

Development of EB Inspection System EBeyeM for EUV Mask

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- Introduction
- Outline of EBeyeM
- Performance result of prototype system
 - Particle inspection
 - Pattern inspection
- Future plan
- Summary

Introduction

Extract from ITRS2009 EUV mask requirements

Year of Production	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
DRAM 1/2 pitch (nm) (contacted)	45	40	36	32	28	25	23	20	18	16	14
DRAM/Flash CD control (3 sigma) (nm)	4.7	4.2	3.7	3.3	2.9	2.6	2.3	2.1	1.9	1.7	1.5
Flash 1/2 pitch (nm) (un-contacted poly)	32	28	25	23	20	18	16	14	13	11	10
MPU/ASIC Metal 1 (M1) 1/2 pitch (nm)(contacte	45	38	32	27	24	21	19	17	15	13	12
MPU gate in resist (nm)	41	35	31	28	25	22	20	18	16	14	12
MPU physical gate length (nm)	27	24	22	20	18	17	15	14	13	12	11
Gate CD control (3 sigma) (nm) [A]	2.8	2.5	2.3	2.1	1.9	1.7	1.6	1.5	1.3	1.2	1.1
Overlay	9.0	8.0	7.1	6.4	5.7	5.1	4.5	4.0	3.6	3.2	2.8
Contact after etch (nm)	51	43	36	30	27	24	21	19	17	15	13
Generic Mask Requirement											
Mask magnification	4	4	4	4	4	4	4	4	4	4	4
Mask nominal image size (nm)	162	141	126	112	100	89	79	71	63	56	50
Mask minimum primary feature size	114	99	88	78	70	62	55	49	44	39	35
Defect size(nm)	36	32	29	25	23	20	18	16	14	13	11

Requirement of defect size is

2Xnm EUV mask -> 20nm order

1Xnm EUV mask -> 10nm order

Introduction

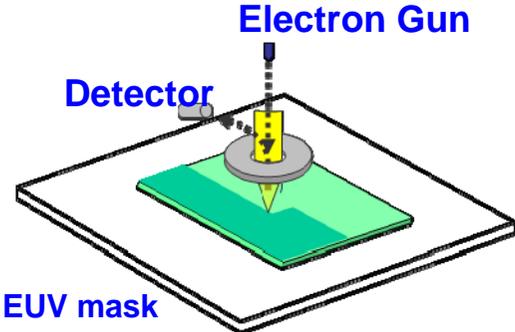
Mask	Inspection Method	Sensitivity	Throughput@ 100mm sqr.	Status
3Xnm	Conventional 19Xnm Optical	Acceptable	Acceptable	Ready
2Xnm	19Xnm Optical + Special Illumination Shape+ Polarization	Acceptable	Acceptable	Under development Will be ready soon
1Xnm	Actinic	Acceptable	Acceptable	Under development
	Electron Beam (SEM)	Acceptable	Unacceptable (40 - 80 hour?)  Acceptable ? with Multicolumn	Under development

Current status of defect inspection for EUV mask

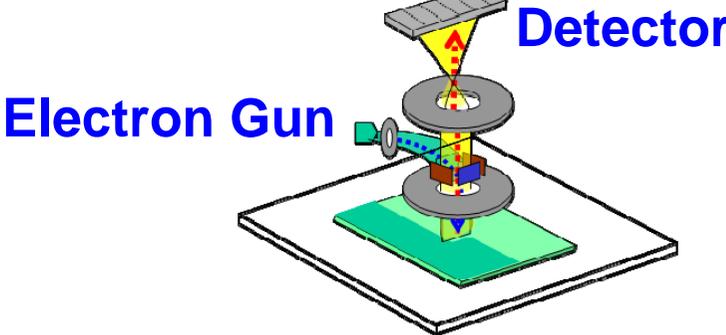
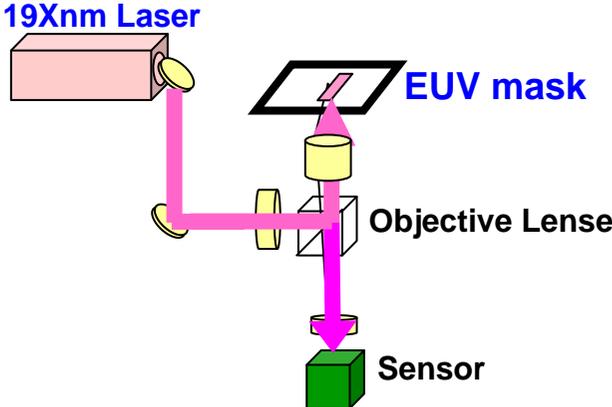
Introduction

Our proposal for EUV mask inspection is

**Sensitivity :
Similar to SEM**



**Throughput :
Similar to Optical**



Projection Electron Microscope

Introduction

We propose projection electron microscope inspection system for EUV mask.

