MA-P07

Overlay accuracy of EUV1 using compensation method for nonflatness of mask

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Outline

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2. Compensation method for nonflatness of mask
3. Image placement corrections for EUV masks
4. Experimental results of intra-field overlay accuracy
5. Experimental results of intra-wafer overlay accuracy
6. Conclusions

Introduction

ITRS 2009 Edition

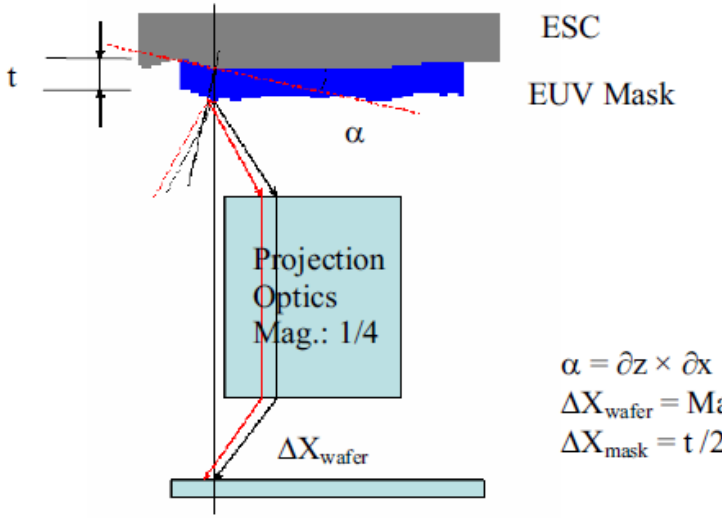
	2010	2013	2016	2019	2022
Half pitch (nm)	45	32	23	16	11
Overlay (nm 3σ)	9.0	6.4	4.5	3.2	2.3
EUV mask requirements					
Mask image placement (nm 3σ)	5.4	3.8	2.7	1.9	1.4
Mask substrate flatness (nm PV)	51	36	26	18	13

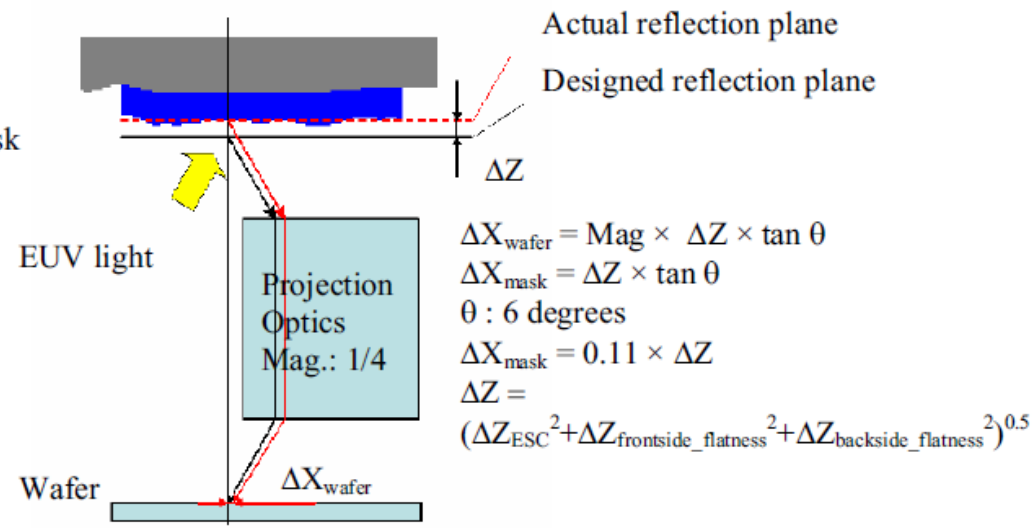
To mitigate the flatness requirements for EUV masks, the use of compensation method of mask nonflatness is desirable.

Purpose of this study:
To verify the effect of flatness compensation method

IP error caused by mask nonflatness

S. Yoshitake, et. al., SPIE vol.6792, 67920T (2008).



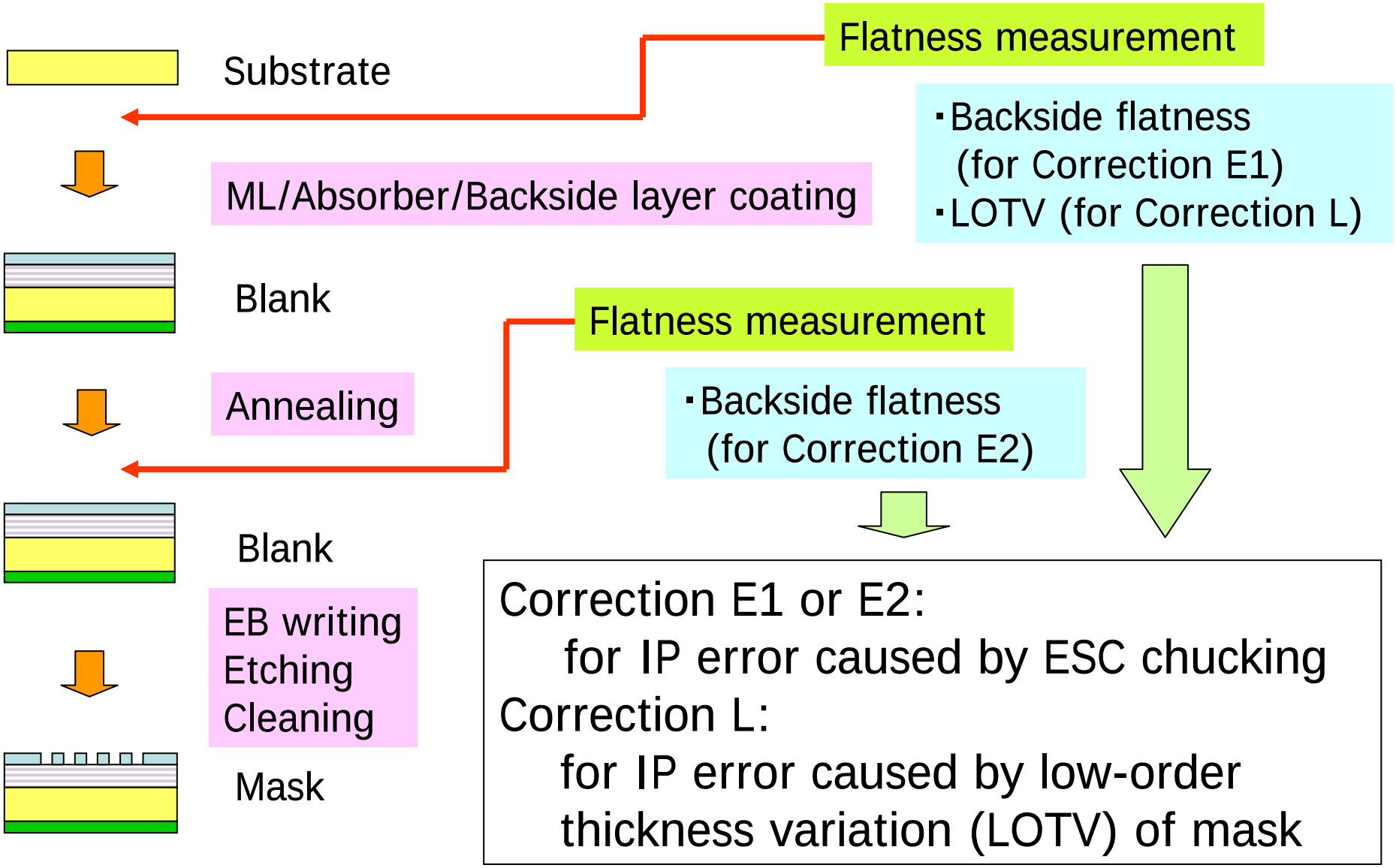


(1) IP error caused by ESC chucking
(related to backside flatness of mask)

(2) IP error caused by flatness variation
(related to low-order thickness variation (LOTV) of mask)

There are two major causes of image placement (IP) error related to mask nonflatness. One is caused by ESC chucking and the other is caused by flatness variation (= LOTV of mask).

