

Fiducial Mark requirements from the viewpoints of EUV Actinic Blank Inspection tool for phase defect mitigation

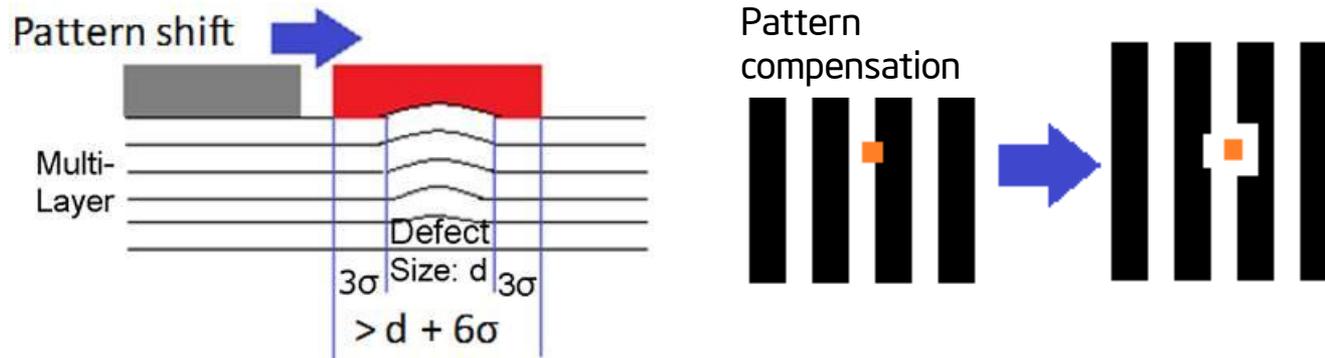
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Introduction (1)

- Fabrication of Multi-Layered (ML) blank with no printable defect is one of the difficult challenges.
- However, we can cover or compensate defects by aligning the locations of patterns and defects.

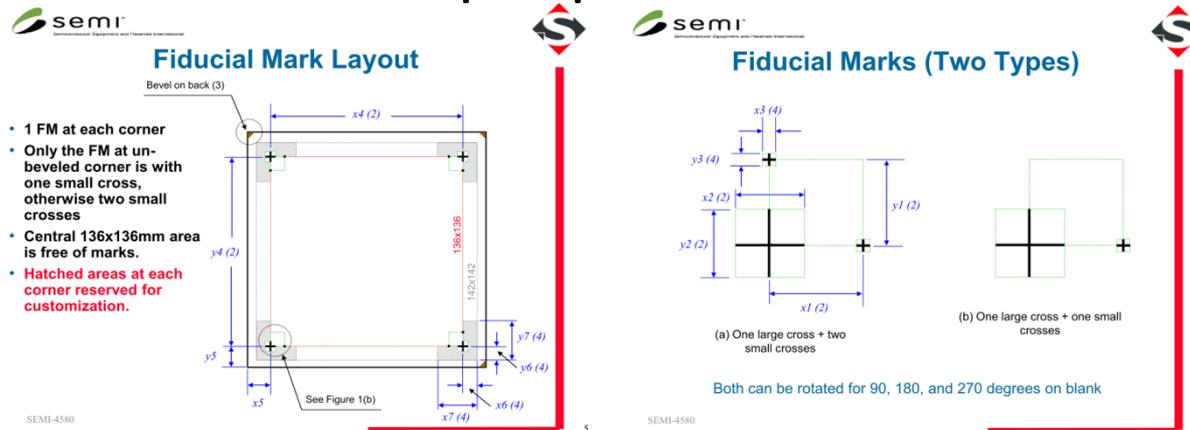


- Fiducial Mark (FM) is required to align locations.
- The proposed requirement of defect location accuracy to defect inspection tool is $< 10 \text{ nm}^*$.

*Pei-Yang Yan, Proc. of SPIE Vol. 8322, 83220Z, (2012).

Introduction (2)

- SEMI defines FM shape specification.



