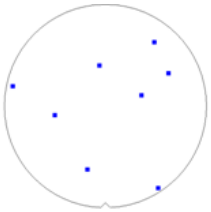
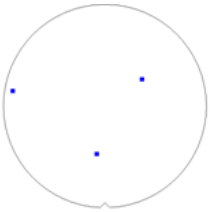
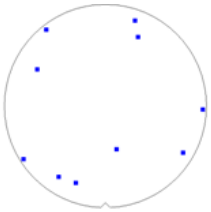
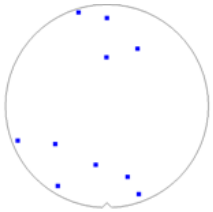
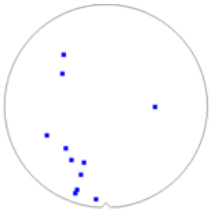
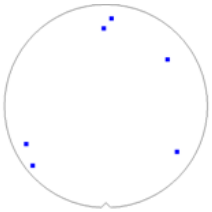
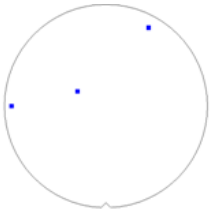
Long term stability (Defectivity)

EBL105A Coating 5nm

	Slot	1	5	10	25	26 (no-process)
Lot-1	Mean (nm)	5.01	5.01	5.01	5.02	-
	Range (nm)	0.039	0.035	0.030	0.039	-
	Wafer Map (0.08um-up)	6	 4	 8	 3	 10

EBL105A Coating 20nm

	Slot	1	5	10	25	26 (no-process)
Lot-1	Mean (nm)	20.01	20.01	20.09	20.02	-
	Range (nm)	0.16	0.16	0.25	0.13	-
	Wafer Map (0.08um-up)	 10	 11	7	 6	 3

♦ **Excellent long term stability of defectivity at each FT.**

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Experimental Conditions

- Resist : Resist-A / 50nm
- UL : AZ® EBL105A / 5nm
  AZ® EBL105A / 20nm

- Scanner : NXE:3100 (Offline)
- Target CD : 27nm L/S
- Reticle : NXE-monitor (thin)
- Illumination : Conventional / NA=0.25 / sigma=0.81
- Chuck : Single Chuck (Chuck1)
- Exposure Condition
  - Dose : Center-dose 14.5mJ/cm^2 / 1.0mJ/cm^2-step
  - Focus : Center-focus 30.0nm / 80nm-step

- Developer Unit : ECO_TS21
- With BSS before exposure
- Developer : TMAH w/o surfactant (0.26N)

- CD-SEM : CG4000(Hitachi)

