
eBeam
Initiative

6th Annual eBeam Initiative Luncheon

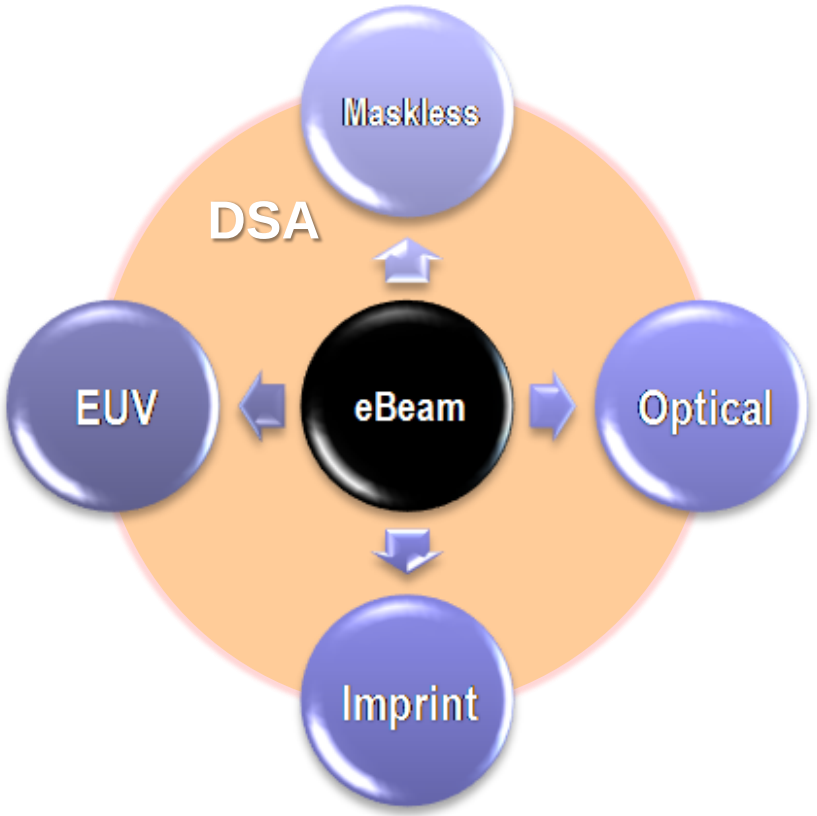
SPIE – February 25, 2014

Aki Fujimura
CEO – D2S, Inc.
Managing Company Sponsor – eBeam Initiative

eBeam Writes All Chips

The eBeam Initiative:

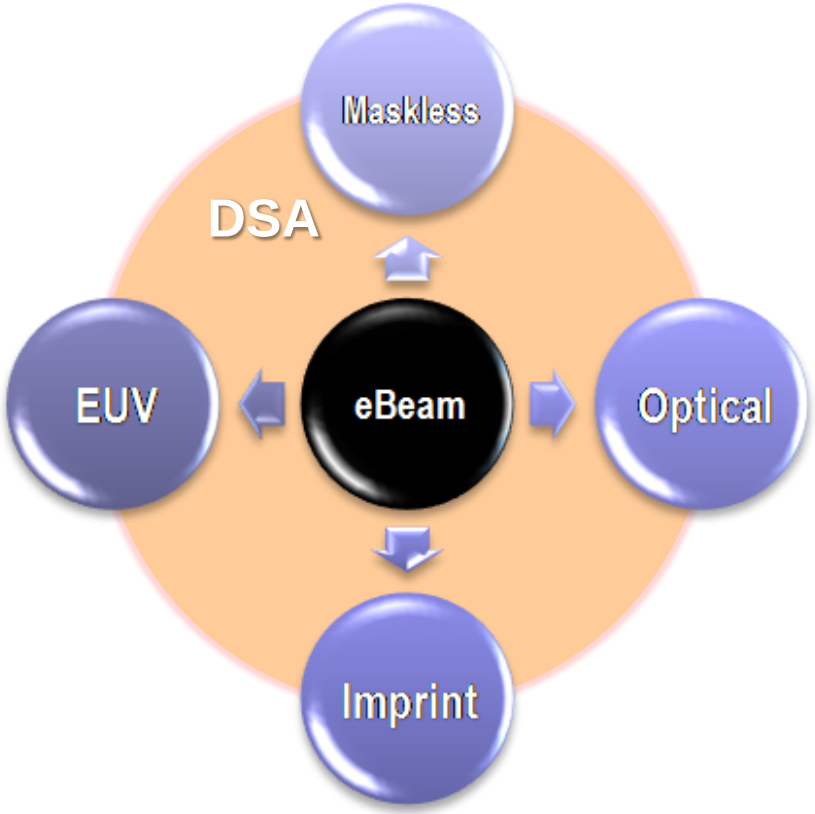
- Is an educational platform for eBeam technology and its impact on all lithography approaches
- Open to any company in the semiconductor design chain with an interest in eBeam technologies



eBeam Writes All Chips

"I would like the eBeam Initiative to help the ecosystem understand the value of higher quality masks."

- Aki Fujimura



40+ Member Companies & Advisors
Now welcoming Sage-DA

eBeam Initiative

www.ebeam.org

aBeam technologies

ADVANTEST

ADVANCED MASK TECHNOLOGY CENTER

alchip

APPLIED MATERIALS

ARTWORK CONVERSION
CAD Translators
Postprocessors
Plotter Drivers

aselta NANOGRAPHICS

cadence

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TOOL

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Xilinx

TOPPAN

Vistec

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Educational Themes for 2014

Drawing on 2013 Survey Results

- Multibeam for Masks
  - Confidence increased from 75% in 2012 to 86% in 2013 that multibeam for production mask writing will occur in 2016
- GPGPUs for Simulation Intensive EDA Applications
  - More than 50% said that one third or more simulation intensive EDA applications would use GPGPUs
- Mask Hotspots
  - More than 75% said that mask hotspots will be significant by 2020; 36% see as significant today (Aug 2013)

Future of Mask Data Prep is Model Based

MB-MDP fixes mask hotspots while reducing write times

- Linearity correction (MPC)
- Dose margin enhancement (MPE)
- Full-chip model-based mask verification (MB-MV)

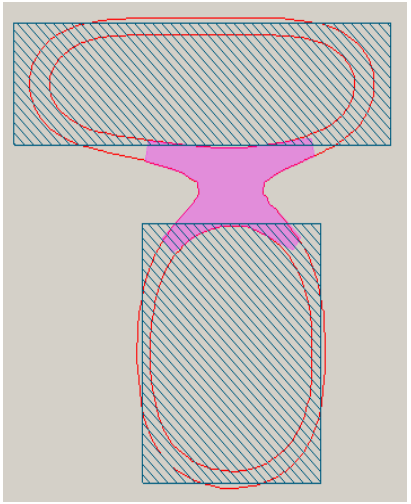
Mask Hotspots Escaping the Mask Shop Today

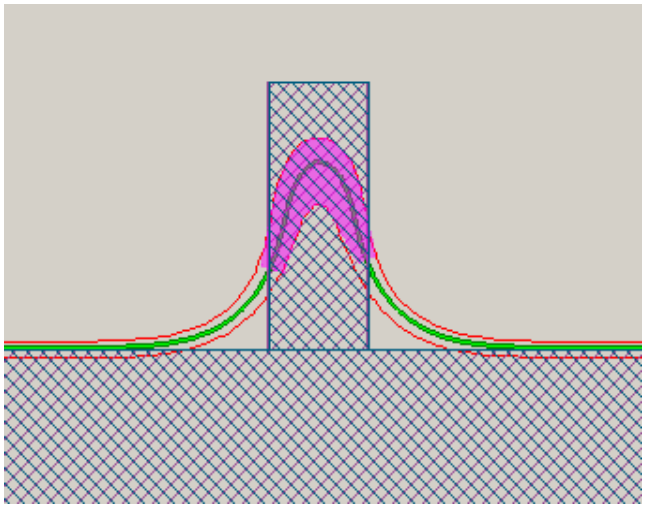
Can we identify issues earlier?