Excerpt from FM shape Specification

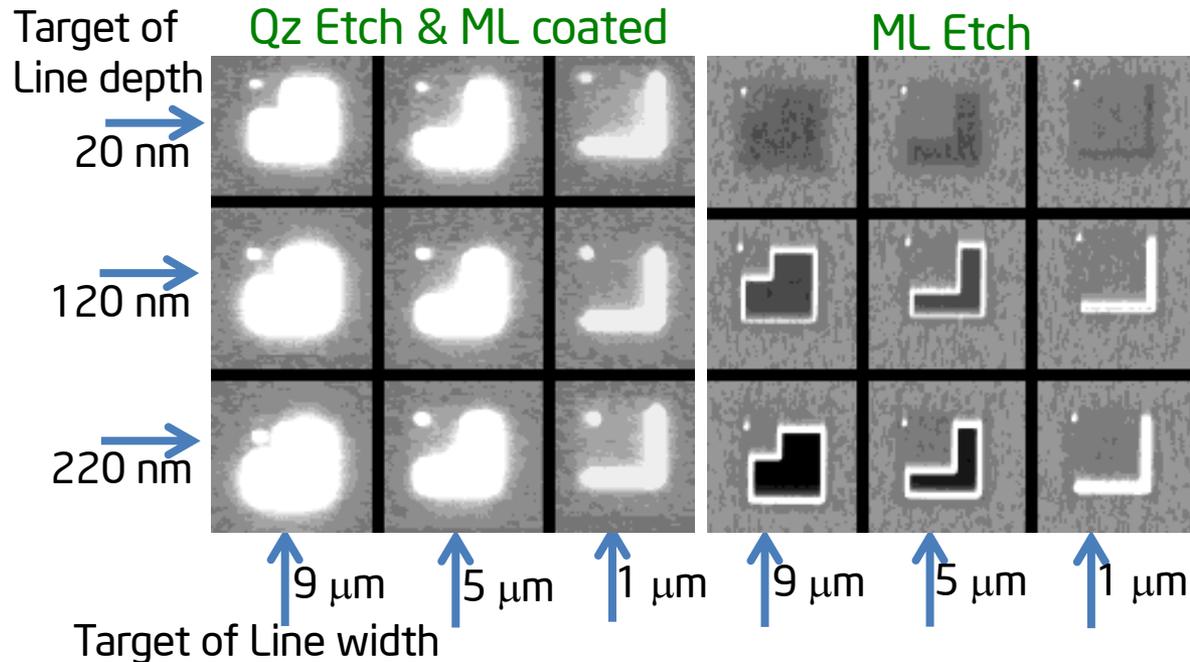
Item	Value (um)
Large cross size	550
Small cross size	100
Distance between centers of large and small cross	1500
Line CD	4 - 8

- So far FM line width, depth and fabrication method are not optimized for better location accuracy.
- We tried experiments to identify the optimum ranges of them.

Previous study reported in SPIE 2012

MIRAI ABI Result of FM etched by FIB

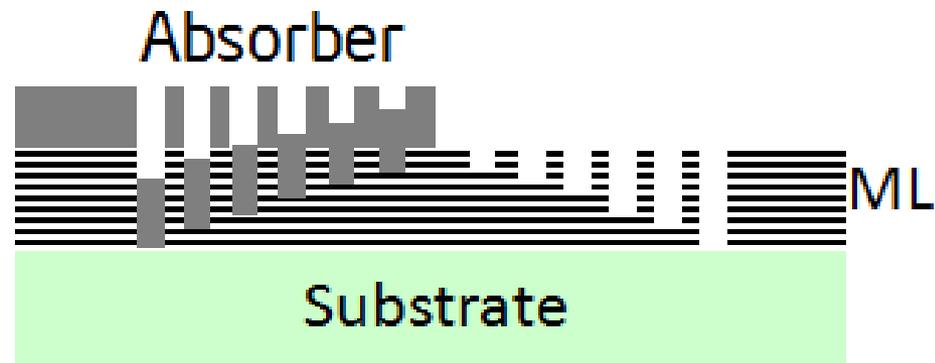
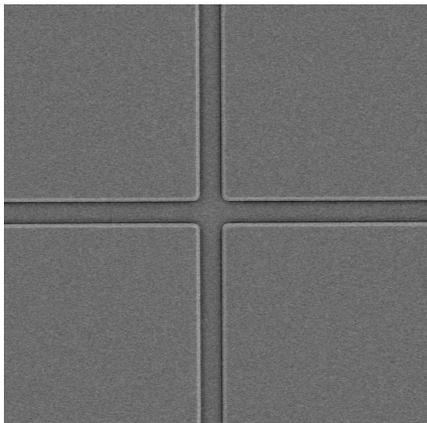
Actinic full-field mask Blank Inspection prototype developed at MIRAI-Selete



- For current MIRAI EUV ABI prototype, the optimum of FM line width, depth, and fabrication method are:
 - ❑ $\geq 5 \mu\text{m}$ line width is preferred
 - ❑ Around 120 nm line depth
 - ❑ ML etching is required
 - ❑ Additional finer FMs for magnified optics

