Viability of e-beam mask inspection solution for EUV in production environment

Michael Ben-Yishai

Applied Materials

Co-authors: Shmoolik Mangan, Lior Shoval, Vivek Balasubramanian, Ishai Schwarzband, Sergey Khristo, Yaron Cohen

Outline

- EUV mask inspection background
- New e-beam mask inspection technology – 2nd generation
- Single-die mask solution
- Summary

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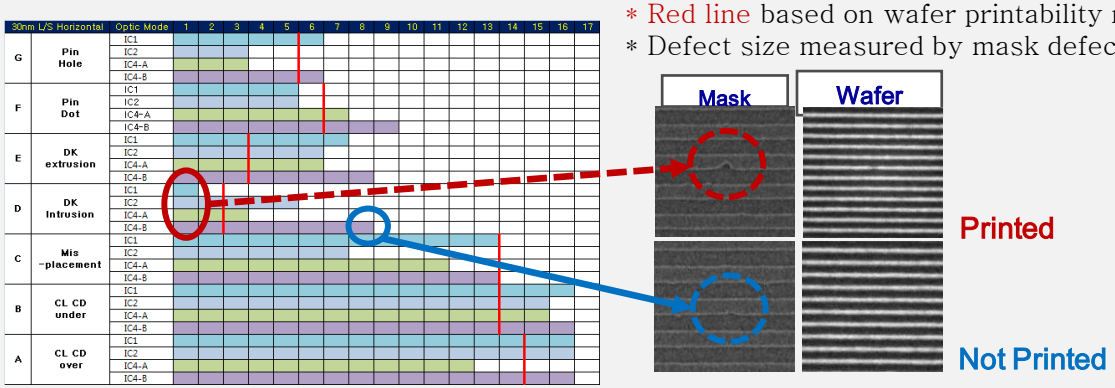
Mask Inspection for EUV - Background

External Use

EUV Mask Inspection by Aera3™ (Optical)

- Meets 30nm L&S printability by enhancing detection using illumination condition

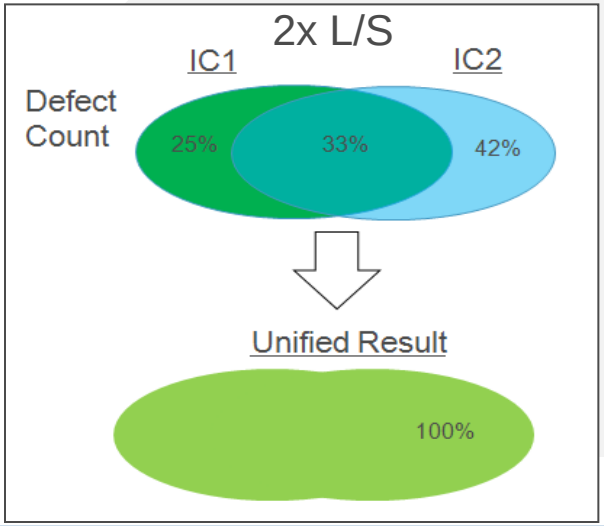


∗ Red line based on wafer printability results
∗ Defect size measured by mask defect review SEM

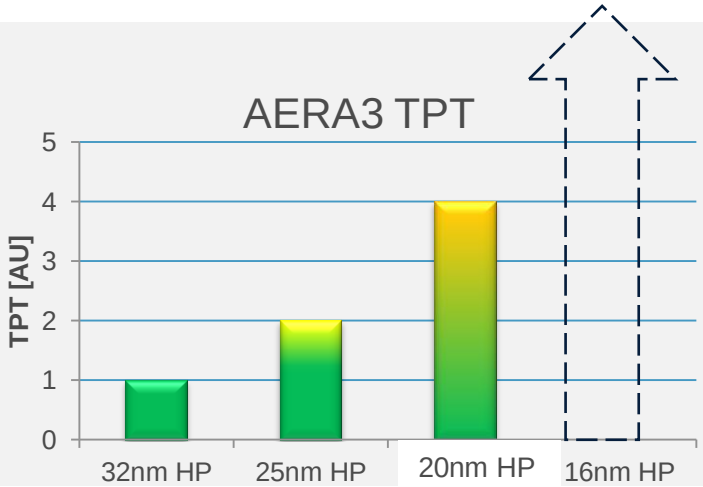
TPT
1.5 hours

Source: Han et. al, EMLC 2011 (Samsung/Applied Materials)