Inspection:

- Hotspots smaller than 20 nm (2D) unlikely to be identified at all
- SEM review of *only flagged* hotspots

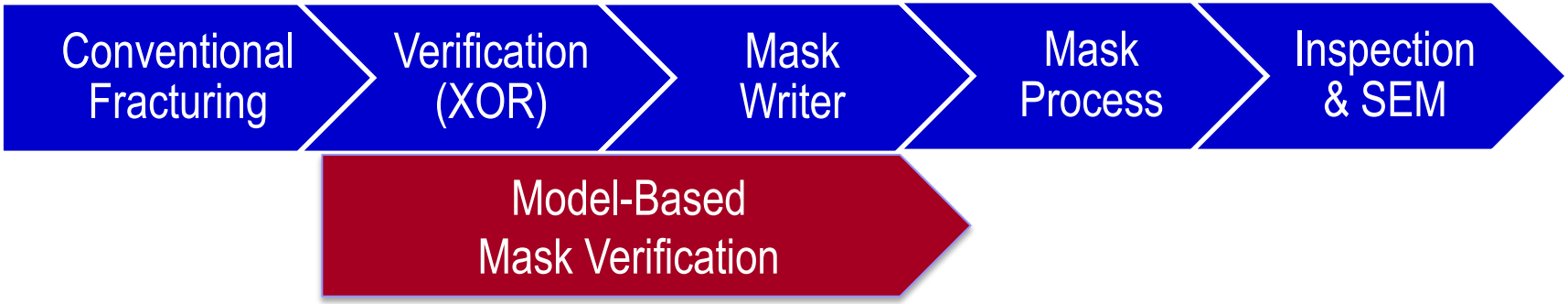
Model-Based Mask Verification (MB-MV) for Full-Chip Detection





- Need to flag mask hotspots with 1-2 nm accuracy
- Need simulation-based Edge-Placement and Dose Margin error detection
- Full chip coverage requires GPGPU acceleration

MB-MV for Conventional Fracturing



- No risk to existing flow
- Finds issues *before* expensive mask processing
- Full-chip coverage

New **Whitepaper on Mask Hotspots at www.ebeam.org**

Our Next Speakers

- **Mask Complexity Issues and MB-MDP Approach**
  - Naoya Hayashi, DNP
- **Mask Synthesis for DSA**
  - Yuri Granik, Mentor Graphics
- **Q&A**

Mask Complexity Issues and MB-MDP Approach

Naoya Hayashi
Dai Nippon Printing Co., Ltd.

eBeam Initiative Member

DNP

Mask Complexity in Optical Lithography Extension

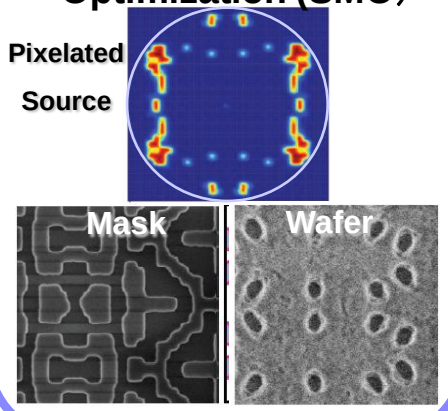
"Litho scaling" should continue.

EUVL still have many issues to resolve.

Optical Litho extension needed.

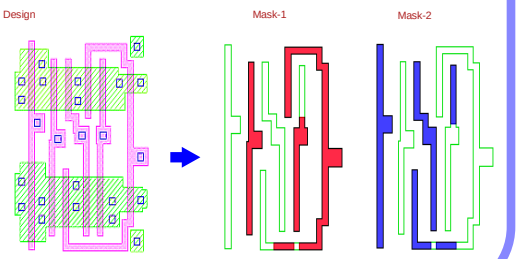
"Optical Lithography Extension" needs very complex mask pattern features and/or multiple masks per layer.

Source Mask Optimization (SMO)

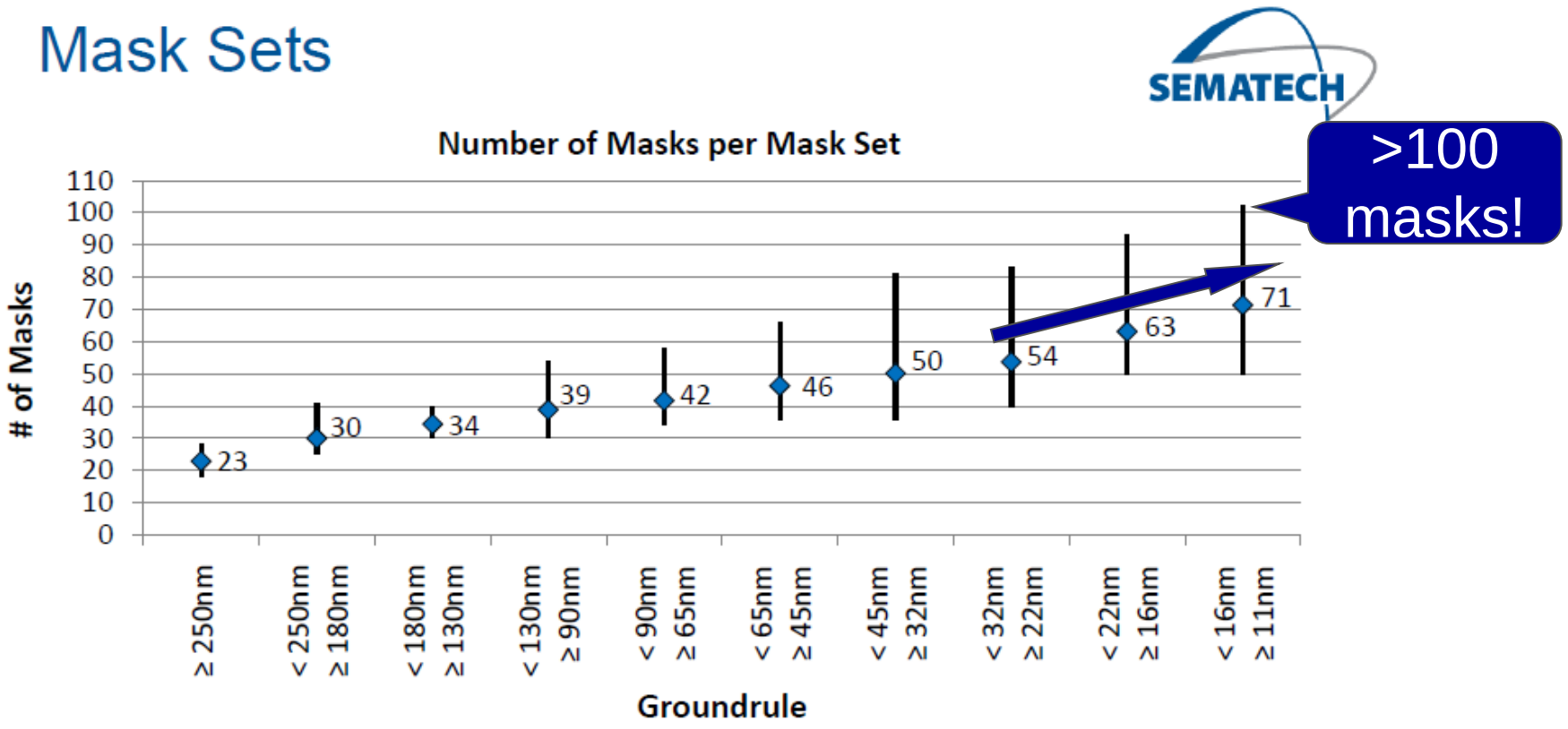


Double Patterning (DPL)