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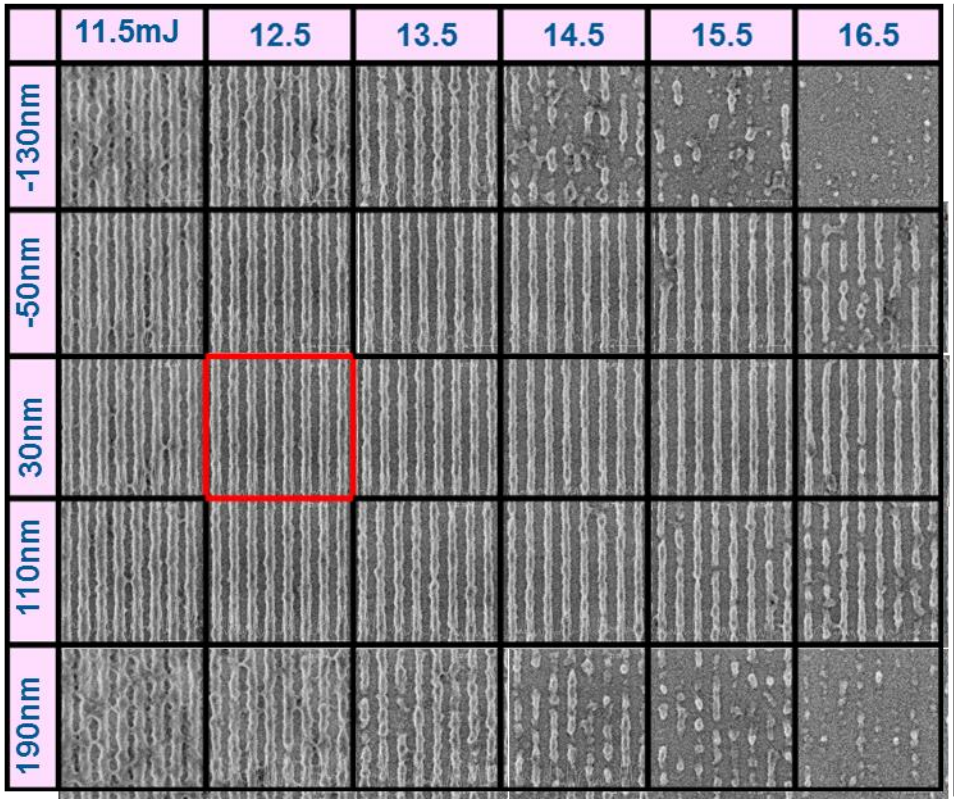
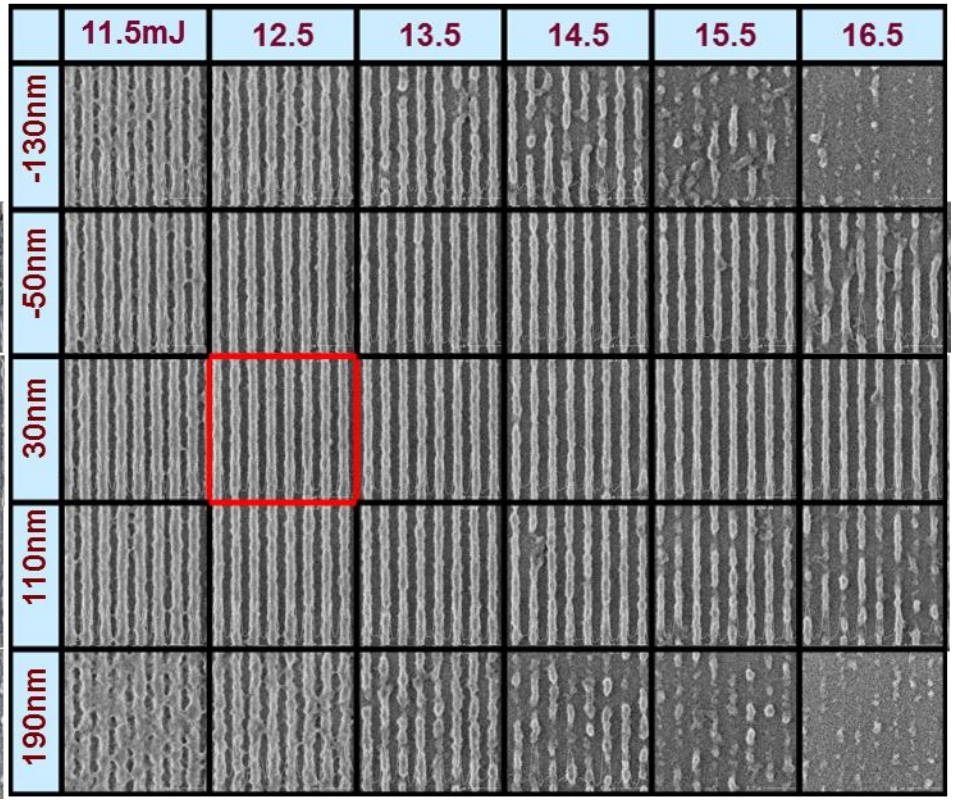
SEM image and CD : 27nm/54nm-pitch

Under layer : AZ® EBL105A / 5nm



	11.5mJ	12.5	13.5	14.5	15.5	16.5
-50	31.66	27.60	24.03	21.30	19.09	
30	31.03	26.93	24.31	20.49	20.25	18.15
110	30.91	27.10	23.99	20.77	18.73	16.69
190		28.57	22.95	21.38		

Under layer : AZ® EBL105A / 20nm



	11.5mJ	12.5	13.5	14.5	15.5	16.5
-50	31.24	27.32	24.23	21.93	19.47	
30	31.78	27.21	24.25	20.41	20.15	18.73
110	31.74	27.07	24.10	21.17	18.44	15.71
190		29.08	23.46	18.78		