- Extendable down to 20nm using dual illumination condition, but TPT a concern

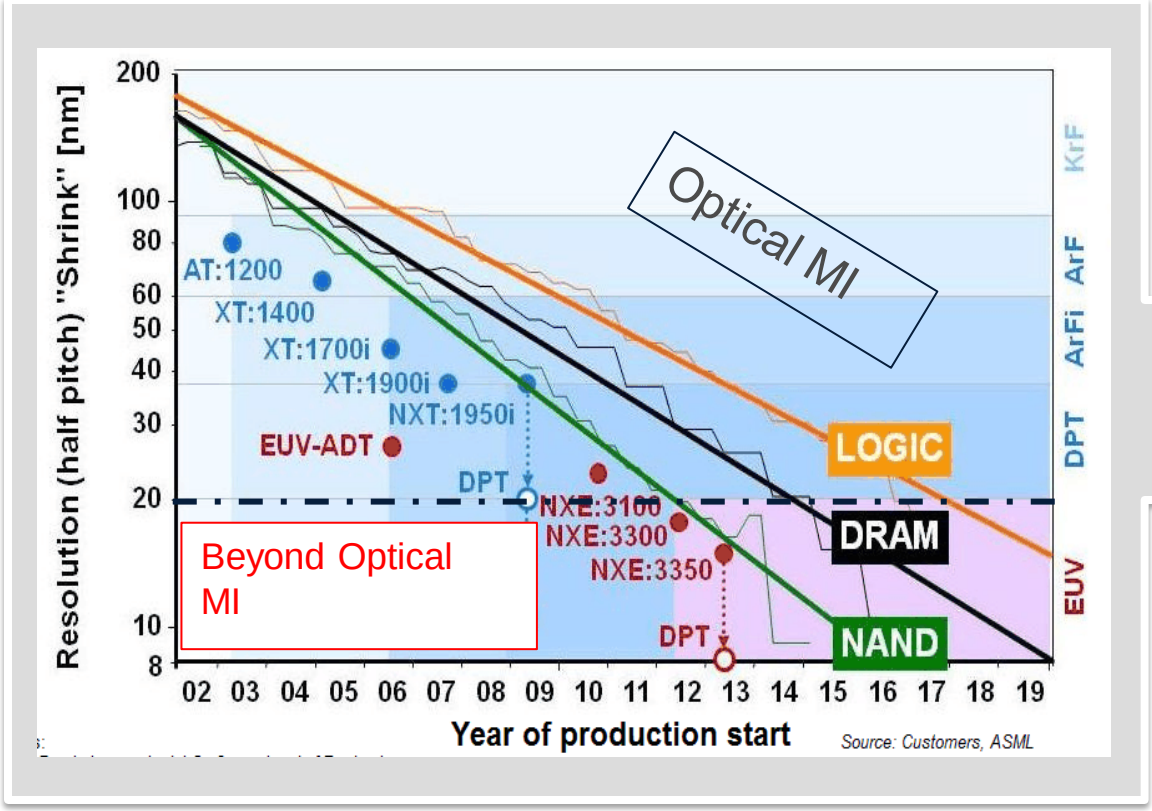


TPT
3 hours



Source: Mangan et. al, BACUS 2011

Optical MI Limits & EUV Scanner Roadmap



New Mask Inspection Technology needed

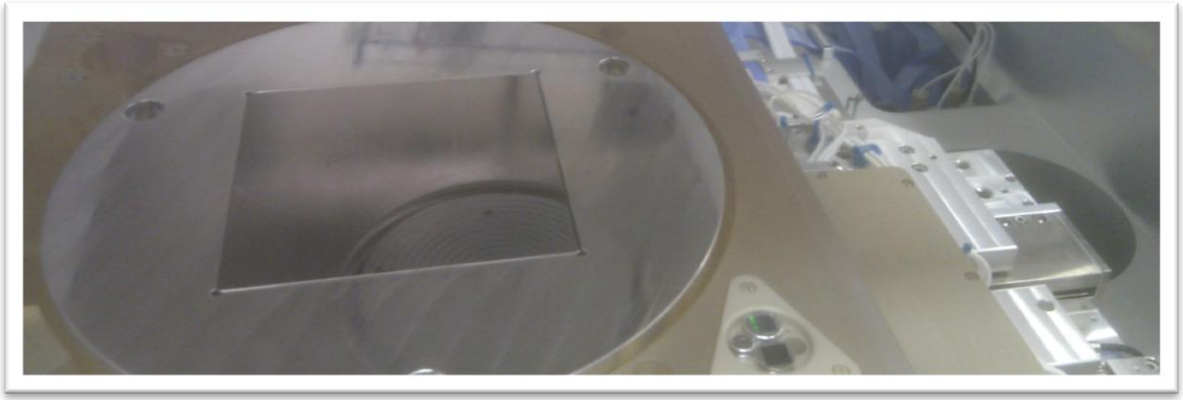
16nmHP MI solutions required by: 2012-3 for R&D, 2014-5 for production

EUV Mask Inspection by e-Beam (EBMI)

- Proposed as a cost-effective solution for EUV high volume manufacturing (HVM) in mask shops and fabs

- e-Beam inspection technology is currently available for wafers

- Same technology adapted for EUV mask inspection
  - Utilizing e-Beam **best resolution** imaging
  - **Scalable** through technology progress



Lab Setup

The following results are obtained using technology demonstration lab setup

EBMI 1st Gen. Prototype Results

imec ADT Printed 32nm L/S, full mask [Bacus 2010]

- EUV full mask - 32nm L/S – with 9 PDMs of programmed absorber defects
- Random absorber defects detected
- Maximizing throughput while meeting print line →15 Hours