Multiple Exposures, Multiple Processes

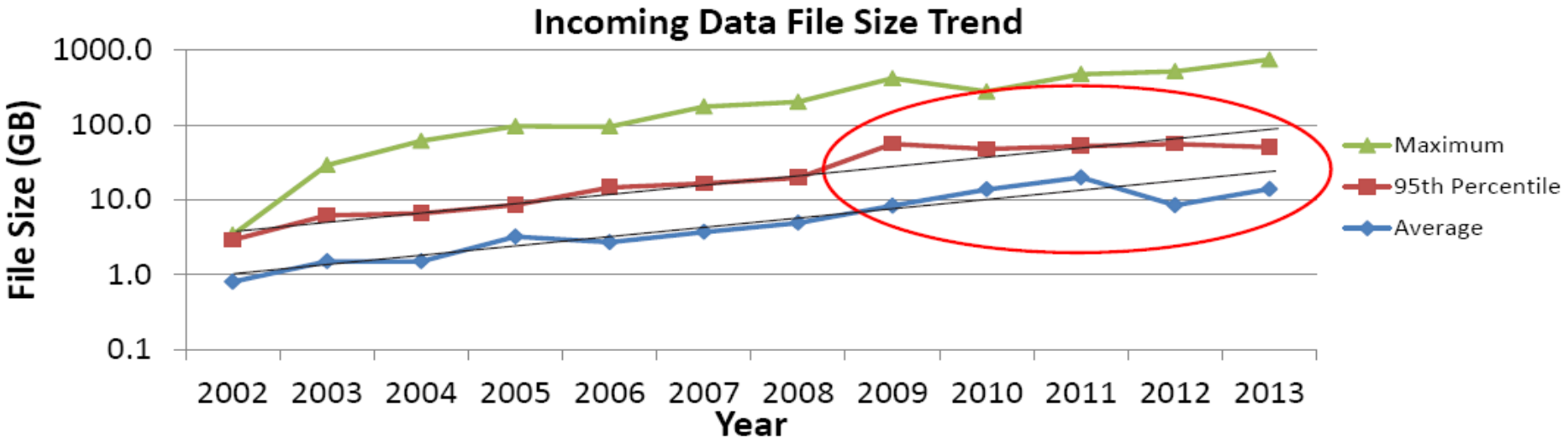


Trend of Number of Masks per Mask Set



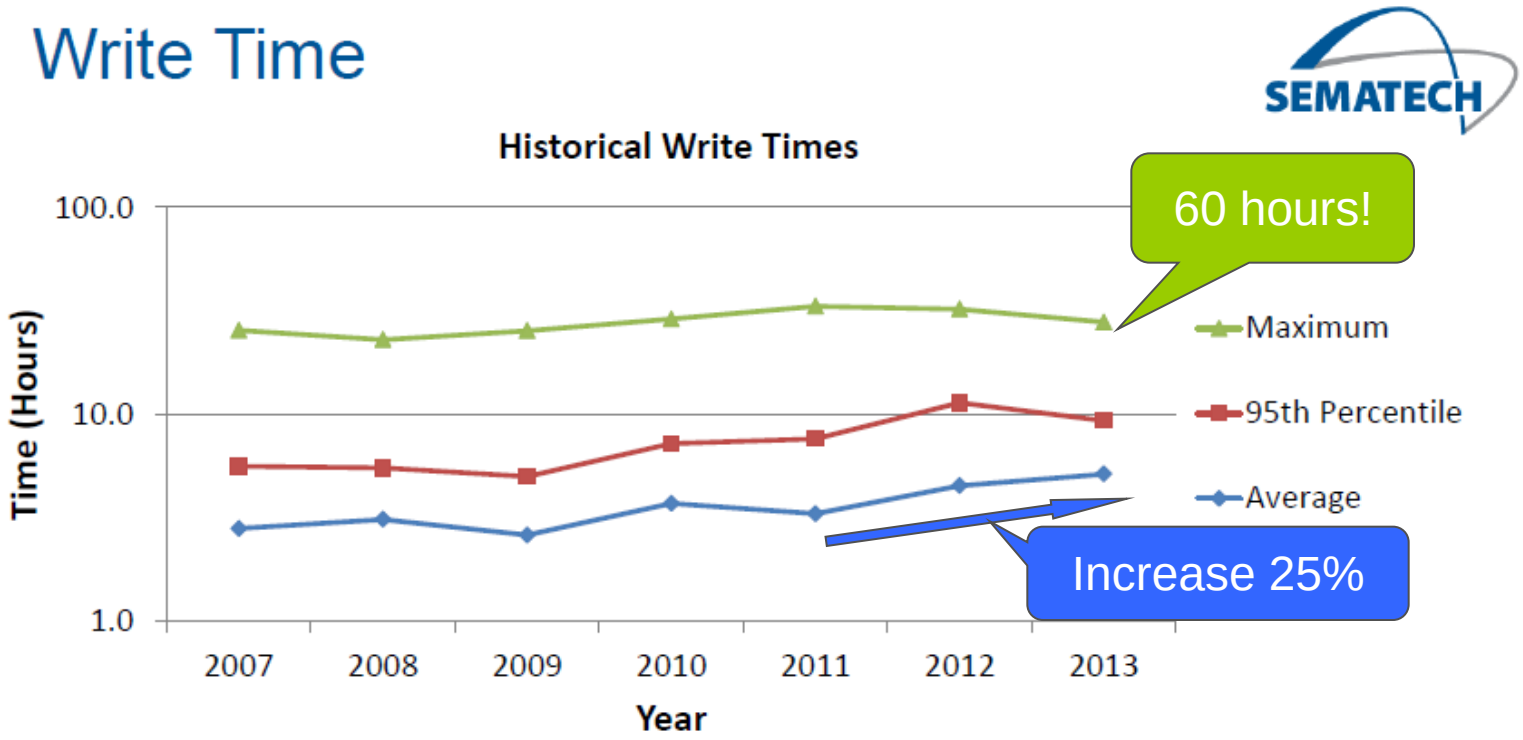
Recent growth rate is ~14%.
High-end products need many masks!

Incoming Data Size and Format



Recent data file size seems to be stabilized.
But maximum data size continues to rise!