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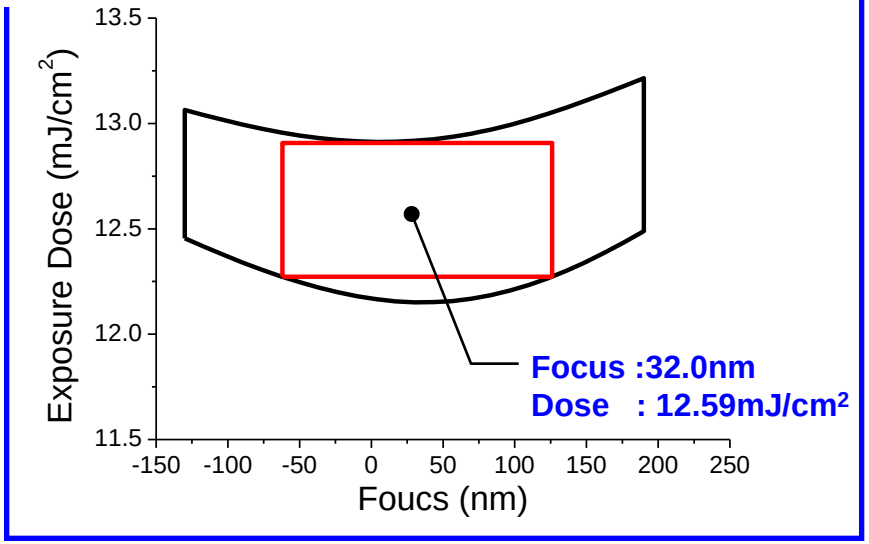
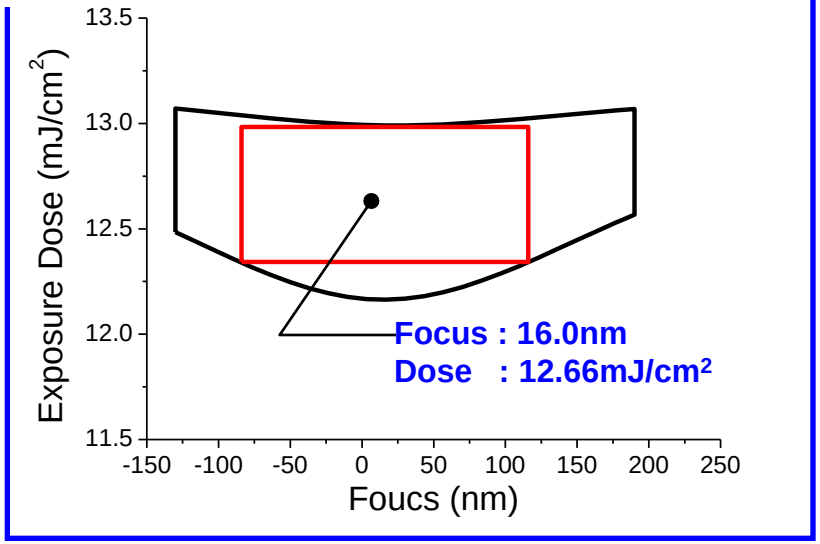
Process window : 27nm/54nm-pitch

Under layer : EBL105A / 5nm



*CD shift : 5%
*Red square : EL 5%

Under layer : EBL105A / 20nm



*CD shift : 5%
*Red square : EL 5%

- **Dose/Focus margin at each FT is almost identical.**
- **Exposure dose at each FT is almost identical.**
  - ✓ **EBL105A / 5nm : 12.59mJ/cm2**
  - ✓ **EBL105A / 20nm : 12.66mJ/cm2**

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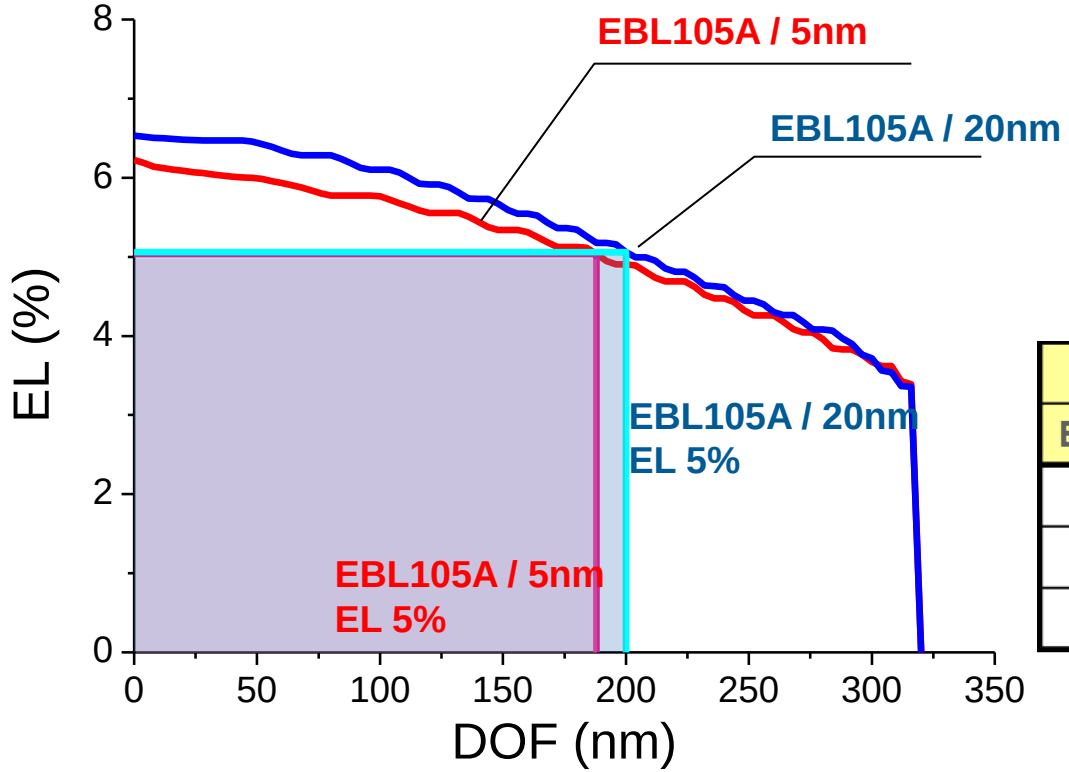
EL/DOF : 27nm/54nm-pitch