Compensation method for nonflatness of mask

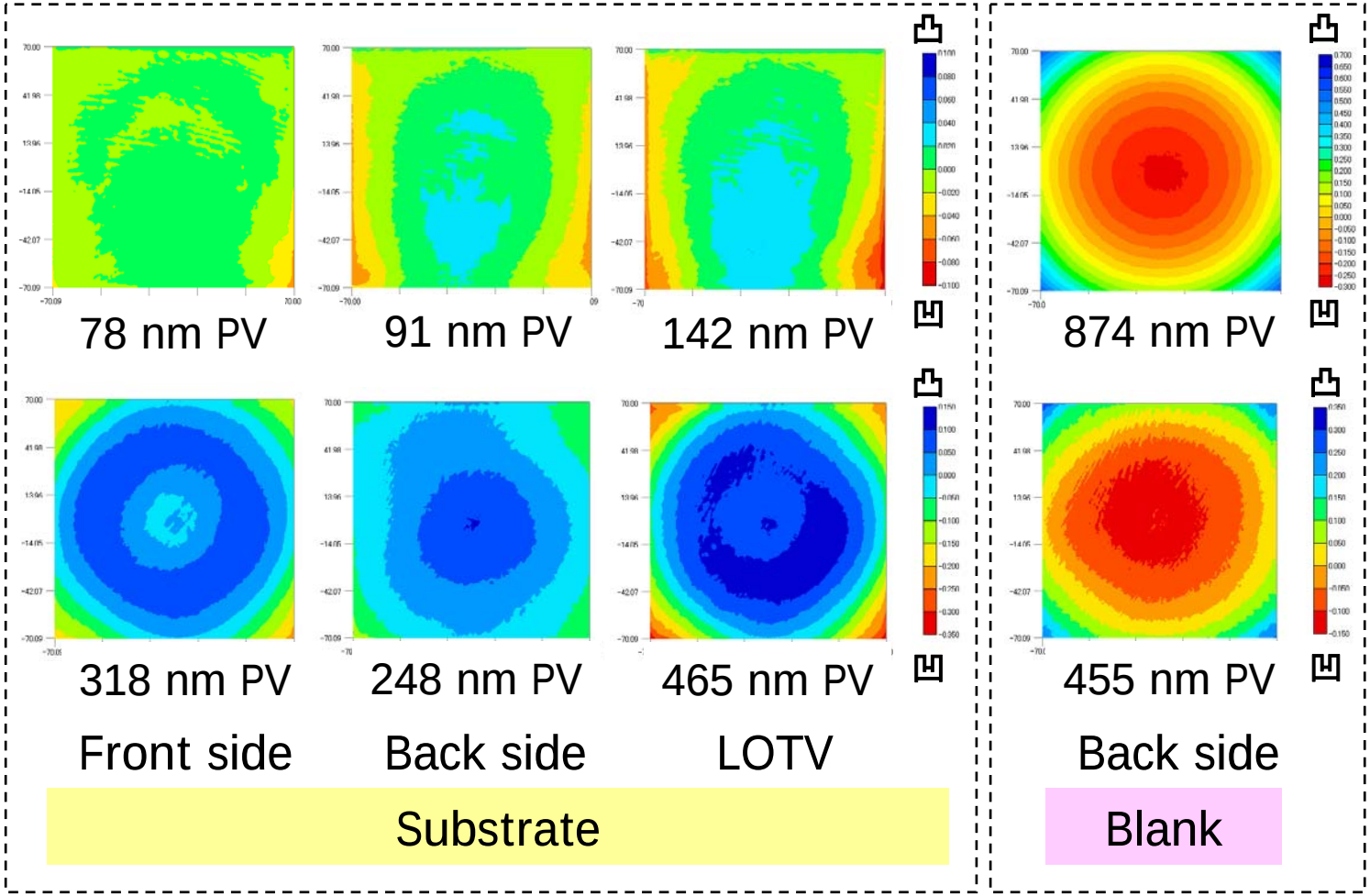


Measured flatness of EUV masks

※142 mm × 142 mm

Mask A
(Flat mask)

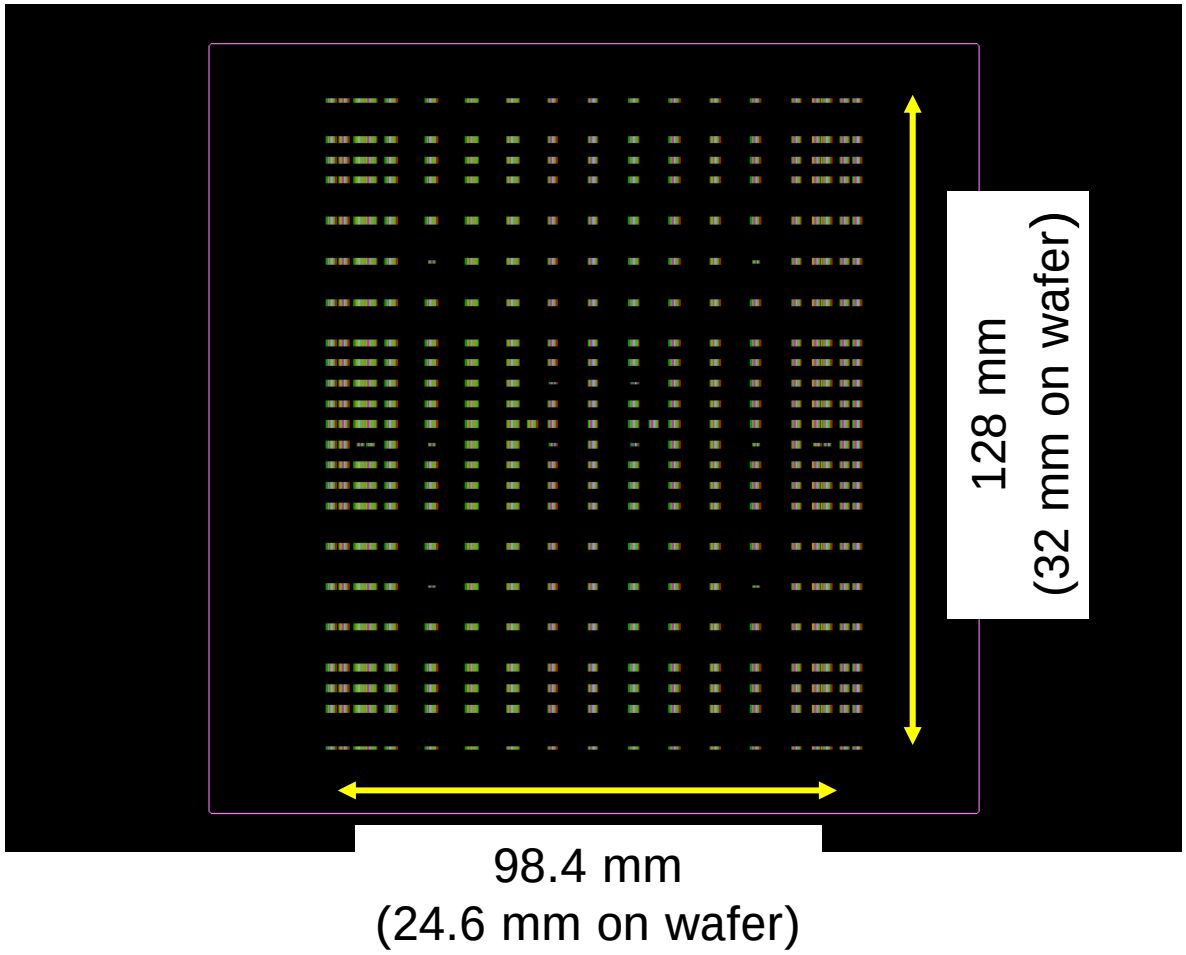
Mask B
(Non-flat mask)

