LithoVision | 2012

Computational Lithography Requirements & Challenges for Mask Making

Naoya Hayashi, Dai Nippon Printing Co., Ltd

DNP

Contents

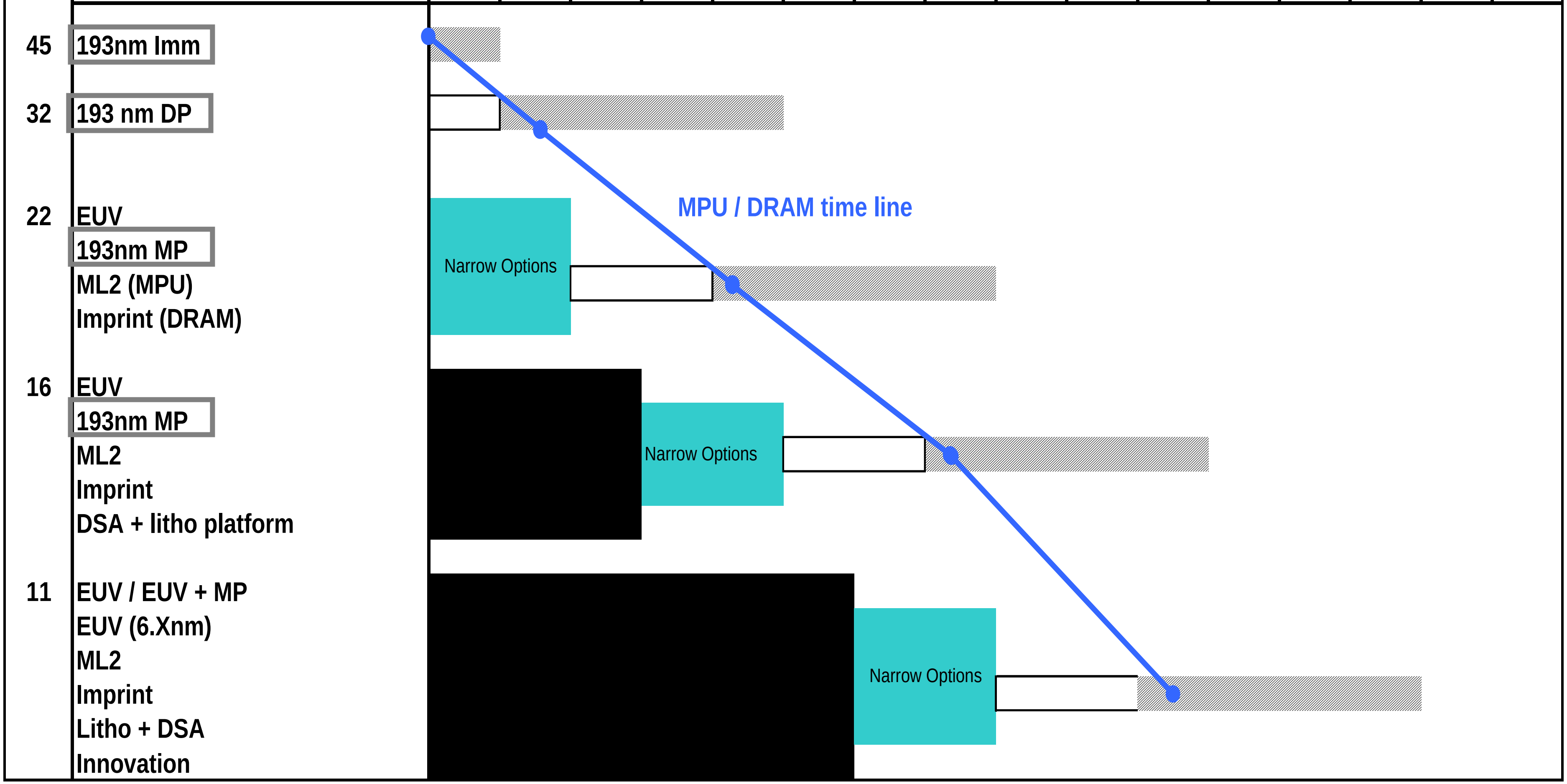
- Introduction
  - Lithography Trends
- Computational lithography options
  - More Complex OPC – SMO, ILT
- Mask challenges
  - Mask fabrication – Shot count
  - Inspection and metrology
- Summary

OPC: optical proximity correction
SMO: source mask optimization
ILT: inverse lithography technology