We call it **EBeyeM**.

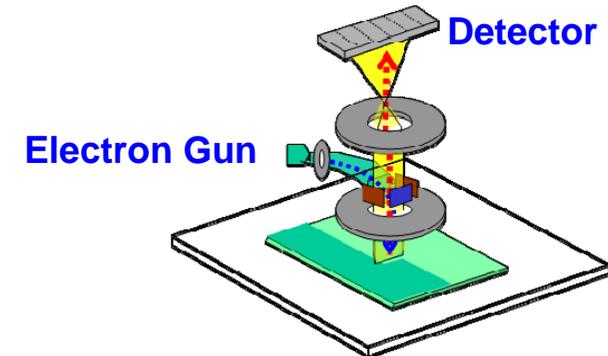
We developed prototype of EBeyeM.

We will report

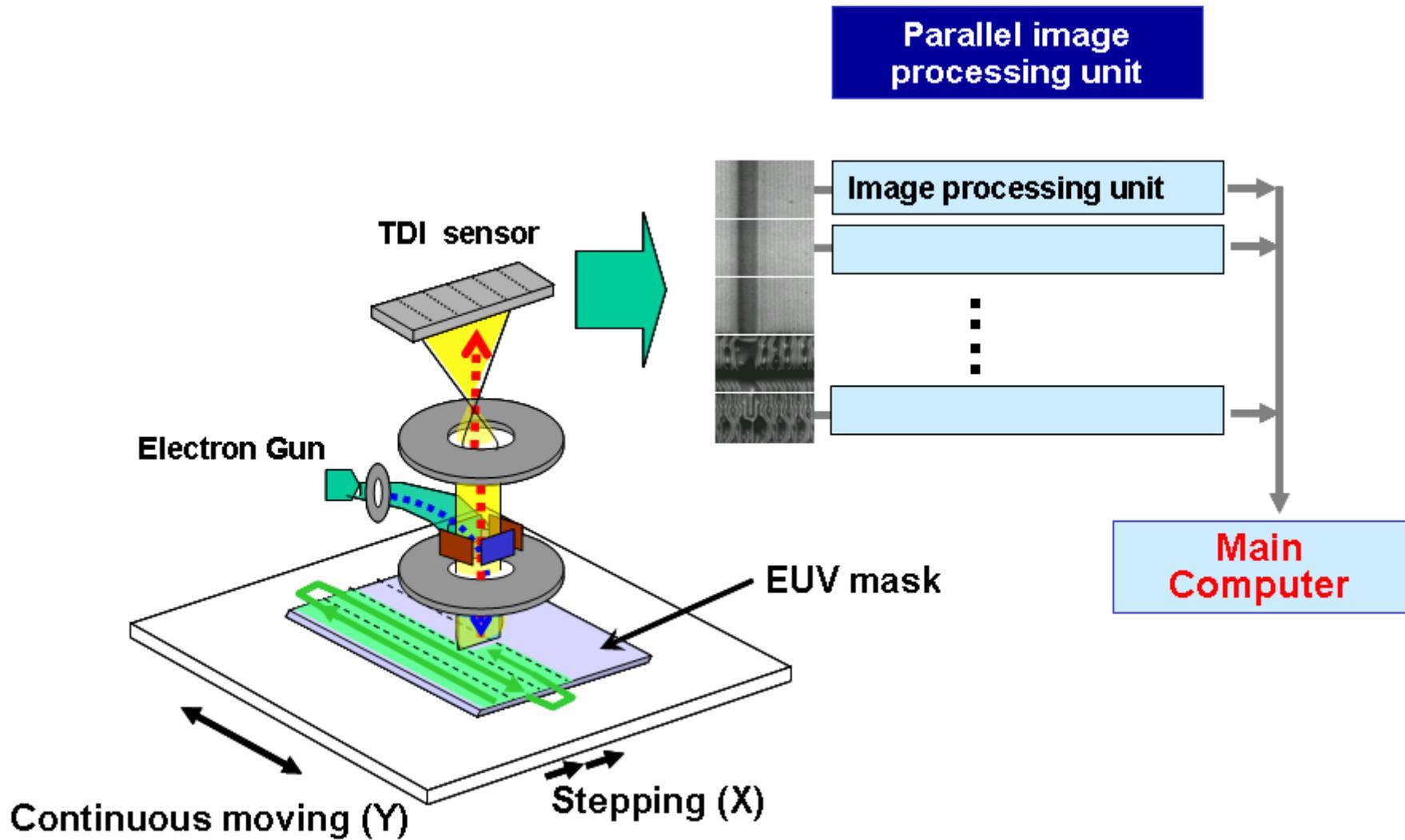
outline of EBeyeM

performance result of prototype system

specification of the system for 2Xnm and 1Xnm EUV mask.



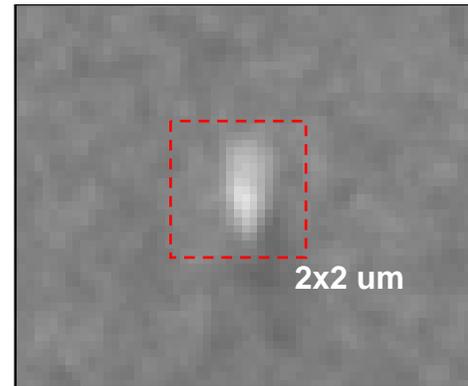
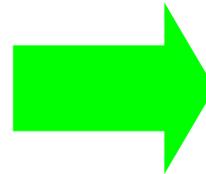
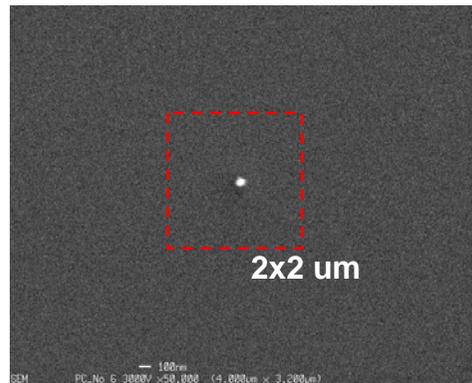