Trend of Mask Writing Time

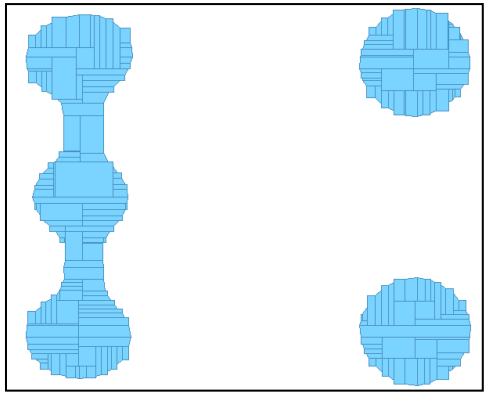


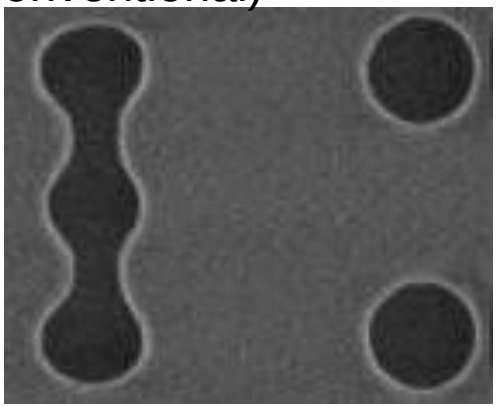
Recent growth rate of average writing time is ~25%.
Maximum writing time reached 2.5 days!
→Need to reduce shot count!

MB-MDP approach

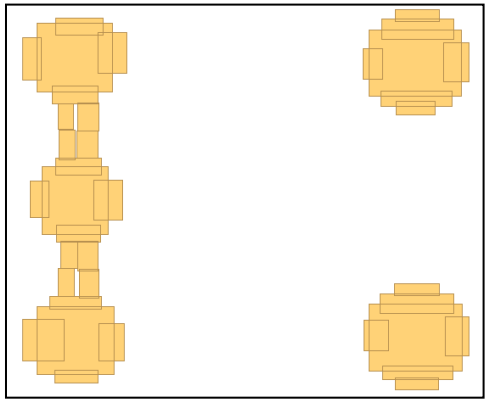
- Model Based Mask Data Preparation has some advantages regarding shot count reduction to reduce actual writing times, and accuracy of very small / complex features which are in non-linear range of an e-beam model.

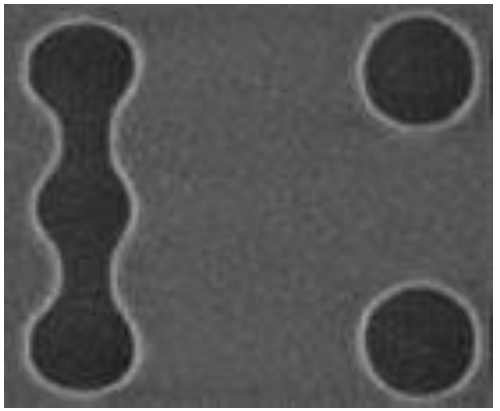
Manhattan (Conventional)





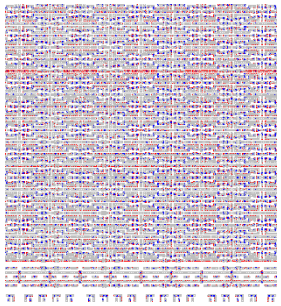
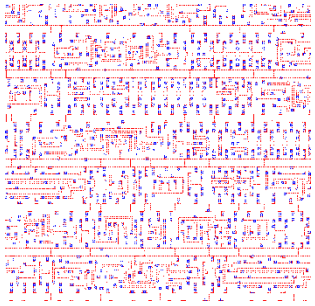
MB-MDP





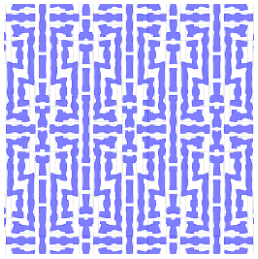
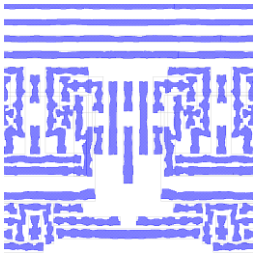
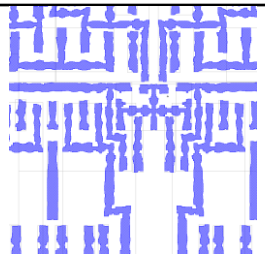
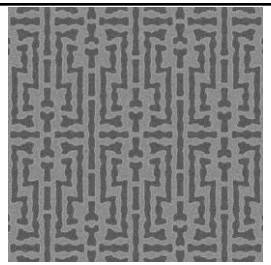
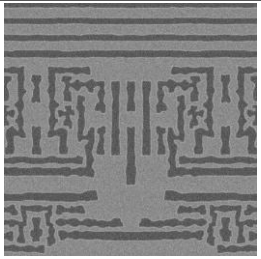
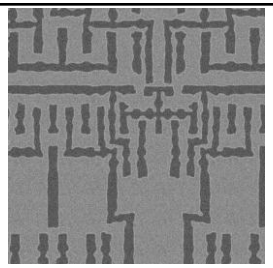
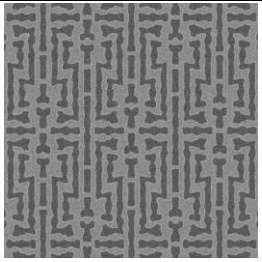
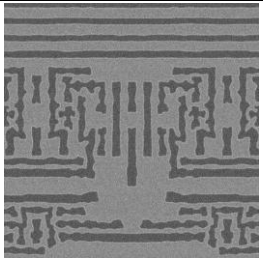
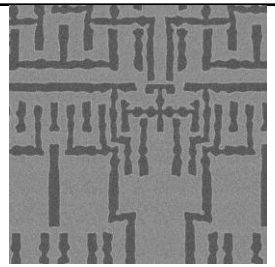
MB-MDP evaluation results

- Experimental
  - Shot data generation by using MB-MDP and a conventional MDP tool for a reference
  - Mask writing on EBM-8000
  - Mask inspection check
  - Metrology
- Motif designs (Total chip size is 5mm x 5mm on wafer)

Nodes	SRAM Cell	Standard Cell
28,20,14nm		

MB-MDP evaluation results

- Pattern quality (SEM features)
- SRAM Metal 1 (20nm)

	Metal 1 #1	Metal 1 #2	Metal 1 #3
Input Data			
MB-MDP			
Conventional MDP			

MB-MDP evaluation results

- Shot count comparison

Nodes / MDP	Metal 1 #1	Metal 1 #2	Metal 1 #3
20nm /Conventional	635,005	678,823	2,286,066
20nm /MB-MDP	301,057	345,613	1,456,902
Reduction Rate	52.59%	49.09%	36.27%

Summary

- Continuous device scaling requires very complex and small mask pattern features, especially for optical lithography extension option, and it will increase data size, shot count, and result in long mask writing time.
- MB-MDP approach has certain advantages to reduce the shot count with equal pattern quality, and better small pattern fidelity.
- Next step :
  - Further results for inspection.
  - Integration into production control system.