Fabrication of FM

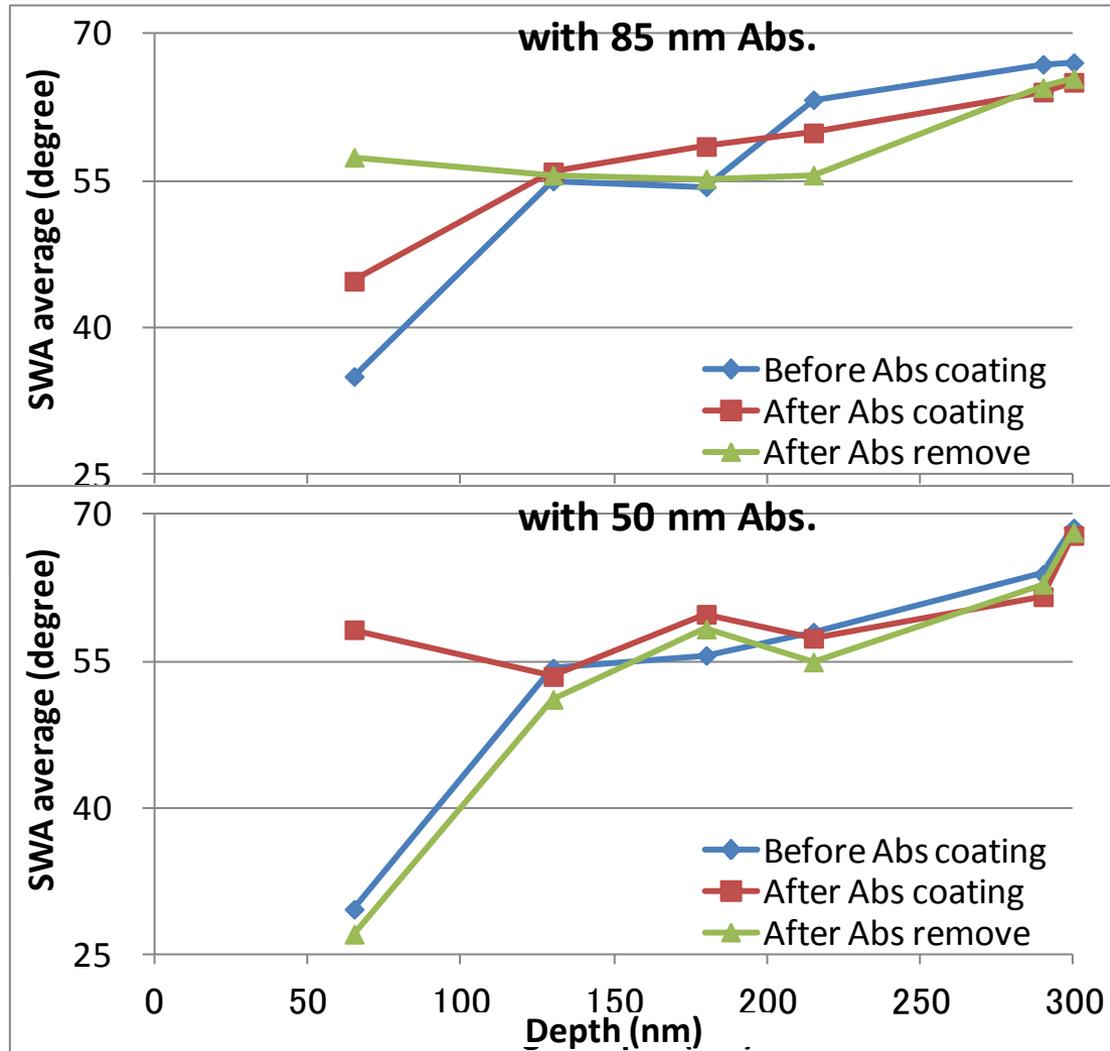
- 2 sets of FM matrix were fabricated by resist exposure by EB writer and ML etching process.
 - Line width: 1, 3, 5, 7 μm
 - Line depth: 65, 130, 180, 215, 290, 300 nm
 - Etching Layer: ML
- One set is covered by absorber, and other one is not.
 - ❑ 2 Masks were prepared. One is coated by 85 nm thickness absorber, and the other is by 50 nm thickness.
- Took data by AFM, SEM, EB writer, and ABI tool.



AFM measurement summary

Sidewall Angle (SWA) average

Calculated from 4 data of same width target FMs

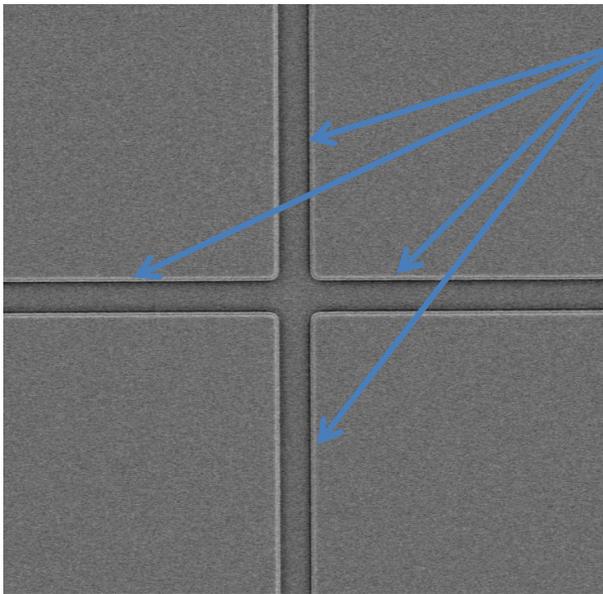


SWA of Shallower depth FMs varied by process.

