



Beam
Initiative

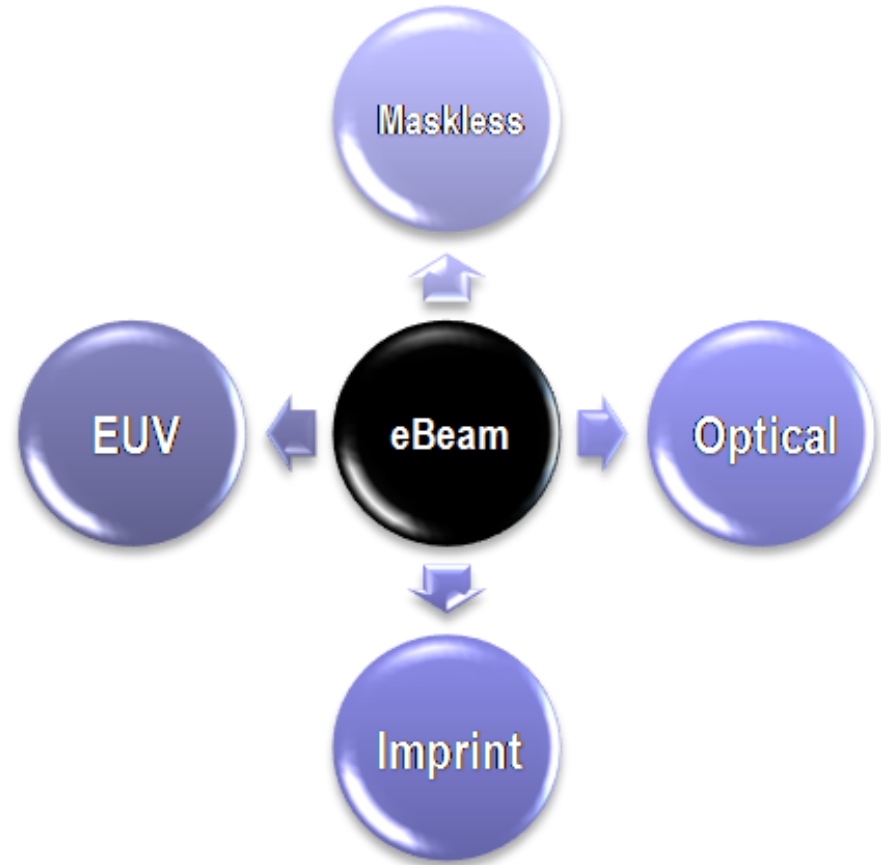
eBeam Initiative Panel & Cocktails

BACUS – September 20, 2011

Jan Willis
Executive Advisor, Calibra
Facilitator – eBeam Initiative

eBeam Writes All Chips

All designs at advanced nodes, regardless of lithographic approach, require eBeam technology.



Welcome to Our Newest Members



41 Member Companies & Advisors



Jack Harding
eSilicon

Grenon Consulting



Colin Harris
PMC-Sierra



Riko Radojic
Qualcomm



Jean-Pierre Geronimi
ST



Today's Presentations



GLOBALFOUNDRIES

Gek Soon Chua



Aki Fujimura



ADVANCED
MASK
TECHNOLOGY
CENTER

Christian Bürgel

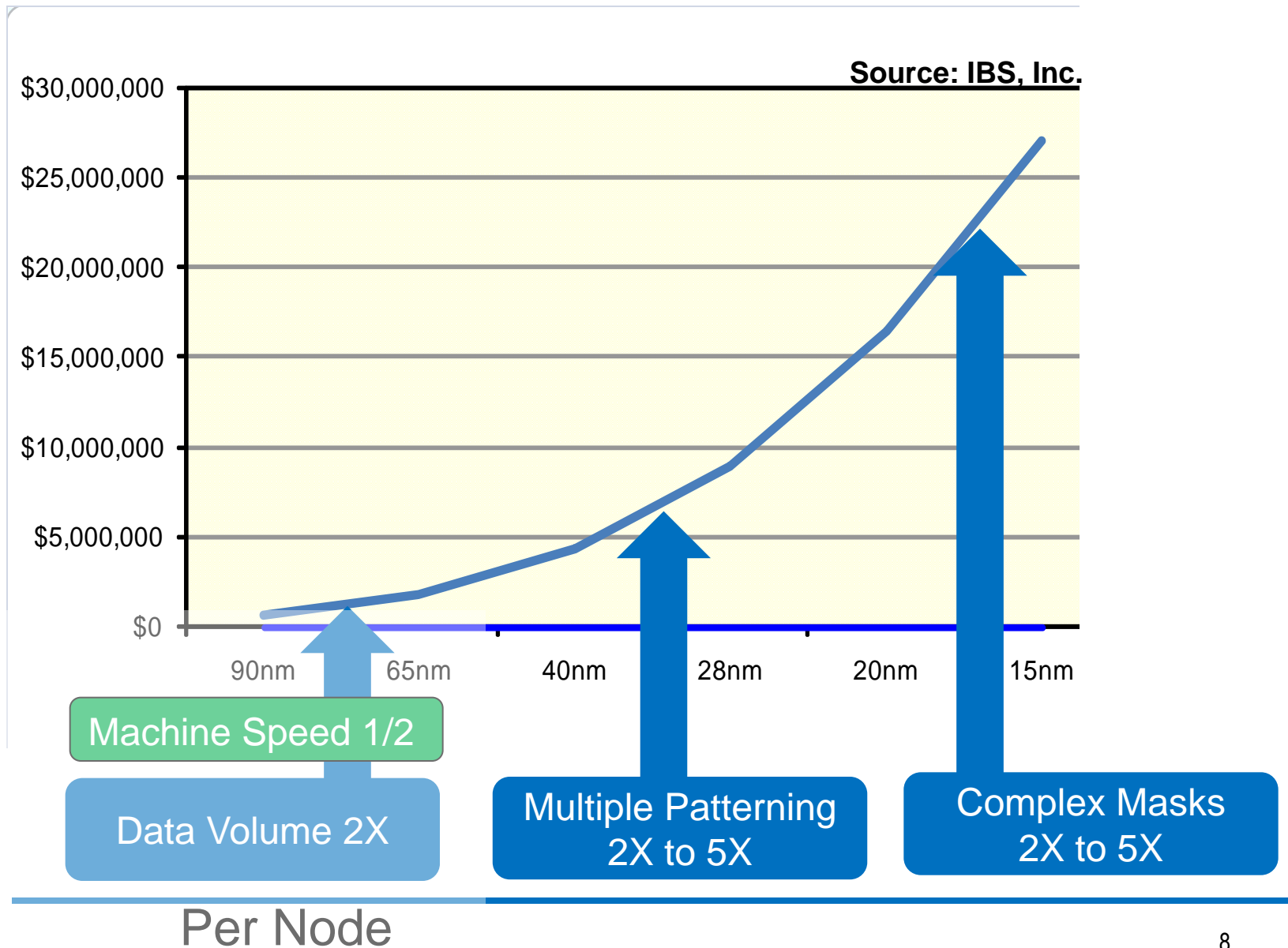
Sub-80nm Discontinuity Has Arrived

Aki Fujimura

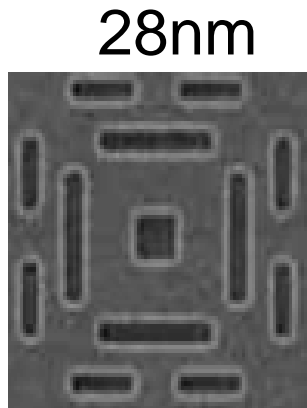
CEO - D2S, Inc.

