Dependence of lithographic performance on light-shield border structure of EUV mask

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Semiconductor Leading Edge Technologies, Inc.

Outline

[1] Introduction
- Background
- Motivation

[2] Dependence of Light-shield Ability on Mask Structure with SFET *
- Reflectivity of Mask with Light-shield Area
- Printed CD Change by Overlapping Exposure of Light-shield Area

[3] Application of Mask with Light-shield Border to EUV1 **
- Experimental Condition (Reticle Masking Blades Setting, Shot Map)
- Printed CD Difference between Shot Arrays

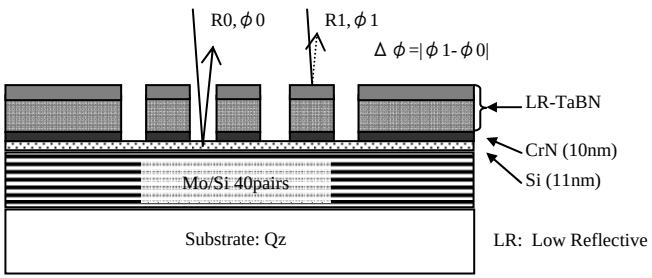
[4] Summary

* SFET: Small Field Exposure Tool (Canon/EUVA)
** EUV1: Full Field Exposure Tool (Nikon)

Merits of Thin Absorber Mask (Att-PSM)

PMJ 2008

Conventional Mask Structure for Simulation & SFET



Phase shift & Reflectivity

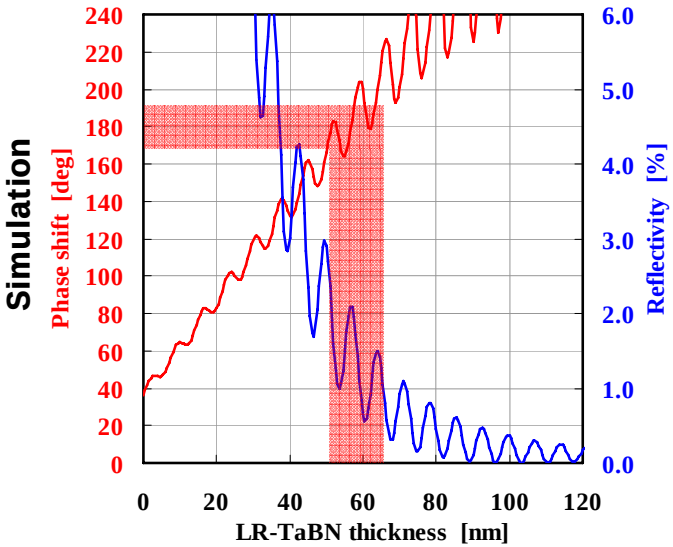
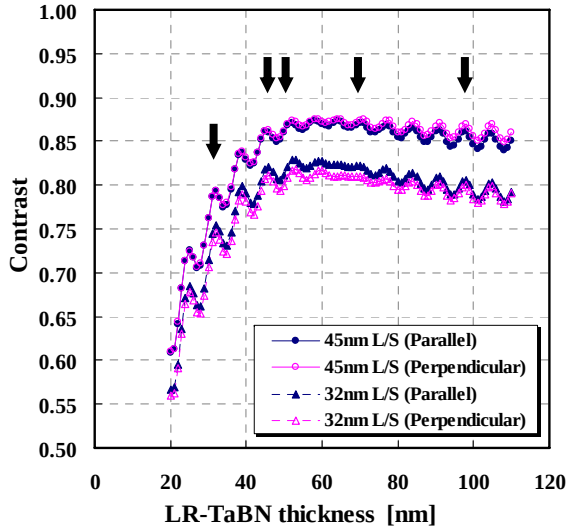
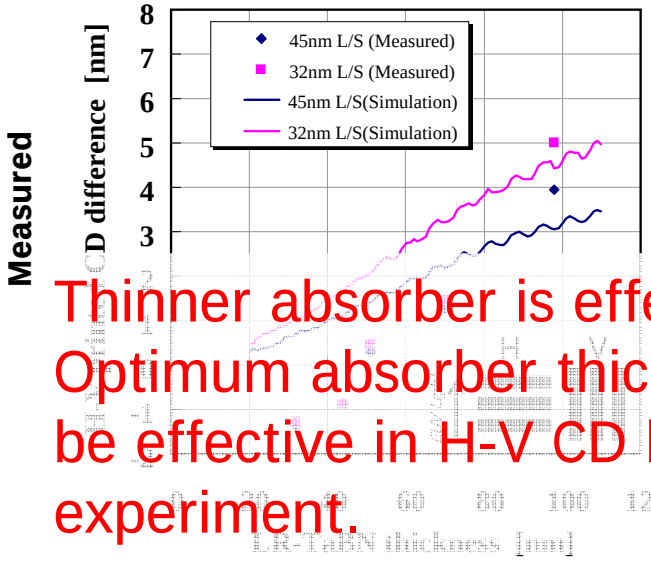


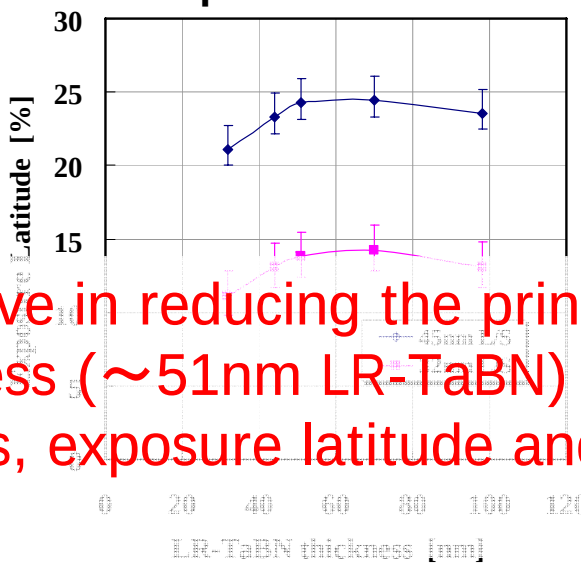
Image Contrast



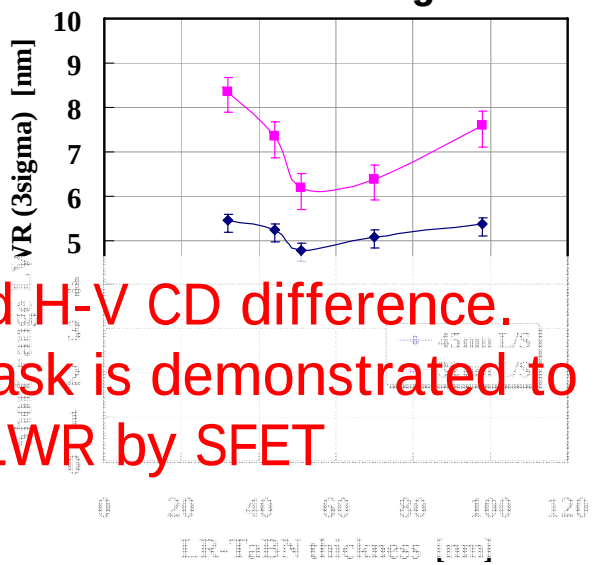
H-V CD bias



Exposure Latitude



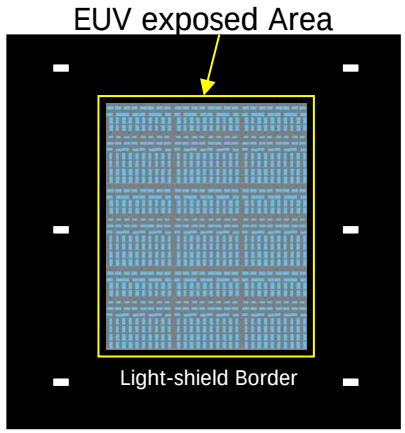
Line Width Roughness



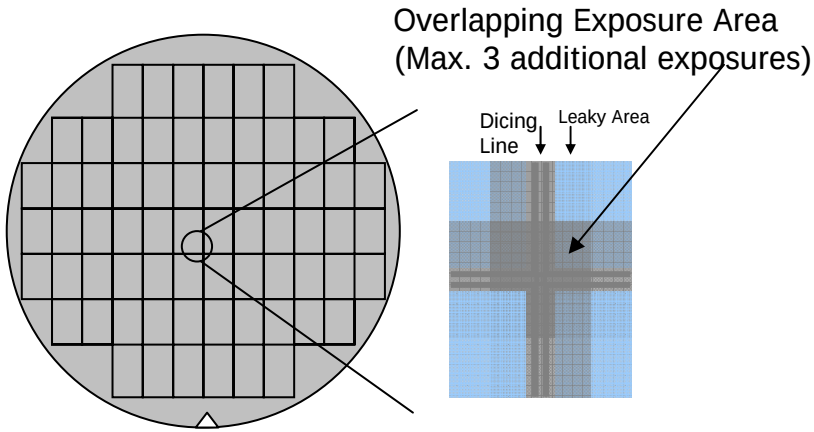
Thinner absorber is effective in reducing the printed H-V CD difference. Optimum absorber thickness (～51nm LR-TaBN) mask is demonstrated to be effective in H-V CD bias, exposure latitude and LWR by SFET experiment.