Deeper ones' are relatively stable.

As SWA change may cause edge position shift, **> 100 nm depth is proper.**

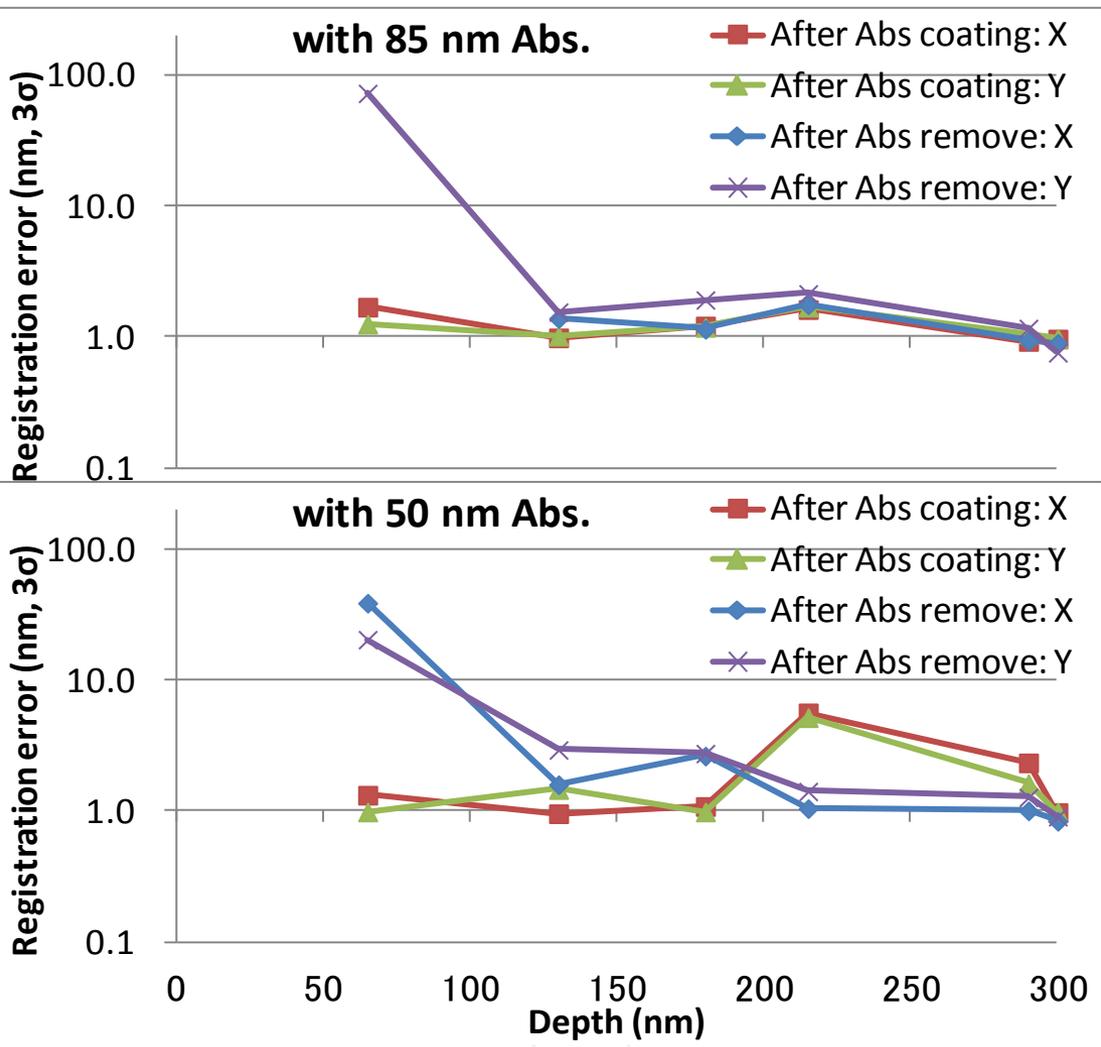
SEM measurement



1. Obtain position information of edge on Vertical & Horizontal lines (total 256 points)
2. Compensate rotation
3. Calculate line center locations and their accuracy on V&H lines

SEM measurement summary

Center registration accuracy



Generally deeper
 ≥ 130 nm depth
 ones are better.