ITRS Lithography Solutions ~ DRAM/MPU

ITRS 2011 edition

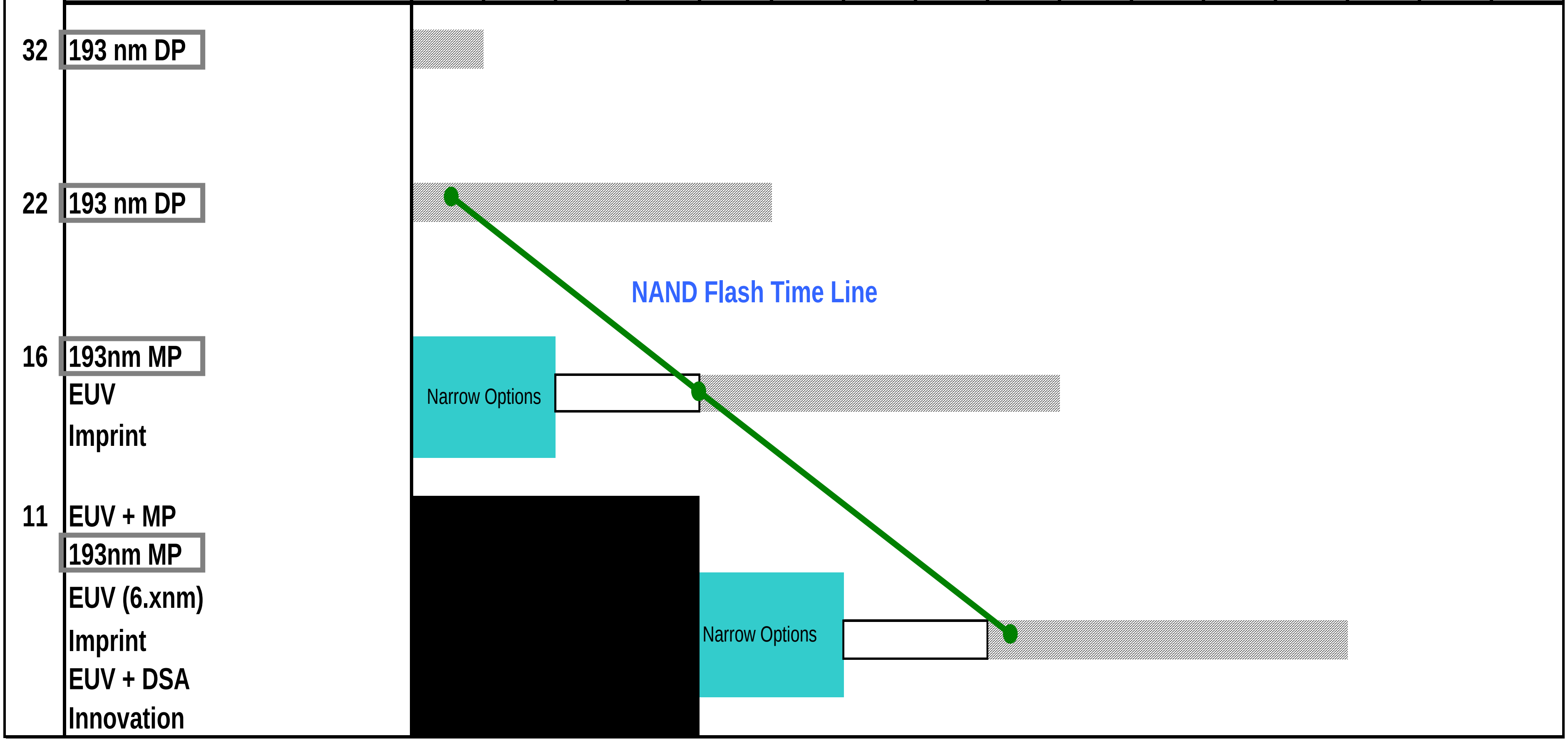
First Year of IC Production	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
DRAM ½ pitch (nm) (contacted)	36	32	28	25	23	20.0	17.9	15.9	14.2	12.6	11.3	10.0	8.9	8.0	7.1	6.3
MPU/ASIC Metal 1 1/2 pitch (nm)	38	32	27	24	21	18.9	16.9	15.0	13.4	11.9	10.6	9.5	8.4	7.5	7.5	7.5



ITRS Lithography Solutions ~ Flash

ITRS 2011 edition

First Year of IC Production	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Flash ½ Pitch (nm) (un-contacted Poly)(f)	22	20	18	17	15	14.2	13.0	11.9	10.9	10.0	8.9	8.0	8.0	8.0	8.0	8.0