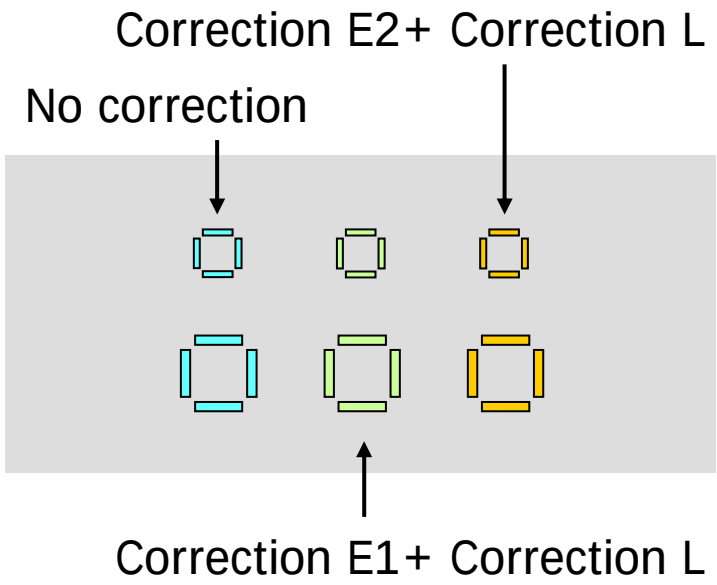


Substrate: ULE
Absorber: LR-TaBN (51 nm)
Buffer: CrN (10 nm)
Backside coating: CrN (70 nm)

We fabricated two EUV masks. Mask A is a flat mask (both surfaces are <100 nm PV), and mask B is a non-flat mask (both surfaces are >200 nm PV).

Mask pattern layout



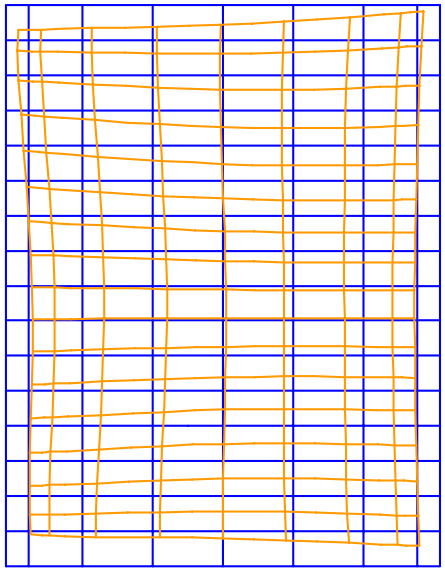


※Use analytical model (GMC-TV) developed by NuFlare Technology.

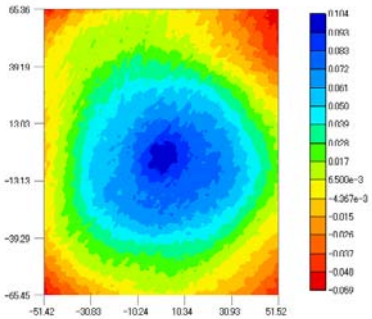
GMC-TV: Grid Matching Correction for Thickness Variation

We used 17x17 overlay units on the masks. Each unit has three sets of measurement marks. IP correction is different for each mark set.

Image placement correction for mask B (1)

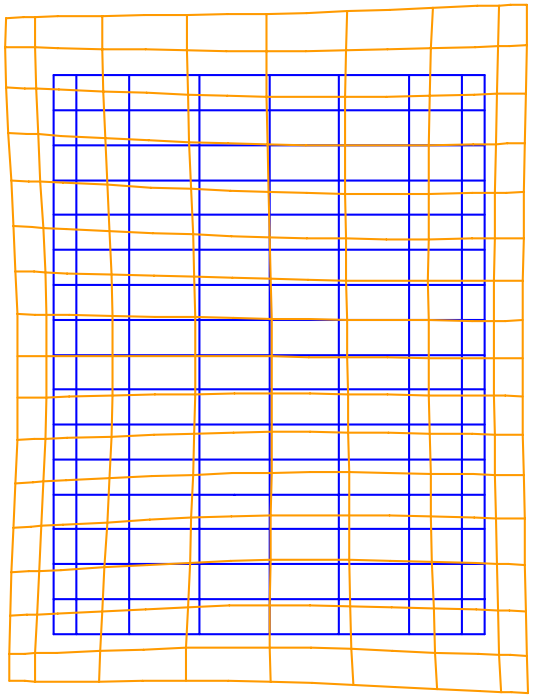


※103 mm
×131 mm

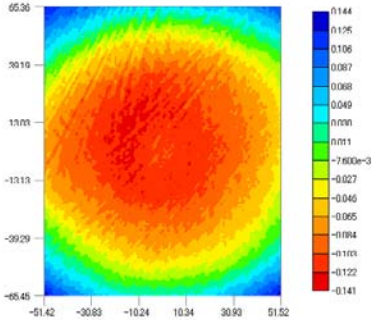


163 nm PV

Backside flatness
(Substrate)



※103 mm
×131 mm



285 nm PV

Backside flatness
(Blank)

3σ (X) = 14.6 nm
3σ (Y) = 12.4 nm

4X

(1) Correction E1

Mag. (X) = -0.55 ppm
Mag. (Y) = -0.39 ppm

3σ (X) = 23.3 nm
3σ (Y) = 31.7 nm

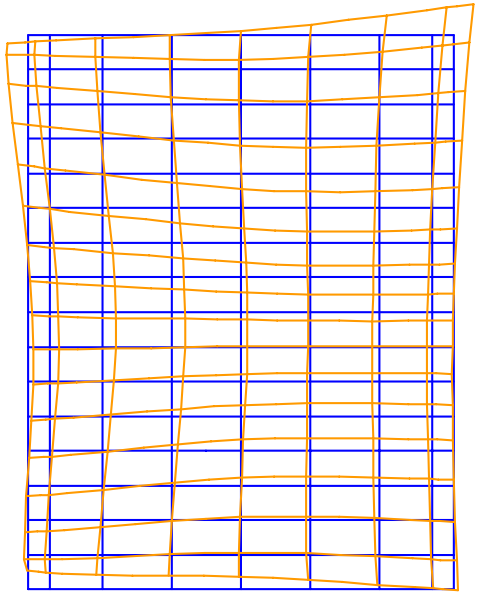
4X

(2) Correction E2

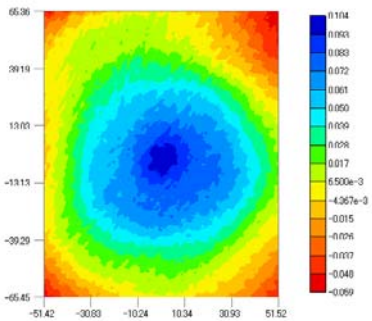
Mag. (X) = +0.89 ppm
Mag. (Y) = +1.06 ppm

Correction E2 is much larger than correction E1.
However, magnification component is dominant in correction E2.