EB measurement conditions

EB writer:	JEOL JBX9000
Acceleration Voltage:	50 keV
Scan step:	2 & 4 nm
Absorber:	Both of w/o & with 85 & 50 nm absorber thickness
Resist:	Coated 100 nm thickness
FM depth:	65, 130, 180, 215, & 290 nm
FM width:	1 μm

EB measurement data 2 nm scan step

65 nm depth

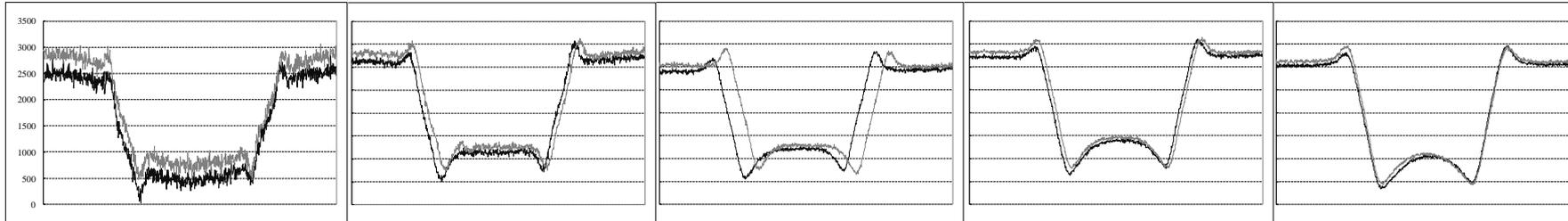
130 nm depth

180 nm depth

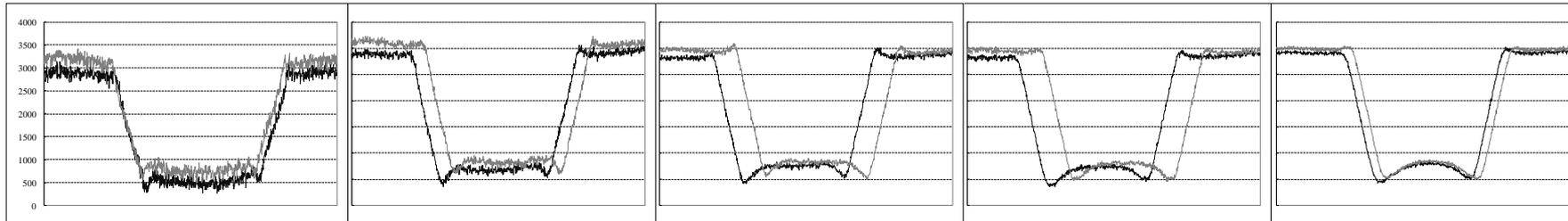
215 nm depth

290 nm depth

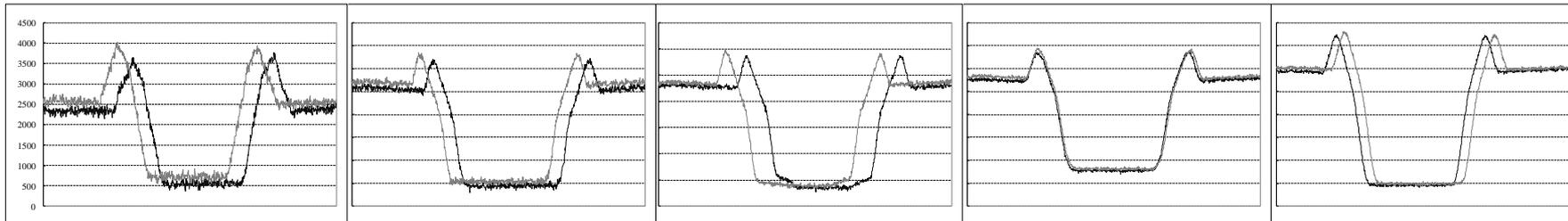
with
85 nm
Abs.



with
50 nm
Abs.



w/o
Abs.