Managing company sponsor of the eBeam Initiative

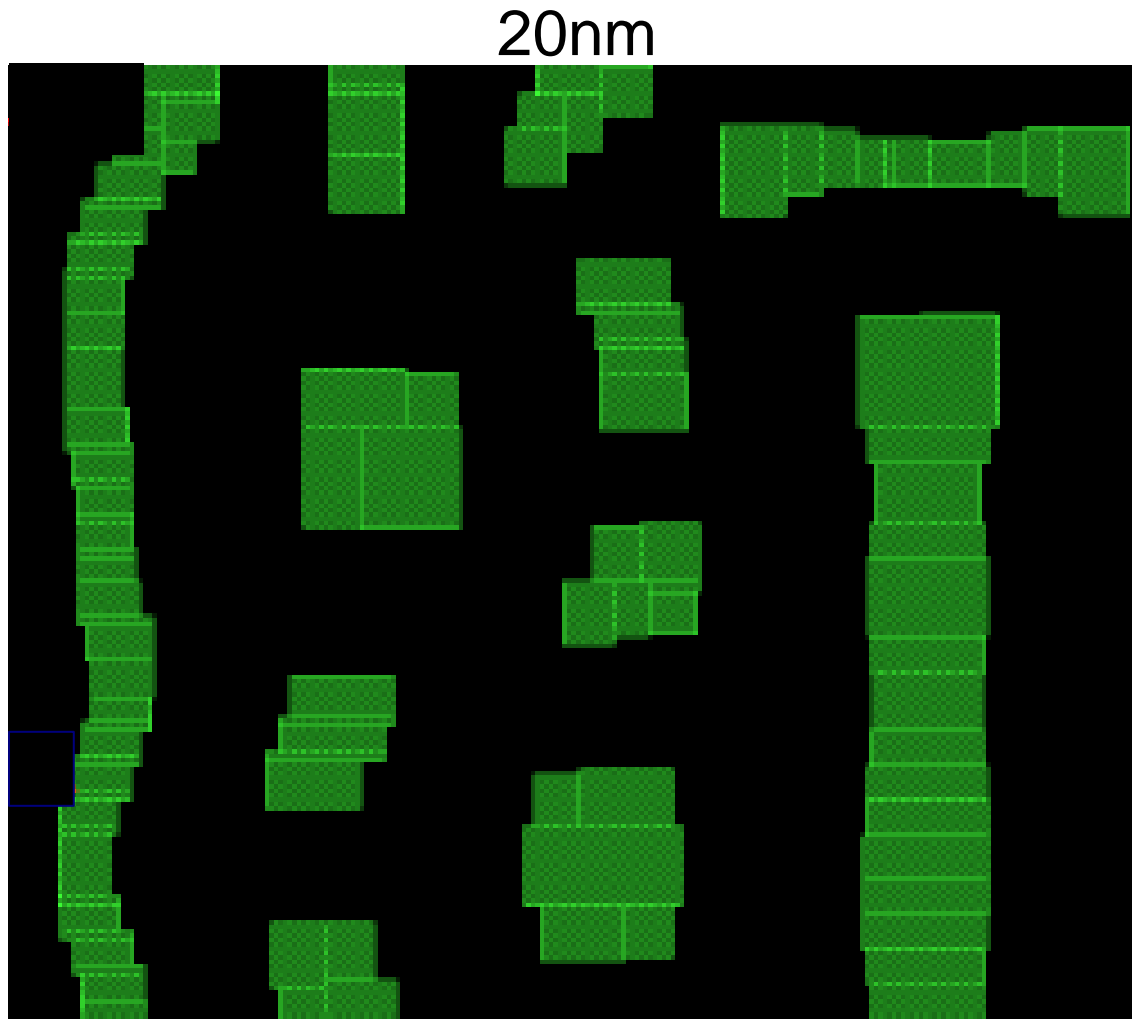
More Complex Mask = Mask Cost Explosion



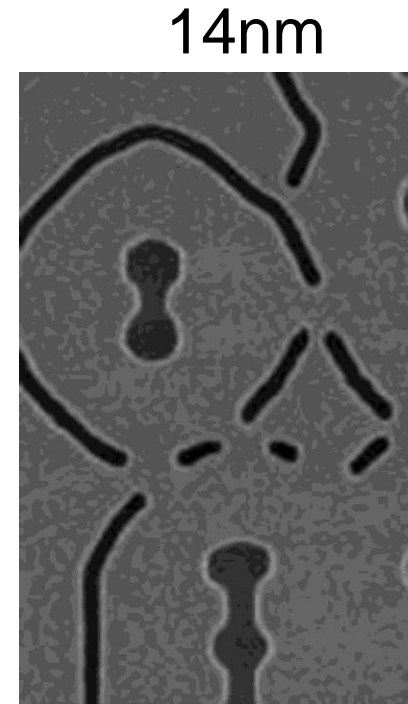
Complex Mask Shapes are Required at 20nm



Courtesy : Samsung



Courtesy : IBM



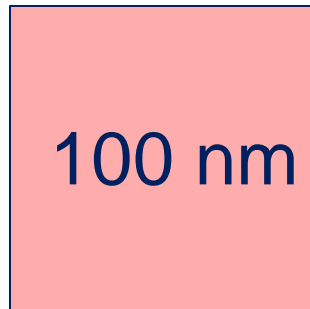
Courtesy : DNP

Sub-80nm Discontinuity Has Arrived

The old assumption : eBeam is accurate

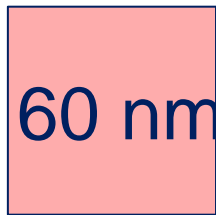
The new world : needs simulation-based correction

Shot Size

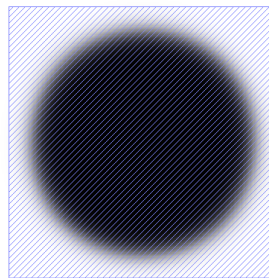
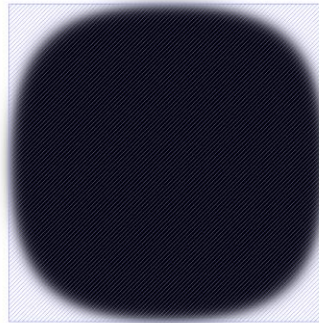


100 nm

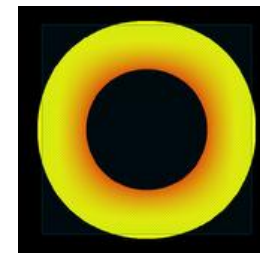
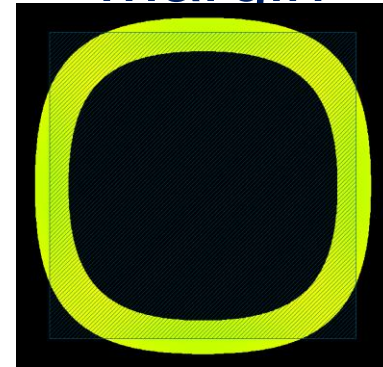
60 nm



Simulated
Pattern

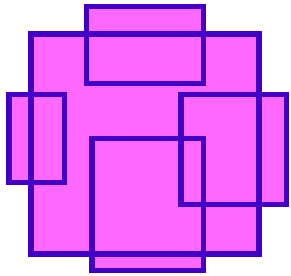


Manufacturing
Margin



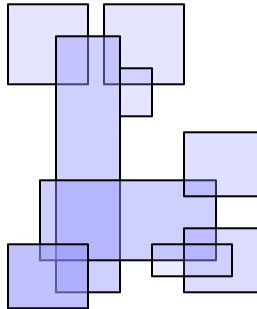
Model-Based Mask Data Prep (MB-MDP) Enables Three Unique Techniques

Overlap Shots

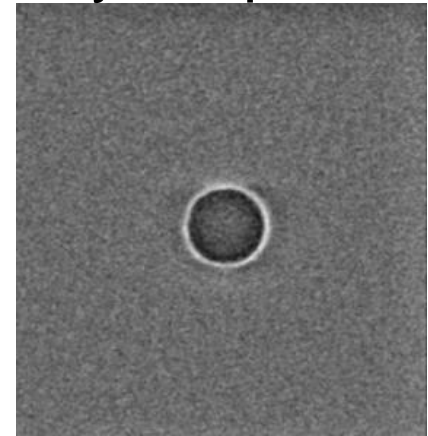


Initial Focus

Assign Dose
for Each Shot



Circle Shots
(or any shape shots)

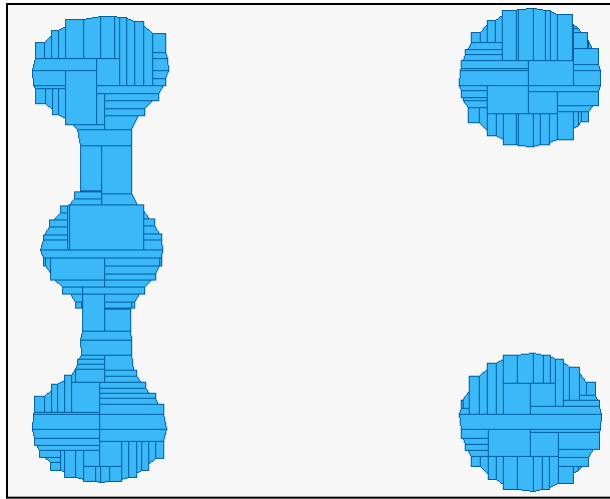


JEOL
JBX-3200MV

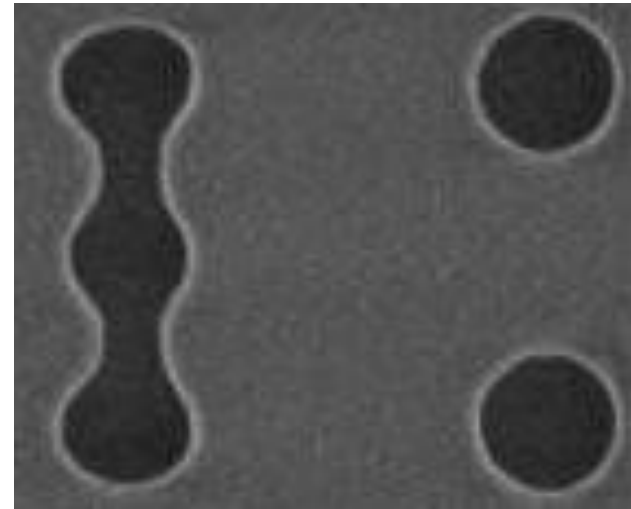
Circle picture courtesy JEOL, Ltd.