Optical lithography extension is expected

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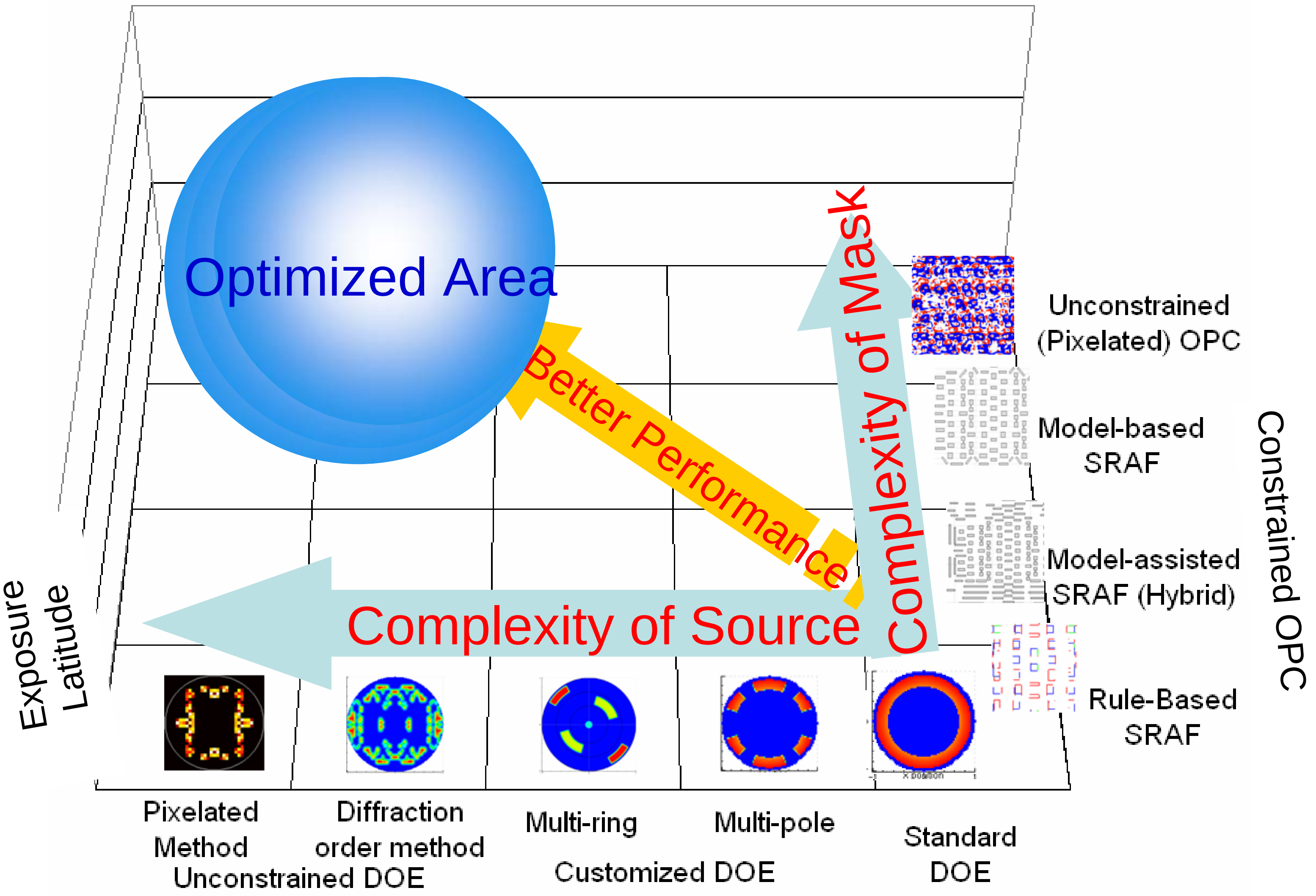
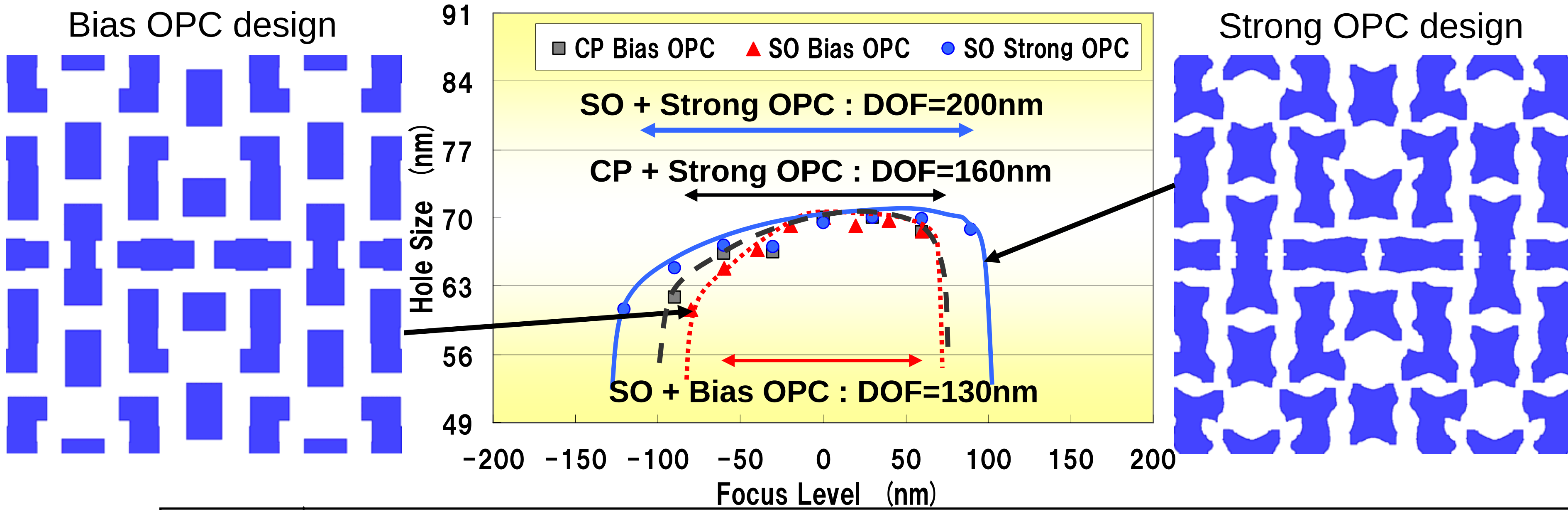
Strong OPC, Source & Mask Optimization