Light-shield border Structure

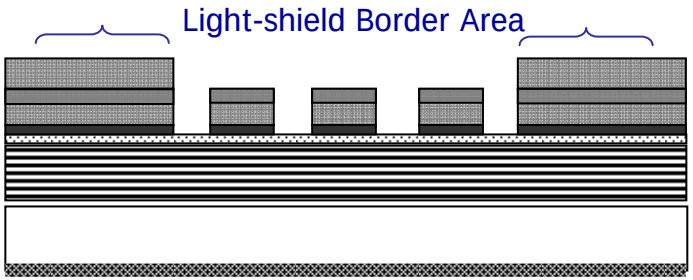
Mask

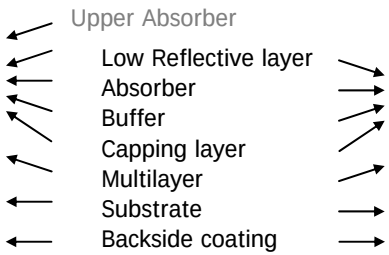


Wafer Exposure Map

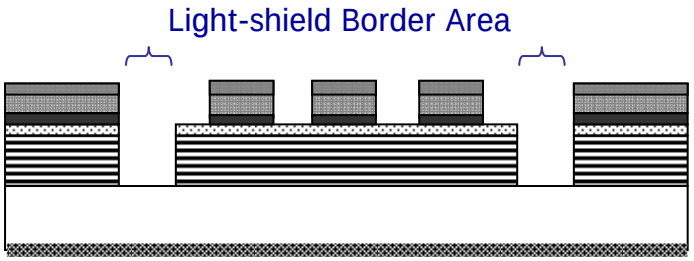


Stacked Absorber Type





Etched Multilayer Type



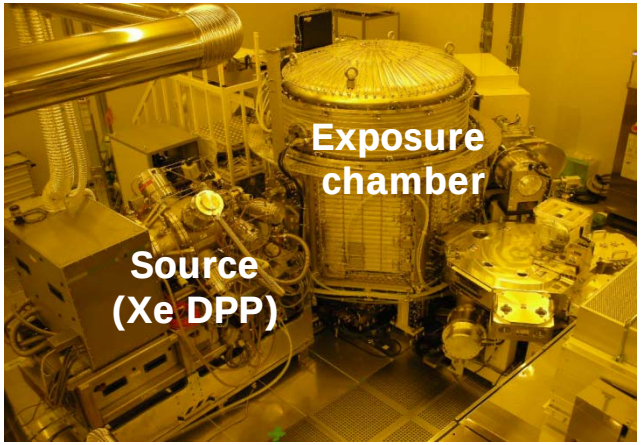
- Similar light-shield border as that of current att-PSM.
- Generally, too thick absorber etching makes mask CD quality poor.

- No extra process for blanks vendor !
- No change of mask CD quality by adding light-shield border.
- Poor mask profile at etched multilayer can cause light leakage.

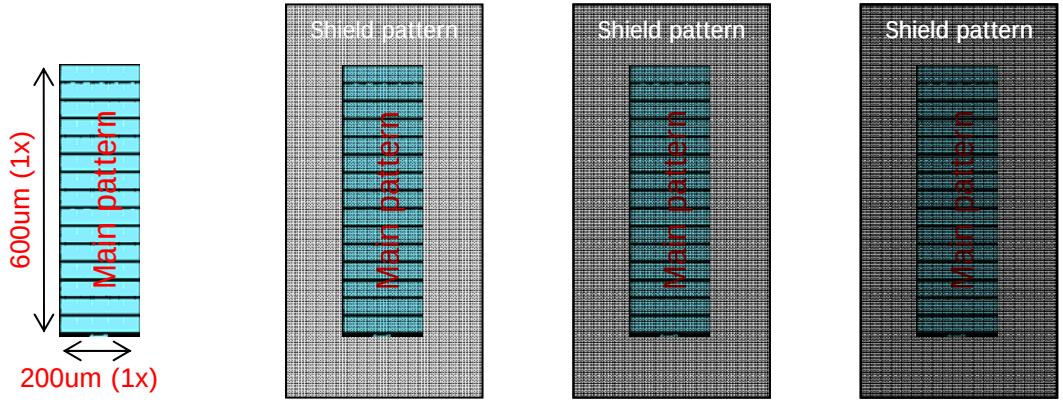
(Need high overlay accuracy between LEVEL1 and LEVEL2 writing)

Light-shield Performance with SFET

SFET (Small Field Exposure Tool)



Method of Overlapping Exposure Experiment:



Single Exposure with Main Pattern Area

Overlapping Exposure x1

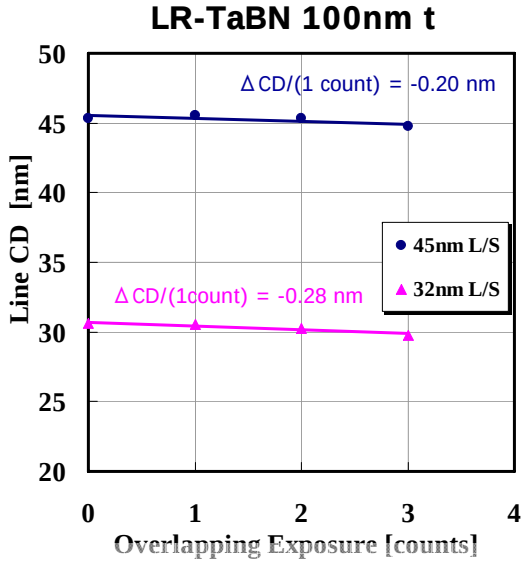
Overlapping Exposure x2

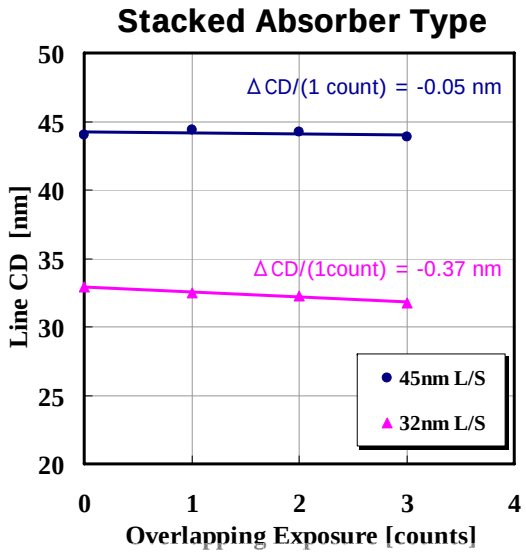
Overlapping Exposure x3

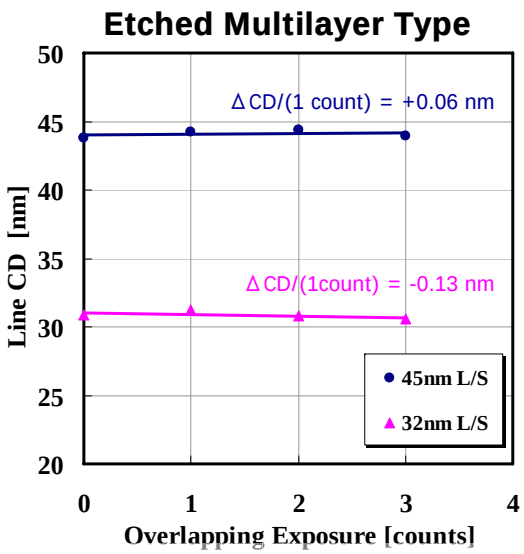
with Light Shield Area

Line CD Change by Overlap w/ SPF (Spectral Purity Filter) Setting

BACUS 2008







Resist: SSR2

High light-shielding performance is demonstrated in both types of stacked absorber and of etched ML.

Requirements for Spectral Purity

EUVL Symposium 2009

Joint Requirements for EUV Source

- Oct 2009

SOURCE CHARACTERISTIC	REQUIREMENT
Wavelength	13.5 [nm]
EUV Power (in-band) at IF	115W @ 5mJ/cm2 - 200W @ 10 mJ/cm2
Repetition Frequency	>10 kHz (2) There is no upper limit.
Integrated Energy Stability	0.2%, 3σ over 50 pulses
Source Cleanliness (debris)	Reflectivity degradation ≤ 10 % (in relative) after 30,000 light -on hours (1)
Etendue of Source Output	Max 3.3 mm2sr (2)
Max. solid angle input to illuminator	0.03 - 0.2 [sr] (2)
Spectral purity: 130-400 [nm] (DUV/UV)	<1% at wafer values at IF-design dependent
≥400 [nm] (IR/Vis) including 10.6 μm (3)	<10 – 100% at wafer values at IF-design dependent

(1) After IF
(2) Design dependent
(3) Assuming 10.6 μm being the excitation laser wavelength

Oct-19-2009, Prague
EUVL Symposium 2009 / Slide 4

K. Suzuki, Nikon
A. Miyake, Canon
N. Harned, ASML

Canon
Nikon
ASML

Motivation

(1) **To evaluate dependence of light-shield ability on mask structure under the condition of EUV light source w/o SPF,** that is to say, irradiated light on mask may contain OoB (Out-of-Band) .