MB-MDP is Faster and Better

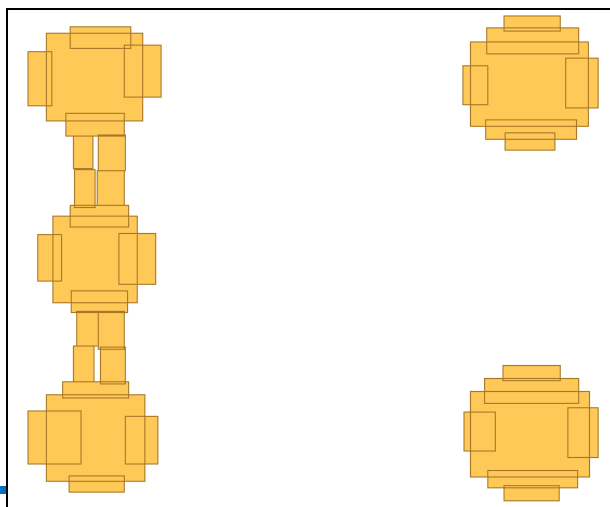
Resist SEM MFG:75K



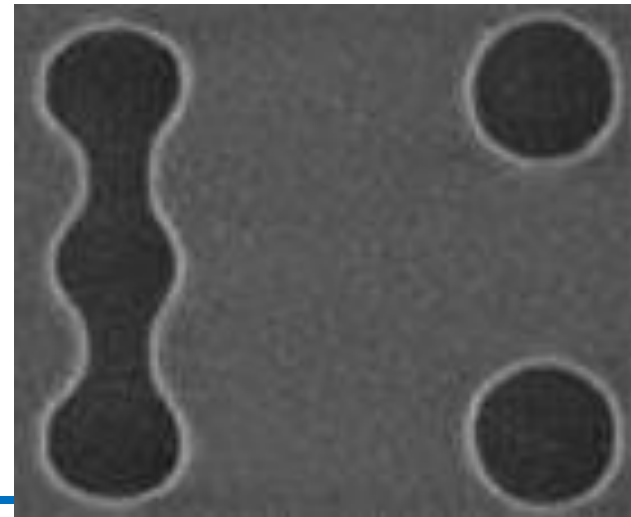
Conventional



5X reduction of shots = 1/3 mask cost



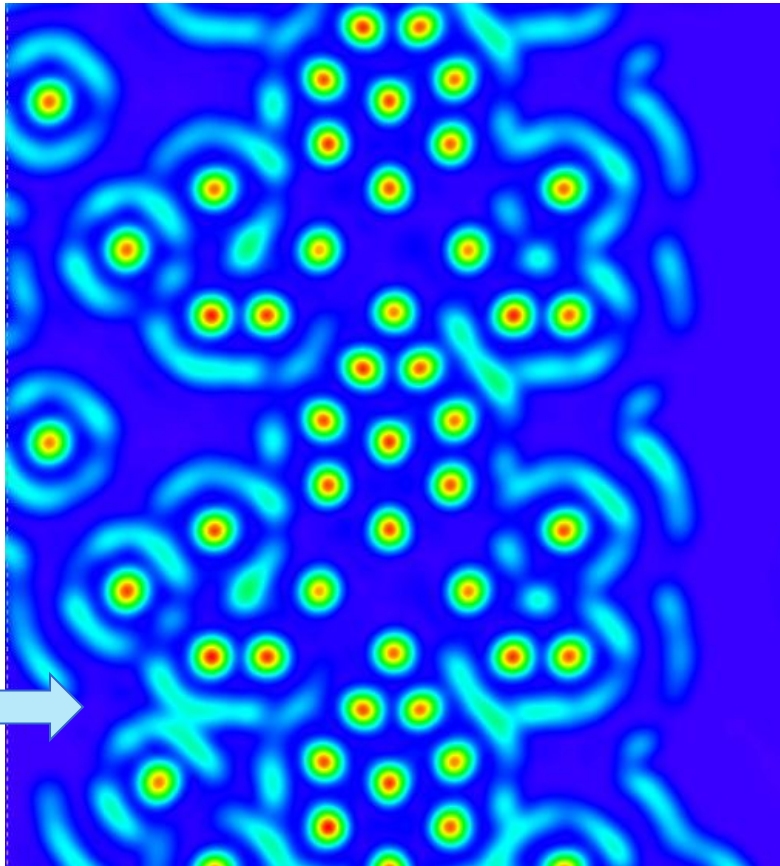
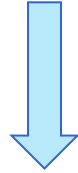
MB-MDP



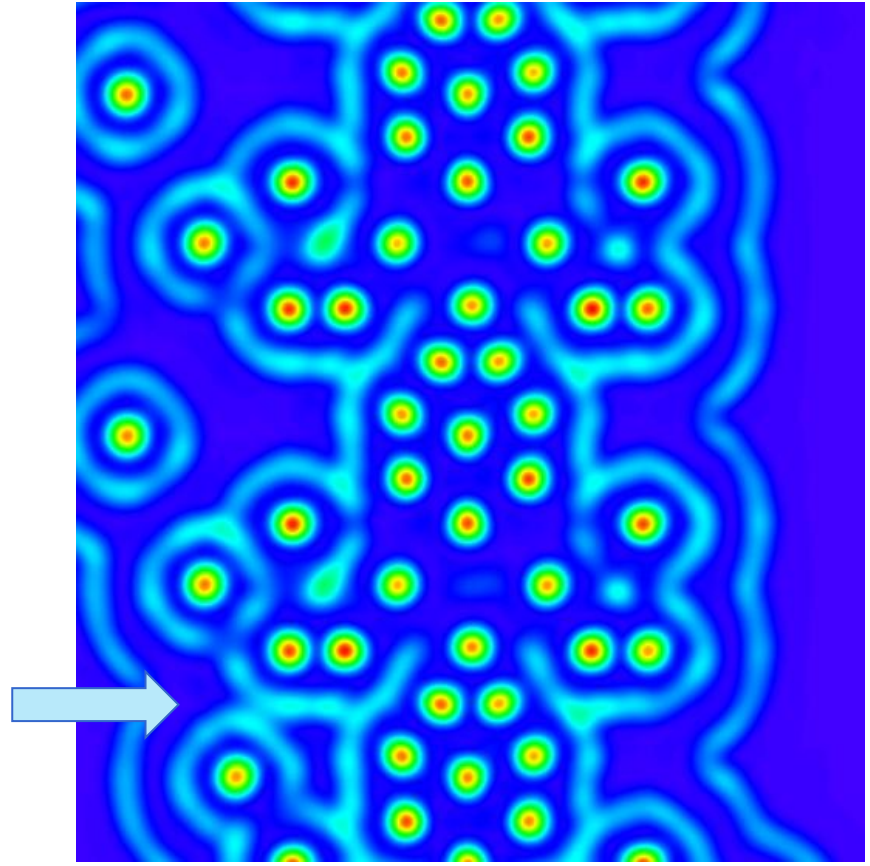
AIMS wafer-level validation shows more reliable SRAF printing with MB-MDP

Does this contribute to better wafer quality?