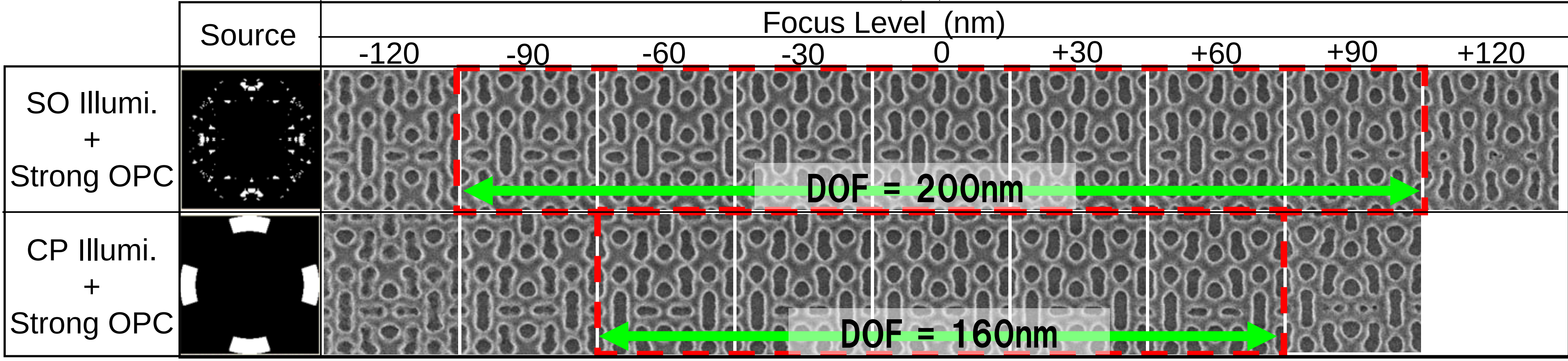


Computational Lithography solutions such as SMO will be needed

Evaluation of DOF improvements with SMO

**** Collaboration work with Nikon***





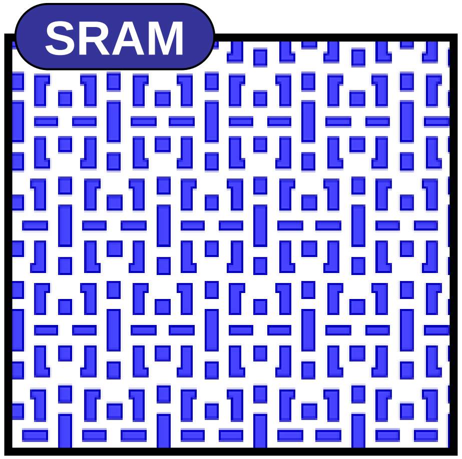
DOF margin was improved by SMO

SO: source optimization, CP: cross pole

Details of SMO Evaluation

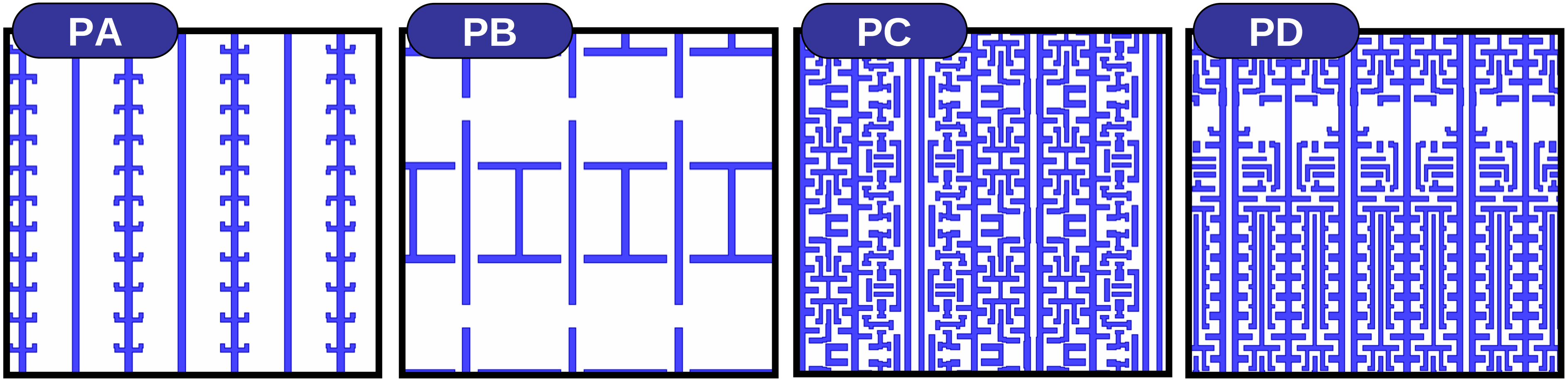
～ Motif patterns vs. Optimized source shapes（Metal Layer）～

** Collaborative evaluation with AIST Japan*



Evaluation of optimized source shapes based on various target patterns.