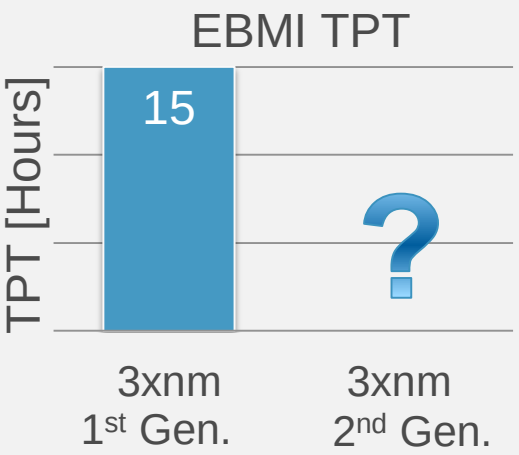
Mask and wafers: courtesy of imec

	8	10	12	14	16	18
Pinspot 1X:1Y						
Pinspot 2X:1Y						
Pinspot 1X:2Y						
Extension 1X:1Y						
Extension 2X:1Y						
Extension 1X:2Y						

Inspection Capture Rate
66-100% Detected
33-66% Detected
1-33% Detected
Not Detected

Wafer Print line

Source: Mangan et. al, BACUS 2010



EBMI 1st generation meets 32nm printability line at 15 hours

New Generation (2nd) of EBMI Technology

External Use

EBMI 6 Hours Inspection (100x100mm)

Using 2nd generation e-beam technology demonstration platform

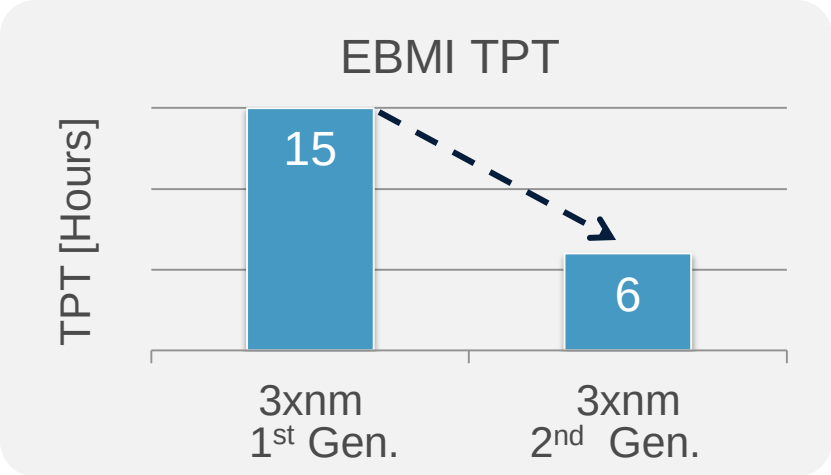
3xnm L&S PDM EUV mask

#	Defect Type	Below SPEC		Above SPEC			
1	Main CD						
2	Line-end CD						
3	Intrusion						
4	Protrusion						
5	Pindot						

	Type	Alg. Used
	On-line	Wafer
	Off-line	Mask
	Not exist on mask	
	No off-line data	

3xnm Contact PDM EUV mask

	Defect Type	Below SPEC			Above SPEC			
1	Pinhole 1							
2	Pinhole 2							
3	Pinhole 3							
4	Pinhole 4							
5	Pindot 1							
6	Pindot 2							

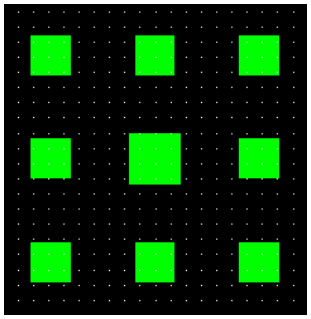


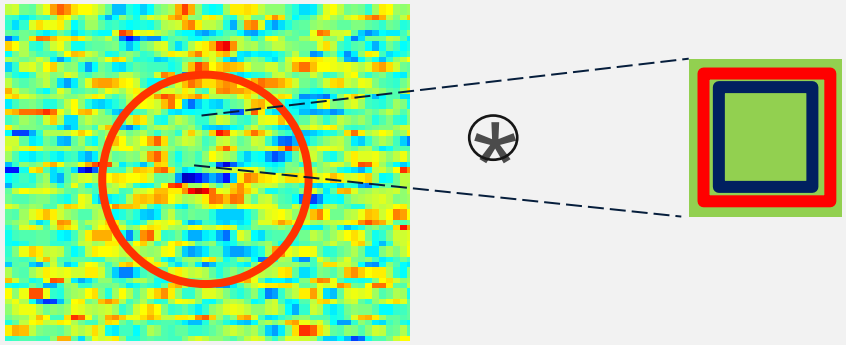
E-beam technology progress enables future throughput scaling

Mask Inspection Alg. vs. Wafer Inspection

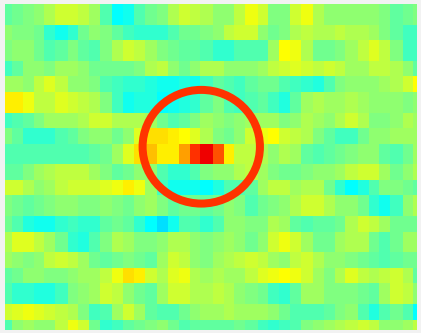
- Current EBMI prototype uses wafer inspection algorithms
- Detection gaps identified when using WI algorithms can be closed by applying MI algorithms
- Example:

Mis-Size Defect





SNR = ~4



SNR = ~8

Image processing gaps were identified using wafer inspection algorithms
Gaps are closed applying available mask inspection algorithms

EBMI Detection Test – 2nd Gen. Technology

Semi-Iso 20nm EUV patterns @ 10 hours

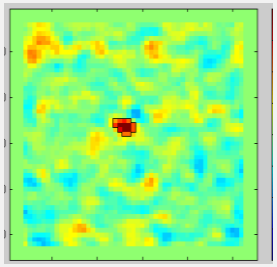
Inspection Results

Defect Type	Actual Size [nm]				
	1	2	3	4	5
Line break	50.7	39.4	25.3	no defect	
Intrusion	22	12.9	8.4		
Intrusion	18.9	13.2	8.4		
Protrusion2	22.5	20.3	11.8	8.4	
Protrusion1	22	18.3	15.5	9	8.4

Legend

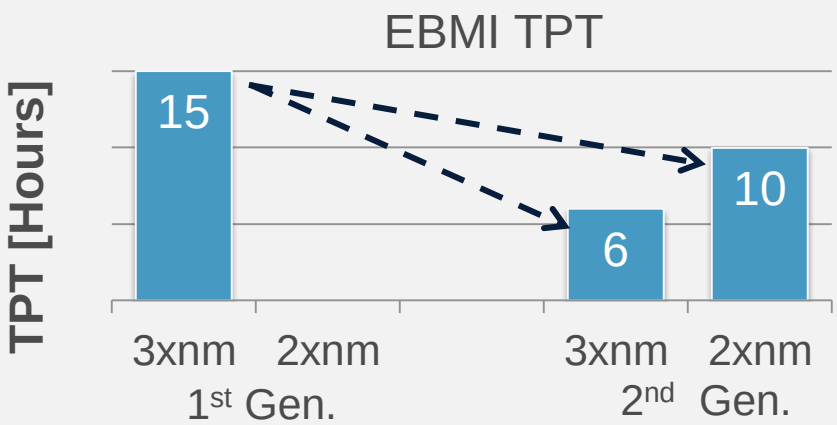
Detectable
Marginal
Not Detectable
Not tested

Protrusion 1 Diff image



Inspection parameters

e-Beam tech	Pixel Size	Hours/mask
2nd Gen	20 nm	10.0



2nd Gen EBMI can meet 20nm sensitivity at 10Hrs/single beam

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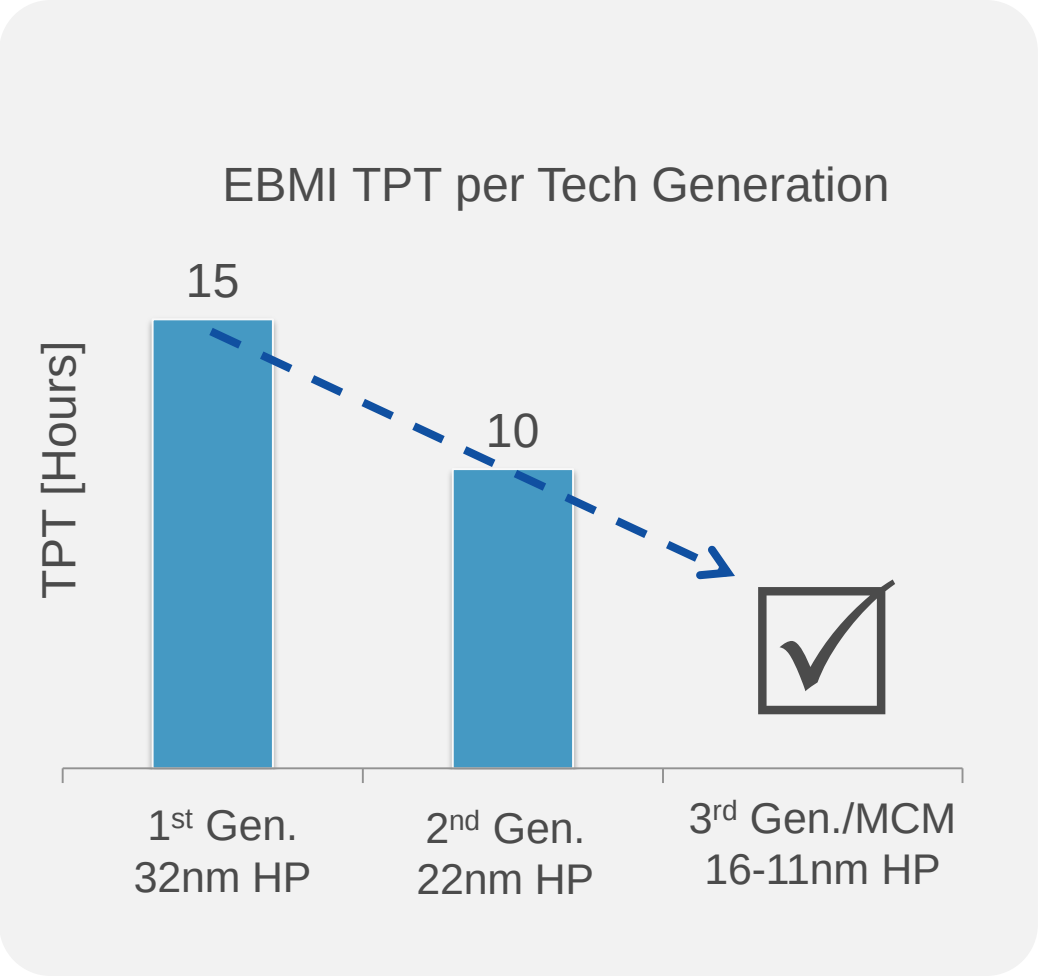
e-Beam Throughput Scalability