Conventional



MB-MDP



Optimization of mask shot count using MB-MDP and lithography simulation

Gek Soon Chua^a, Wei Long Wang, Byoung IL Choi, Yi Zou, Cyrus Tabery, Ingo Bork^b, Tam Nguyen, Aki Fujimura

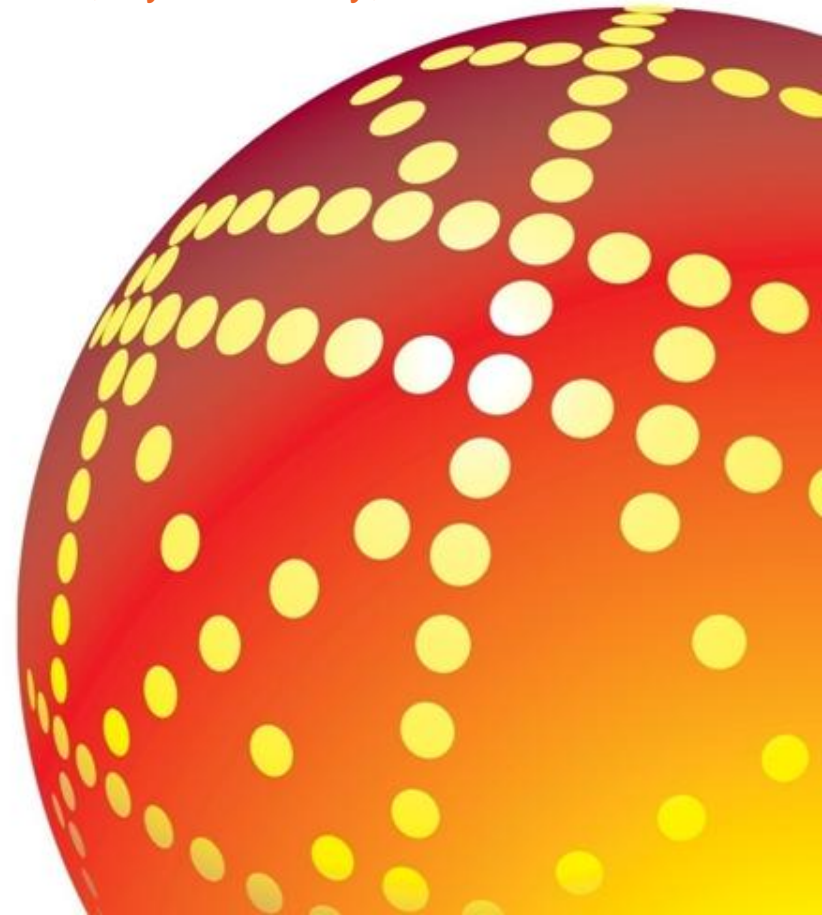
^a GLOBALFOUNDRIES

^b D2S Inc.



GLOBALFOUNDRIES

September 20, 2011

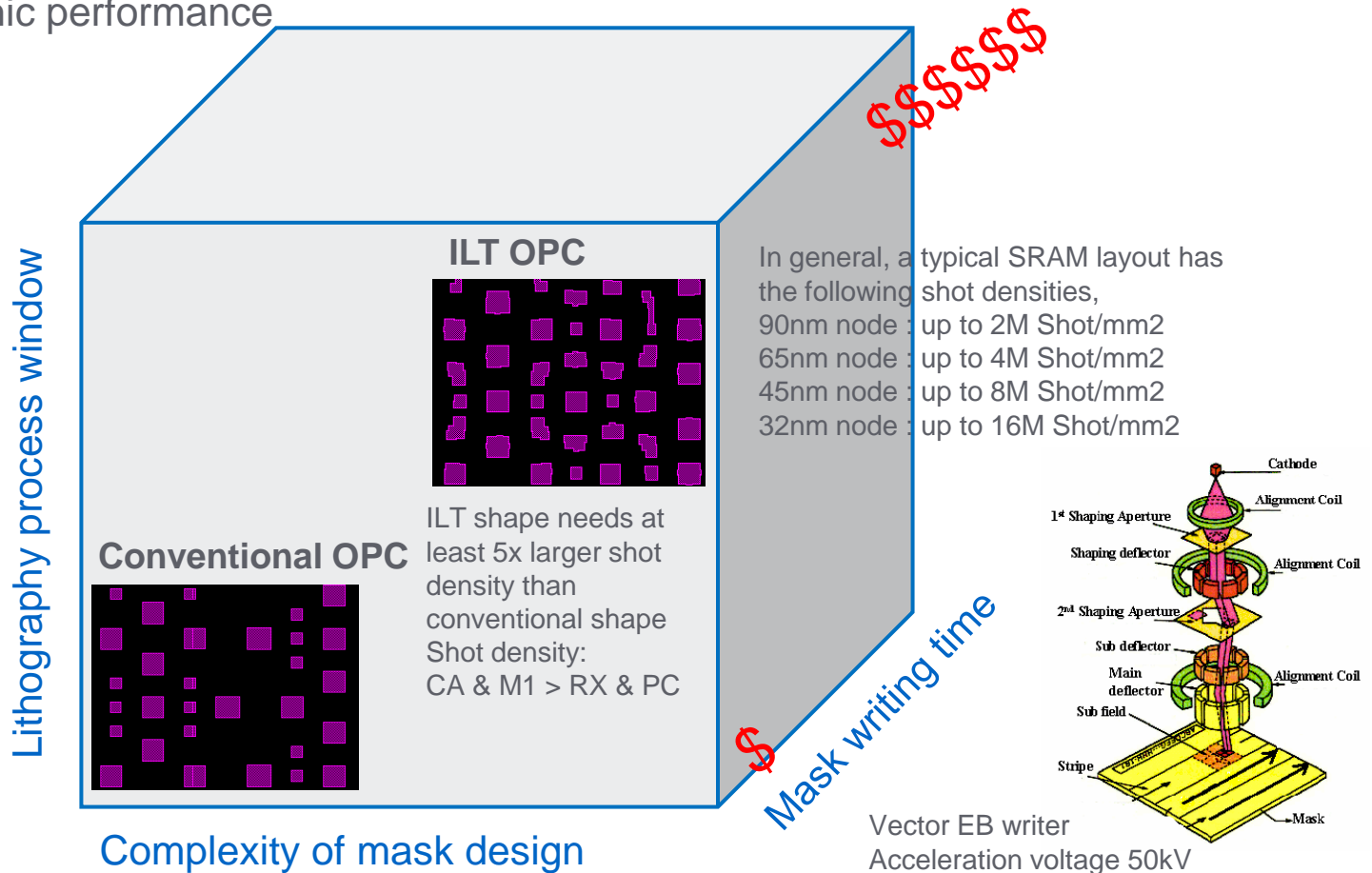




Background/Motivation

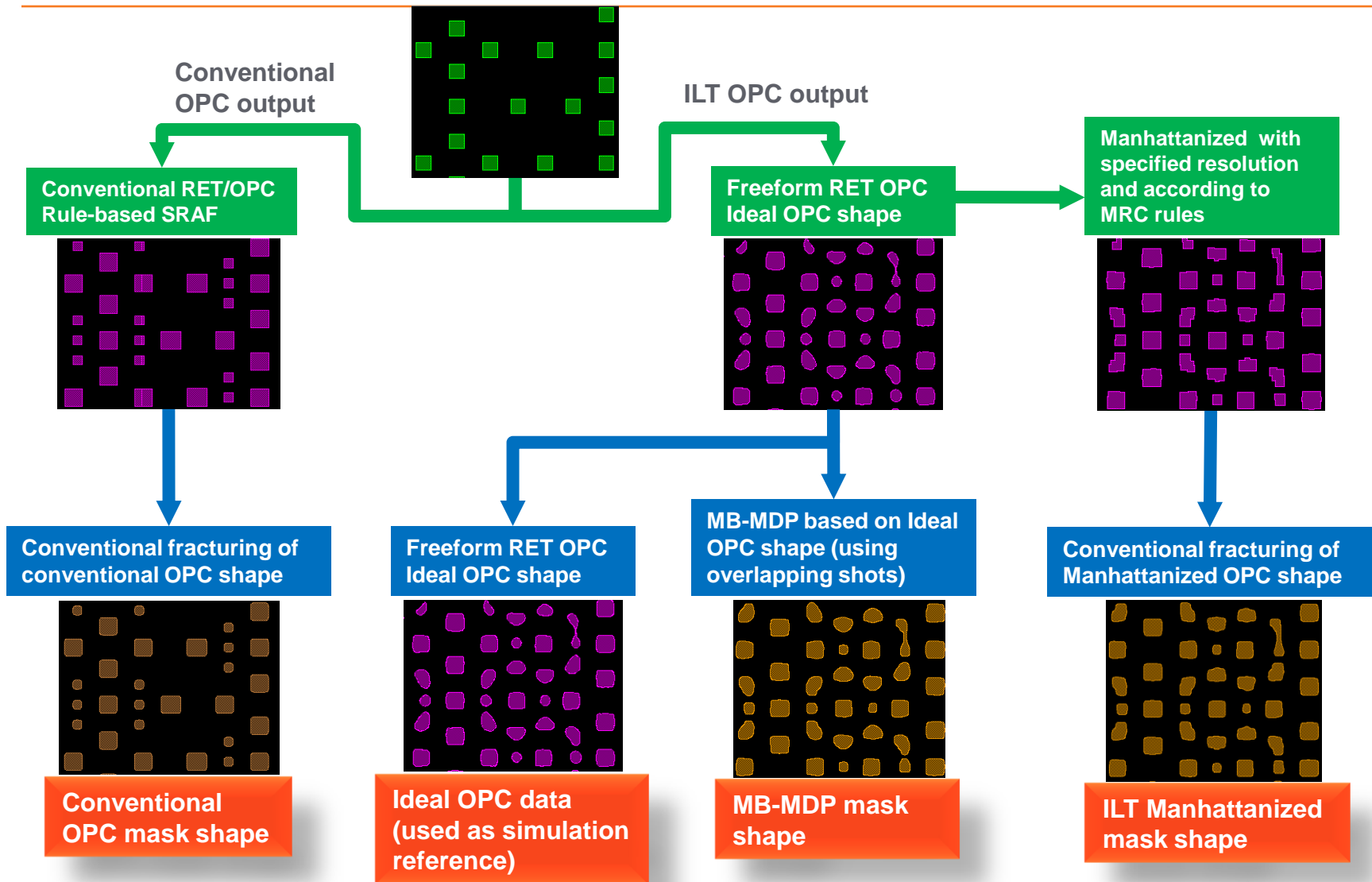
The ability to use curvilinear features for mask lithography becomes critical, especially for SMO & advanced mask optimization