Learn the balance of optimized source shape across the pattern layout？

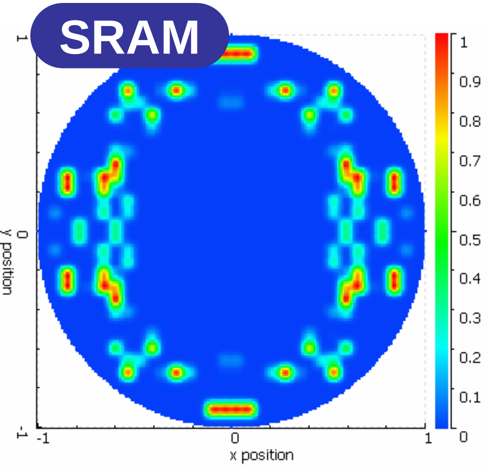


* Motif patterns are from sparse to dense.

Details of SMO Evaluation

～ Motif patterns vs. Optimized source shapes（Metal Layer）～

SRAM



** Collaborative evaluation with AIST Japan*

Evaluation of optimized source shapes based on various target patterns.

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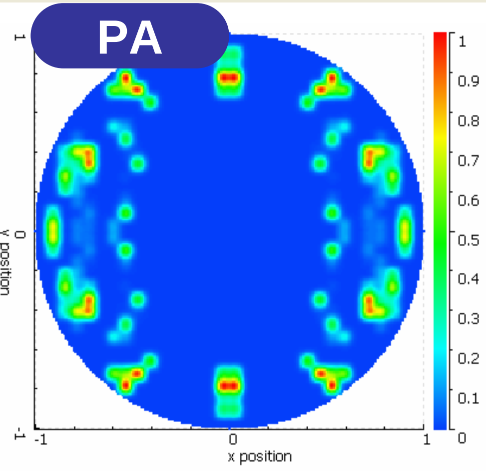
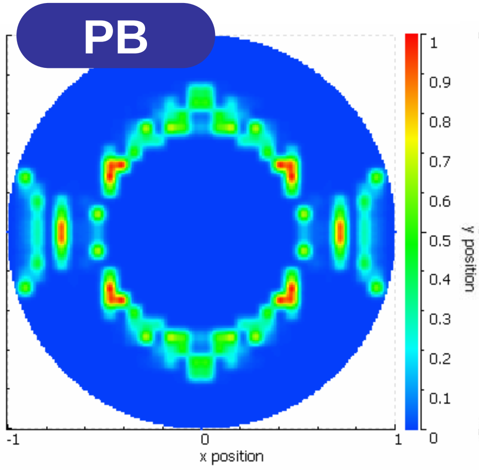
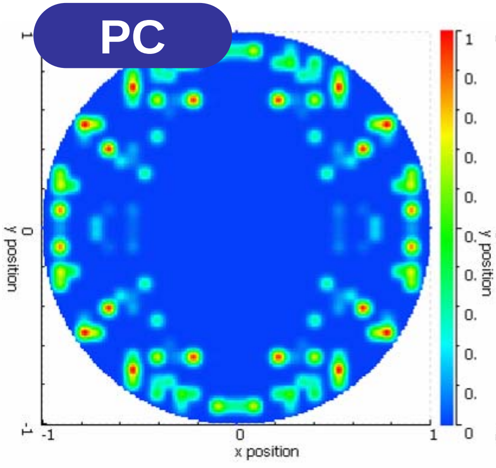
PA