- Throughput can be scaled through technology extensions to meet future nodes, via:
  - Higher beam voltage
  - Higher beam current
  - Faster detectors
  - Multi column



EBMI throughput scalable through engineering efforts

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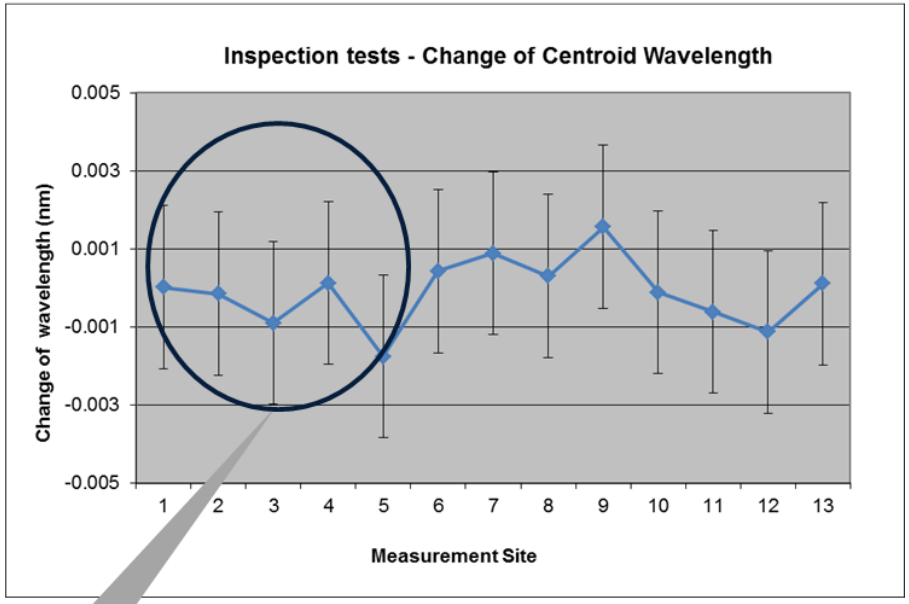
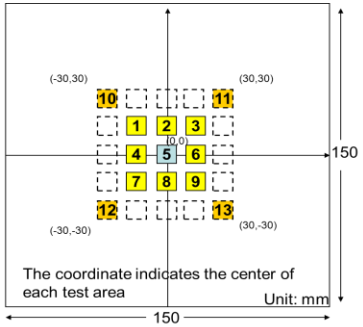
Inspection Conditions Study – 2nd Gen.

No sign for eBeam damage to ML

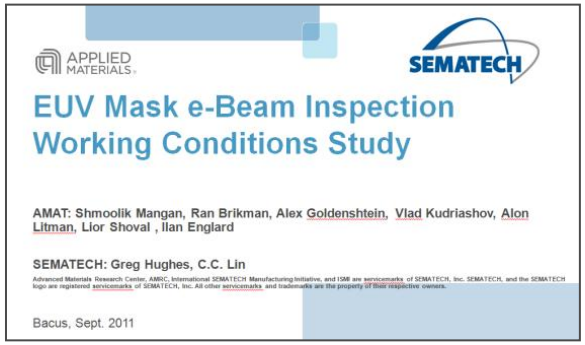




Condition
medium low
low
medium 1
typical 1
no scan
medium 2
typical 2
Extreme 1
Extreme 2
control
control
control
control

Control points

Source: Mangan et. al, BACUS 2011



EBMI does not damage the EUV mask

There is no detectable change of λ-centroid

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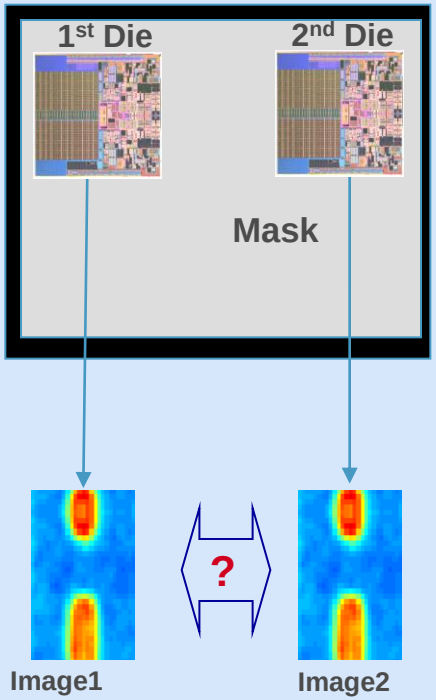
EBMI Single Die Inspection Die-to-Model