However there is a trade-off between complexity of optimized mask, mask write time & lithographic performance





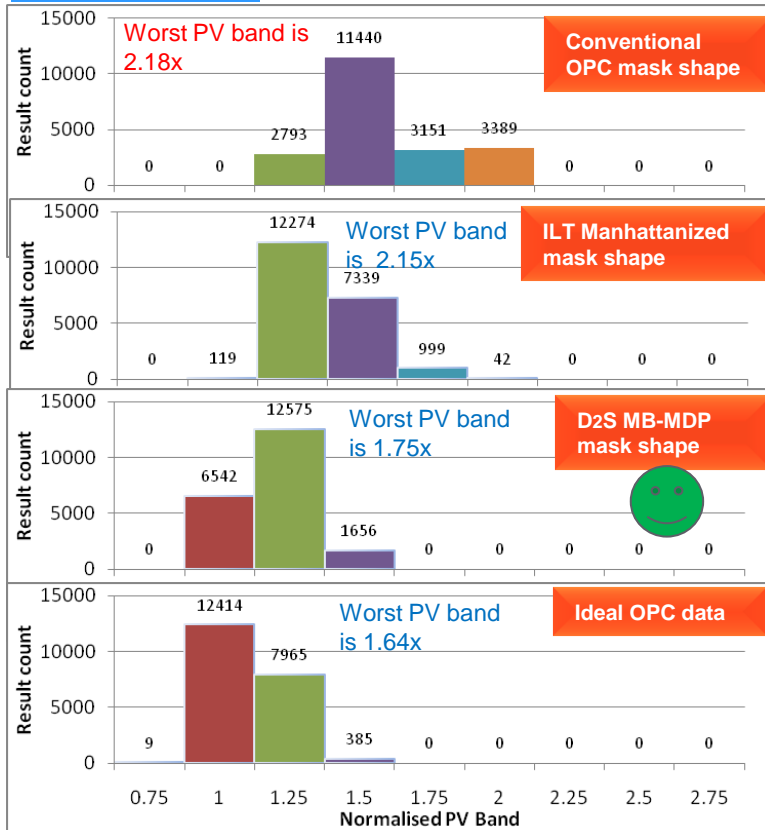
Terminology & Definition





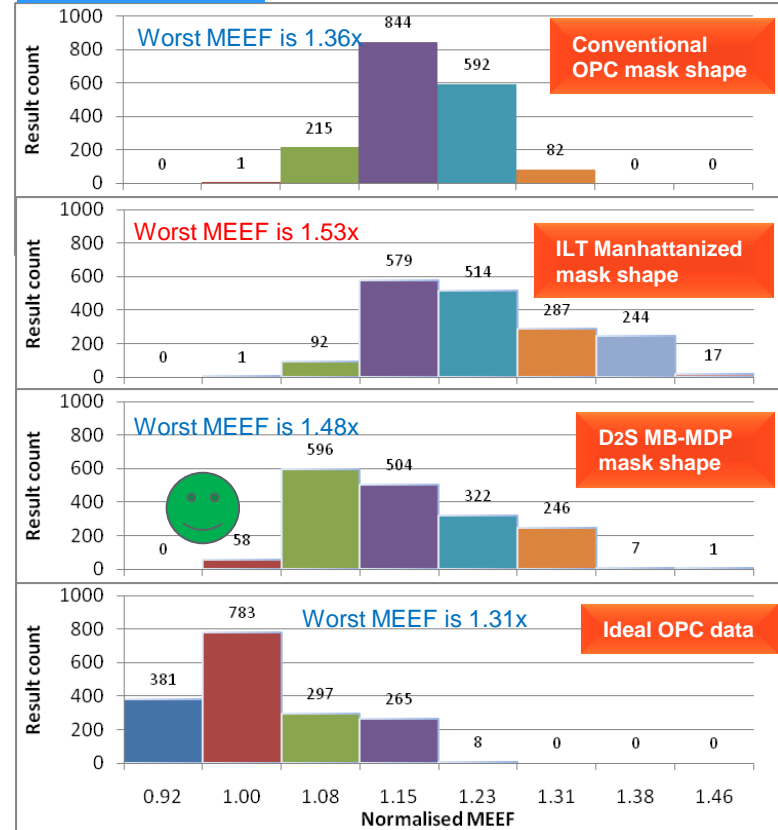
Litho simulation verification on 20nm Via SRAM

PV Band



Remark: Worst PV band for the simulated mask image of D2S shots is so much better off than PV band for the simulated mask image of Manhattanized OPC shape

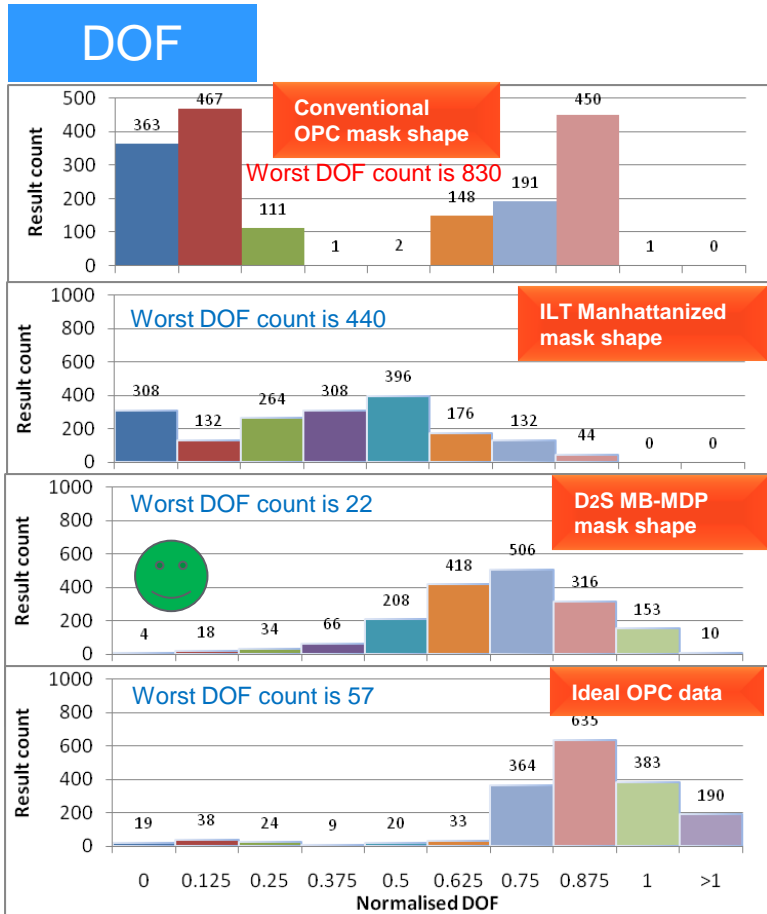
MEEF



Remark: There are more counts of lower MEEF for the simulated mask image of D2S shots as compared to the simulated mask image of Manhattanized OPC shape