(2) **To demonstrate lithographic performance of thin absorber mask with light-shield border using full-field exposure tool (EUV1)** under the current practical condition of EUV light source (w/o SPF).

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[3] Application of Mask with Light-shield Border to EUV1 **
- Experimental Condition (Reticle Masking Blades Setting, Shot Map)
- Printed CD Difference between Shot Arrays

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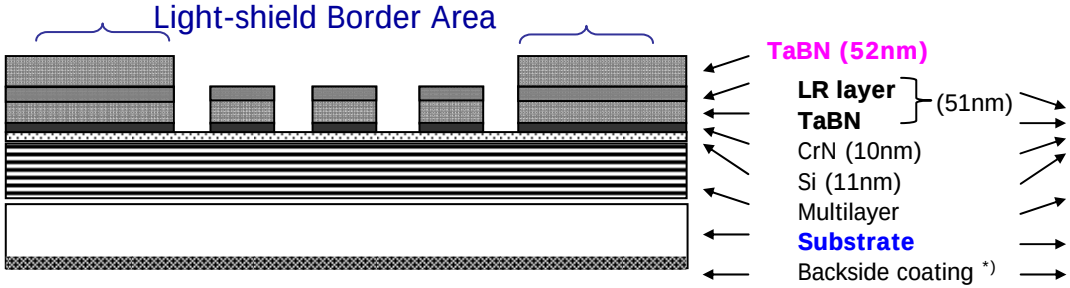
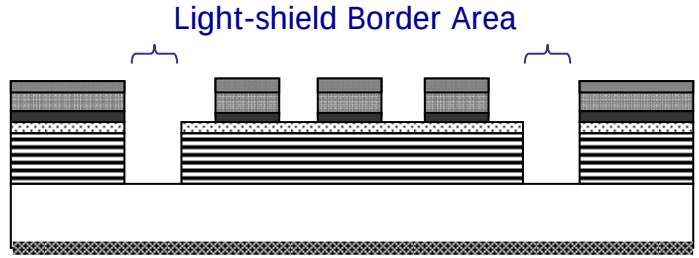
** EUV1: Full Field Exposure Tool (Nikon)

Reflectivity of EUV and DUV~VIS Wavelength

Stacked Absorber Type

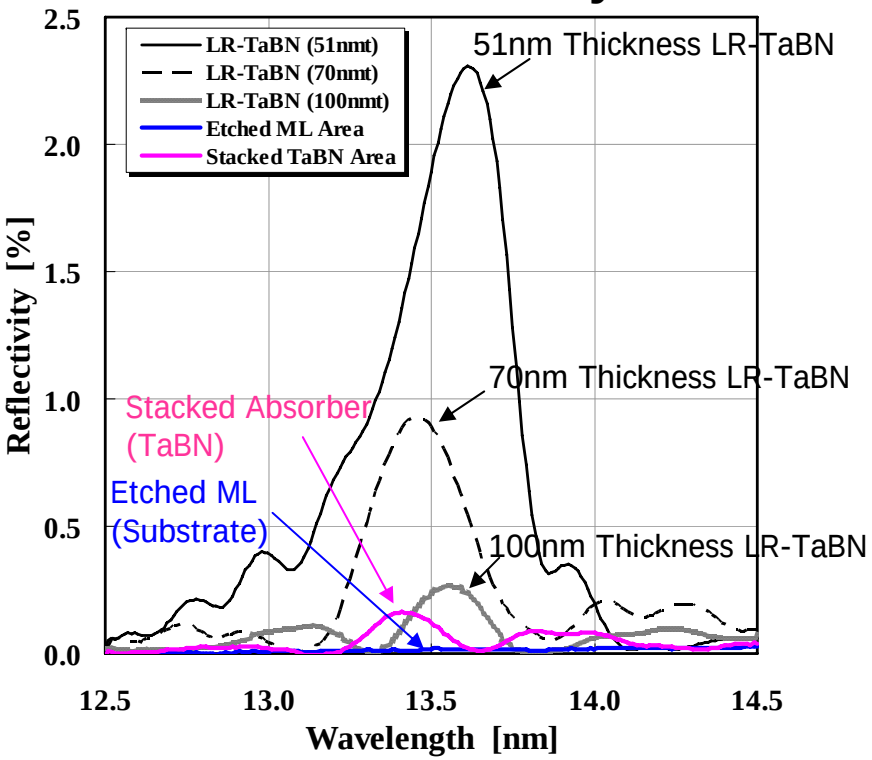


Etched Multilayer Type

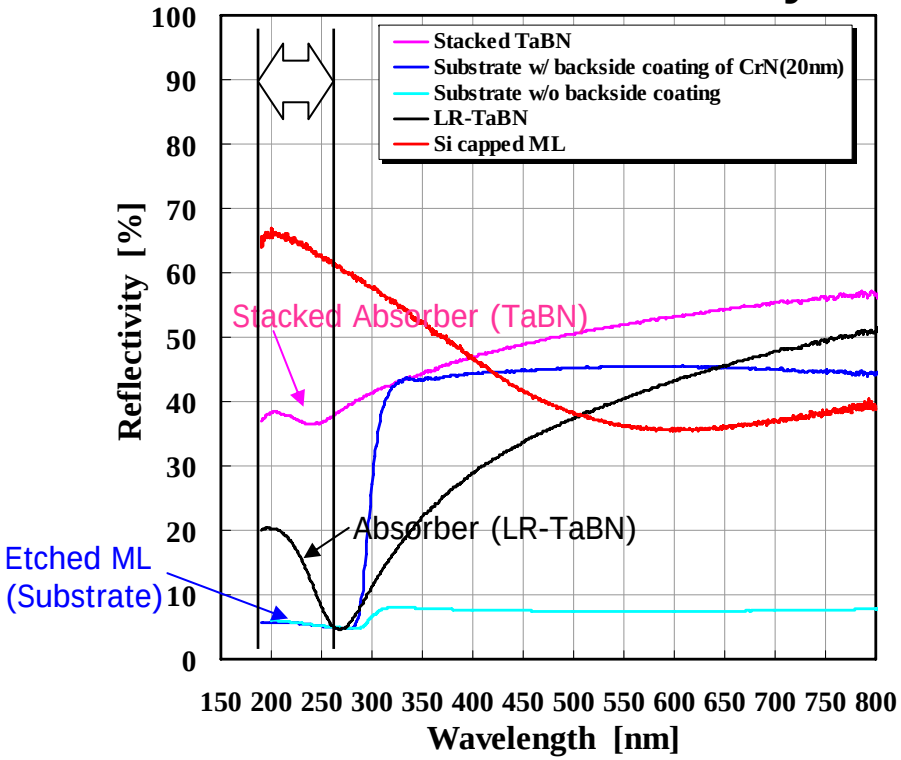


*) Mask for SFET has NO backside coating

EUV Reflectivity



DUV~VIS Reflectivity



DUV (190nm~260nm) Reflectivity: Etched ML (Substrate) < LR-TaBN < Stacked TaBN

Experimental Condition of SFET

Mask Structure:

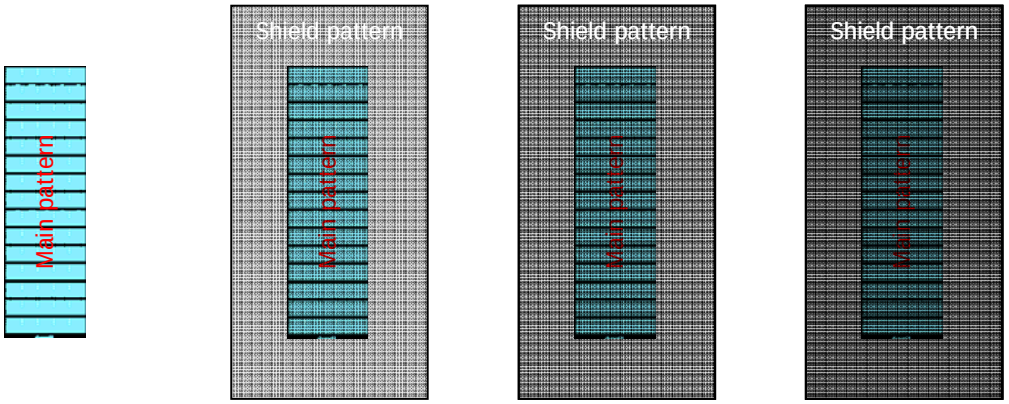
(1) LR-TaBN(100nm) / CrN(10nm) / Si(11nm) / ML (Mo/Si 40pairs) / Qz
(2) LR-TaBN(51nm) / CrN(10nm) / Si(11nm) / ML (Mo/Si 40pairs) / Qz with light-shield area of stacked absorber
(3) LR-TaBN(51nm) / CrN(10nm) / Si(11nm) / ML (Mo/Si 40pairs) / Qz with light-shield area of etched ML

SFET Exposure Condition and Resist CD Evaluation:

Exposure condition:	NA=0.3 (central obscuration: 30%), sigma (inner/outer)=0.3/0.7, Incident angle=6deg, Magnification=1/5, Xe DPP source with or without SPF *)
Resist :	Selete Standard Resist 4 (SSR4) 50nm thickness (on Bare Si)
Resist CD evaluation:	S9380II (HITACHI High-Technologies)

*) The ratio of OoB to EUV on wafer is estimated to be about 1% in the experiment w/o SPF setting.