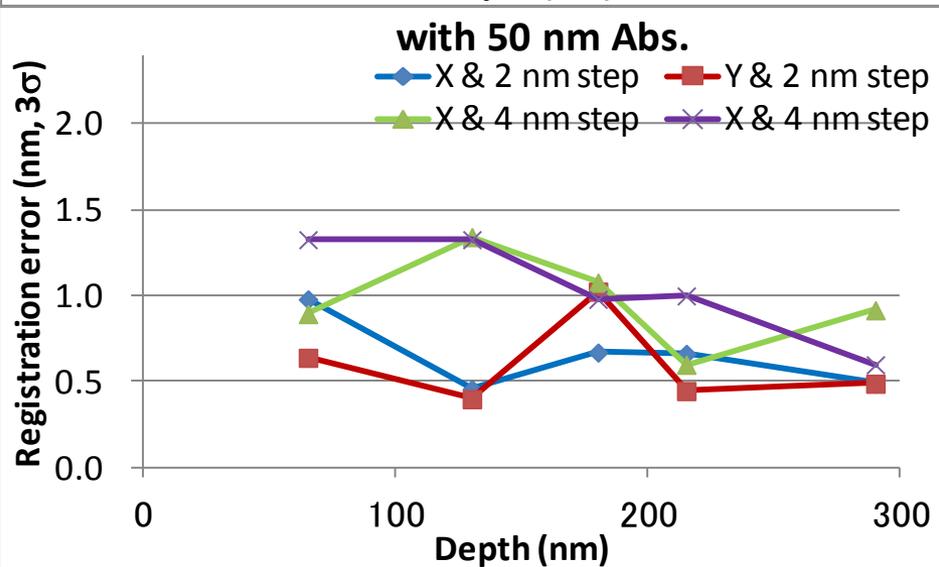
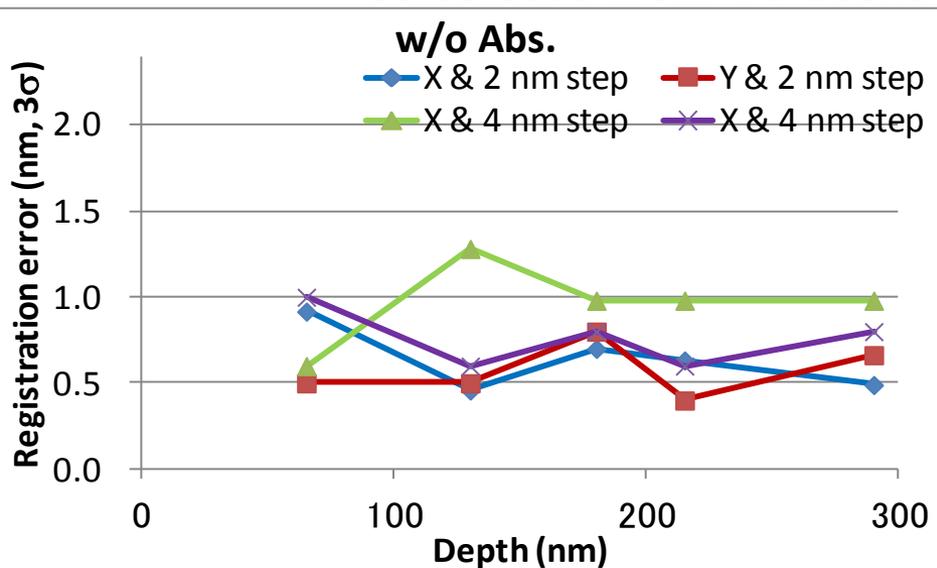
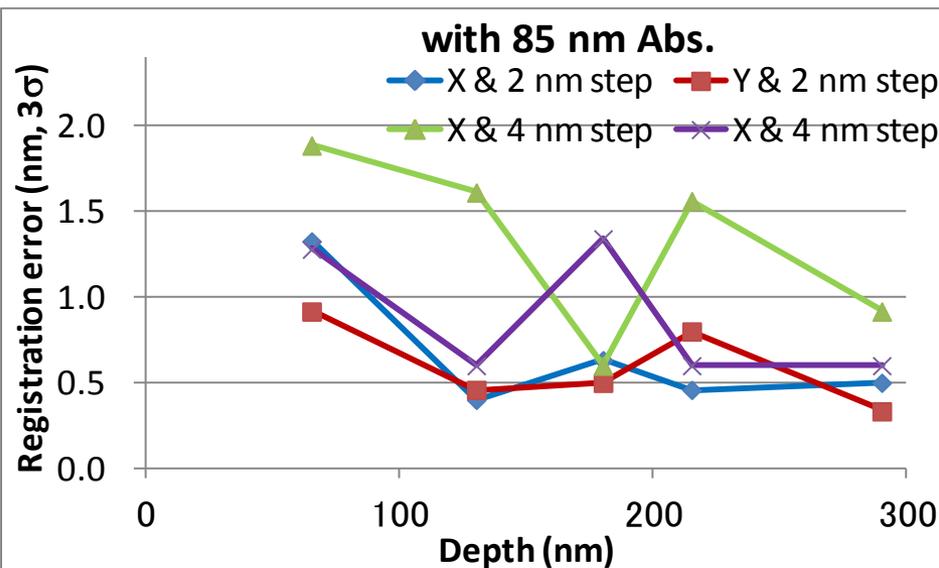