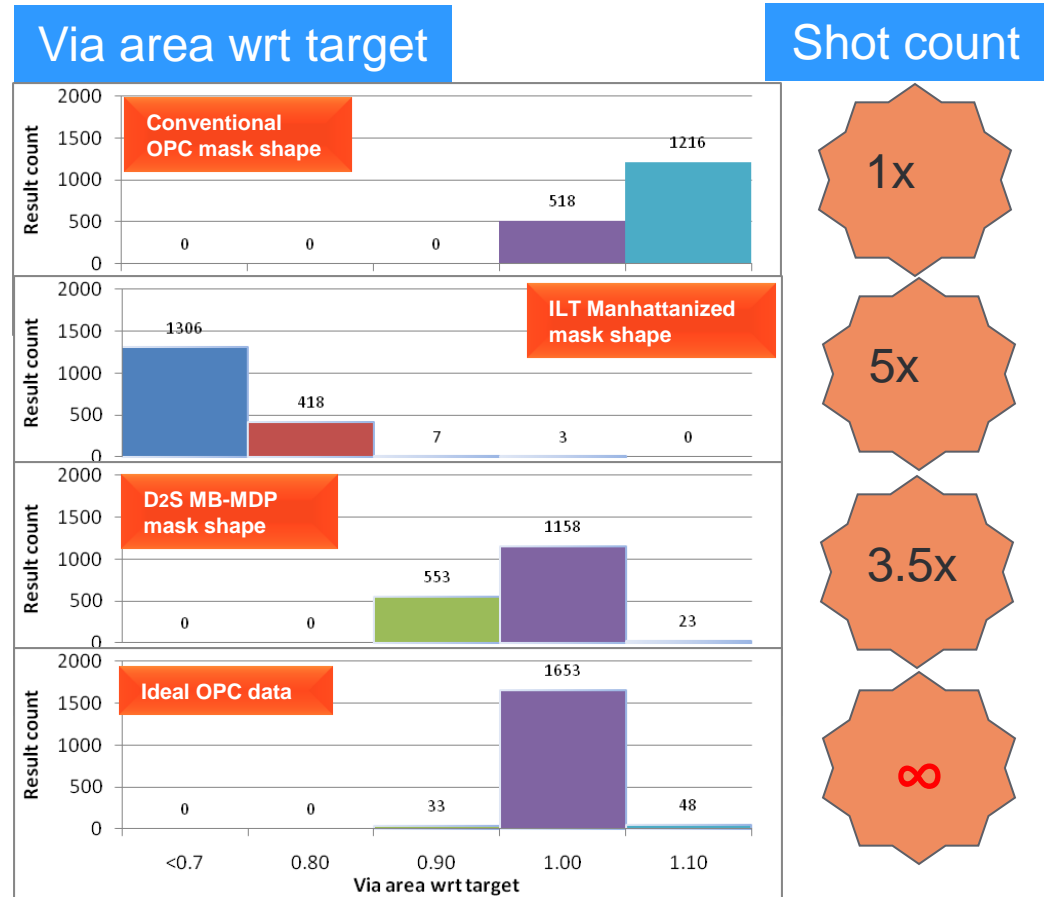


Litho simulation verification on 20nm Via SRAM



Remark: DOF are matched closer to what an ideal OPC mask can offer after D2S MB-MDP

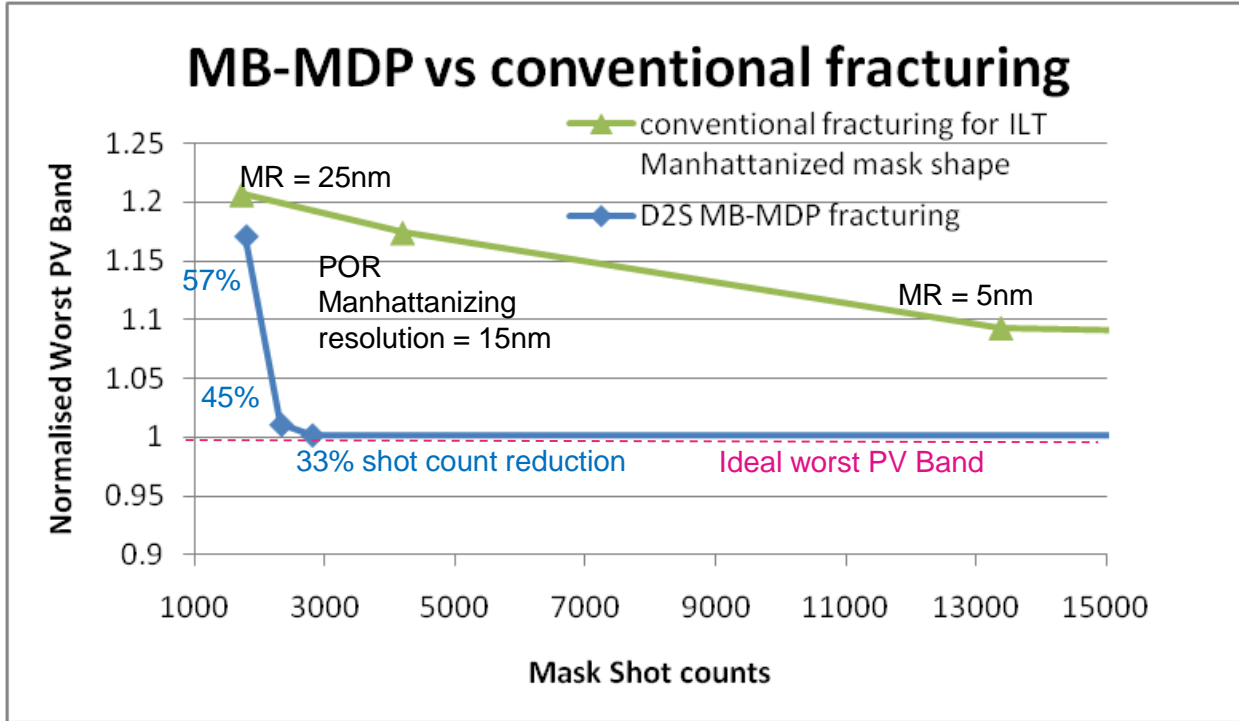
- We are able to harness the benefits of larger process window for an ideal OPC mask solution using MB-MDP with manageable shot counts and mask writing time



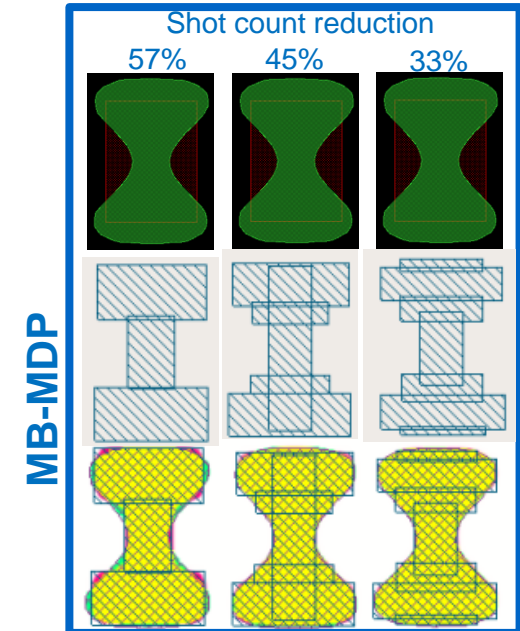
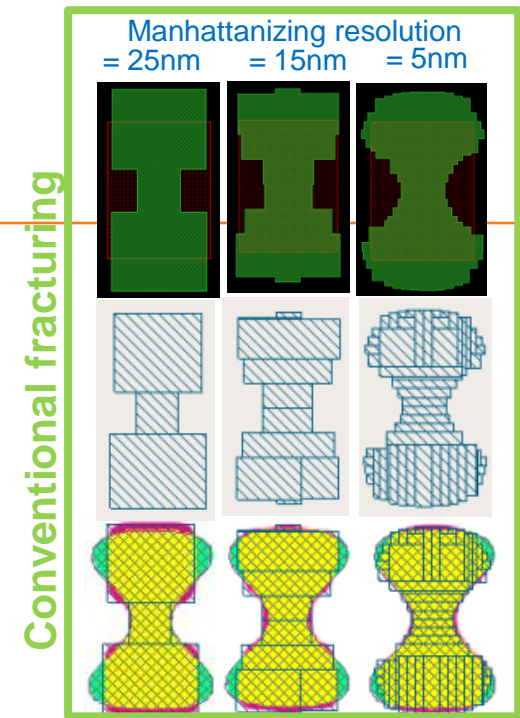
Remark: There are increased number of bigger (closer to target) vias after D2S MB-MDP



