The Challenges in Making NIL Master Templates

Naoya Hayashi
Dai Nippon Printing Co., Ltd.

A Member of the eBeam Initiative
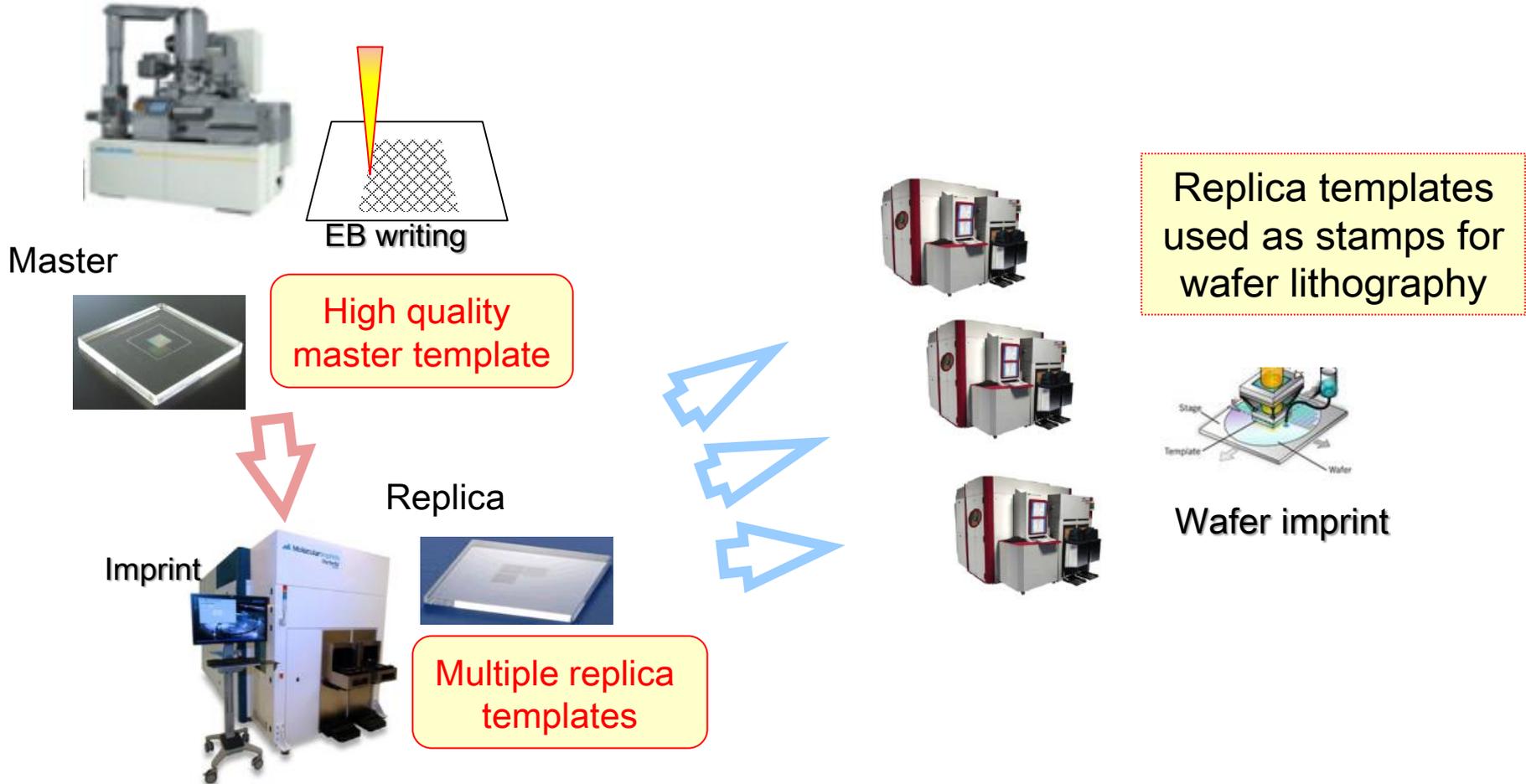
DNP

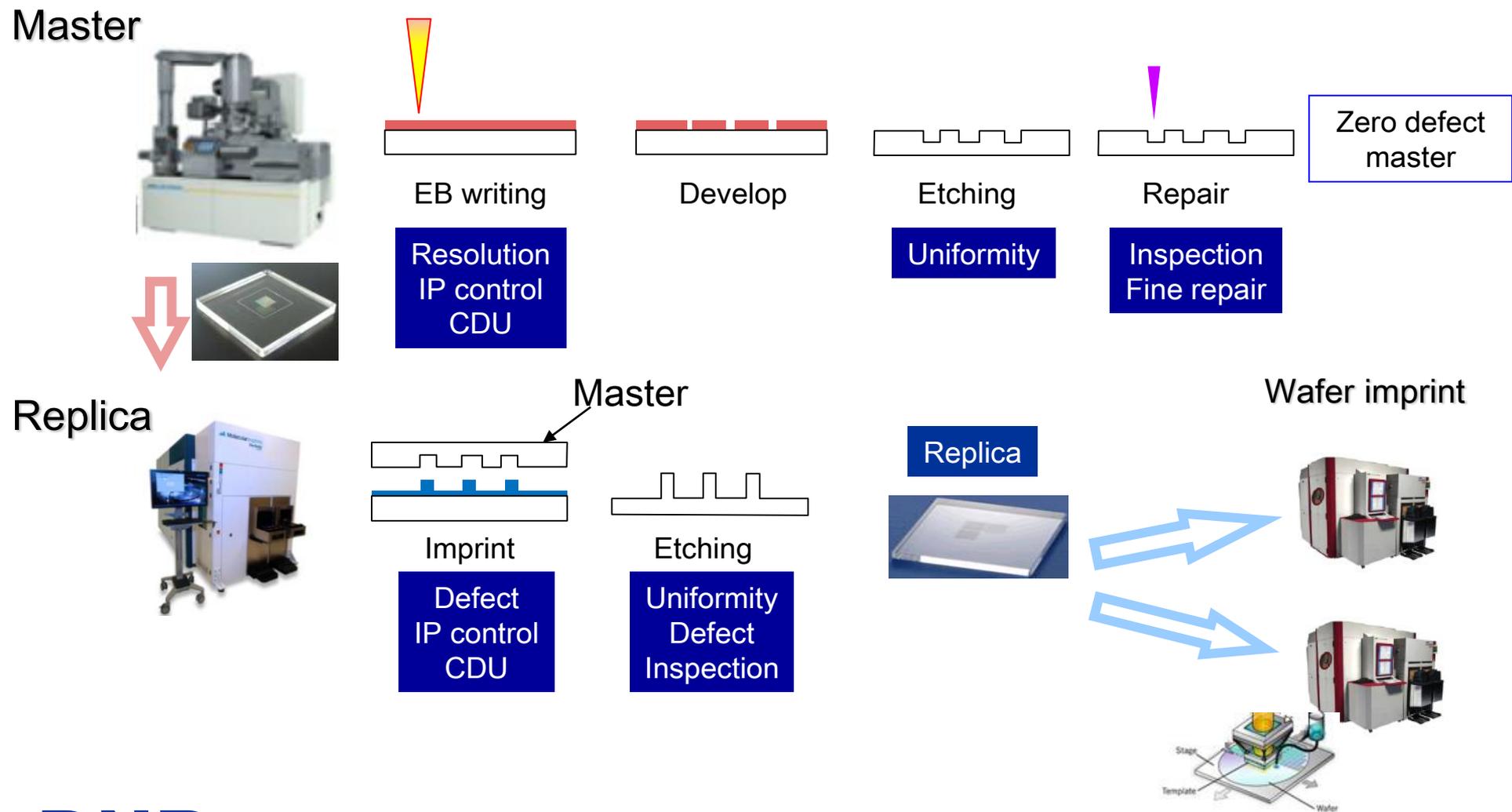# OUTLINE

◆ Recent Progress in Nanoimprint for CMOS

◆ Challenges in NIL master templates

◆ Patterning challenges

◆ Summary

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NIL template strategy

Multiple replica templates will be duplicated from high quality EB written master template.