Gray line: Horizontal line
Black line: Vertical line

**Shallower ones look noisy.
Deeper ones look clear.**

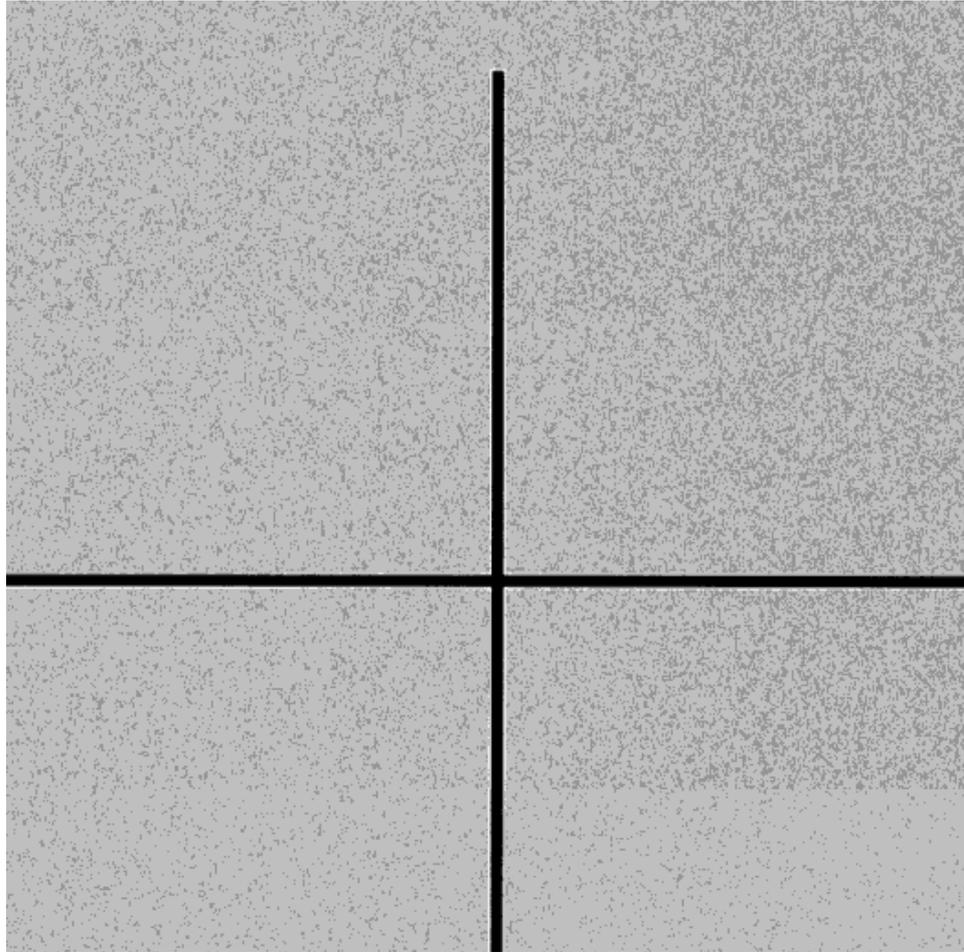
Registration error vs. depth of FM by EB

Calculated from 10 scans



Generally, deeper FM with
> 130 nm depth
2 nm scan step is better

ABI Measurement & Center location calculation



1. Obtain position information of edge on V&H lines (total 128 points)
2. Compensate rotation
3. Calculate line center locations and their accuracy on V&H lines