Quality vs. shot count



- ❑ **D2S MB-MDP:** Using overlapping shots, we can mimic the ideal OPC data/mask shape to realize lithography performance and at the same time achieve significant shot count reduction
- ❑ **Conventional fracturing:** Shot count for conventional fracturing will explode for lower Manhattanizing resolution setting and unable to capture the ideal OPC lithography performance
- ❑ This shows that D2S MDP shot count reduction at production-worthy level is feasible without compromising lithography performance





Conclusion

- D2S Model Based Mask Data Preparation (MB-MDP) technique is effective for writing complex curvilinear or Manhattanized shapes like SMO on mask without the exploding shot count by using overlapping shots
- By mimicking ideal OPC data/mask shape, approximately 30% shot count reduction compared to a Manhattanized mask can be achieved for a SRAM without compromising litho performance compared to the ideal target while keeping mask data size reasonably small
- This enables fewer shots (and therefore shorter write-times) while maintaining sufficient PW on the wafer (SRAM example is demonstrated on 40um x 40um small clip)
- Depending on the amount of shot count reduction the contour of the mask shapes is changed thus influences wafer performance



ACKNOWLEDGEMENTS

The authors would like to thank and acknowledge

- Takamizawa-san, Tsujimoto-san, Hayano-san, Migita-san, Motonaga-san and Takayanagi-san (Dai Nippon Printing, Co. Ltd) for their support & discussion for mask-making in future work
- Please come and visit us @ Poster Session: 20-Sep Tues. 6:00 to 7:30 pm: Optimization of mask shot count using MB-MDP and lithography simulation

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eBeam Challenges for Sub-80nm Assist Features and EUV Mask Exposure

Christian Bürgel

AMTC EN LM

eBeam Challenges for sub-80nm assist features and EUV mask exposure

- ❑ eBeam exposure process generates multi-range effects that deteriorate pattern performance
- ❑ eBeam effects on different scales is driving CD Errors
 - ❑ So far, conventional proximity effect (~10 μ m scale) was dominant and corrected by the writer
 - ❑ There is additional mid-range effect (~500nm – 2 μ m) effect, especially for EUV, that needs to be corrected for
 - ❑ The short-range (20-30nm) effect is becoming more significant as feature sizes shrink below 80nm on mask
- ➔ **Simulation-based software correction during mask data preparation will be needed for both optical and EUV masks**

- ❑ **Background exposure is reducing contrast of mask images**
 - ❑ This can limit the ultimate resolution, especially for sub-resolution assist features (SRAFs), *even independent from resist performance*
- ➔ **Contrast enhancement is needed**

- ➔ **The observed limitations are beyond the conventional way of process development and require a fundamentally new approach to the 50 kV exposure**

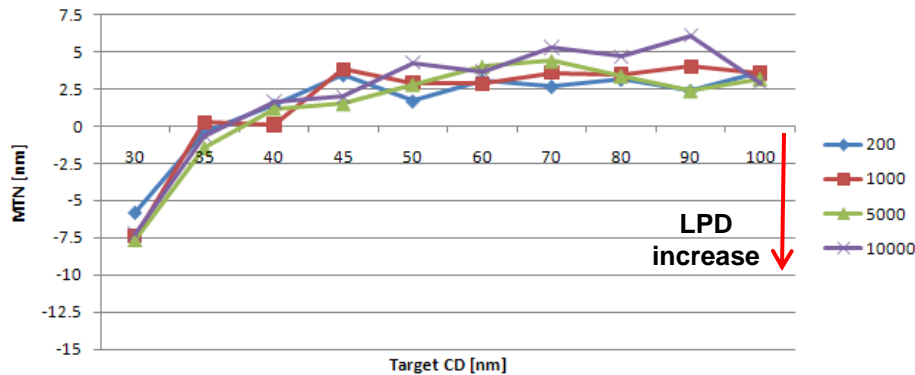


Current PEC is working well for ~10 μm proximity effects on ArF masks

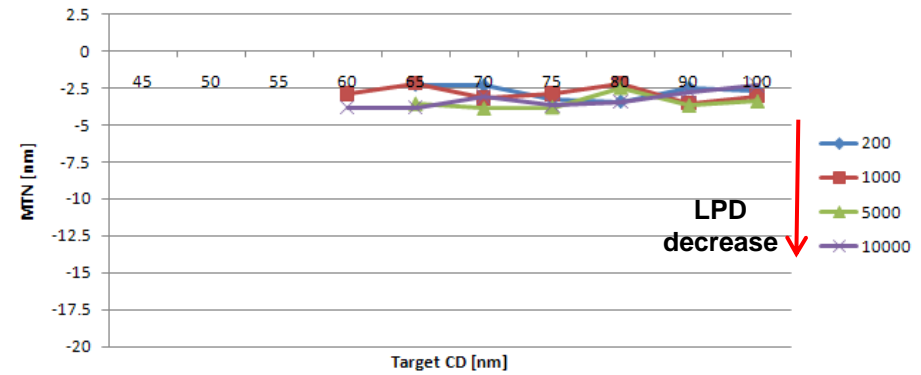
Scattering effects

Proof of impact MTN vs. Local Pattern Density (LPD): OMOG process

MTN Clear SRAFs in different LPD



MTN Opaque SRAFs in different LPD



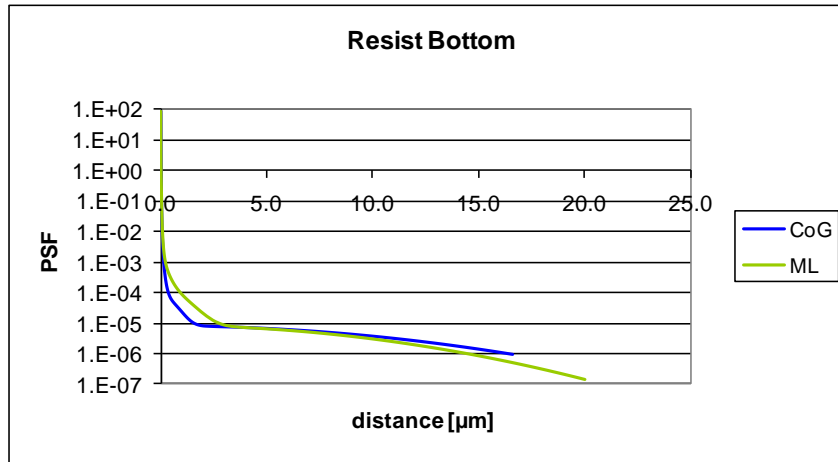
- Very small CD error vs. LPD for both Spaces and Lines
- Very small Linearity down to 45nm (Spaces) and 65nm (Lines)

➔ Electron scatter effects sufficiently considered and corrected

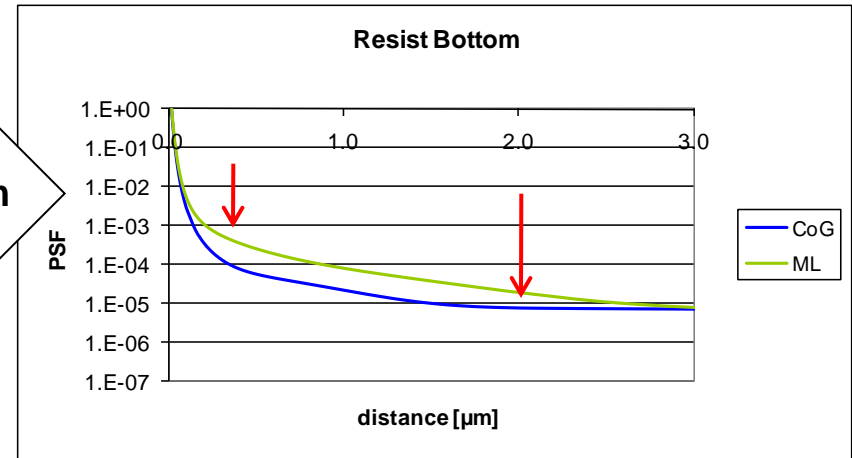
For EUV masks, there is a mid-range effect 2 μ m to 500nm that is clearly observable*

Scattering effects:

PSF Differences conventional COG blanks vs. EUV blanks**



Zoom



Significant higher scatter effect at mid range, lower effect at large range

There might be even more than 1 mid range effects: \sim 2 μ m and \sim 500nm effect are clearly visible

\rightarrow But, is this really a problem? YES

* Hiroyoshi Tanabe, Proc. of SPIE Vol. 7748 774823

* Jin Choi, Proc. of SPIE Vol. 7823 78230D

* Takashi Kamikubo, Proc. of SPIE Vol. 7823 782331

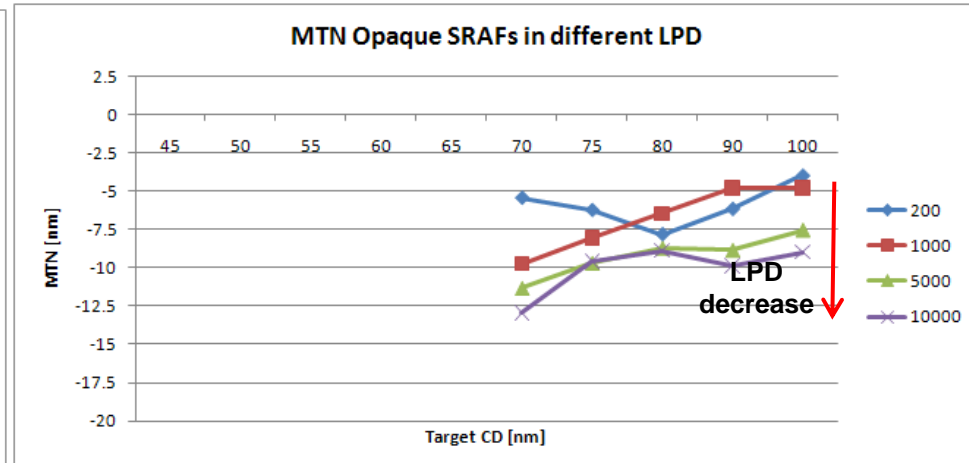
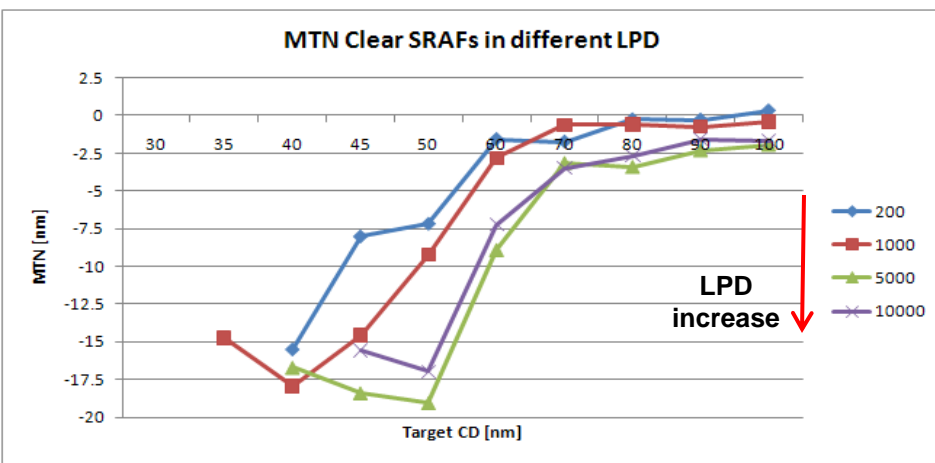
** Courtesy of Martin Sczyrba, AMTC



You can see that the CDs are significantly different depending on local density of the patterns

Scattering effects

Proof of impact MTN vs. Local Pattern Density (LPD): **EUV** process



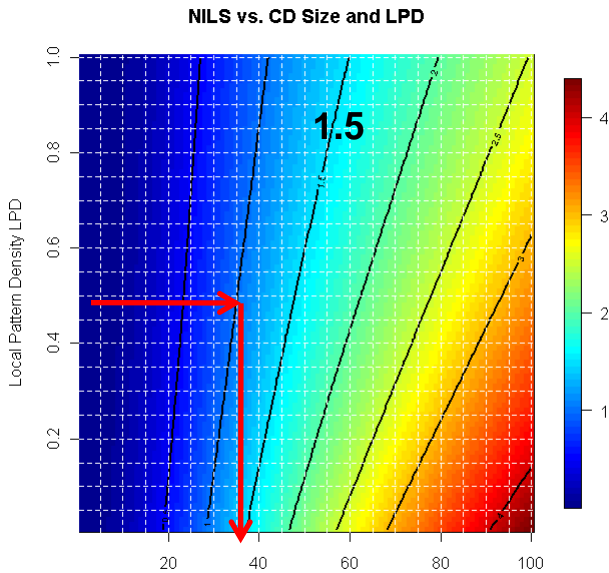
- ❑ Increased CD Error with LPD for Spaces and Lines
- ❑ Space CD error requires a reduction of PEC while Line CD Error requires an increase of PEC

→ **Machine's PEC mechanism not able to correct for mid-range effects!**

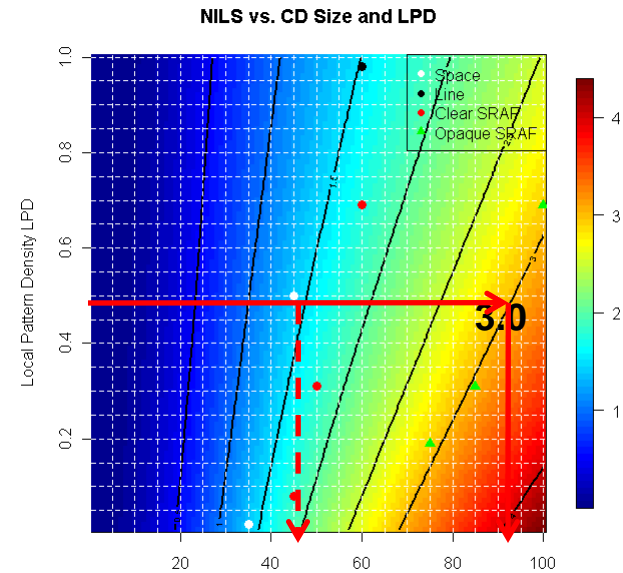
Dose-modulation-based correction during mask data preparation is required to improve contrast

Resolution

Resolution is limited by the amount of background exposure



NILS vs. LPD for current OMOG process



NILS vs. LPD for current OMOG process
Added inspection based SRAF capability *
→ NILS of 3.0 for opaque SRAF needed

In order to get better SRAFs, one has to

- 1) Reduce the Blur of the process (difficult !)
- 2) Reduce the amount of BS electrons (impossible !)
- 3) Work on contrast enhancement to improve NILS

* Christian Bürgel, Proc. of SPIE Vol. 7823 78230I



eBeam Challenges for sub-80nm assist features and EUV mask exposure

Conclusion

- ❑ <20nm masks are significantly affected by short-range effects for both ArF and EUV masks, and by mid-range effects for EUV masks
- ❑ These effects cannot be corrected real-time in the eBeam writers due to unacceptable run time

➔ **Dose Modulation must be implemented in fractured Data!**

Model Based Mask Data Preparation is a must for further nodes and EUV to properly correct the exposure effects

- ❑ This methodology is already a standard for EBDW, so let's learn and transfer the knowledge to the mask level!



Acknowledgements

AMTC is a joint venture of GLOBALFOUNDRIES and Toppan Photomasks, and gratefully acknowledges the financial support by the German Federal Ministry of Education and Research BMBF under contract numbers 13N11303 (EXEPT).

GEFÖRDERT VOM



Bundesministerium
für Bildung
und Forschung



Thank You to the Members

- Membership in the eBeam Initiative grows to 41
 - Applied Materials, IMS Chips, Mentor Graphics, Multibeam, SoftJin Technologies
- Presentation viewpoints and results:
 - “Sub-80nm Discontinuity” requires eBeam simulation and model-based mask data preparation (MB-MDP) for 193i masks
 - Applies to EUV as well to correct the exposure effects
 - With MB-MDP, better wafer yield achieved with faster mask write times
- BACUS papers/posters presented by eBeam Initiative members
 - D2S, GLOBALFOUNDRIES, Mentor Graphics, NuFlare, Synopsys

Today's Panel

EUV or not: What challenges and solutions lie beyond 20nm for the eBeam-based mask design chain?

- **Panelists include:**
 - Christian Bürgel, AMTC
 - Aki Fujimura, D2S
 - Naoya Hayashi, DNP
 - Franklin Kalk, Toppan Photomasks



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