EB writing

Master

High quality master template

Replica templates used as stamps for wafer lithography

Replica

Imprint

Multiple replica templates

Wafer imprint

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Template fabrication process

Master

EB writing — **Resolution / IP control / CDU**

Develop

Etching — **Uniformity**

Repair — **Inspection / Fine repair**

Zero defect master

Replica

Master

Imprint — **Defect / IP control / CDU**

Etching — **Uniformity / Defect / Inspection**

Replica

Wafer imprint

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Comparison between Optical masks and NIL templates

◆ <u>Difficulties in NIL template fabrication</u>

- Master template resolution and throughput are the most critical issues for X1 lithography
- Defect control becomes difficult due to near field (contact) lithography
- Duplication from master to replica template degrades master template performance

	NIL template	Optical/EUV mask
Lithography	Near field lithography	Far field lithography
Magnification	X1	X4
Field size	26mmx33mm	112mmx132mm
Substrate	6025 Quartz	6025 Quartz
Mask fabrication	Master: EB / Replica: NIL	EB lithography
EB process	High resolution / low sensitivity / Non-CAR	High sensitivity / CAR

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General performance status at hp3x nm generation

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Replica Template CD uniformity

CD map of the current template

○ : −

● : +
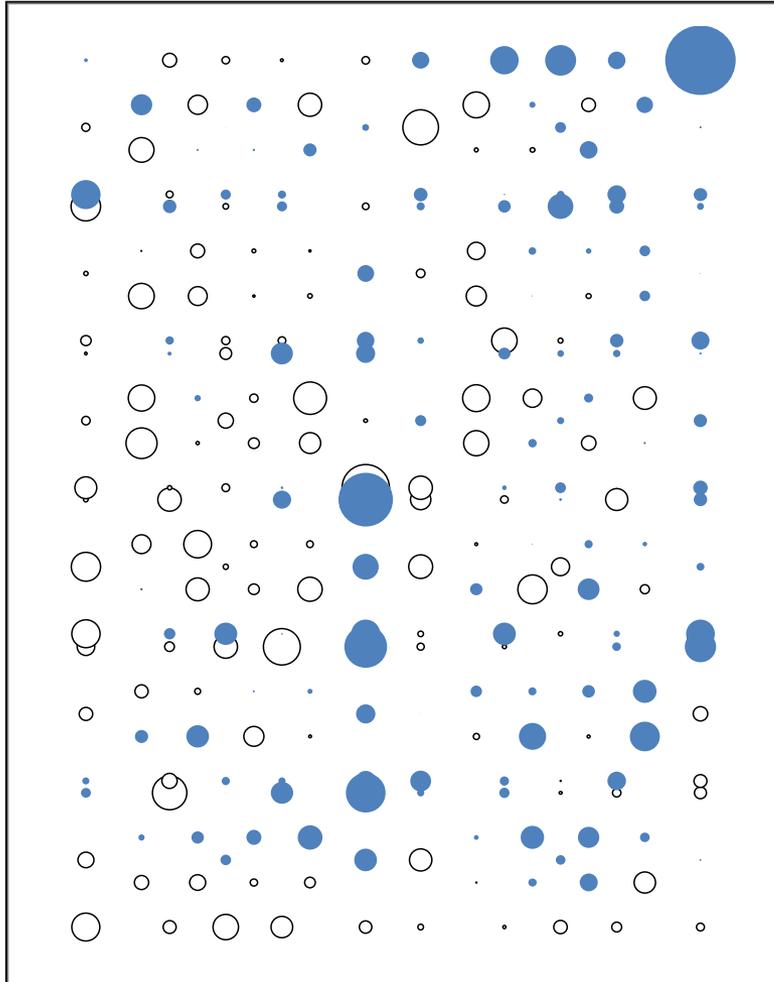
Error sources:
Master uniformity,
RLT uniformity,
Etching uniformity,
need to be optimized.

Master

RLT
(Residual film
thickness)

CDU(3σ) = 1.5nm

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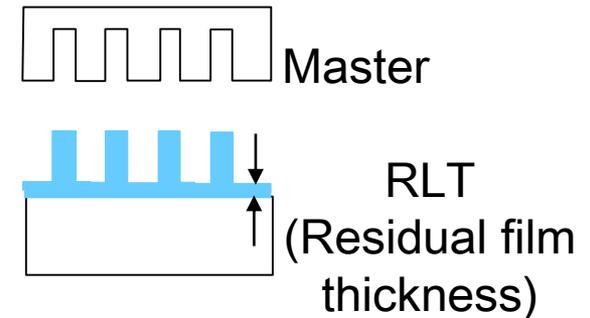
IP : Master & Replica

Image placement has been reached to less than 2.5nm.