External Use

What is Die-To-Model (D2M)

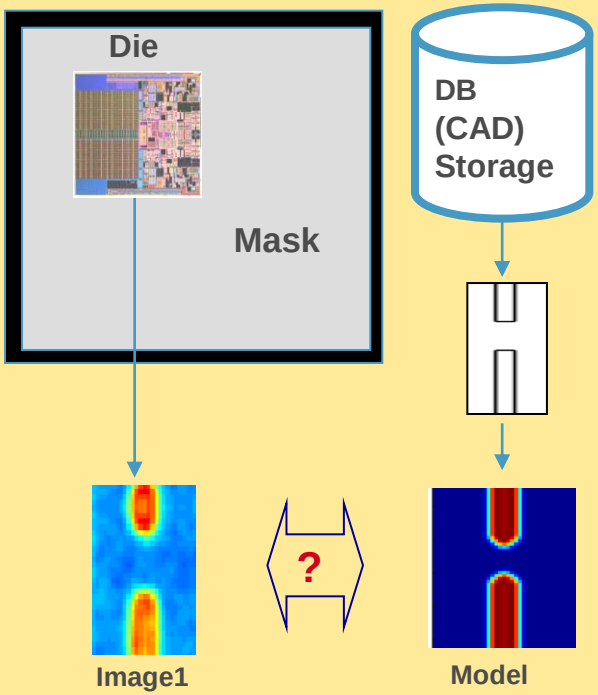
Die-to-Die



Compare image to image

- D2D scheme is not suitable for Single-Die situations

Die-to-Model

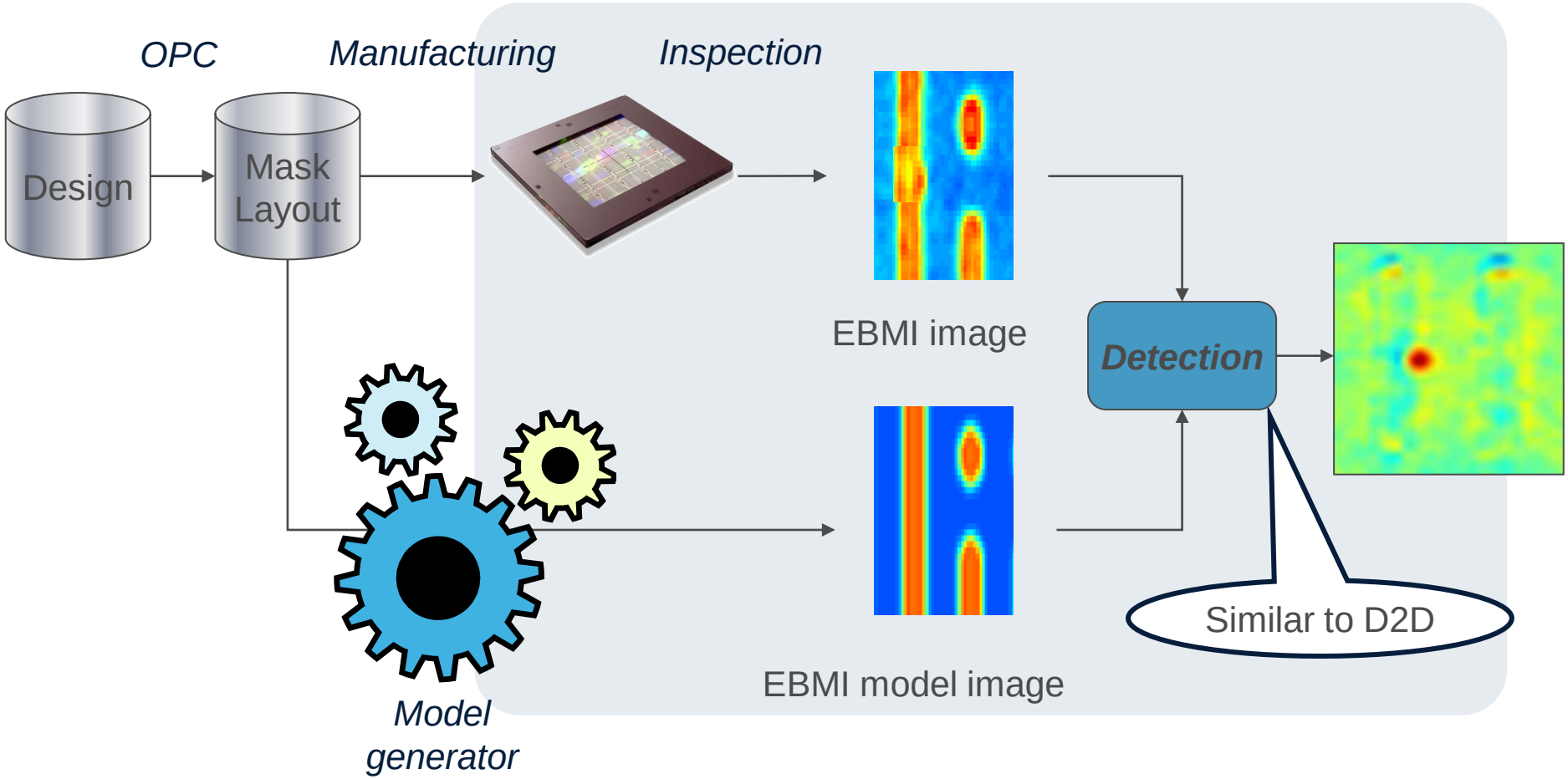


Compare image to image model