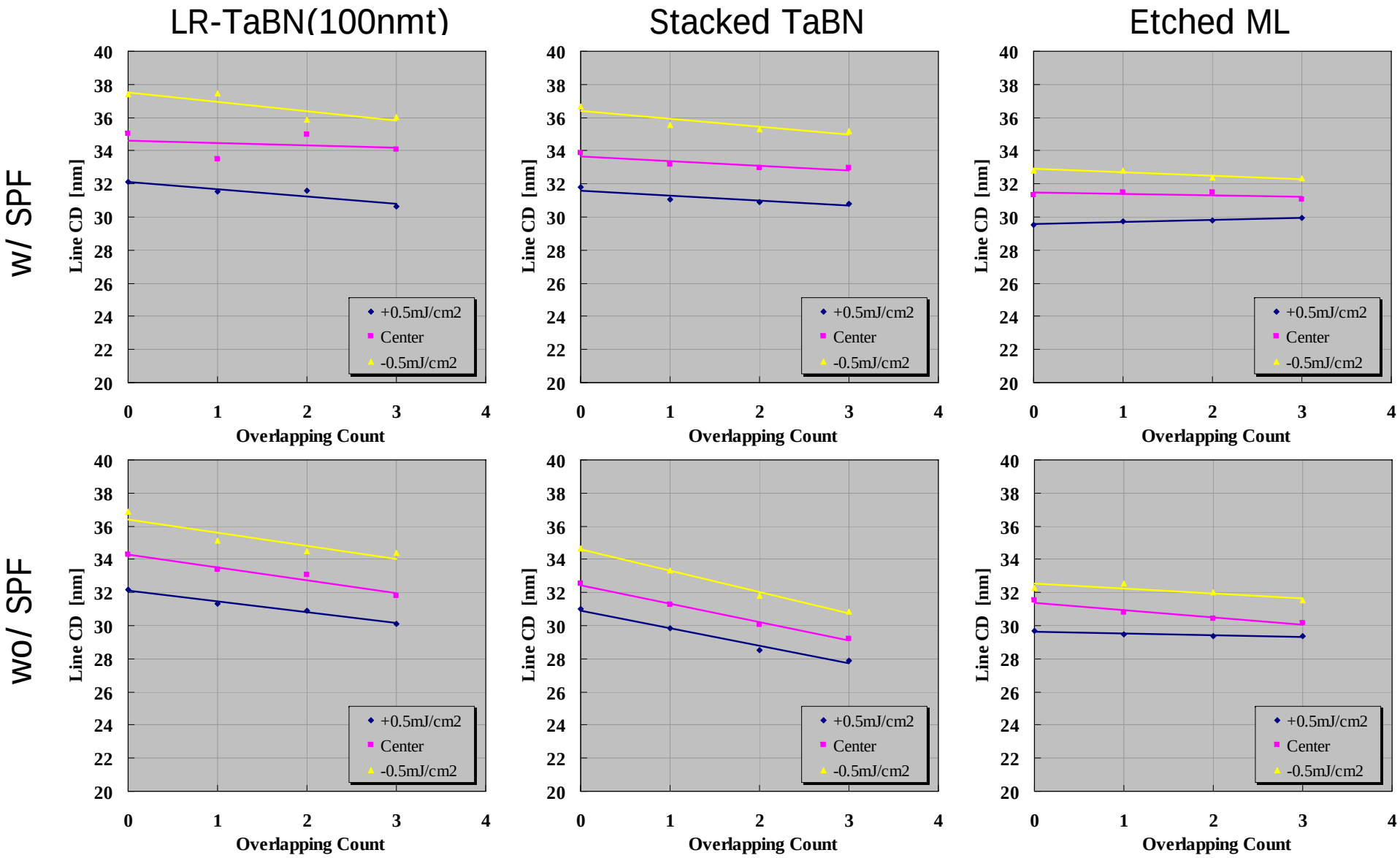
Method of Overlapping Exposure Experiment:



Single Exposure with Main Pattern Area | Overlapping Exposure x1 | Overlapping Exposure x2 | Overlapping Exposure x3

with Light-shield Area

Printed Line CD Change after Overlapping Exposure (32nmHP)



Line CD change after overlapping exposure is very small with SPF setting.

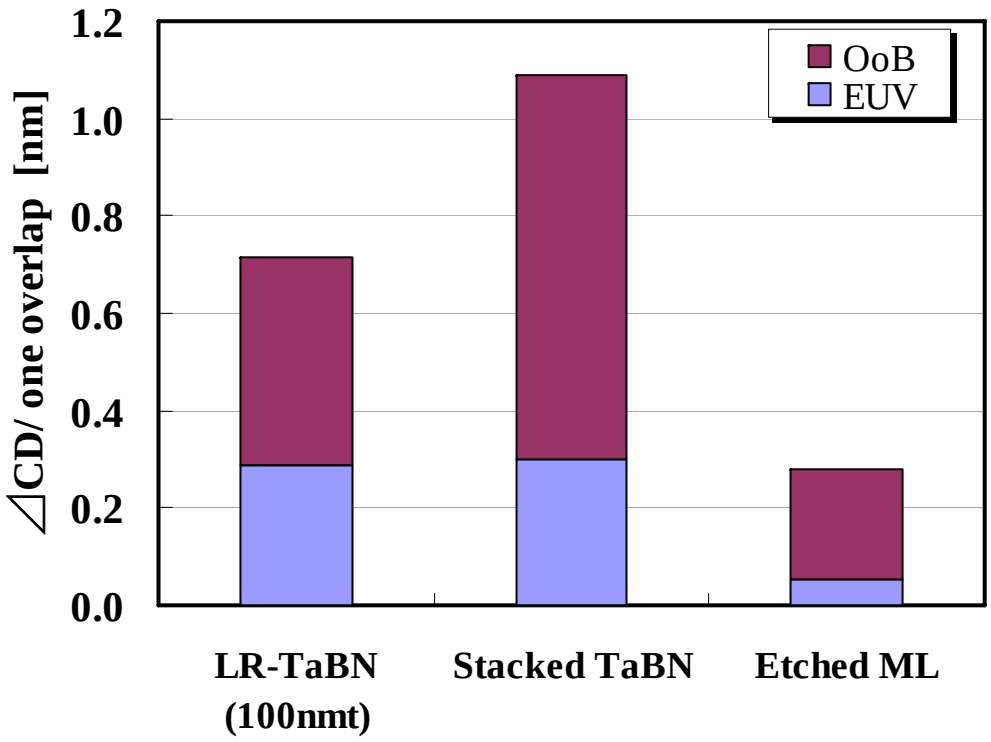
Line CD change after overlapping exposure is more clearly observed w/o SPF than w/ SPF.

Summary of Light-shield Performance

⊿CD after one overlapping exposure (32nm HP)

	LR-TaBN (100nm t)	Stacked TaBN	Etched ML
w/ SPF (EUV)	0.3nm	0.3nm	< 0.1nm
wo/ SPF *	0.7nm	1.1nm	0.3nm
wo/ SPF - w/ SPF (OoB)	0.4nm	0.8nm	0.2nm

* The ratio of OoB to EUV on wafer is estimated to be about 1% in the experiment w/o SPF setting.



The light-shield ability of etched multilayer type is highest for both EUV and OoB.

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- **Printed CD Difference between Shot Arrays**

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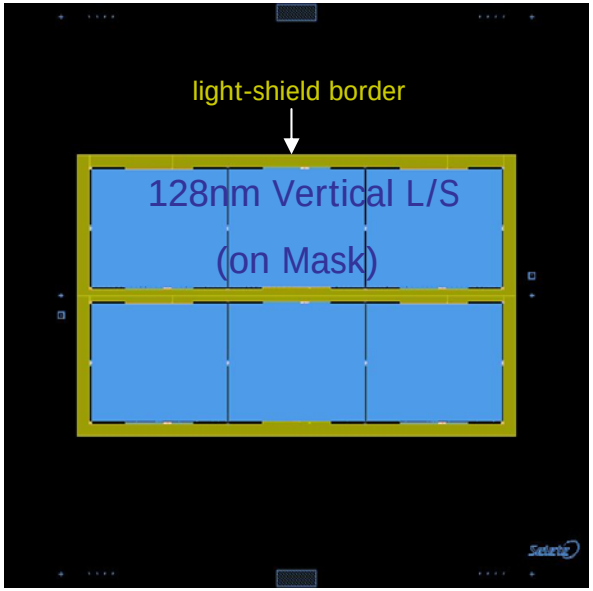
* SFET: Small Field Exposure Tool (Canon/EUVA)
** EUV1: Full Field Exposure Tool (Nikon)

Experimental Condition (Blanks/ Mask)