Mask Synthesis for DSA

Yuri Granik

Chief Scientist

February 2014

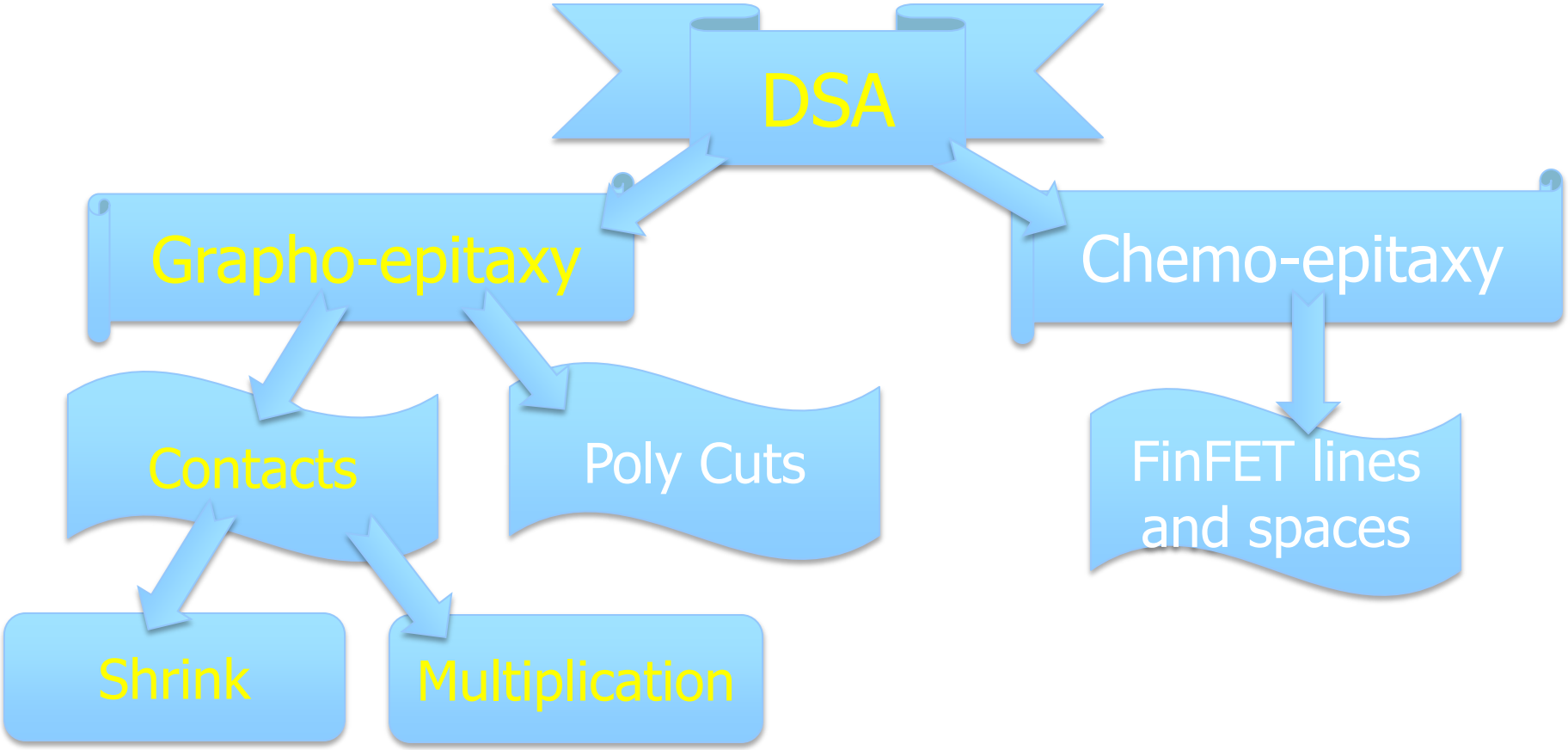
eBeam Initiative Member

Mentor Graphics

Outline

- DSA in IC manufacturing
- DSA grapho-epitaxy primer
- DSA mask synthesis flow
- DSA mask synthesis example
- DSA pilot production
- Conclusions

DSA in IC manufacturing

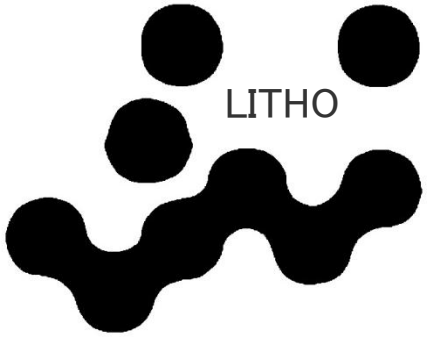


DSA grapho-epitaxy primer

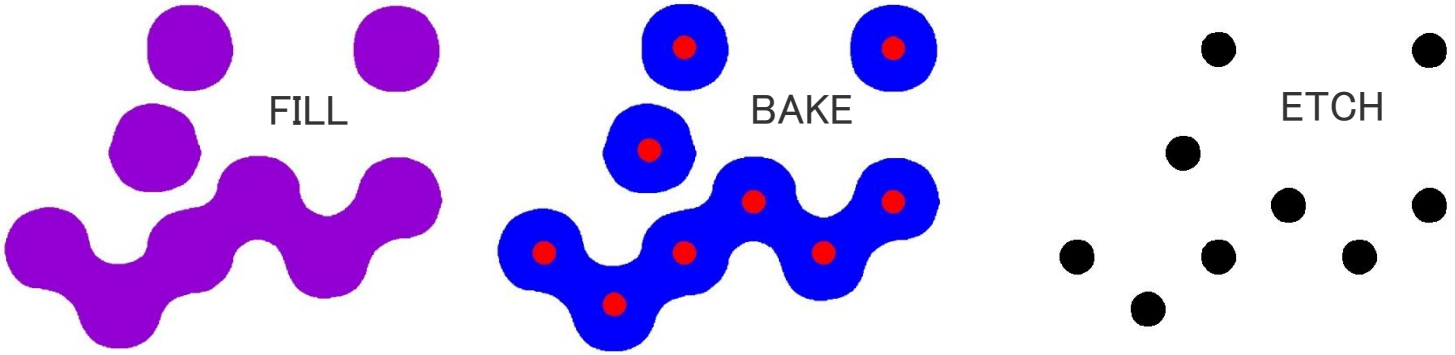
Grapho-epitaxy is a two-step dance

-Yan Borodovsky

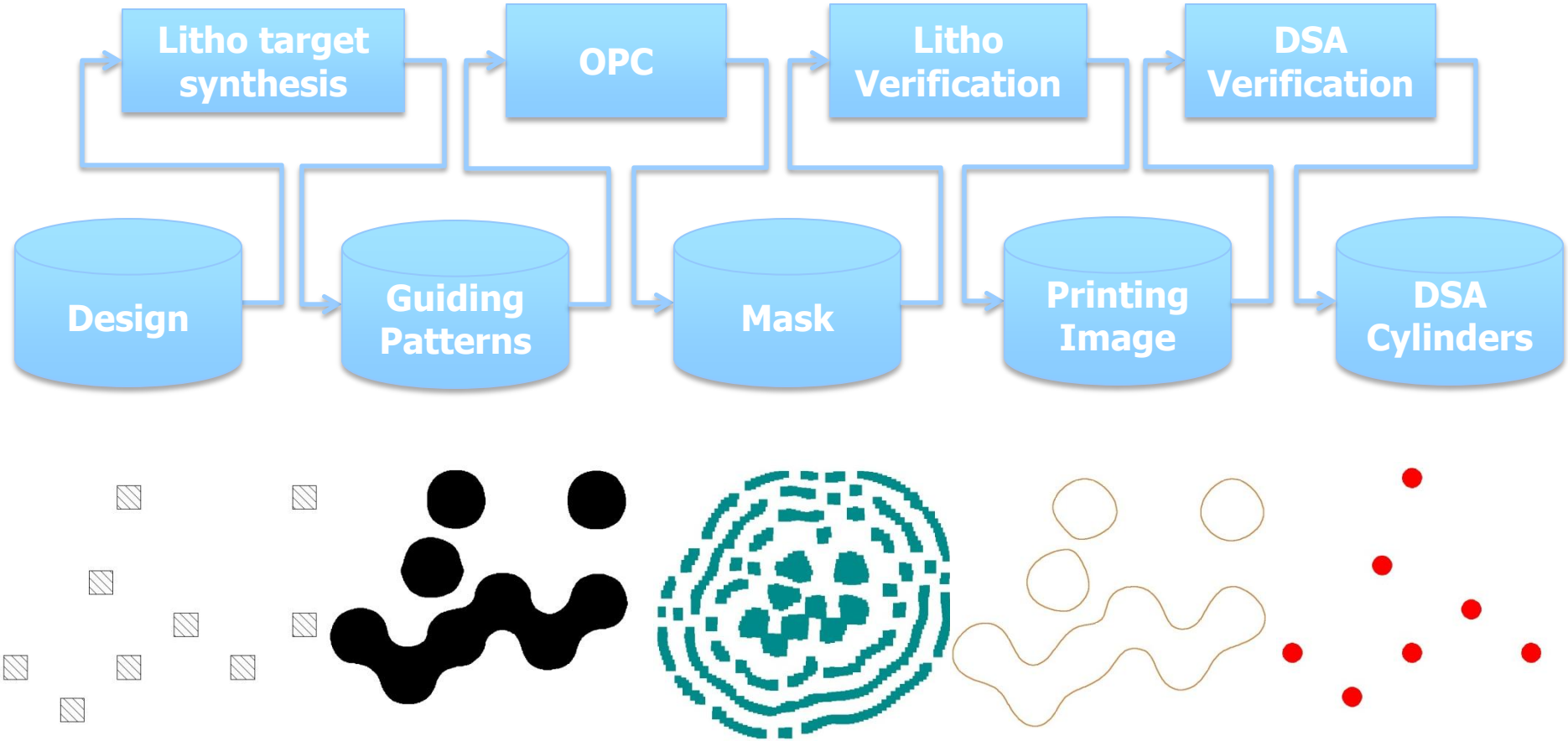
- Firstly, lithography patterns guiding wells on wafer