Master residual
x=1.13nm, y=1.82nm

Replica residual
x=2.00nm, y=2.48nm

Master

10nm

Replica

10nm

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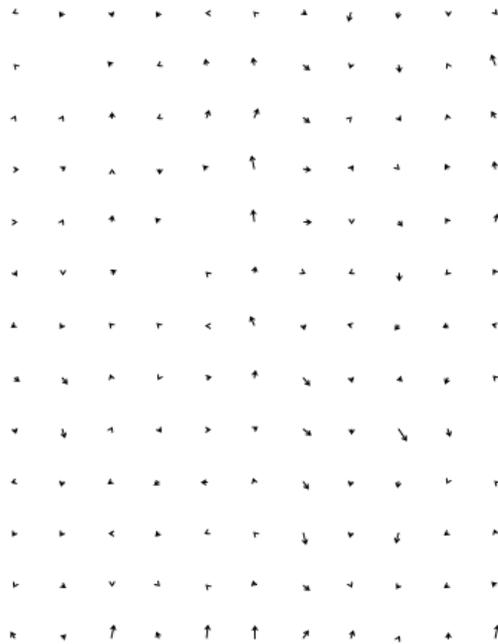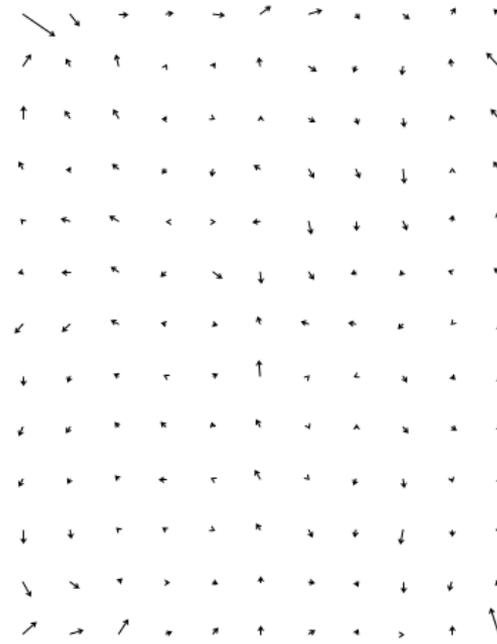
History of replica template defect improvement

Defect density (DD) has been reduced to 0.6 pcs./cm^2 by defect source analysis and process optimization.