Schematic View of EBeyeM



Development Target of EBeyeM Prototype System

	Particle	Pattern Defect
Pixel Size	100nm	29nm
Inspection Mode	Blank -> Threshold	Die-Die Cell to Cell
	Pattern -> Die-Die Cell to Cell	
Throughput @100mm sqr	8.2 hour	98 hour
Sensitivity	30nm	50nm

Particle Inspection



SEM Image of 42nm PSL

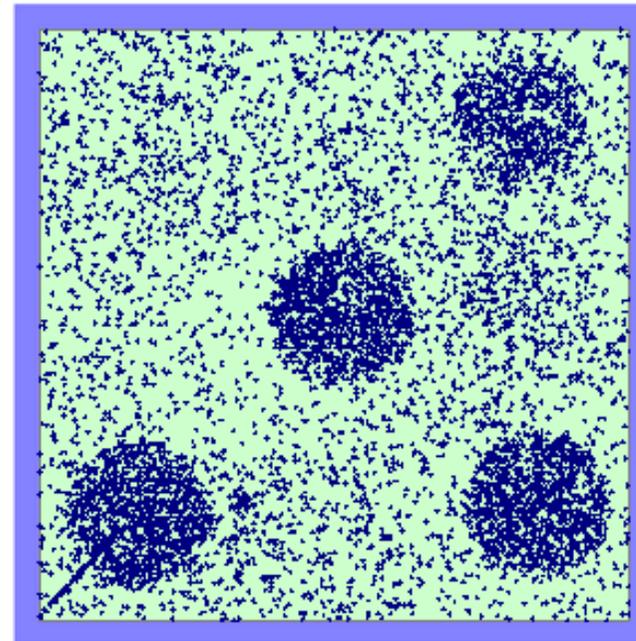
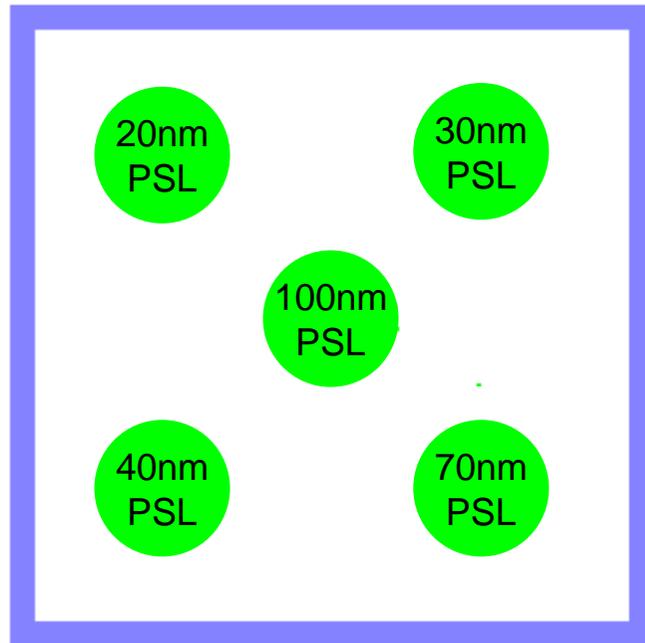
Pixel size is 3nm