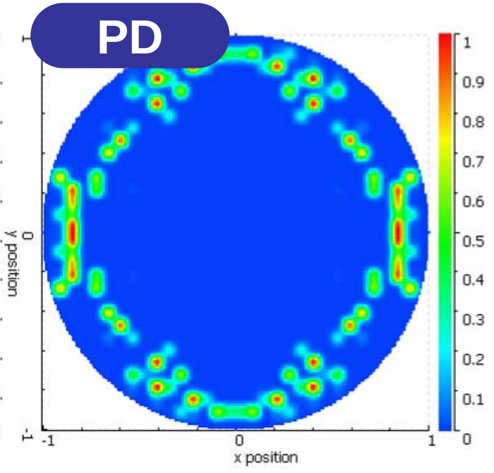
PB



PC



PD

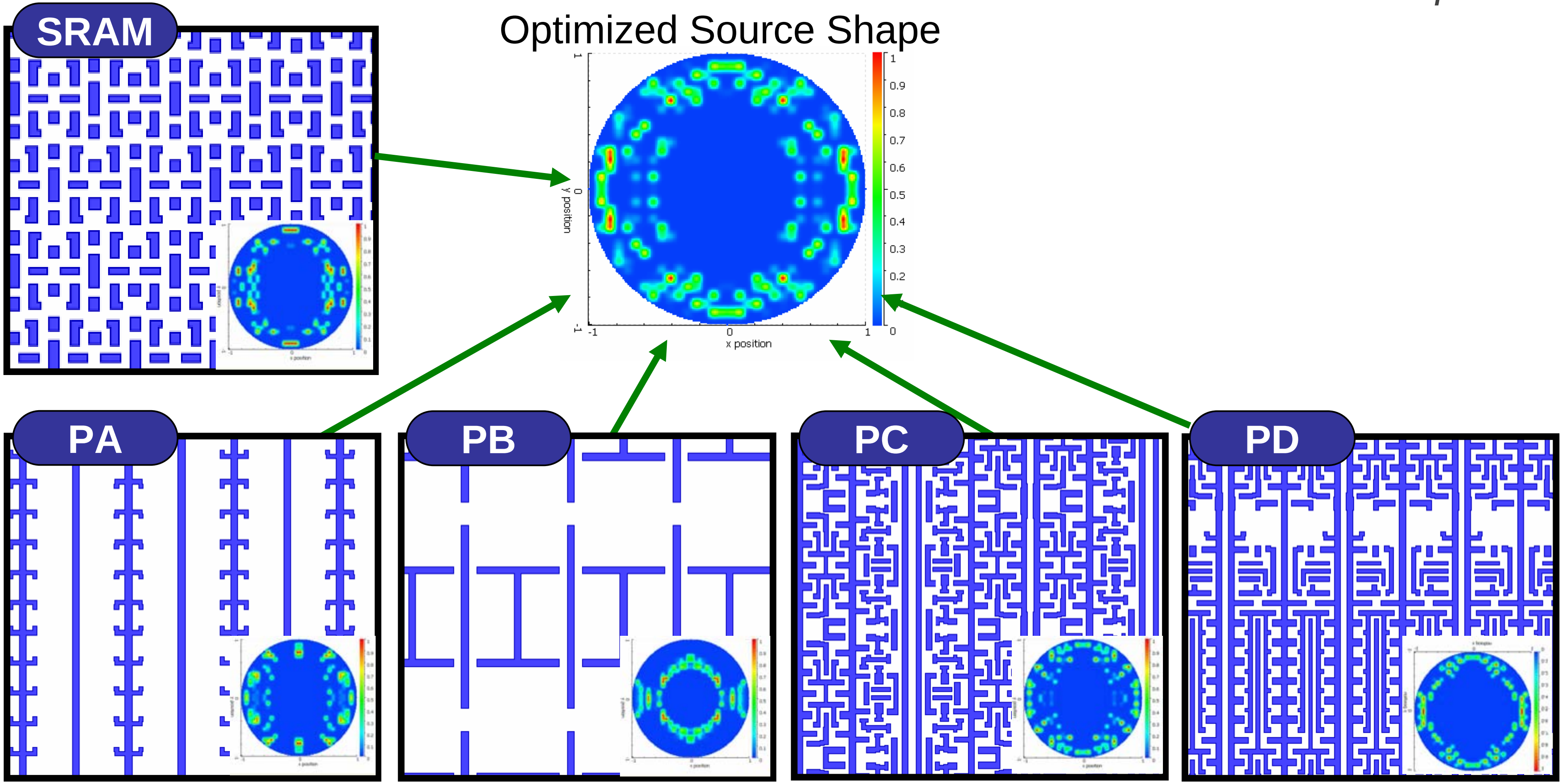


Even within a layer, optimized source shape varies greatly

Details of SMO Evaluation

～ Motif patterns vs. Optimized source shapes（Metal Layer）～

** Collaborative evaluation with AIST Japan*



Optimized source shape can be obtained with wider reference points

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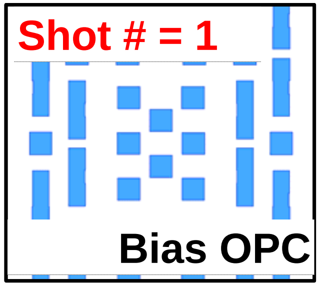
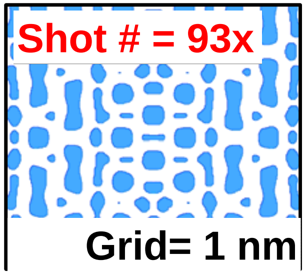
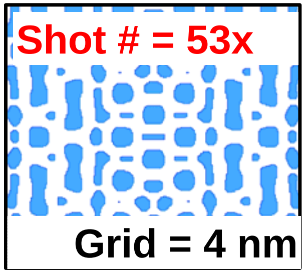
EB Data Grid Size vs. Lithography Margin

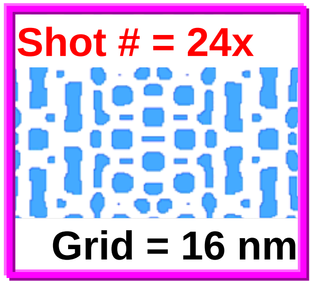
**** Collaboration work with Nikon***

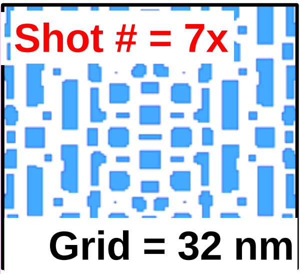
Optimum data grid balancing litho margin and mask complexity