Image placement correction for mask B (2)



※103 mm
×131 mm



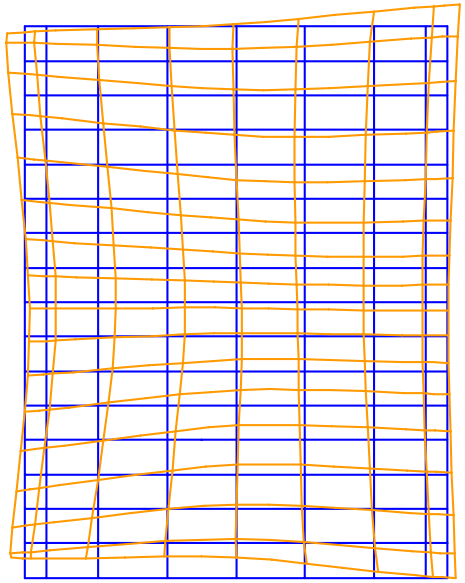
163 nm PV

Backside flatness
(Substrate)

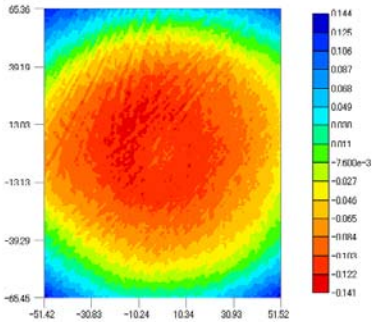
3σ (X) = 2.9 nm
3σ (Y) = 4.9 nm

4X

(3) Correction E1
(after the removal of linear components)



※103 mm
×131 mm



285 nm PV

Backside flatness
(Blank)

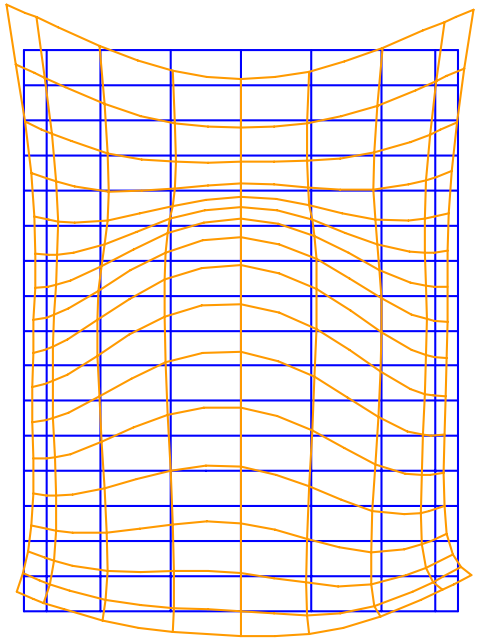
3σ (X) = 3.5 nm
3σ (Y) = 5.4 nm

4X

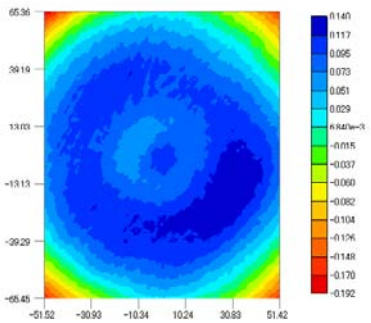
(4) Correction E2
(after the removal of linear components)

After the removal of linear components, correction E2 is similar to correction E1.

Image placement correction for mask B (3)



※103 mm
×131 mm



332 nm PV

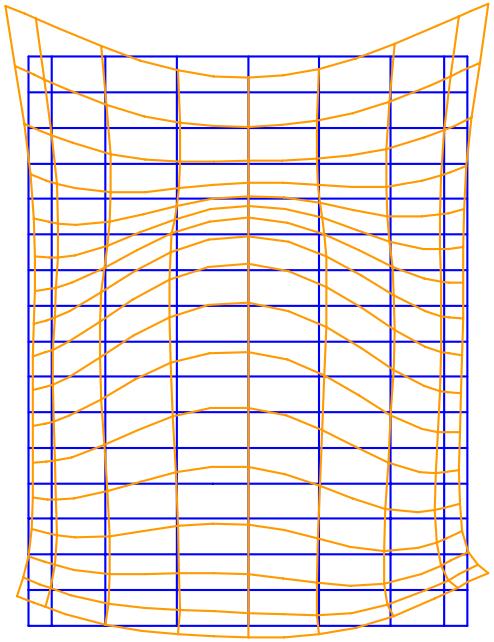
LOTV
(Substrate)

3σ (X) = 2.8 nm
3σ (Y) = 11.1 nm

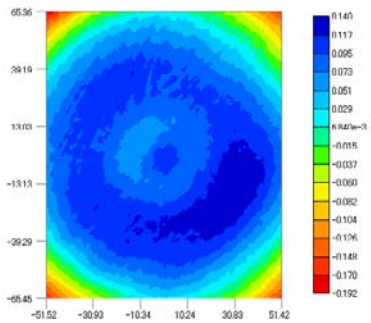
(5) Correction L

4X

Mag. (X) = -0.07 ppm
Mag. (Y) = +0.02 ppm



※103 mm
×131 mm



332 nm PV

LOTV
(Substrate)

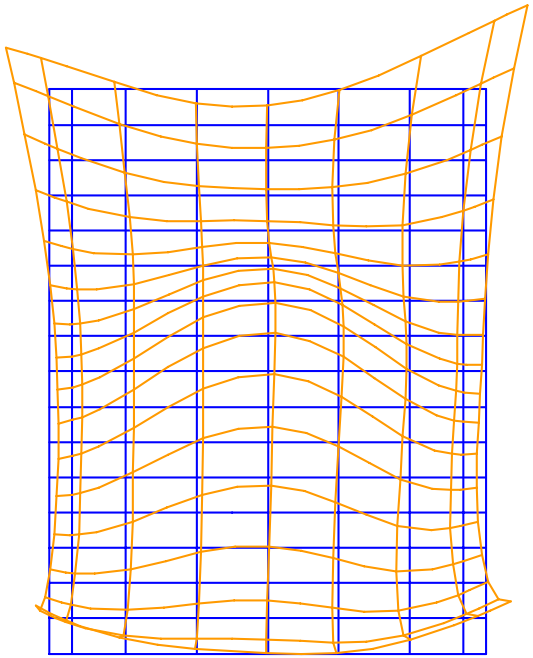
3σ (X) = 2.3 nm
3σ (Y) = 11.0 nm

4X

(6) Correction L
(after the removal of linear components)

Since the linear components are small, correction L is much larger than correction E1 or E2.

Image placement correction for mask B (4)

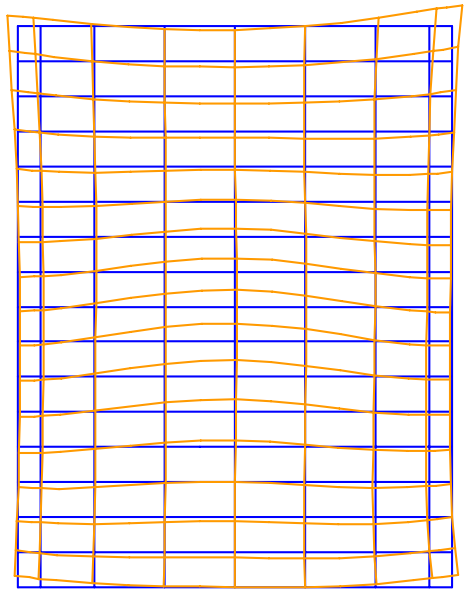


3σ (X) = 4.1 nm
3σ (Y) = 11.6 nm

4X

(7) Correction E1 + L
(on mask)

1/4



3σ (X) = 1.0 nm
3σ (Y) = 2.9 nm

1X

(8) Correction E1 + L
（on wafer）

In mask B, total correction (E1 + L) on wafer is 1.0 nm (3σ) in X direction and 2.9 nm (3σ) in Y direction.