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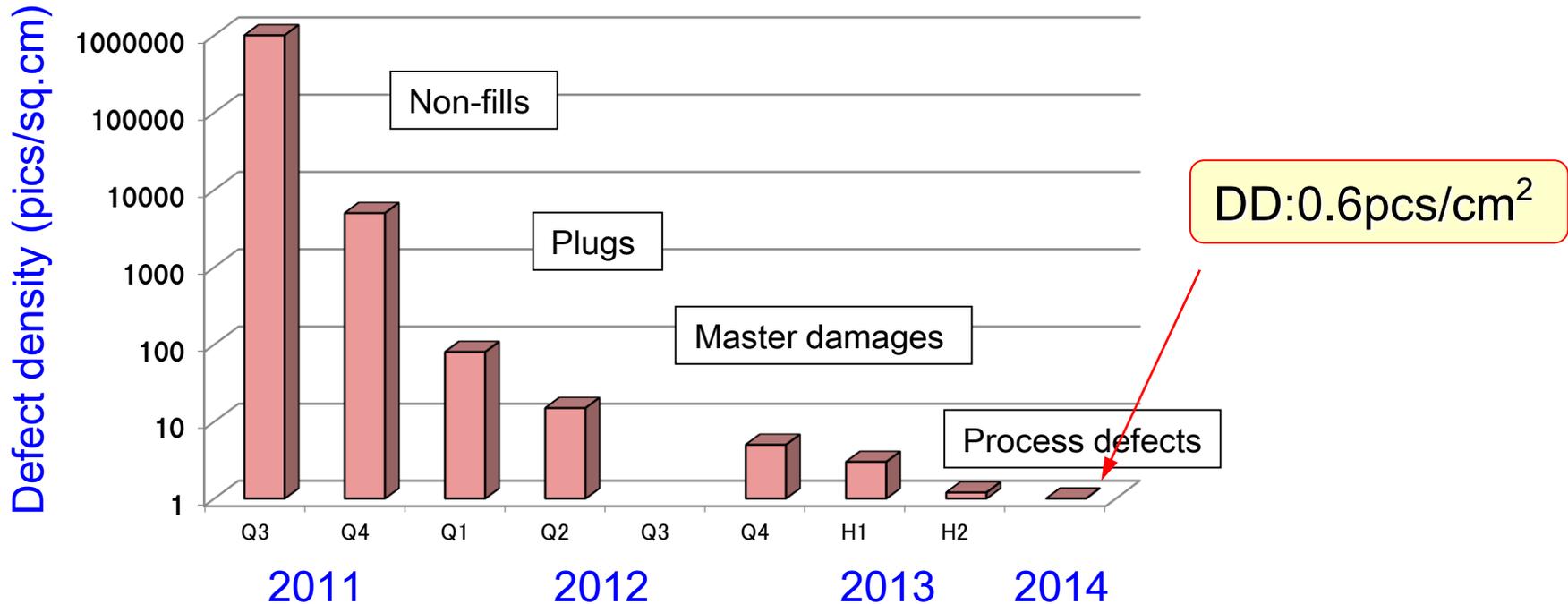
Defect density of replica

Defect density of replica template is now less than 5 pieces/cm^2

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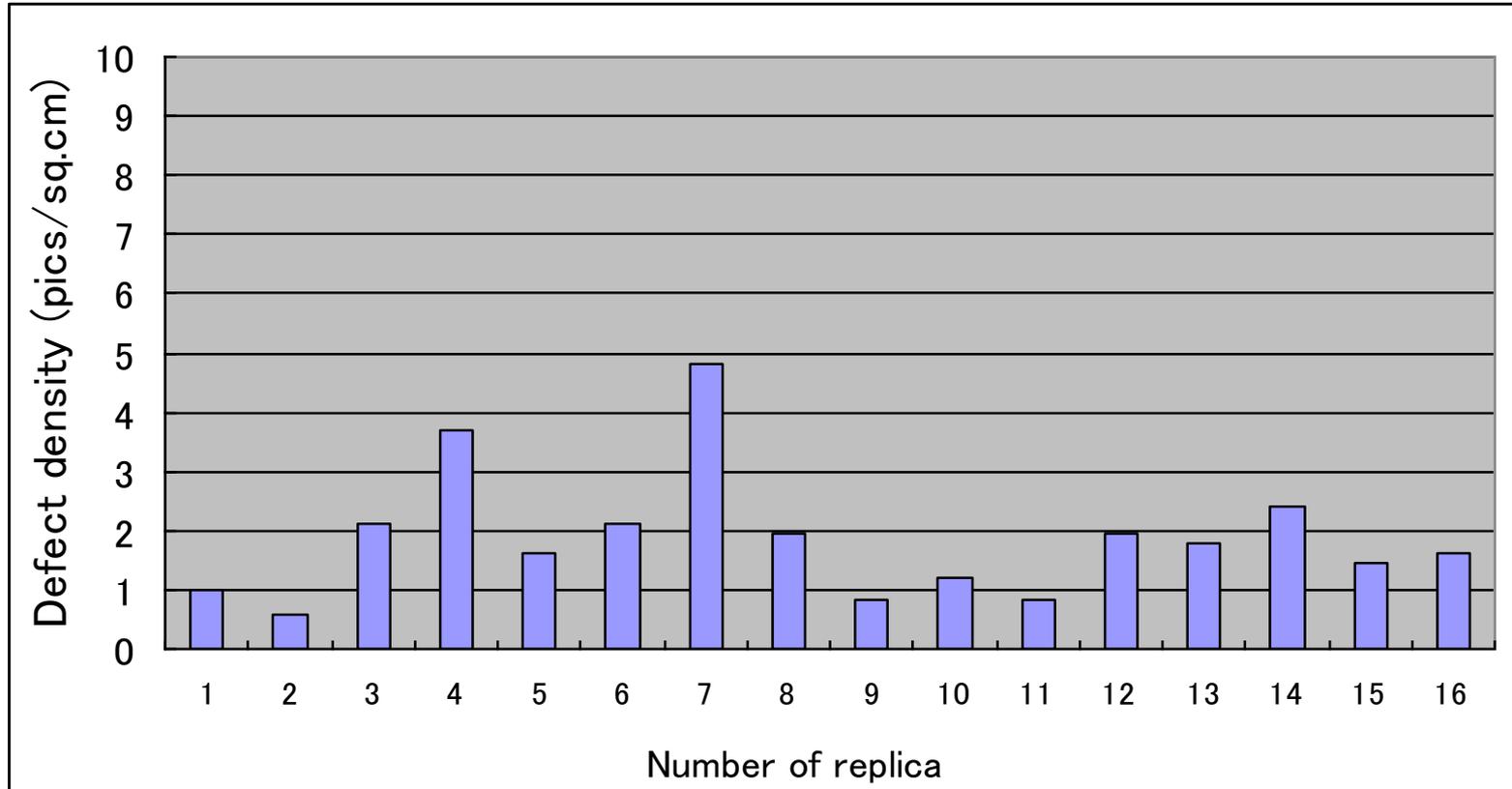
NIL Template Readiness