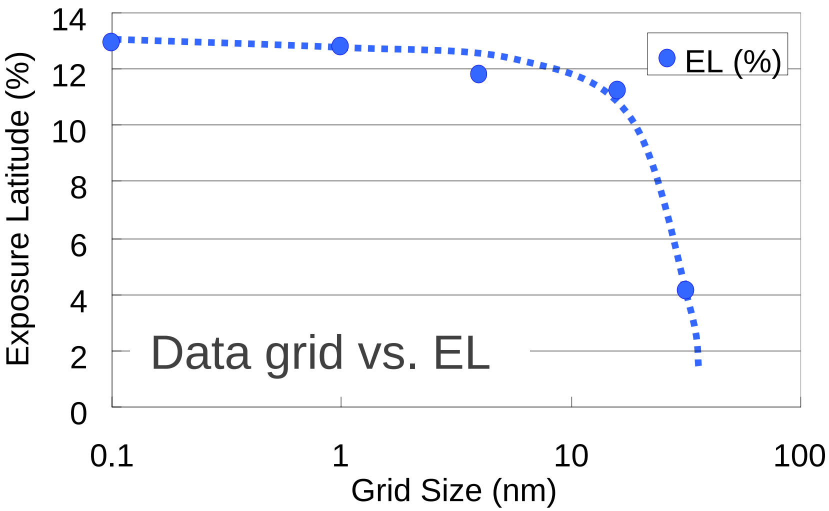


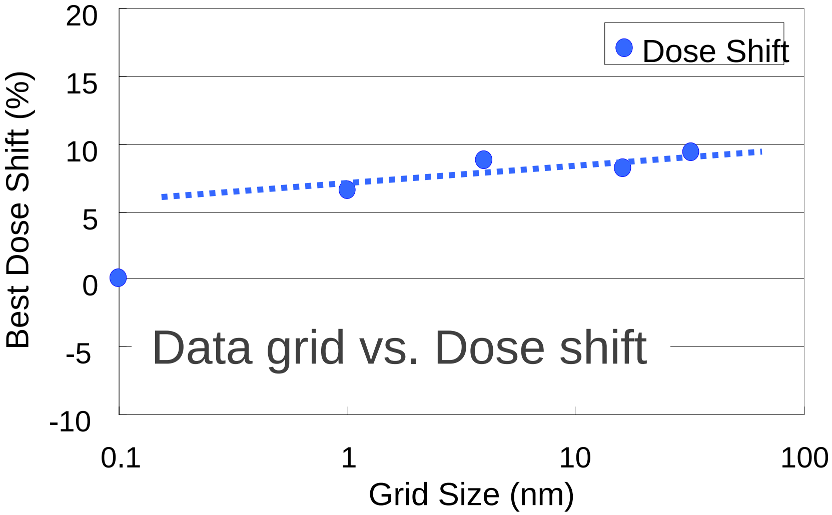








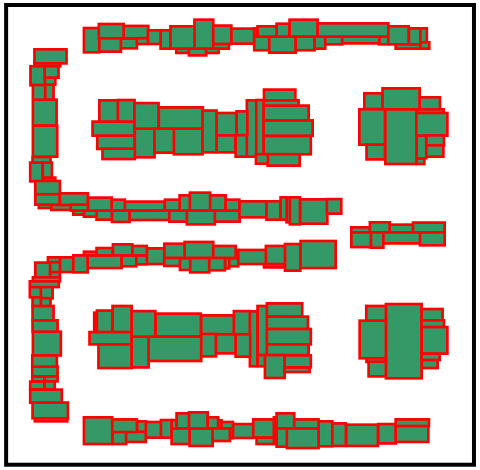




< 1/10 of EB shots with optimum grid size

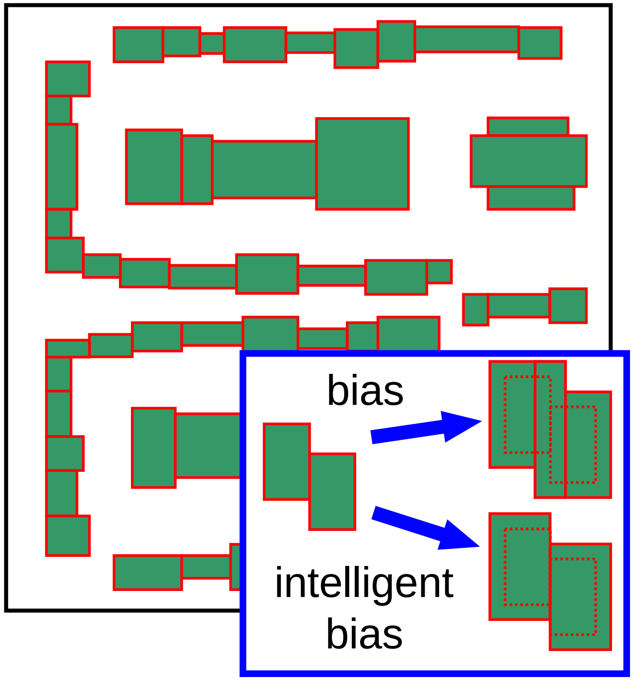
Shot Count Reduction Approaches

conventional fracturing



optimized fracturing

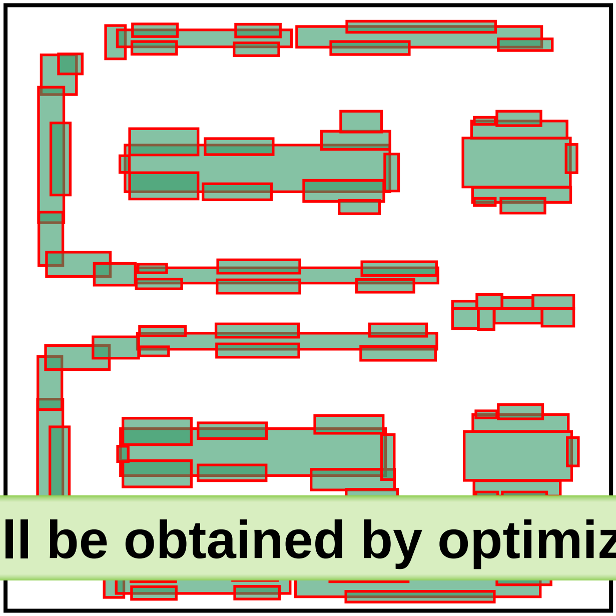
litho-check



MB-MDP*
overlapped shots

MB-MDP : Model-Based Mask Data Preparation

litho-check
EB writing check

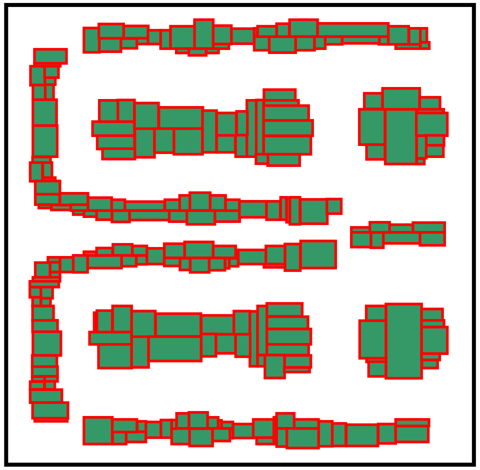


** virtual pattern

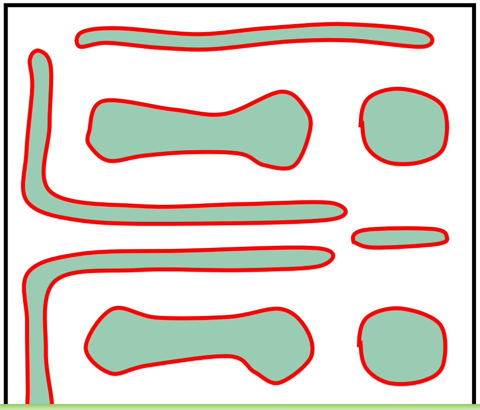
Fewer shot counts will be obtained by optimized overlapping shots