EBeyeM Image of 42nm PSL

Pixel size is 100nm

Image enlargement effect is observed in EBeyeM electron optics.

Particle Inspection of EUV Blank with PSL



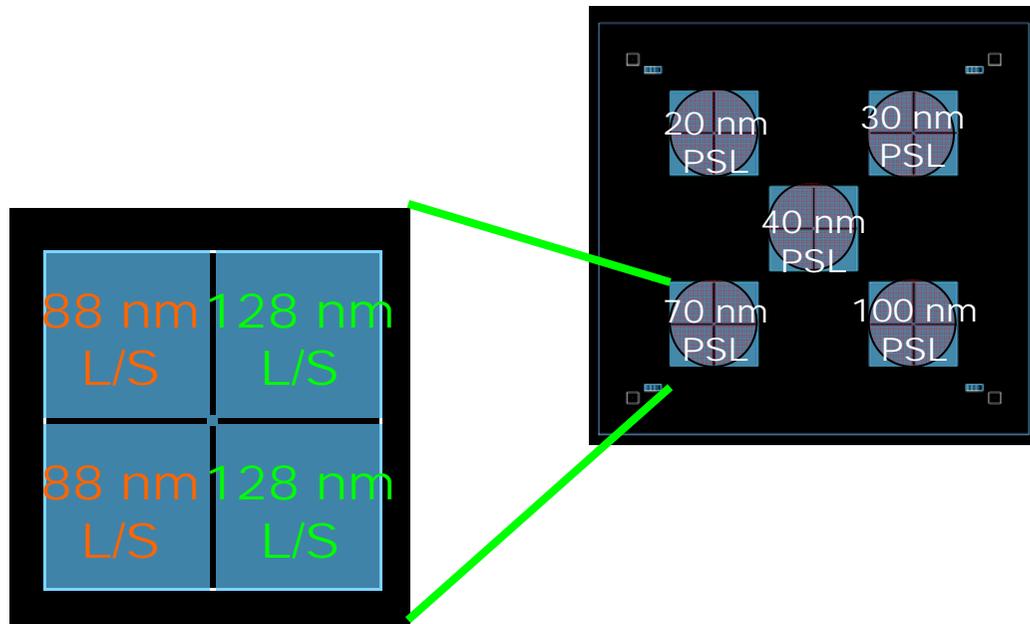
Evaluation EUV Blank with PSL

PSL : Polystyrene Latex

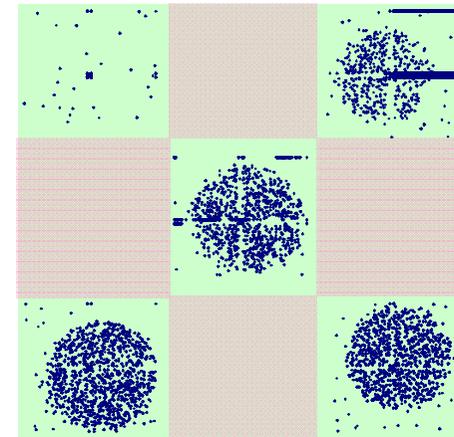
Defect Map of EBeyeM

**EBeyeM can detect 30nm PSL.
Achieve the development target !**

Particle Inspection of L/S Pattern with PSL



Evaluation of L/S pattern with PSL

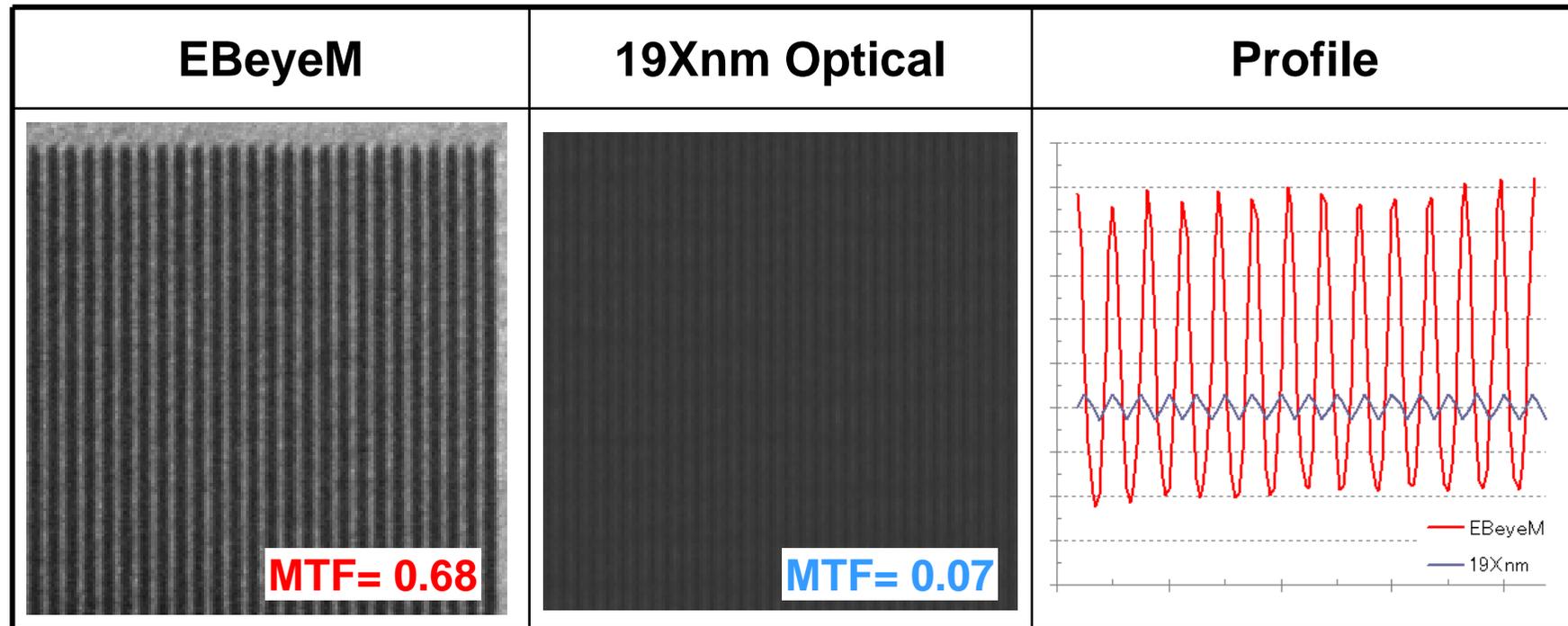


■ Not inspected area

Defect map of EBeyeM

**EBeyeM can detect 30nm PSL on L/S pattern of EUV mask.
Achieve the development target !**

MTF of HP100nm on Ru-capped EUV Mask



Pattern : HP100nm on Ru-capped EUV mask

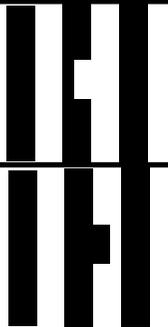
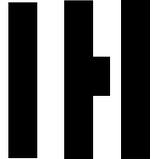
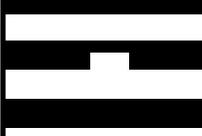
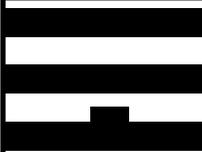
EBeyeM : Pixel Size is 29nm

19Xnm : Pixel Size is 50nm

MTF of EBeyeM is much bigger than that of 19Xnm optical inspection.