Experimental conditions for intra-field O/L evaluation

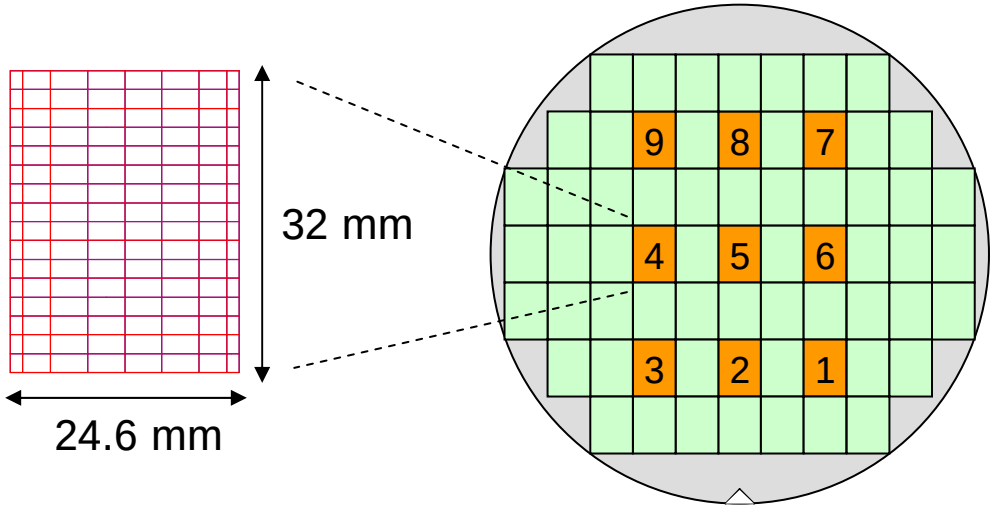
Exposure Tool (EUV1)
- NA: 0.25
- Illumination: Conventional (σ=0.8)
- Number of shots: 9shots/wafer

Resist
- SMR51（70 nm thick）

Base wafer
- SiO_2 etched wafer fabricated with S610C

Overlay measurement
- Archer10 AIM（KLA Tencor）

EUV1
（EUV full-field scanner）



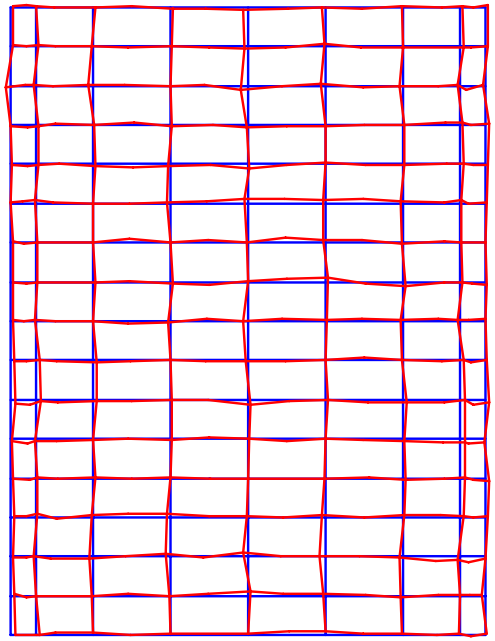
◆ Base wafer method

① Mask A / Base wafer 1
② Mask A or B / Base wafer 2

Compare intra-field overlay between these two wafers.

Reproducibility of overlay & flatness in mask loading

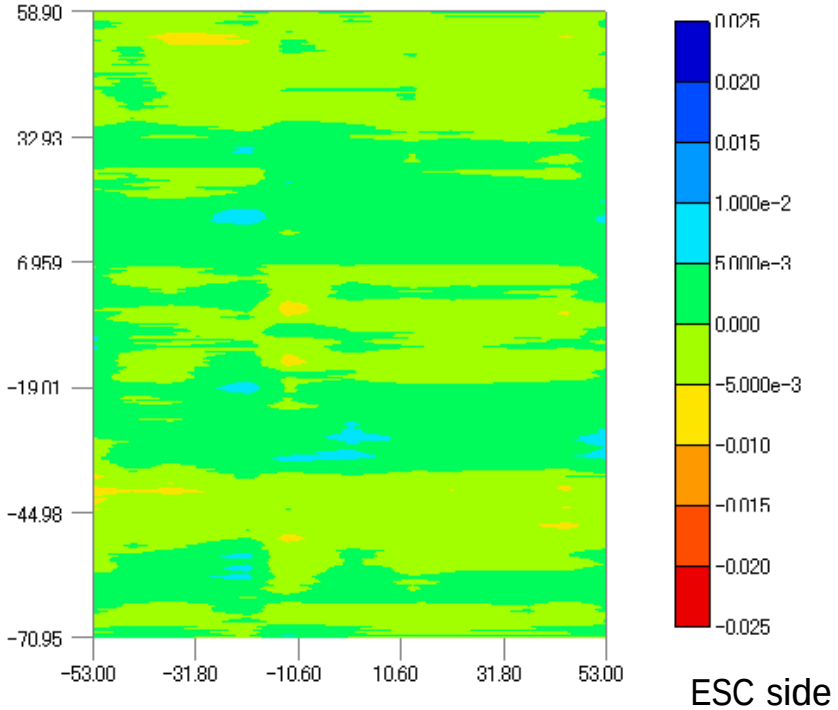
※Average of 9shots



3σ (X) = 1.0 nm　　Max (X) = 1.0 nm
3σ (Y) = 0.7 nm　　Max (Y) = 0.7 nm

(1) Reproducibility of intra-field overlay in mask loading

※106 mm × 130 mm



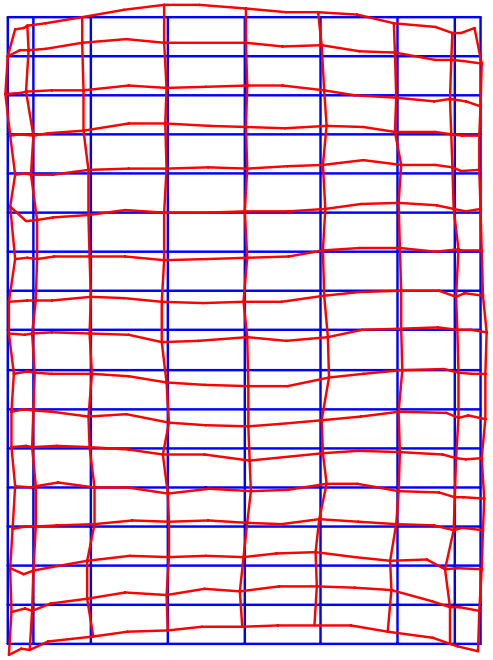
PV = 15 nm

(2) Reproducibility of the flatness of a chucked mask in mask loading

Using the same mask (mask A), the reproducibility of intra-field overlay in mask loading is better than 1 nm (3σ). The reproducibility of the flatness of a chucked mask is better than 20 nm.