- Secondly, block-copolymer fills wells then it is baked and etched

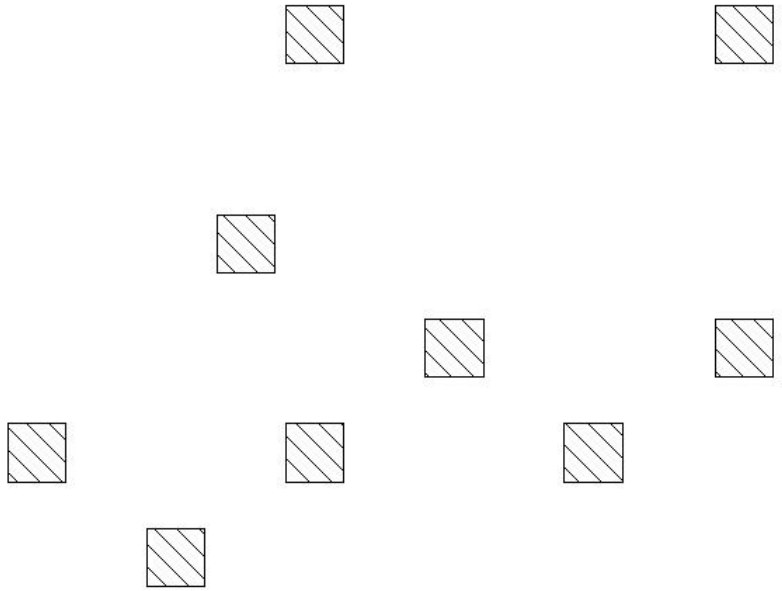


DSA mask synthesis flow



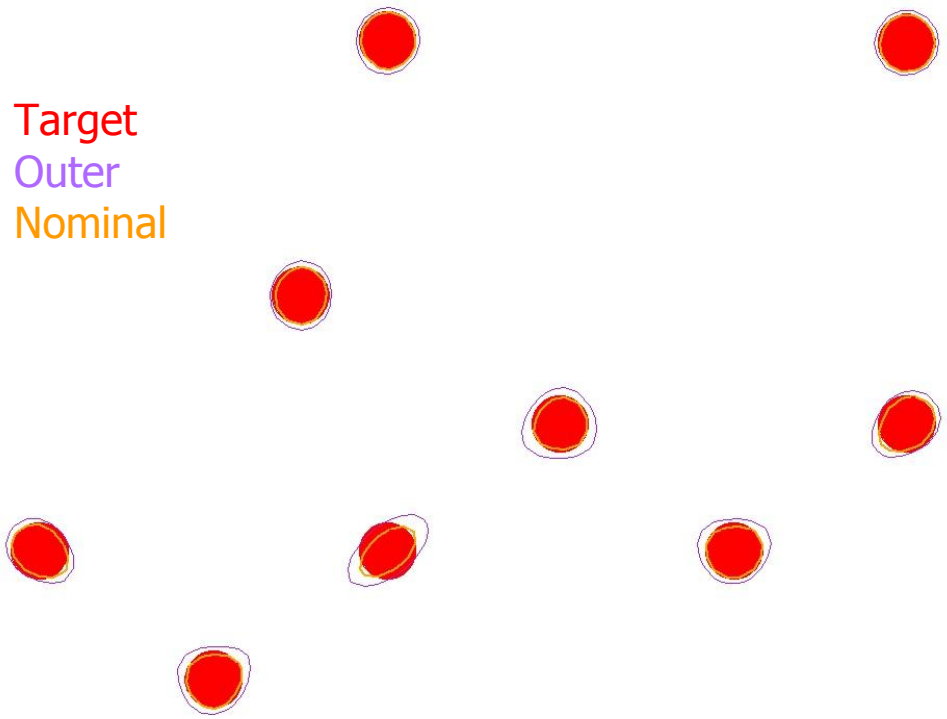
DSA mask synthesis example

- Example of **DSA contact multiplication** technology
- Mask is synthesized by industry-standard ILT tool **pxOPC** by Mentor Graphics
- Generic 193 immersion
- Clip from a contact layer
- 20 nm CD
- MRCs are ignored



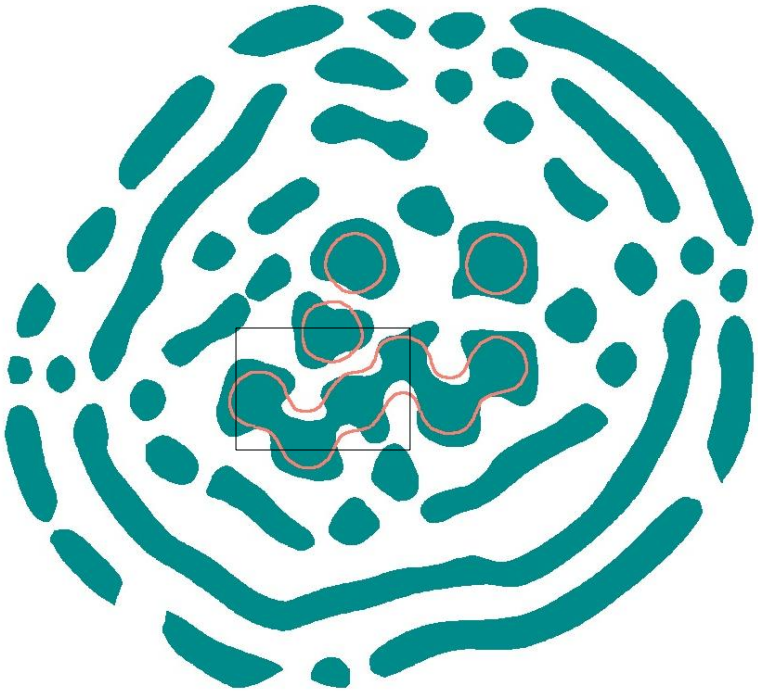
Regular Litho without DSA

- Litho alone does not work: no process window
  - Outer and nominal PV-contours are OK
  - Inner PV-contour collapses