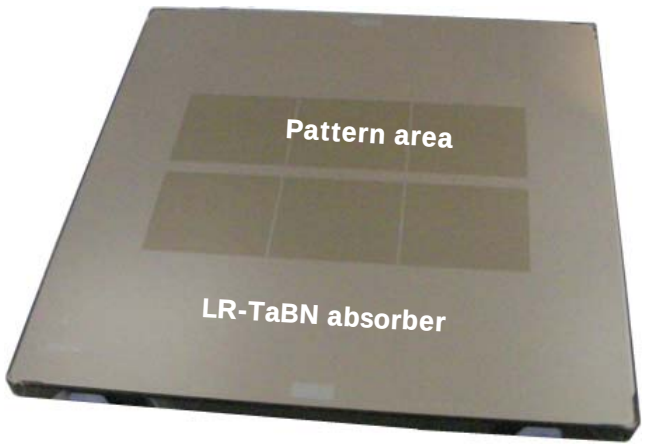
Blanks/Masks

Blanks :	LR-TaBN (51nm or 70nm) / CrN buffer(10nm) / Si cap (11nm) / M.L. 40pairs (Mo/Si) / LTEM substrate/ CrN(20nm)-B
Mask Structure:	Conventional structre (LR-TaBN thickness: 51nm, 70nm)
	Thin Absorber (LR-TaBN thickness: 51nm) with light-shield border of etched multilayer (border width: 3mm on mask scale)

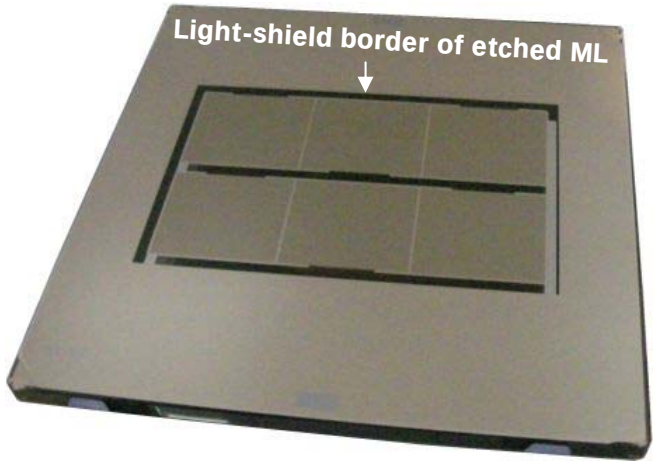
Mask Layout



Conventional structure



Light-shield border of etched ML

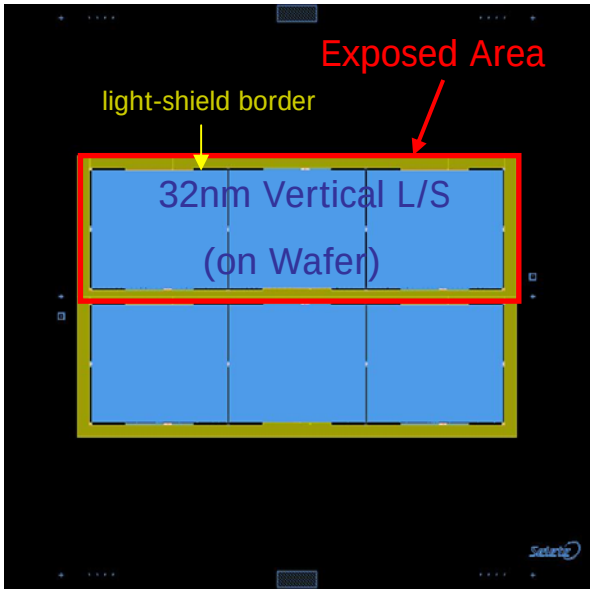


EUV1 Exposure

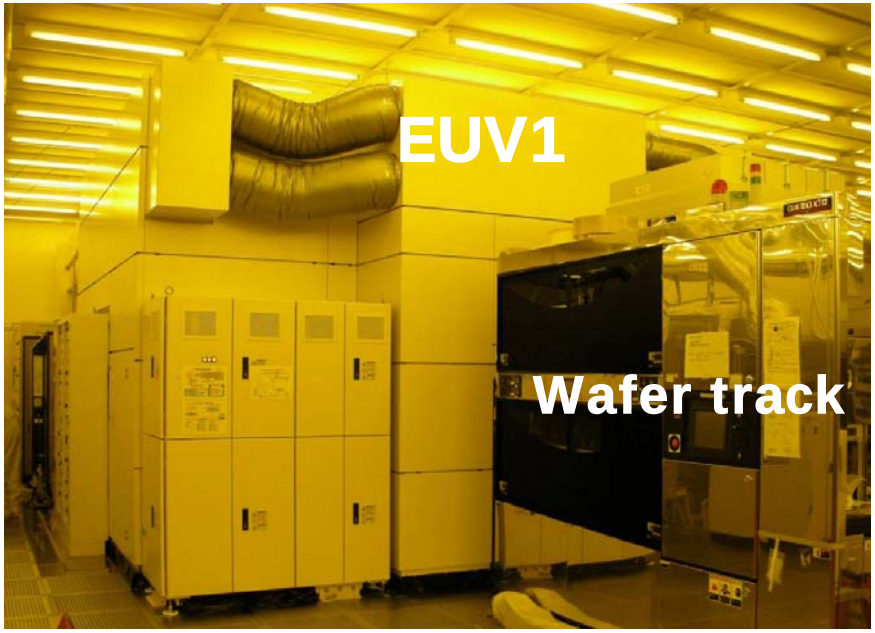
EUV1 Experiment

Exposure condition :	NA=0.25, sigma=0.8(Conventional illumination), Incident angle=6deg, Magnification=1/4, Xe DPP Light Source
Resist :	Selete Standard Resist 4 (SSR4) 50nm thickness (on Bare Si)
Coater & development :	ACT-12 (Tokyo Electron)
Resist CD evaluation :	CG4000 (HITACHI High-Technologies)