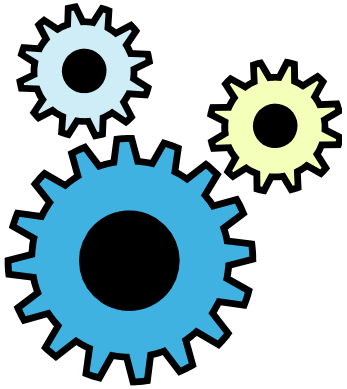
- D2M scheme is designed to work ***At same Resolution***
- Providing solution for ***Single Die inspection***

Die-To-Model Flow

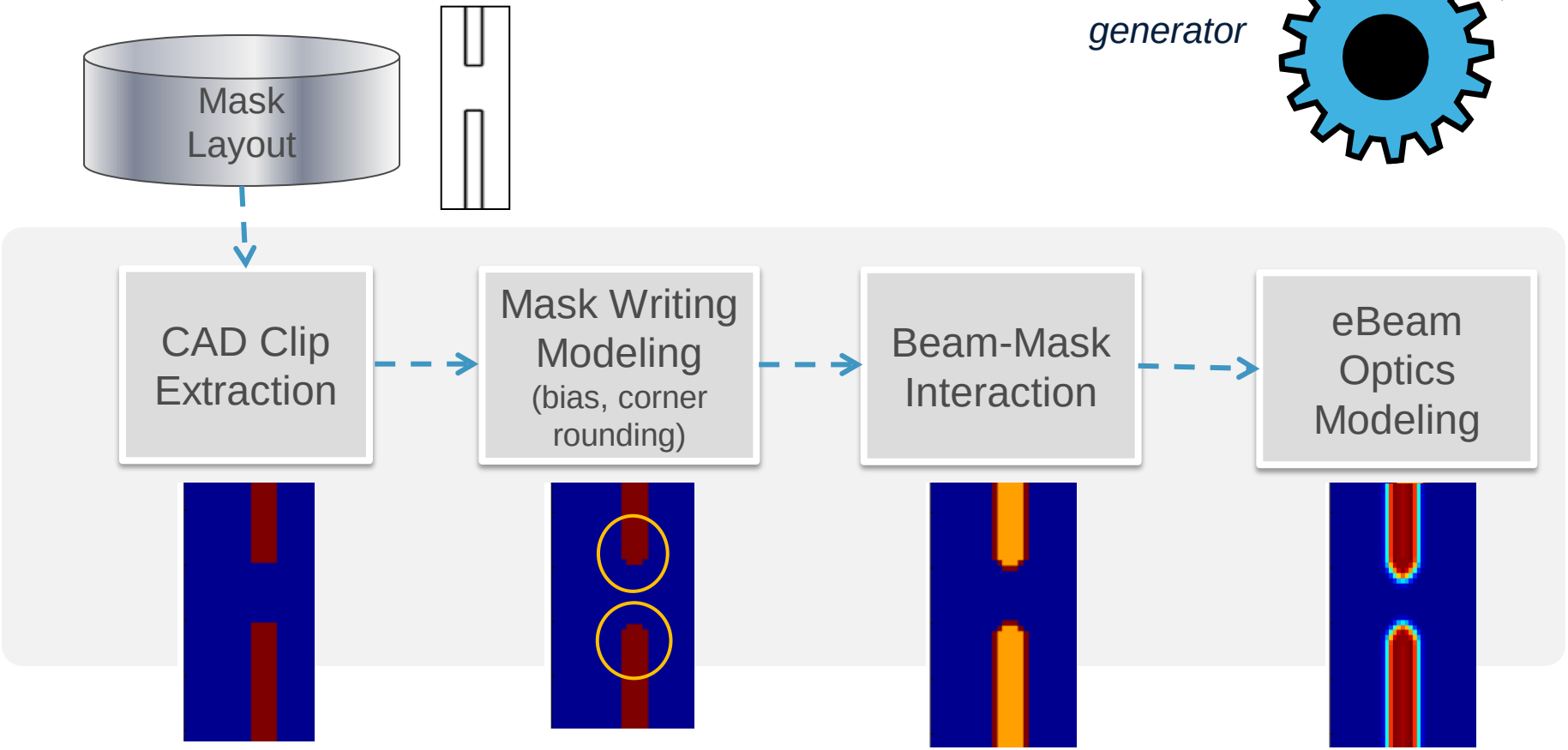
D2M Principle: Comparing tool image to model image built from mask layout