Sensitivity Result with Program Defect Mask

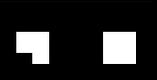
PDM is HP100nm of Ru-Capped. Inspection mode is Cell-Cell.

Type	Measured Defect Sizes & Sensitivity	<div style="display: flex; align-items: center; justify-content: space-between;"> Large  Small </div>																
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
	Defect Size	54	52	44	48	44	36	35	33	30	24							
	Result	Pass																
	Defect Size								51	47	42	40						
	Result	Pass																
	Defect Size						41	49	23	39	23							
	Result	Pass																
	Defect Size						61	59	35									
	Result	Pass																

Sensitivity of prototype EBeyeM is around 45nm.
Achieve the development target !

Sensitivity Result with Program Defect Mask

PDM is CH150nm of Ru-Capped. Inspection mode is Cell-Cell.

Type	Measured Defect Sizes & Sensitivity	<div style="display: flex; justify-content: space-between; align-items: center;"> Large  Small </div>																
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
	Defect Size	59	50	56	46	50	43	36	40	41	38	38	30	30	27	23	36	33
	Result																	
	Defect Size	58	59	59	55	54	51	51	38	41	40	39	30	35	32	29	41	25
	Result																	
	Defect Size	67	72	62	56	50	52	53	51	38	37	37	39	25	26	26	20	13
	Result																	
	Defect Size	60				43		37	37									
	Result																	

**Sensitivity of prototype EBeyeM is around 40nm.
Achieve the development target !**

Summary of Prototype Performance

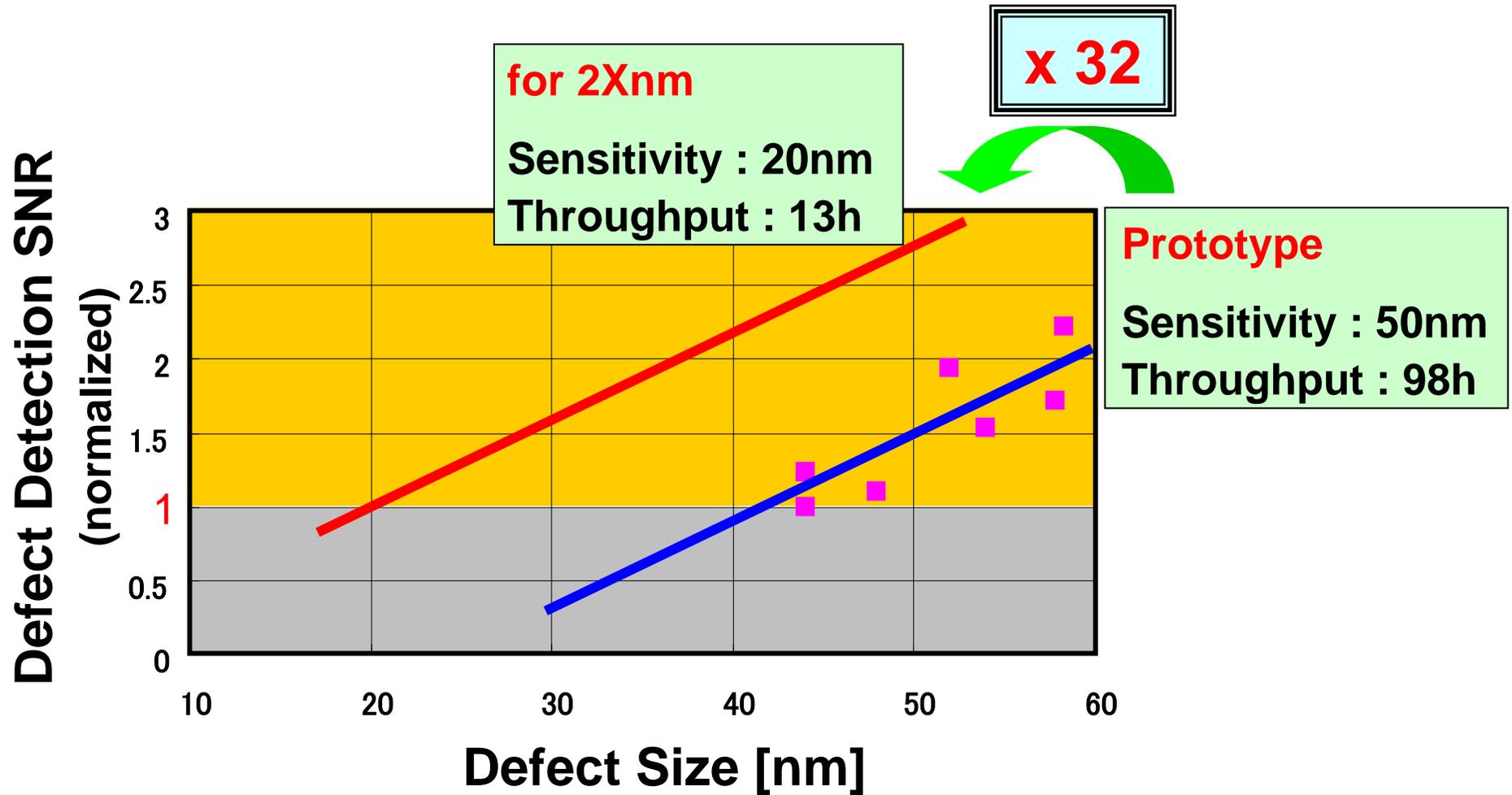
	Development Target	Performance Result
Particle on Blank	30nm	30nm
Particle on Pattern	30nm	30nm
Pattern Defect	50nm	40 - 45nm