Mask Layout



Flare Correction is applied

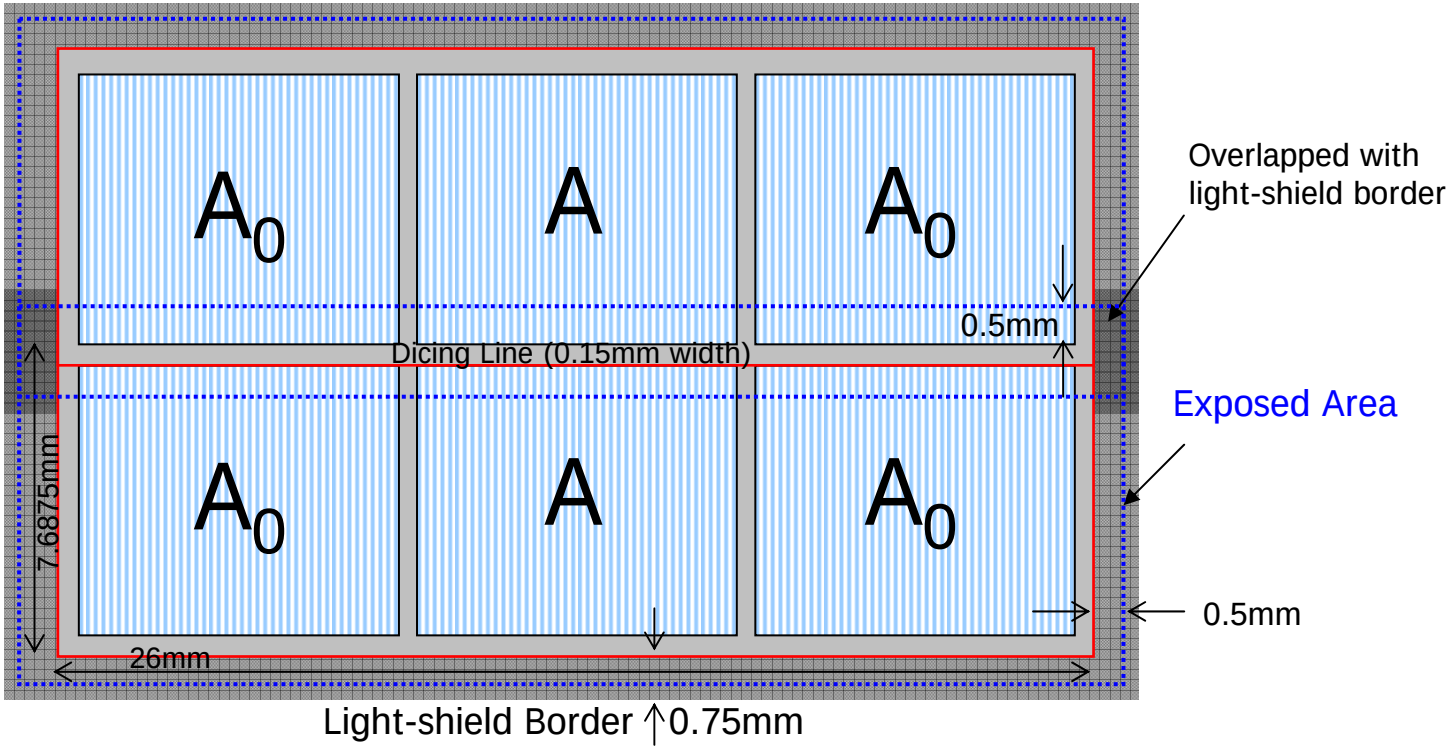


Reticle Masking Blades Setting and Adjacent Shot of Minimum Pitch

Reticle Masking Blades Setting

and

Adjacent Shot of Min. Pitch

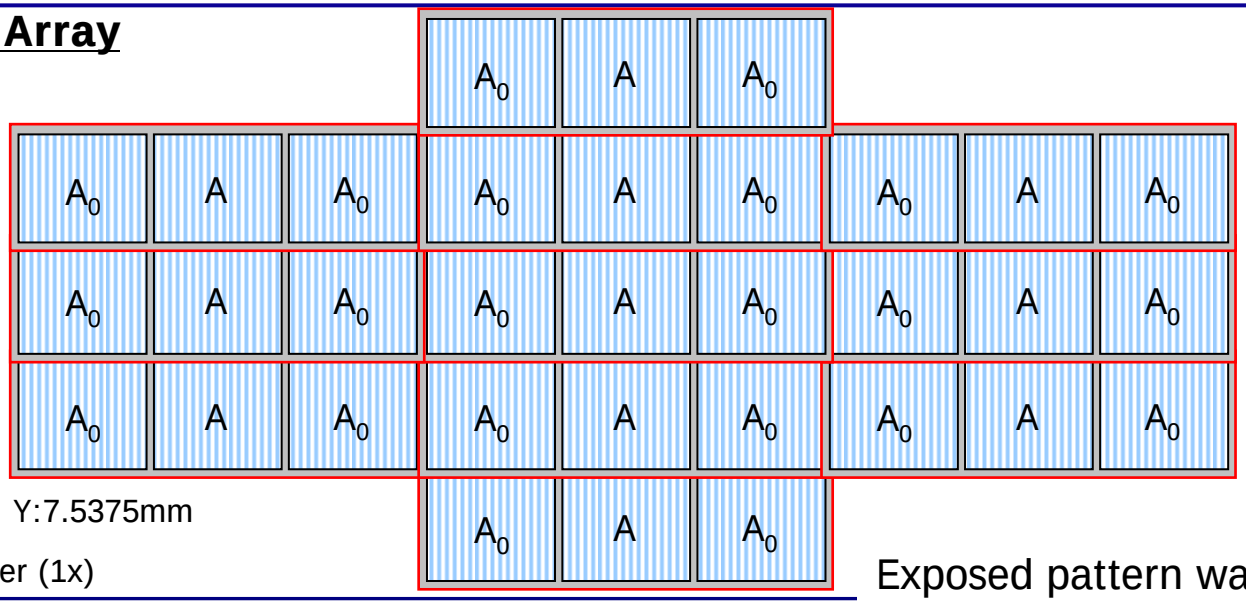


Chip A contains programmed defect pattern area of 369umx308um near at the chip center

Scale: on Wafer (1x)

Exposure Shot Map (11 Shot Array)

Min. Pitch Shot Array



Step Pitch:

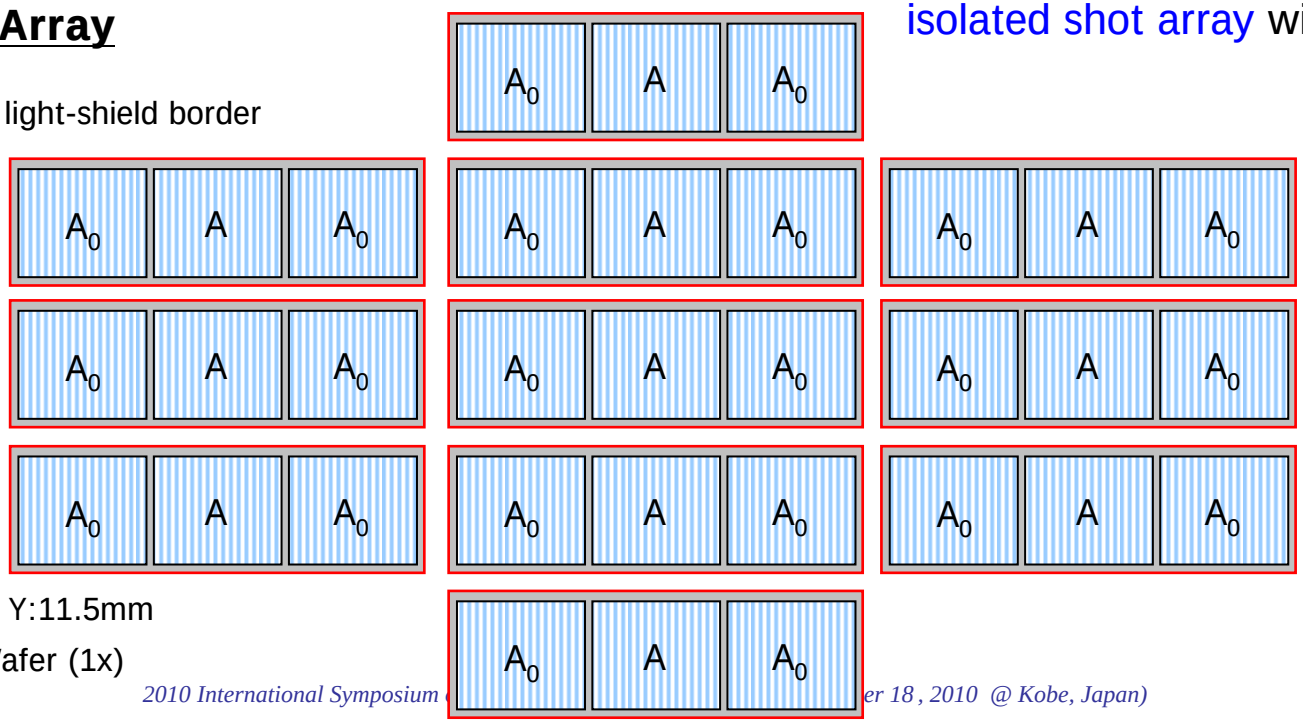
X: 25.850mm, Y:7.5375mm

Scale: on Wafer (1x)

Exposed pattern was optimized for isolated shot array with flare correction.