Mask-to-mask overlay & difference of flatness

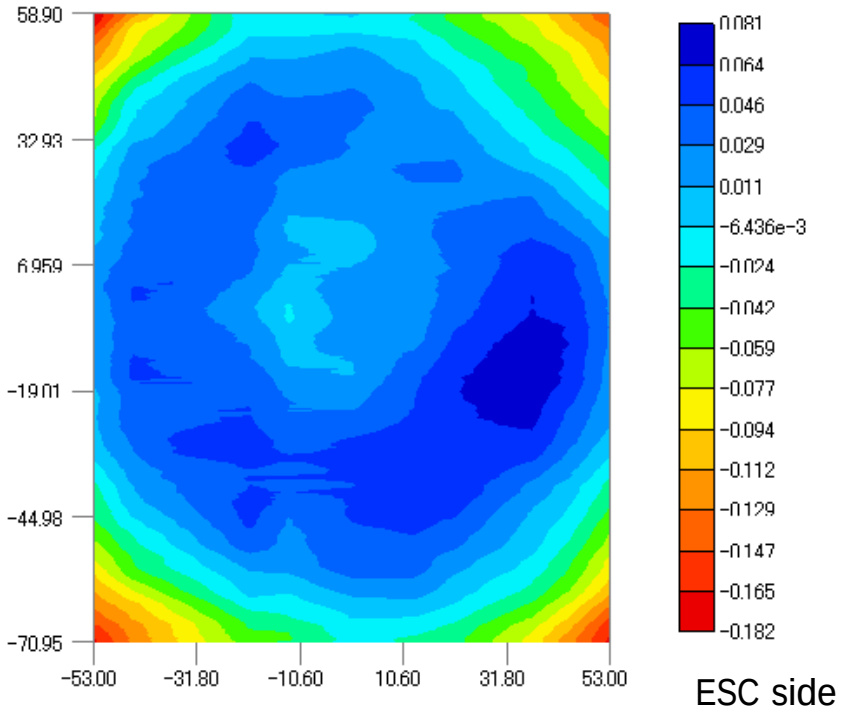
※Average of 9shots



3σ (X) = 1.5 nm Max (X) = 1.4 nm
3σ (Y) = 2.9 nm Max (Y) = 2.4 nm

(1) Intra-field overlay between mask A & B

※106 mm × 130 mm



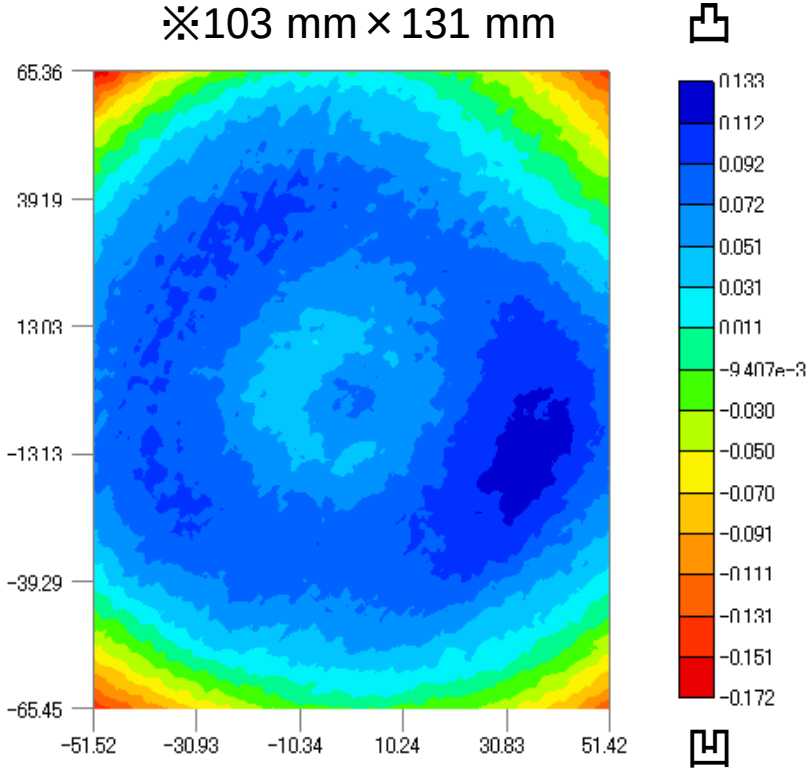
PV = 264 nm

(2) Difference of surface flatness between mask A & B measured on EUV1

Without IP correction, intra-field overlay between mask A & B is about 3 nm (3σ). The difference of surface flatness between the two masks measured on EUV1 is about 260 nm.

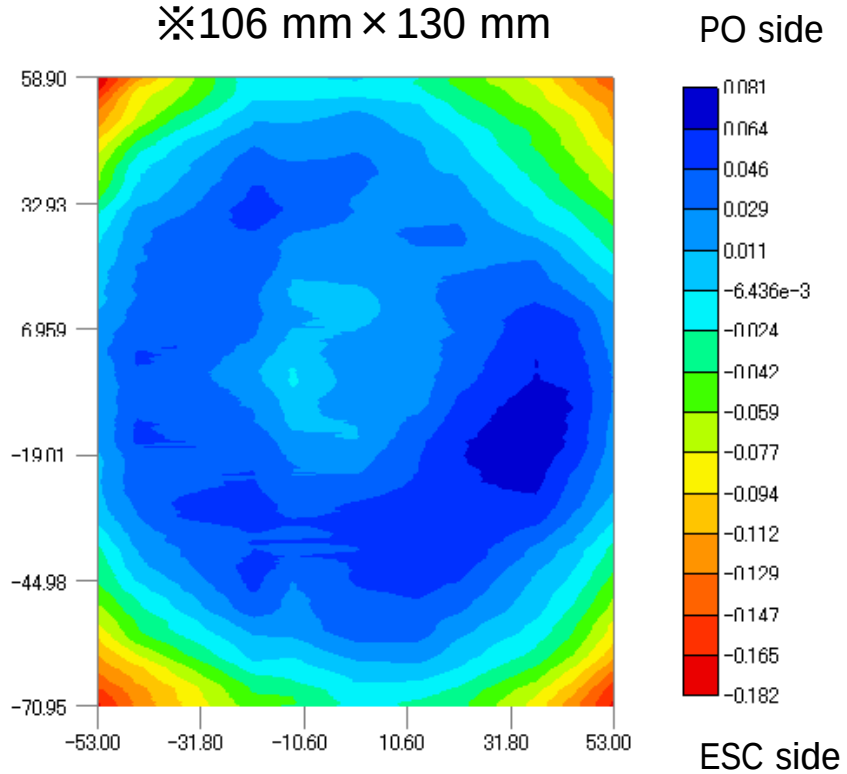
Comparison of LOTV & surface flatness

※103 mm × 131 mm



PV = 304 nm

※106 mm × 130 mm



PV = 264 nm

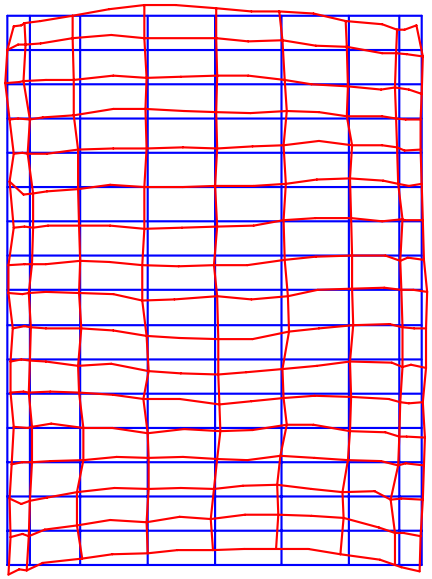
(1) Difference of LOTV between mask A & B measured at blank supplier

(2) Difference of surface flatness between mask A & B measured on EUV1

The difference of surface flatness between mask A & B measured on EUV1 is similar to the difference of LOTV measured at blank supplier.