EBMI Model Image Creation



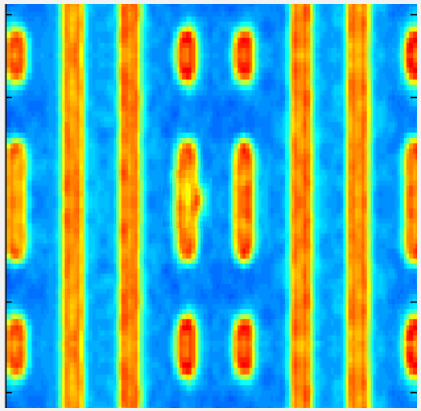
Model generator



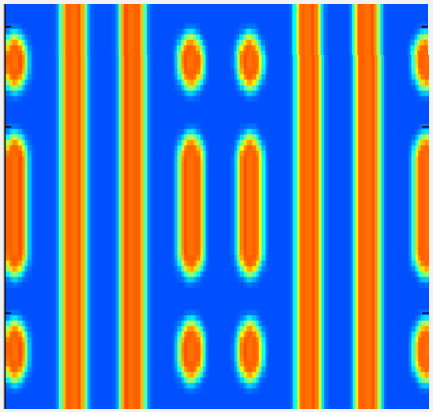
Model image generation form D.B.

Die-To-Model Example

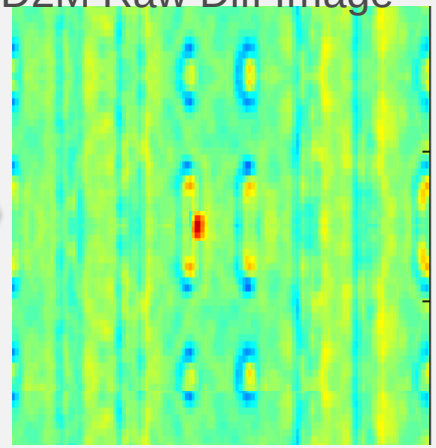
EBMI Image



Model Image



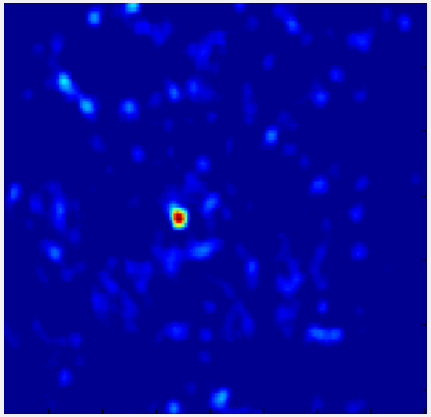
D2M Raw Diff Image



SNR = ~5

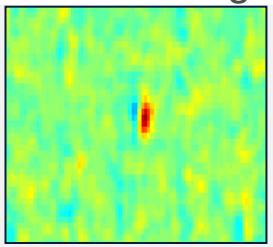
Systematic Noise Removal

D2M Final Diff Image



SNR = ~20

C2C Diff Image



SNR ~9

EBMI die-to-model yields better SNR than D2D

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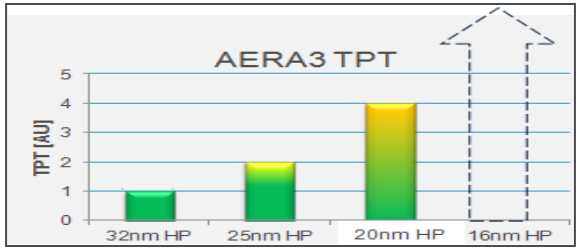
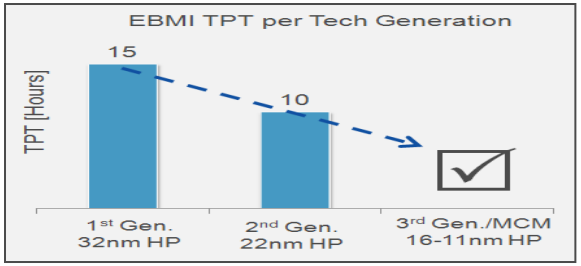
Summary

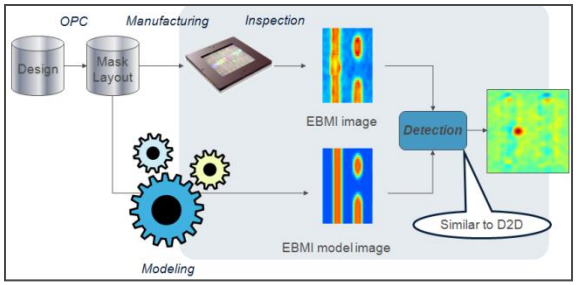
- Aera3 (193nm) – proven for 30nm
  - Extendable down to 20nm
  - Limits of optics – rising TPT



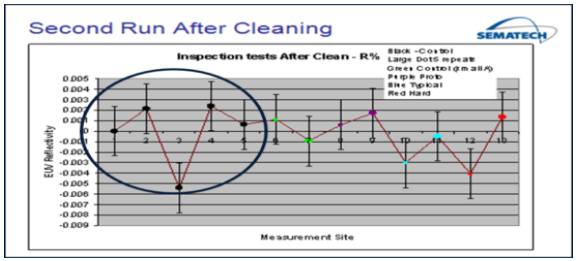
- e-Beam inspection for sub 20nm masks
  - Existing technology, best resolution
  - Scalable through technology progress



- EBMI single die
  - D2M concept demonstrated
  - Infrastructure migration from Aera



- EUV compatibility
  - No damage to ML



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