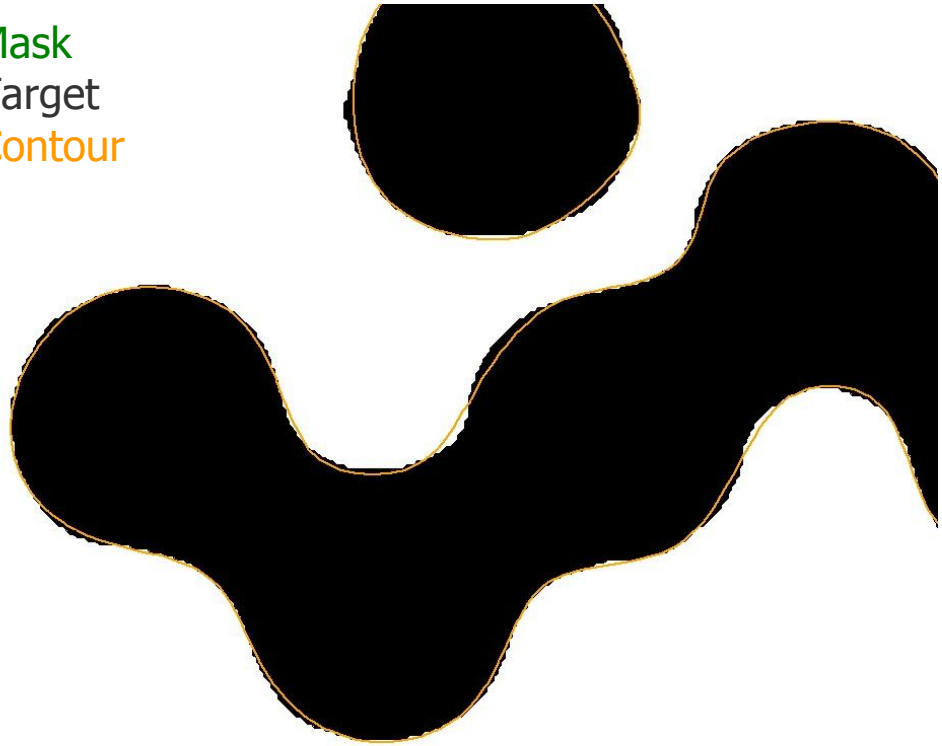


Aggressive smooth mask for DSA

- Aggressive **pxOPC** mask results in maximum Litho EPE of 2.8 nm

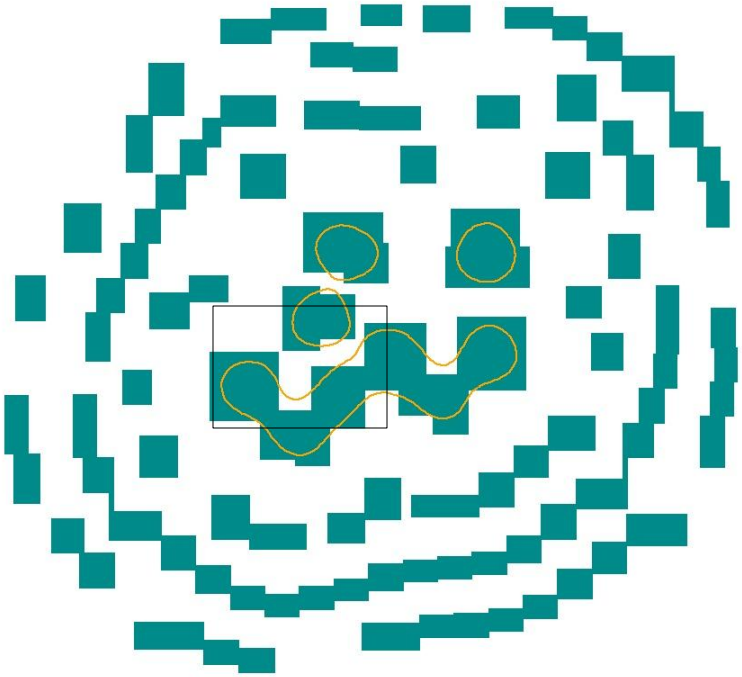


Mask
Target
Contour



Modest Manhattan mask for DSA

- Modest **pxOPC** mask of 40 nm fragments
- Maximum Litho EPE is 12.8 nm

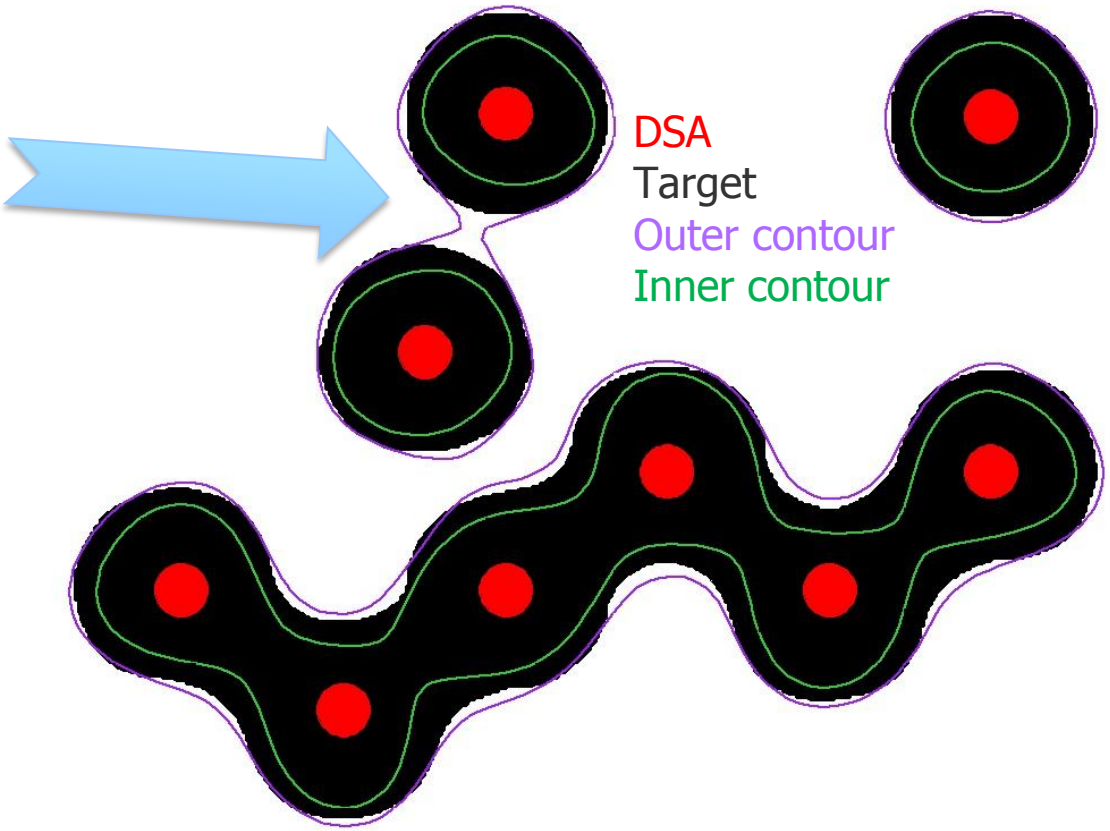


Mask
Target
Contour

Nature of DSA resolution enhancement

- PV-bands are acceptable even though pinching is present in outer contour

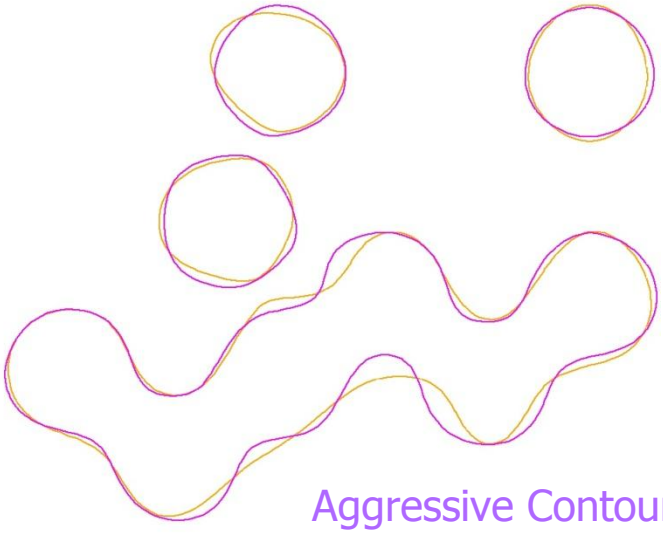
DSA enhances resolution by forming correct final contacts even when guiding pattern fidelity is compromised



Error versus mask aggressiveness

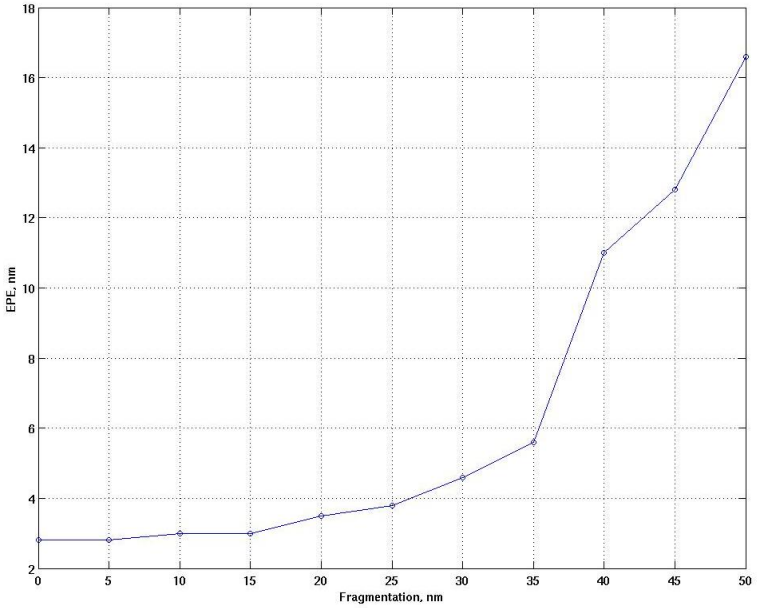
- **pxOPC** mask fragmentation flavors from 0 (smooth mask) to 50 nm are demonstrated

0 10 20 30 40 50



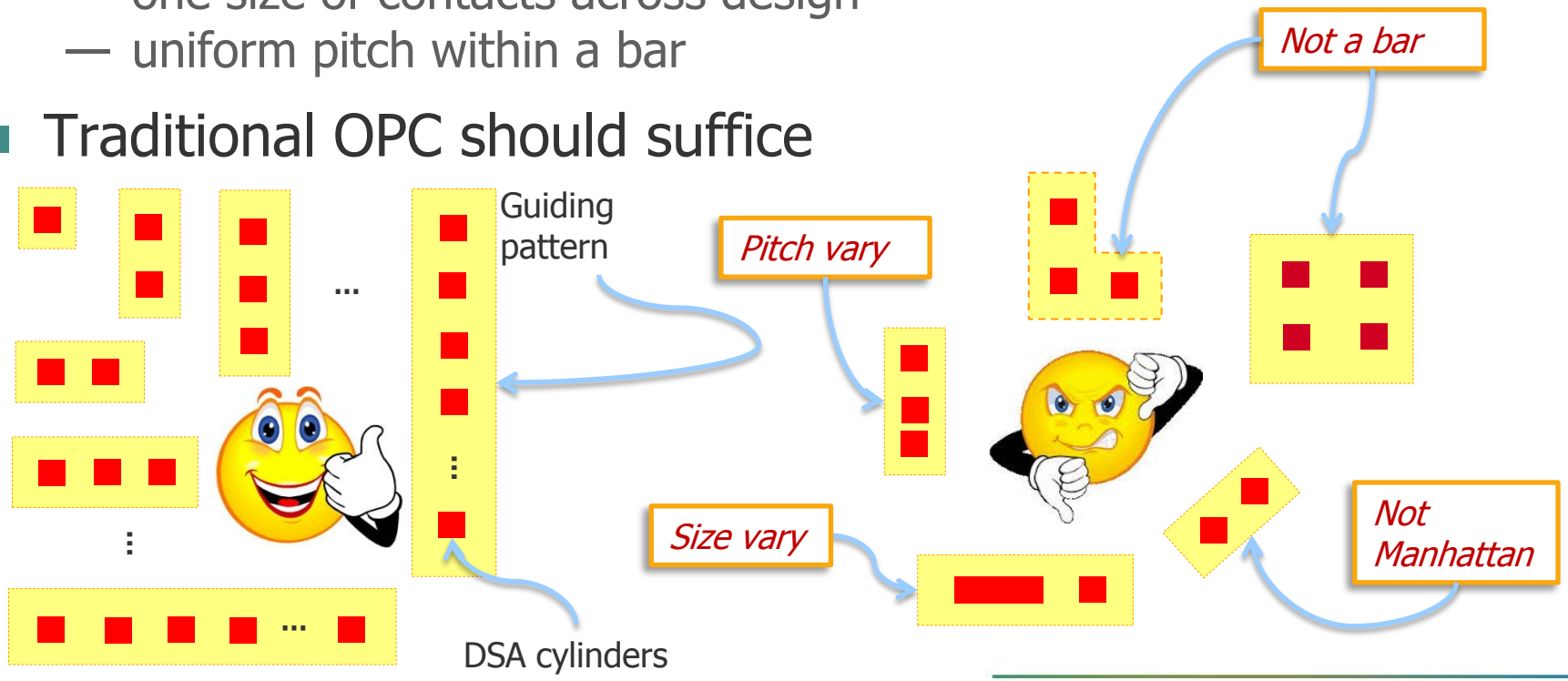
Aggressive Contour
Modest Contour

For coarser masks printing image degrades and can cause failure of guiding pattern to control positions of DSA cylinders



DSA pilot production

- Pilot production starts this year 2014 for **DSA contact shrink** technology
- Severe design restrictions are enforced
  - vertical/horizontal bars
  - one size of contacts across design
  - uniform pitch within a bar
- Traditional OPC should suffice



Conclusions

DSA is dirt cheap

-C. Grant Willson

- DSA chemical components are cheap
  - Come think of it, DSA actually costs nothing to mask makers
- **DSA contact shrink** is easy
  - Minimal impact on mask making
  - Traditional OPC should suffice

HOWEVER…

- **DSA contact multiplication** for optical lithography is hard
- Inverse Litho Corrections are desirable to control guiding patterns through process window

Acknowledgements

My colleagues from Mentor Graphics Alex Tritchkov and Aleks Bezman setup and run experiments

Thank you for attending!

Q & A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