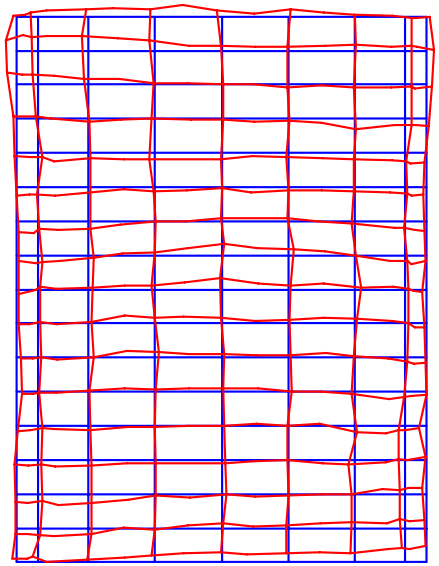
Effect of IP correction for nonflatness of mask

Intra-field overlay between mask A & B



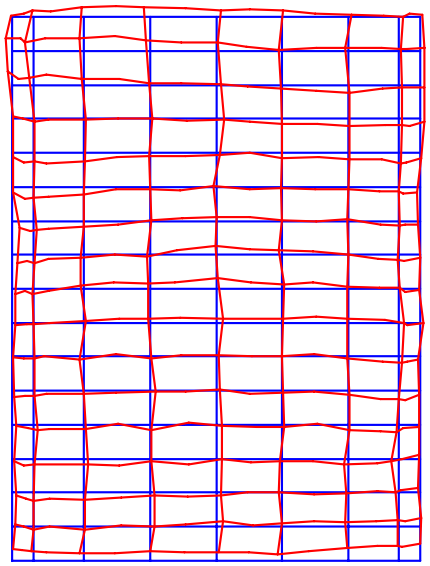
3σ (X) = 1.5 nm
3σ (Y) = 2.9 nm

(1) No correction



3σ (X) = 1.5 nm
3σ (Y) = 2.5 nm

(2) With correction
E1 + L



3σ (X) = 1.3 nm
3σ (Y) = 2.5 nm

(3) With correction
E2 + L

Overlay accuracy was improved by using corrected patterns.
The difference between correction E1 and E2 was little.

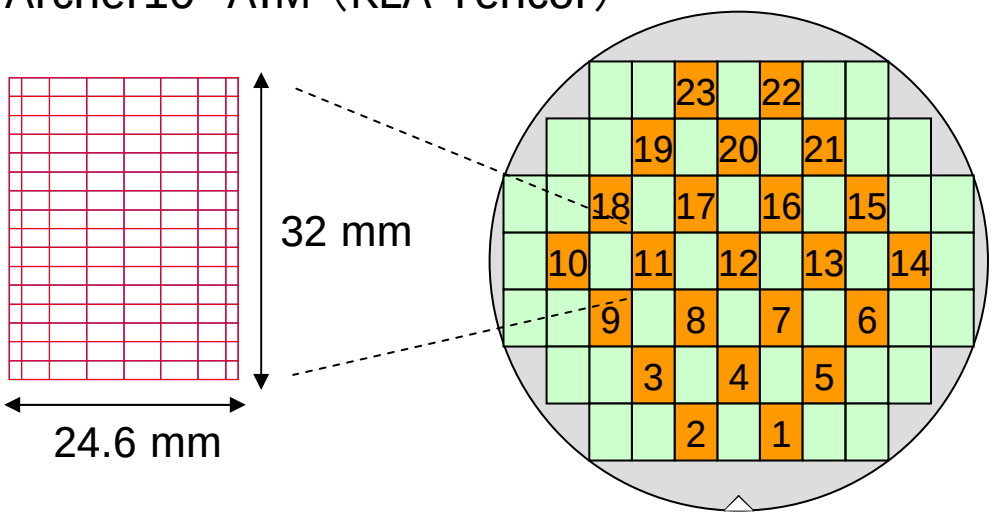
Experimental conditions for intra-wafer O/L evaluation

Exposure Tool (EUV1)
- NA: 0.25
- Illumination: Conventional (σ=0.8)
- Number of shots: 23shots/wafer

Resist
- SMR51（70 nm thick）

Wafer
- Bare Si (for SMO)
- SiO_2 etched wafer fabricated with S610C (for MMO)

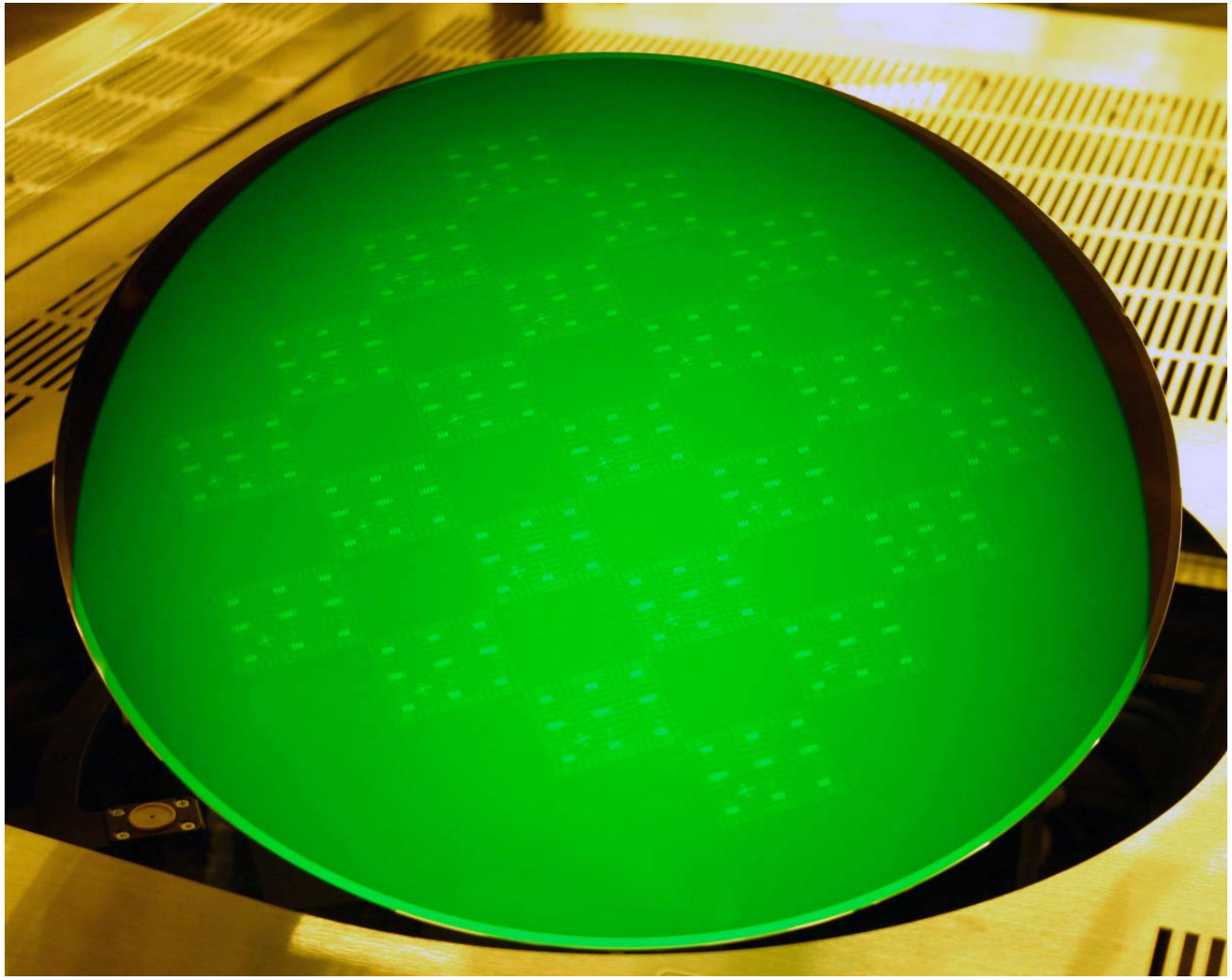
Overlay measurement
- Archer10 AIM（KLA Tencor）