EBL105 / 5nm		EBL105 / 20nm	
EL (%)	DOF (nm)	EL (%)	DOF (nm)
0.0	320	0.0	320
5.0	188	5.0	200
6.2	0	6.6	0

- **EL and DOF at each FT are almost identical.**

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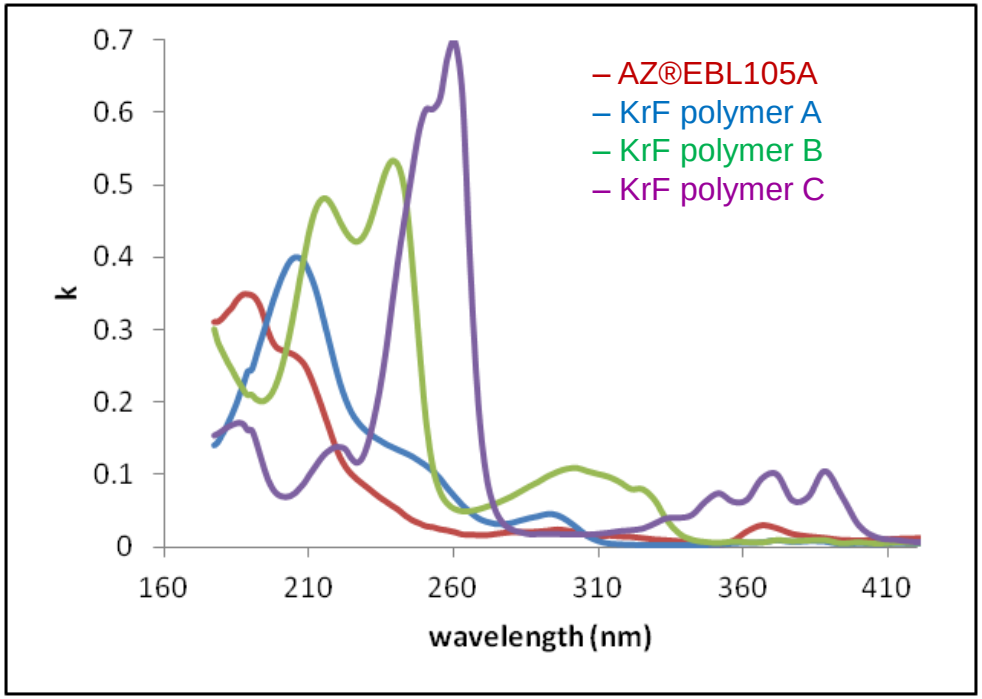
New Development

Reduction of LWR by Increasing Out of Band (OOB) Absorption

Absorption curves for films of AZ® EBL105A and KrF polymer A, B, and C



Polymer A increases absorption window of AZ® EBL105A beyond 200 nm up to ~260 nm.

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Comparison of LWR and DOF Results on AZ® EBL105A, AZ® EBL133A, and AZ® EBL133E Underlayers.

27nmHP	AZ®EBL105A	AZ®EBL133A	AZ®EBL133E
	ArF polymer	ArF&KrF polymer	PAG E
LWR*(nm)	5.1	4.8	4.6
DOF(um)	0.13	0.12	0.12

AZ® EBL133A suppresses OOB radiation efficiently and reduces LWR.
AZ® EBL133E containing PAG can further reduce LWR without causing line collapses.