Templates are ready for use!

	Target	Status
Defectivity (pcs/cm2)	1.0	0.6
CD Uniformity (3σ, nm)	2.2	1.5
Image Placement (3σ, nm)	2.5	2.5

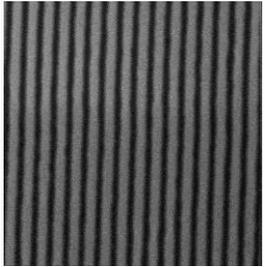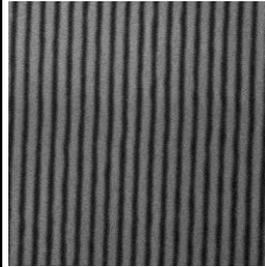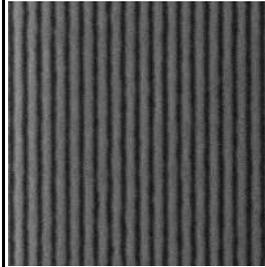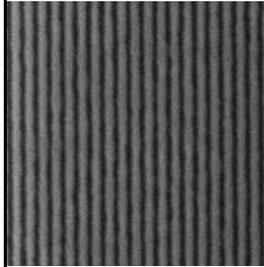* Status of hp2x and 1x nm generation were updated at the morning sessions of today.

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Patterning Challenges
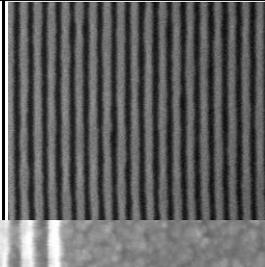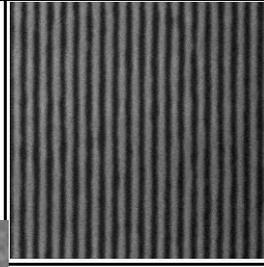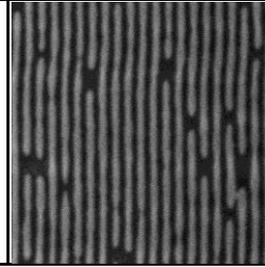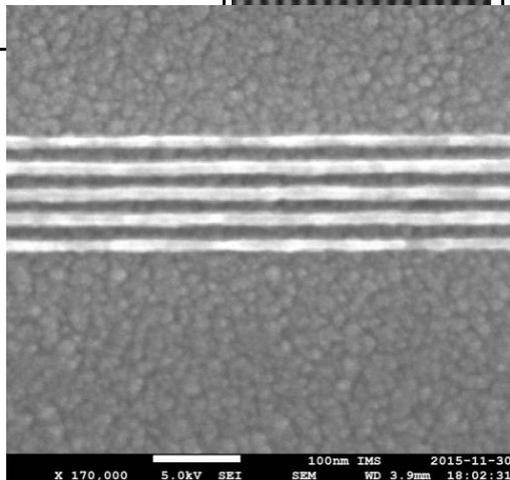
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1x nm template

1x nm replica fabrication is confirmed down to 18nm LS. Master resolution is a key to extend NIL.