Prototype system achieved development target !!

Future Plan of EBeyeM

	Prototype (Current)		for 2Xnm(upgrade)	
	Particle	Pattern	Particle	Pattern
Pixel Size	100nm	29nm	100nm	20nm
Inspection Mode	Blank -> Threshold	Die-Die Cell-Cell	Blank -> Threshold	Die-Die Cell-Cell
	Pattern -> Die-Die Cell to Cell		Pattern -> Die-Die Cell to Cell	
Sensitivity	30nm	50nm	20nm	20nm
Scan Time @100mm sqr	8.2h	98h	0.83h	13h
Mask Load	SMIF		Dual Pod	
Available	Ready		2011/Q1	

Improvement of EBeyeM for 2Xnm EUV mask



Improvement Items of EBeyeM for 2Xnm EUV Mask

Improvement Item		Prototype	for 2Xnm (upgrade)
TDI Sensor	Improve sensitivity	1	1.4
Imaging Optics	Incident electron number to TDI	1	3
	Aberration	1	2
Illuminating Optics	Beam current	1	2
Others	Lens Alignment Inspection Algorithm	1	2
Estimated Total SNR		1	33.6
Required SNR		1	32

Specification of EBeyeM for 2Xnm Mask	Sensitivity	50nm	20nm
	Throughput	98hour	13hour

Future Plan of EBeyeM

	Prototype (Current)		for 2Xnm(upgrade)		for 1Xnm	
	Particle	Pattern	Particle	Pattern	Particle	Pattern
Pixel Size	100nm	29nm	100nm	20nm	80nm	16nm
Inspection Mode	Blank->Thr.	Die-Die Cell-Cell	Blank->Thr.	Die-Die Cell-Cell	Blank->Thr.	Die-Die Cell-Cell
	Pattern->DD C-C		Pattern->DD C-C		Pattern->DD C-C	
Sensitivity	30nm	50nm	20nm	20nm	16nm	16nm
Scan Time @100mm sqr	8.2h	98h	0.83h	13h	0.33h	3h
Mask Load	SMIF		Dual Pod		Dual Pod	
Available	Ready		2011/Q1		2014/Q2	



Under consideration of tool concept to meet the specification.

Summary

- We propose projection electron microscope inspection system, EBeyeM, for EUV mask.
- We develop prototype system.
- **Prototype system could achieve development target.**
 - Sensitivity of particle on blank : 30nm
 - Sensitivity of particle on pattern : 30nm
 - Sensitivity of pattern defect : 40 - 45nm
- We could prove the concept of EBeyeM.
- We estimated specification of the system for 2Xnm EUV mask.
- We are considering tool concept for 1Xnm EUV mask.

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