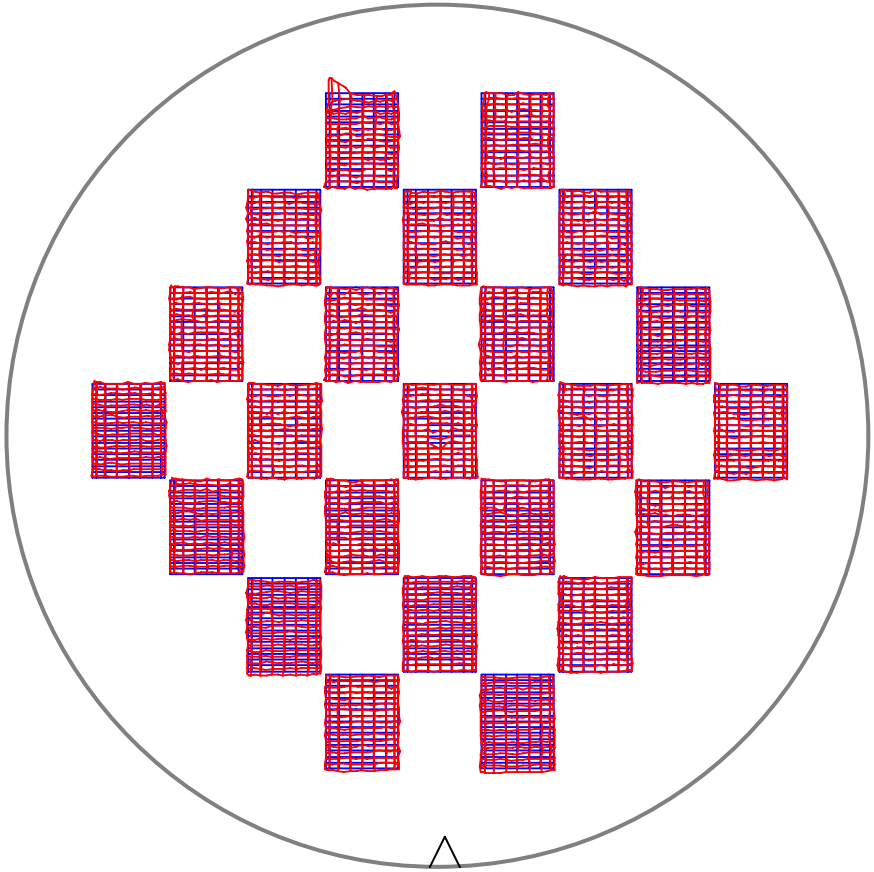
EUV1
（EUV full-field scanner）

- Double exposure method
  for single machine overlay
- Single exposure method
  for mix & match overlay

Full-field scanned wafer exposed with EUV1



Single machine overlay of EUV1



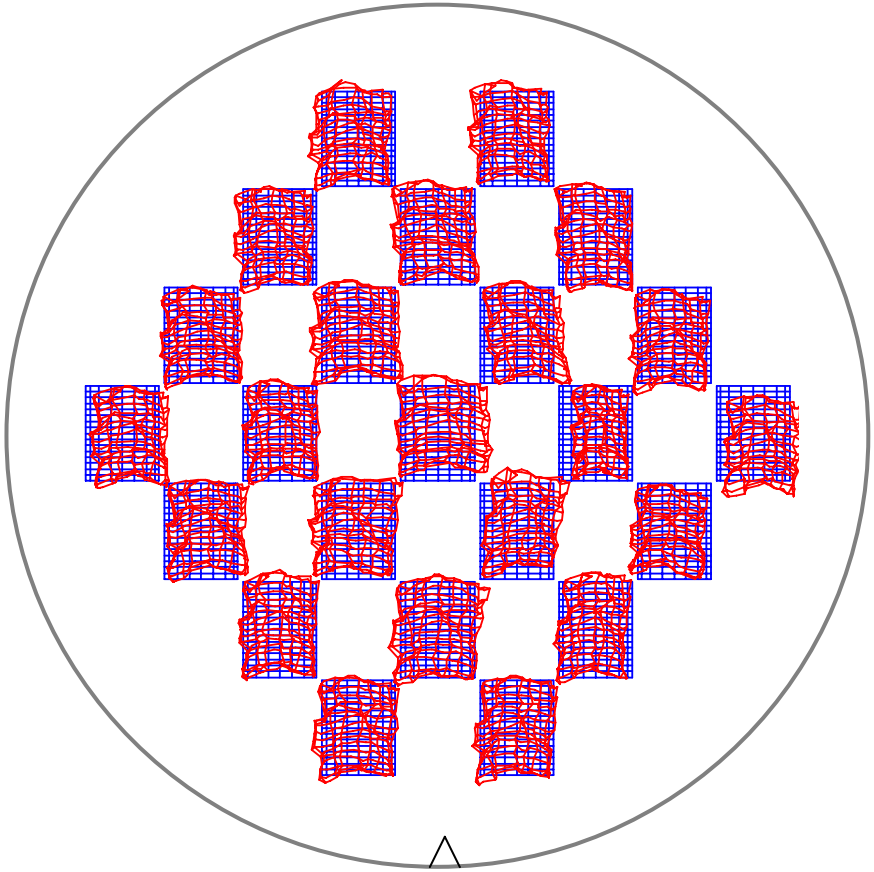
23shots, 24.6 mm × 32 mm		X	Y
Mean	Raw data	-2.1	+0.3
3σ	Raw data	2.6	6.2
	After the removal of linear components	2.1	3.9
	Intra field	1.1	1.4
	Inter field	1.8	3.7

$3\sigma_{nonlinear}$ (X) = 2.1 nm
$3\sigma_{nonlinear}$ (Y) = 3.9 nm

Mean + $3\sigma_{nonlinear} \leqq 4.5$ nm

Single machine overlay accuracy of EUV1 meets the overlay target for hp 32 nm node.

Mix & match overlay between EUV1 and S610C



23shots, 24.6 mm × 32 mm		X	Y
Mean	Raw data	0.0	-3.6
3σ	Raw data	18.5	18.0
	After the removal of linear components	18.1	16.6
	Intra field	7.1	10.9
	Inter field	16.6	12.6

$3\sigma_{nonlinear}$ (X) = 18.1 nm
$3\sigma_{nonlinear}$ (Y) = 16.6 nm

Mean + $3\sigma_{nonlinear}$ ≒ 20 nm

Mix & match overlay accuracy between EUV1 and S610C (ArF-i) is about 20 nm. More improvements are required for both intra-field and inter-field overlay (for both EUV1 and S610C).

Conclusions

- Since the reproducibility of the flatness of a chucked mask in mask loading is better than 20 nm in the EUV1, the reproducibility of intra-field overlay is better than 1 nm (3σ) for the same mask.
- We fabricated two EUV masks using flatness compensation method, called GMC-TV, and found that the intra-field overlay between the two masks was improved from 2.9 nm (3σ) to 2.5 nm (3σ) by using the corrected patterns.
- We also evaluated the intra-wafer overlay of the EUV1. Single machine overlay is better than 4.5 nm ($M+3\sigma_{nonlinear}$), which meets the overlay target for half-pitch 32 nm node.

Acknowledgements

We would like to thank Masato Saito, Koji Murano, Kunihiro Ugajin, and Kosuke Takai (Toshiba Corporation) for their support in mask fabrication and fruitful discussion.

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