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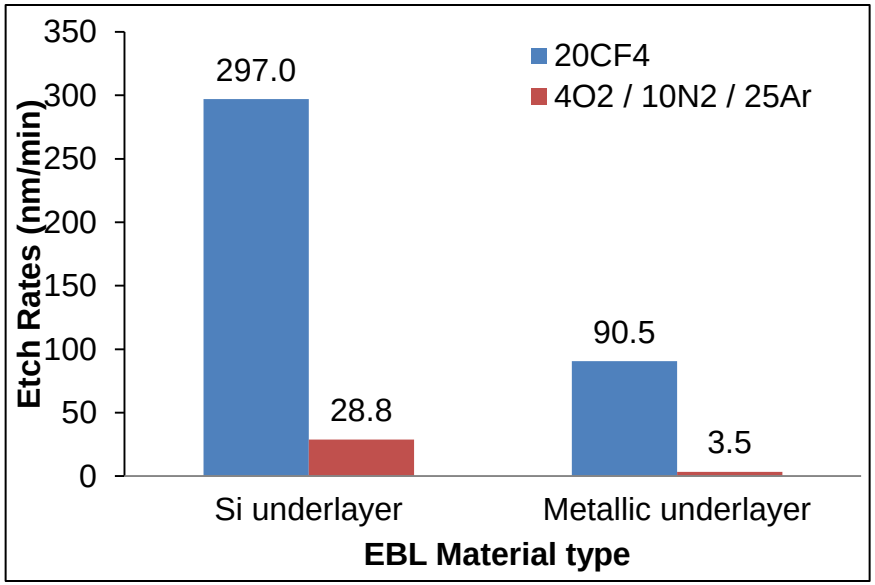
New Development

New Metallic Underlayers with Excellent Etch Selectivity

Etch rate comparison of metallic and silicon underlayers at CF_4 and O_2 plasma etch conditions.



Metallic underlayers provide excellent etch resistance to fluorine and oxygen plasma etch chemistries.

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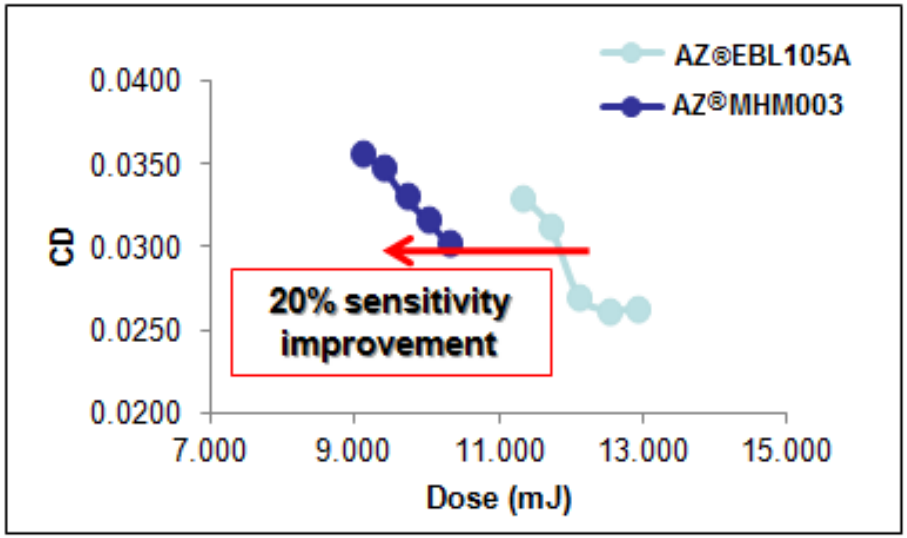
Comparison of Resist Sensitivity on Metallic Underlayer AZ® MHM003 and AZ® EBL105A Underlayer



MHM003 provides 20% sensitivity improvement compared to organic EUV UL.

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Summary

Coating Uniformity, stability, coated film defects and litho performance were compared for AZ® EBL105A EUV under-layer material at 5 & 20nm film thickness (FT) using SOKUDO Track and NXE:3100 EUV exposure tool.

AZ® EBL105A shows excellent coating uniformity & film thickness stability with low defect counts. Exposure dose, DoF and DoF @ 5% EL were also comparable at 5nm and 20nm FT.

New Formulations AZ® EBL 133A (incorporating OOB absorbing groups) and AZ® EBL 133E (using new PAG) provides improved LWR maintaining same dose and DoF

Use of metal containing underlayer MHM003 provides 20% improvement in sensitivity. Further studies on-going to address the resist compatibility issues.

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