Shot Count Reduction Approaches

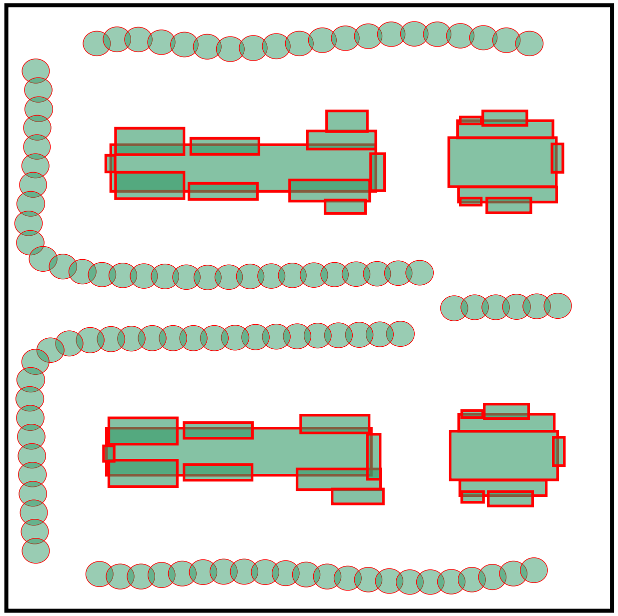
conventional fracturing



simplifying assist features

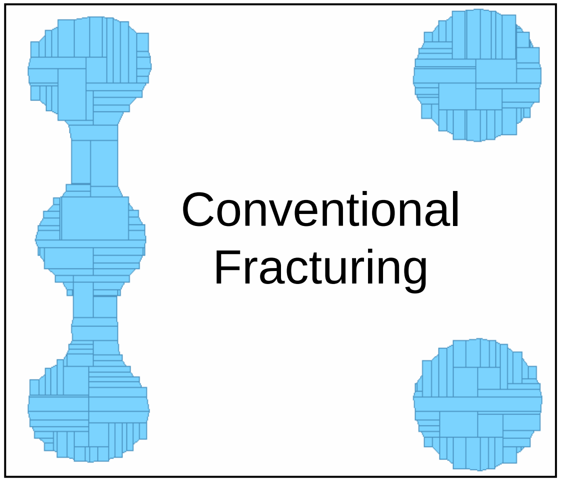


MB-MDP overlapped shots
with circular shape

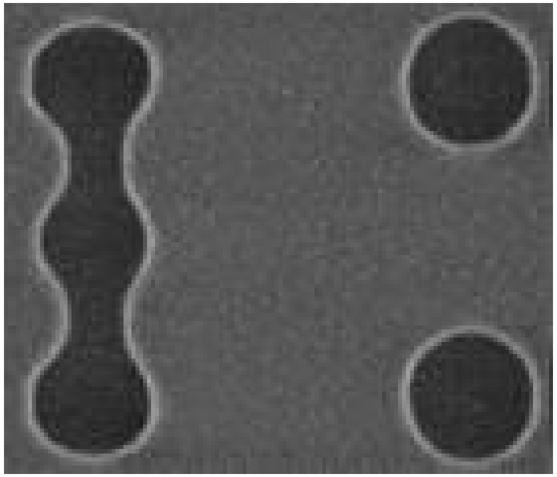


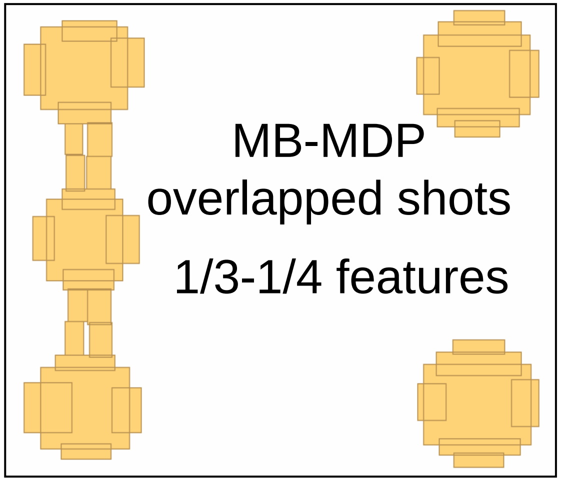
Fewer shots will be obtained by dedicated shot shapes

Trials & Examples



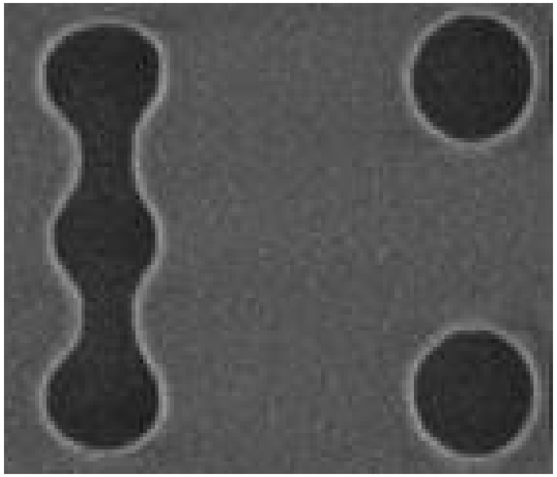
Conventional
Fracturing





MB-MDP
overlapped shots

1/3-1/4 features



Courtesy of D2S

Overlapped fracturing reduces the shot counts with optimal effect

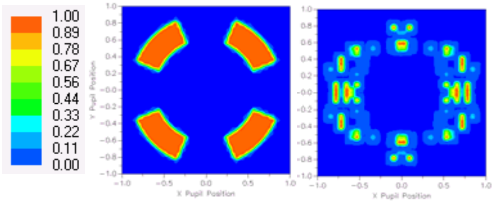
Mask Defect Inspection Tools

Tool		**KLA597XR**	**Teron617**	**NPI-6000**
Vendor		KLA-Tencor	KLA-Tencor	NuFlare
Technology node (nm)		45-32 nm	32-22 nm	45-22 nm
Wavelength (nm)		257	193	198.5
Pixel size (nm)		72 / 90 / 125	55 / 72	50 / 70 / 92
Performance	**Min. sense.** (nm)	36	30	30

Advanced inspection systems must be adopted

Printability Metrology Tool ~ AIMS32

Tool	AIMS45	AIMS32
Vendor	Carl Zeiss	Carl Zeiss
Technology node (nm)	90-32 nm	90-22 nm
Wavelength (nm)	193	193
Illumination numbers	24	100
Measurement repeat. (3σ, nm@wafer)	2	0.5
Stage accuracy (nm)	< 2000	< 150
TAT (stack/hrs)	40	120
Wafer level CD application	No	Yes
SMO application	No	Yes



Advanced printability evaluation tool will be needed

Summary

- ArF lithography will be extended with computational lithography technologies
- Further optimization of SMO may be needed
- Mask data is becoming more complex and intensive
- Successful trials are underway using overlapped shots with MB-MDP
- Mask defect inspection and printability metrology tools for computational lithography mask have been evaluated
- More close collaboration needed for future work among mask suppliers, mask users, and related tool suppliers

Acknowledgement

- Nikon for collaboration work on SMO evaluation
- D2S for overlapped shot trial
- K. Kadota of AIST for SMO evaluation, and the part of work was supported by NEDO
- E. Tsujimoto, and K. Hayano of DNP for providing evaluation data, and N. Toyama of DNP for shot reduction approach