	HP22nm	HP20nm	HP19nm	HP18nm	HP17nm
Master					
Replica					

Multi-beam Mask Writer : 10nm beam resolution

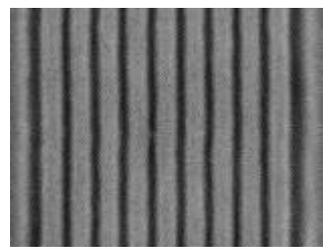|	HP22nm	HP20nm	HP19nm	HP18nm	HP17nm
Master					
Replica					

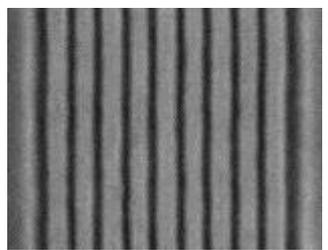EB with Non-CAR

MBMW with Non-CAR
15nm L&S

Multi-beam Mask Writer : 10nm beam resolution

Resolution with 100kV EB Writer

Resist images

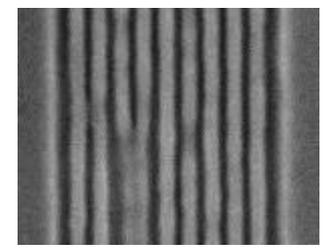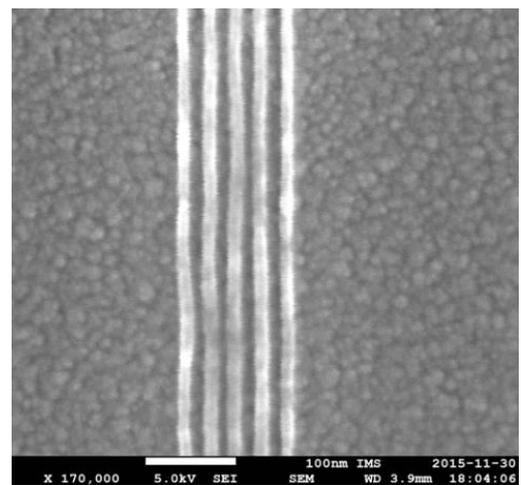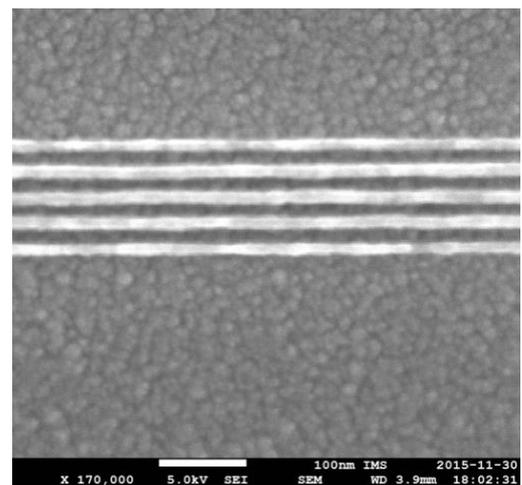

| hp16nm | hp15nm | hp14nm | hp13nm |

100KeV EB with Non-CAR

MBMW with Non-CAR 15nm L&S

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Summary

- ◆ **NIL template progresses in CMOS application**
  - ➢ CD uniformity of 1.5nm has been obtained.
  - ➢ Image placement of within 2.5nm residual distortion has been obtained.
  - ➢ Defect density on templates has been improved to zero defect on master template, and <1 defect/cm2 on replicated template at hp3x nm generation. We have been working on further improvement on hp2x/1x nm.
- ◆ **Patterning challenges in master templates**
  - ➢ Resolution down to 1x nm and beyond
  - ➢ Throughput
- ◆ **Promising solution**
  - ➢ Multi e-beam mask writer will provide the solution!