FM registration error (3σ) by ABI tool

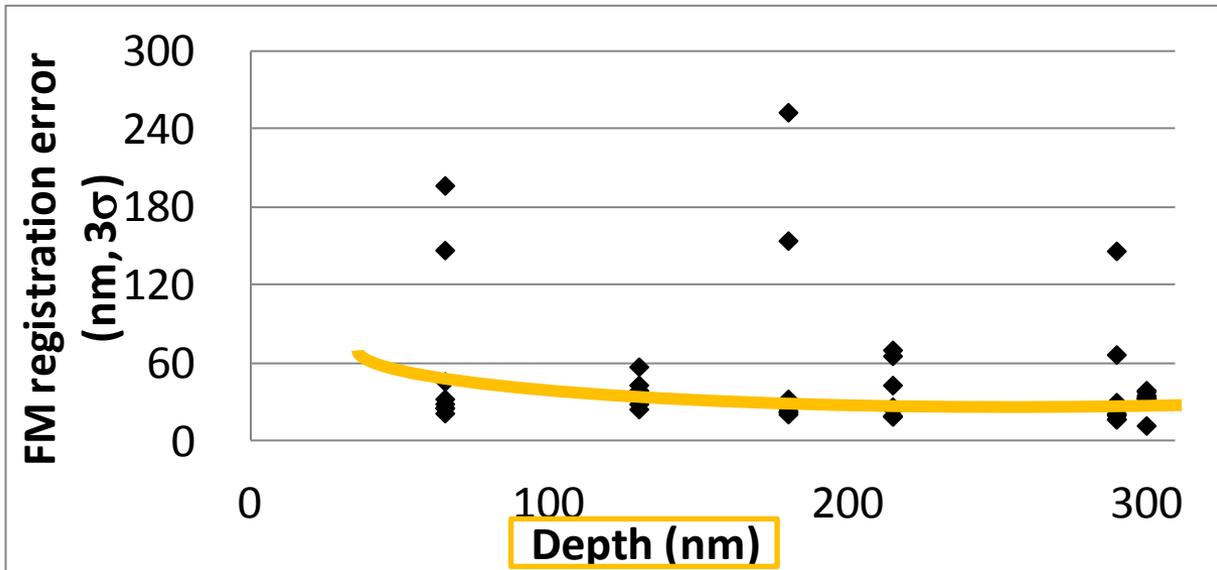
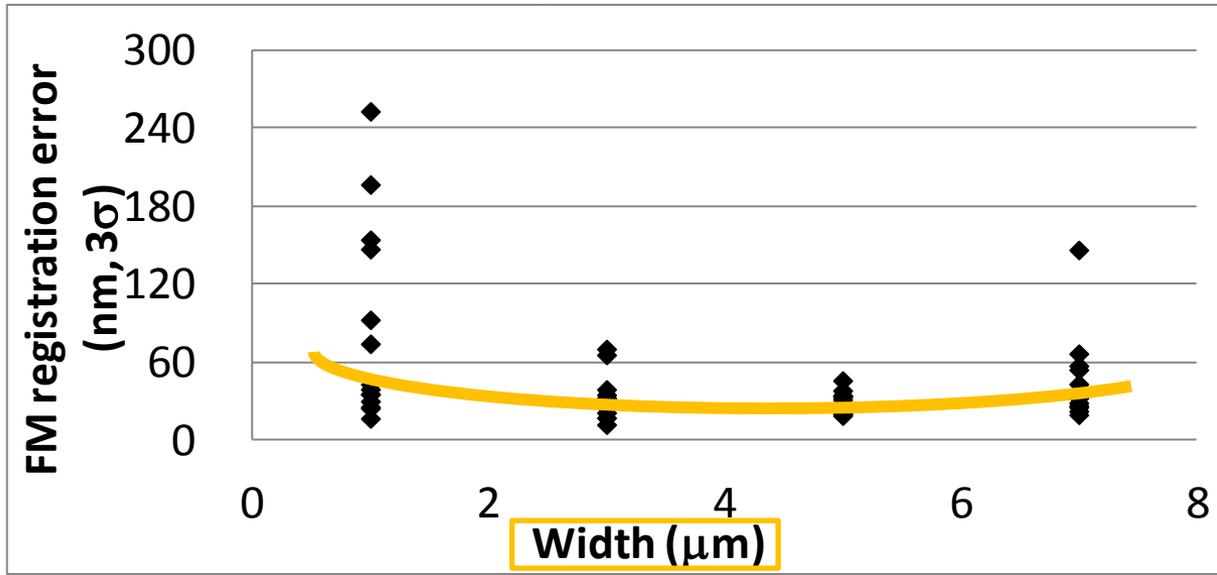
Width (μm)	Direction	Depth (nm)					
		65	130	180	215	290	300
1	X	147.08	35.49	154.36	43.11	29.95	35.42
1	Y	196.81	24.65	253.16	25.60	16.73	39.19
3	X	25.64	39.10	25.29	70.23	17.25	32.37
3	Y	32.49	28.59	29.00	65.66	21.16	12.00
5	X	21.51	34.08	23.08	18.93	20.05	33.41
5	Y	45.94	34.44	20.76	24.41	23.97	38.19
7	X	25.47	43.22	22.40	19.60	66.64	32.77
7	Y	28.71	57.28	32.49	26.46	146.44	34.08

*MIRAI ABI tool's pixel size is 500 nm on mask.

*ML etched FMs w/o absorber by EB resist exposure and etching process steps

*In addition to this error there are location errors of stage and defect by ABI tool

FM registration error (3σ) by ABI



Generally, deeper & wider FM is better. However, these results don't meet the proposed requirement.
($< 10 \text{ nm}$)

Need ABI's improvement of FM registration accuracy.

Summary

FM recommendations are:

- ✓ ML etched
- ✓ > 100 nm line depth
- ✓ 3-5 μm line width

ABI tool is required to equip Magnified Optics to achieve $< 10 \text{ nm}$ (3σ) error for mitigation ^(MO) i.e. smaller pixel size on mask (position & size).

We need further optimization of FM for the MO of LT ABI tool.

Acknowledgement

We would like to thank to following personals.

- ◆ Takeshi Yamane of EIDEC
- ◆ Engineers of HOYA and Dai Nippon Printing

This work was supported by the New Energy and Industrial Technology Development Organization (NEDO).



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