Isolated Shot Array

No overlapping with light-shield border

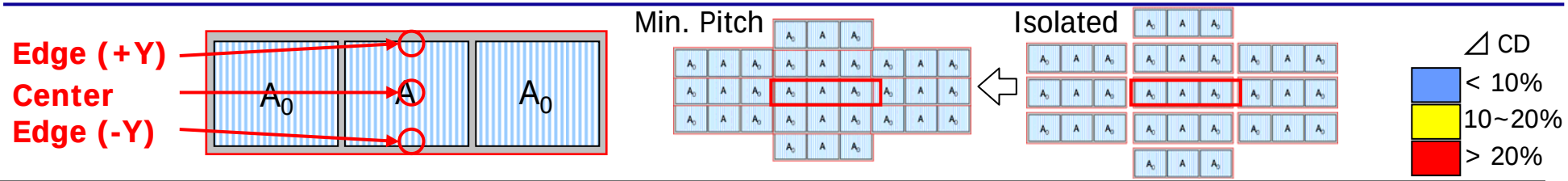


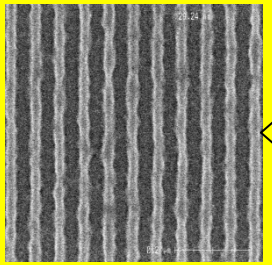
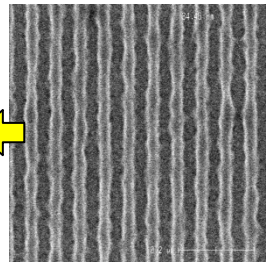
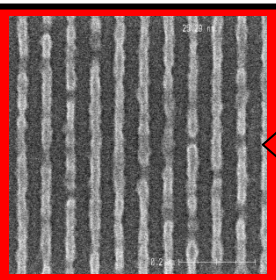
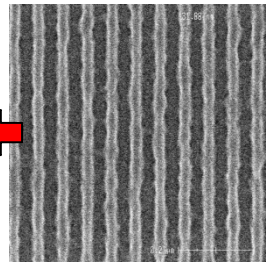
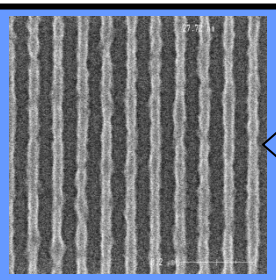
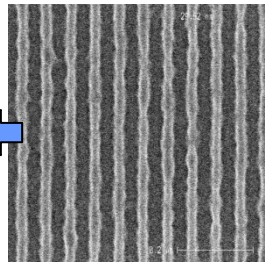
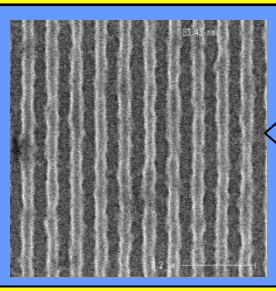
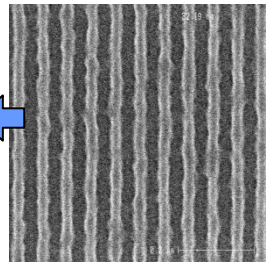
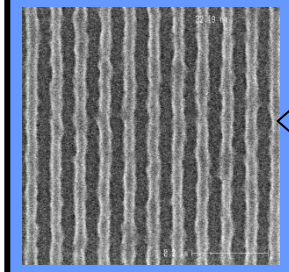
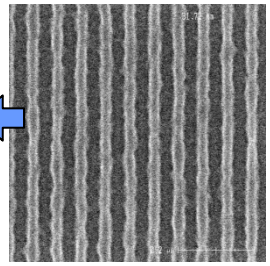
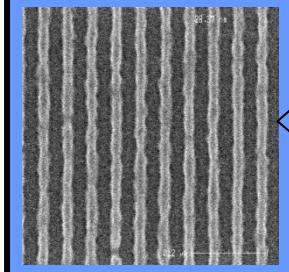
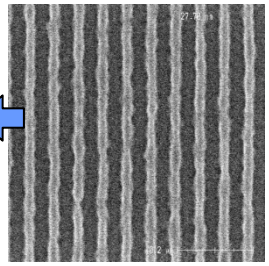
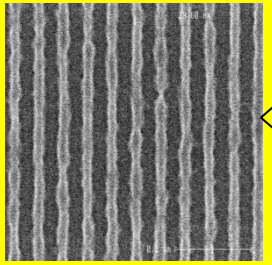
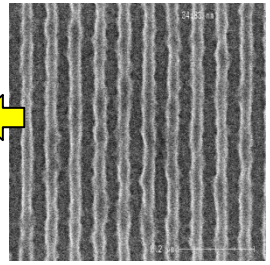
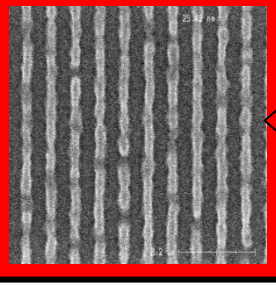
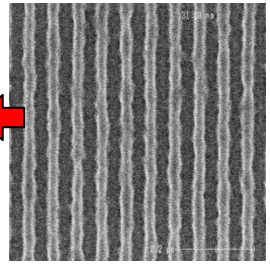
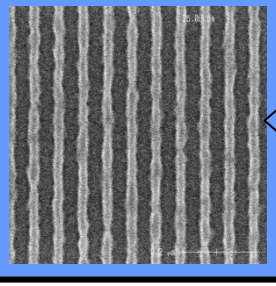
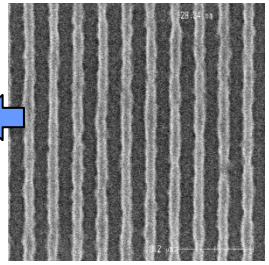
Step Pitch:

X: 27.0mm, Y:11.5mm

Scale: on Wafer (1x)

32nm HP Pattern SEM Image of Min. Pitch and Isolated Shot



	LR-TaBN (70nm) Conv. Structure		LR-TaBN (51nm) Conv. Structure		LR-TaBN (51nm) w/ Border of Etched ML	
	Min. Pitch Shot	Isolated Shot	Min. Pitch Shot	Isolated Shot	Min. Pitch Shot	Isolated Shot
Edge (+Y)						
Center						
Edge (-Y)						

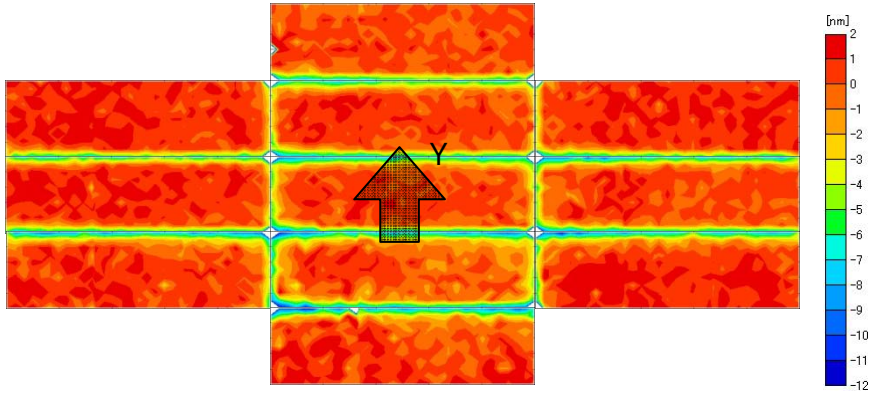
Line CD Difference between Min. Pitch and Isolated Shot

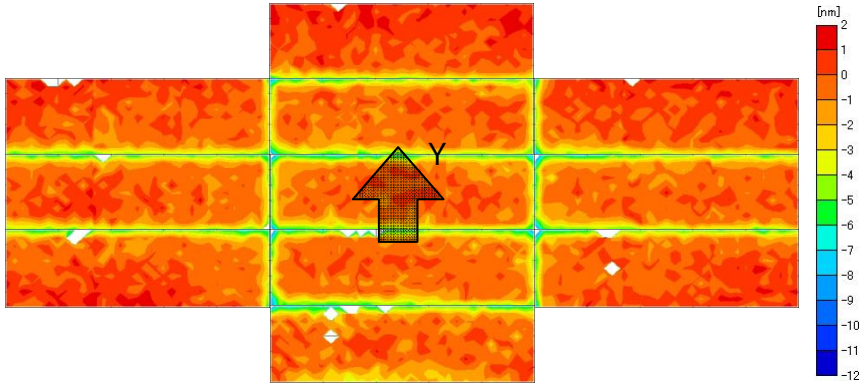
⊿ Line CD (Min. Pitch Shot - Isolated Shot)

Exposure w/o SPF

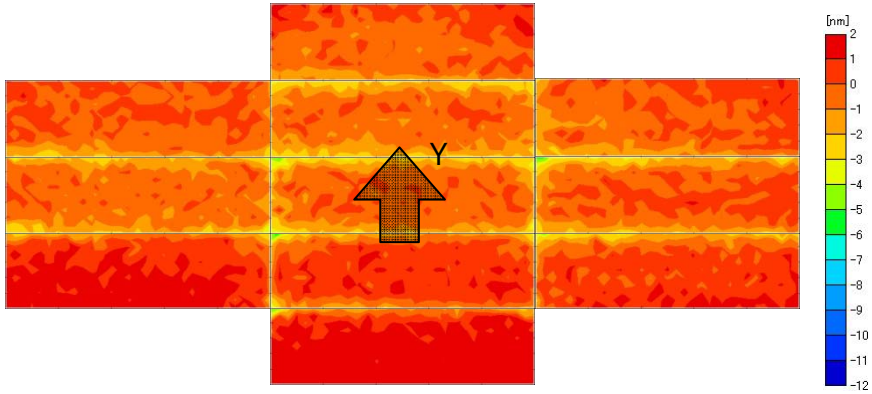
LR-TaBN: 51nm thickness | **LR-TaBN: 70nm thickness**

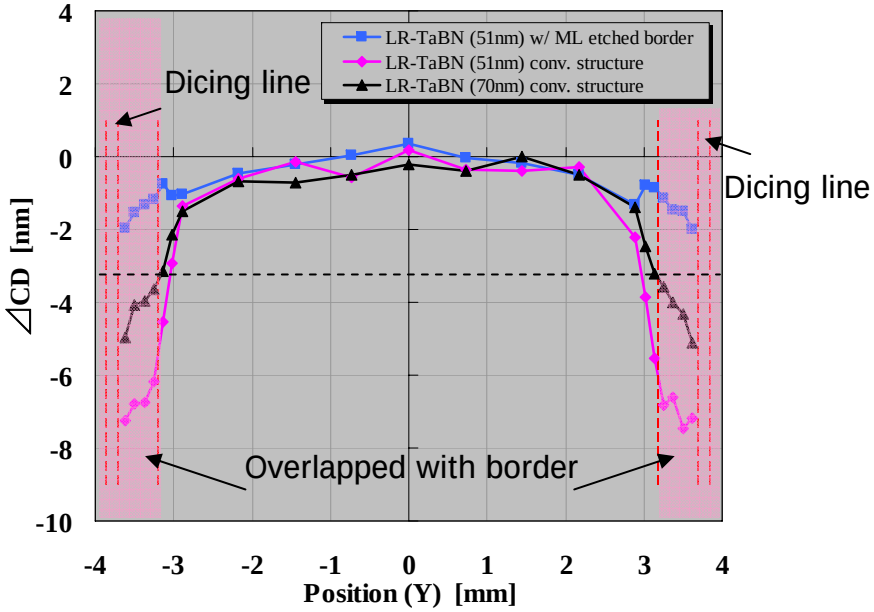
Conventional Structure





ML etched Light-shield Border



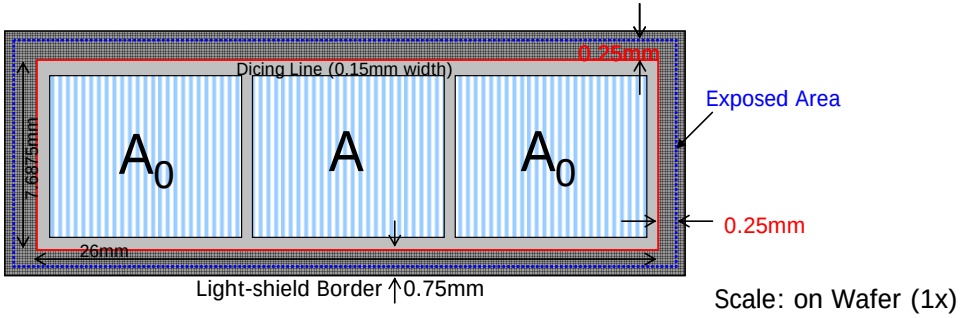


Printed Line CD difference at the overlapped area is reduced down to 32nmHP +/-10% by applying etched ML border. However, a CD change of less than 2nm can still be observed in the overlapped area.

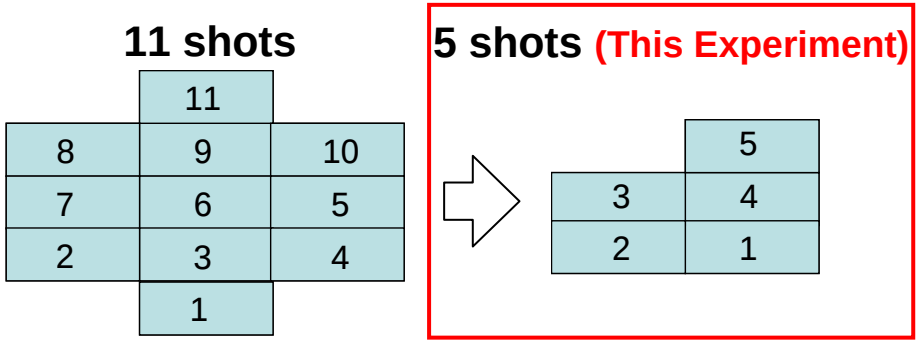
⊿ Line CD Uniformity w/SPF (Special Setting of EUV1)

Mask: Thin Absorber (LR-TaBN: 51nm t) with light-shield border of etched multilayer

Reticle Masking Blades Setting



Exposure Shot Map

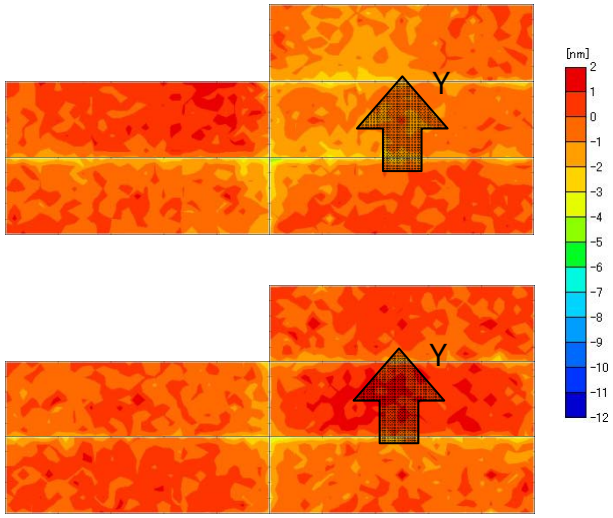


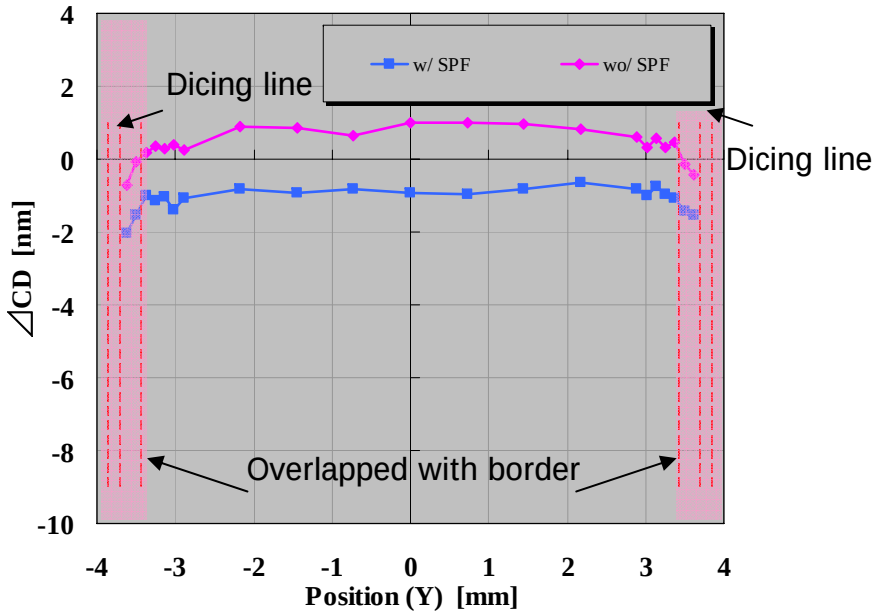
⊿ Line CD

(Min. Pitch Shot - Isolated Shot)

w/ SPF

wo/ SPF (reference)





With SPF setting, CD change (< 2nm) can still be observed in the overlapped area as without SPF.
OoB leakage from light-shield border w/o SPF (practical condition of EUV1) is estimated to be very small.

Possible Cause of CD change

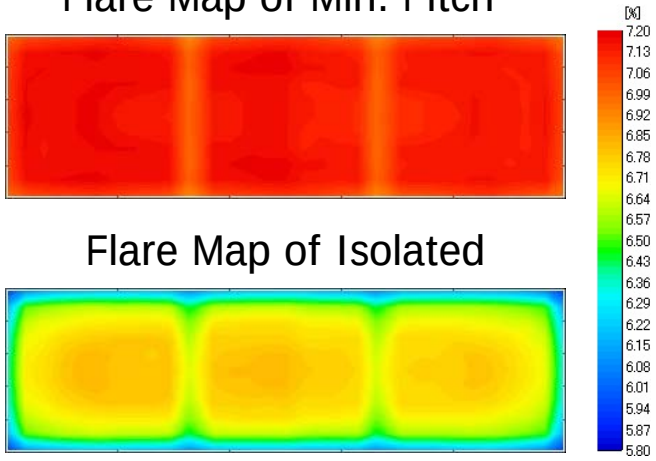
Possible cause of CD change (< 2nm) at overlapped area with light-shield border:

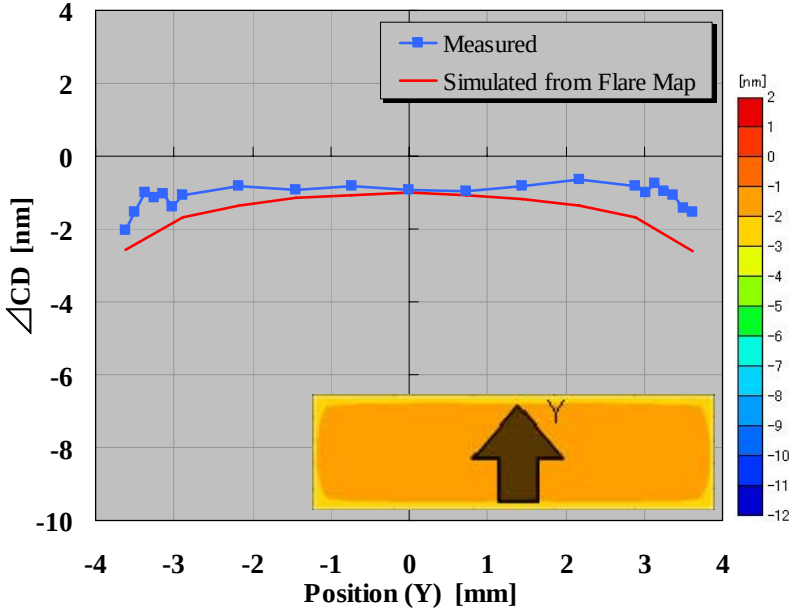
(1) Flare difference between min. pitch shot and isolated shot

CD uniformity of min. pitch array changes from isolated shot array because flare map is different between shot arrays.
→ This will be main factor of CD change at overlapped area.

Flare Map of Min. Pitch

Flare Map of Isolated





(2) Loading effect difference of resist development process
→ This should be small because resist development process is matured.

Outline

[1] Introduction
- Background
- Motivation

[2] Dependence of Light-shield Ability on Mask Structure with SFET *
- Reflectivity of Mask with Light-shield Area
- Printed CD Change by Overlapping Exposure of Light-shield Area

[3] Application of Mask with Light-shield Border to EUV1 **
- Experimental Condition (Reticle Masking Blades Setting, Shot Map)
- Printed CD Difference between Shot Arrays

[4] Summary

* SFET: Small Field Exposure Tool (Canon/EUVA)
** EUV1: Full Field Exposure Tool (Nikon)

Summary

[1] Dependence of Light-shield Ability on Mask Structure with SFET

The light-shield ability of etched multilayer type is highest for both EUV and OoB.

[2] Application of Mask with Light-shield Border to EUV1

Printed Line CD difference at the overlapped area is reduced down to 32nmHP +/-10% by applying a light-shield border of etched ML.

CD change of less than 2nm can still be observed in the overlapped area. A major contribution to this CD change is coming from the flare difference between the minimum pitch array and the isolated array.
--> NOT an issue of light-shield border.

Thin absorber mask with light-shield border of etched ML is most promising structure for high lithographic performance.

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