
eBeam
Initiative

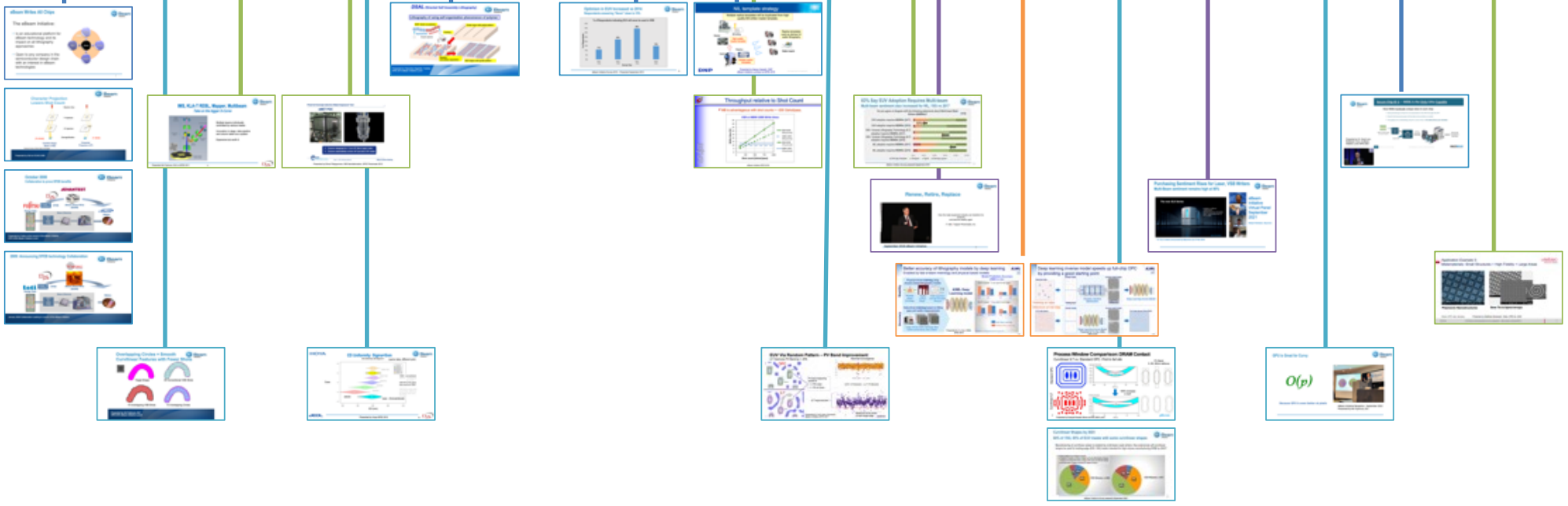
We've Come a Long Way in 15 Years!

65nm 45nm 28nm 22nm 14/10nm 7nm 5nm 3nm 2nm

Member Companies:

20 53

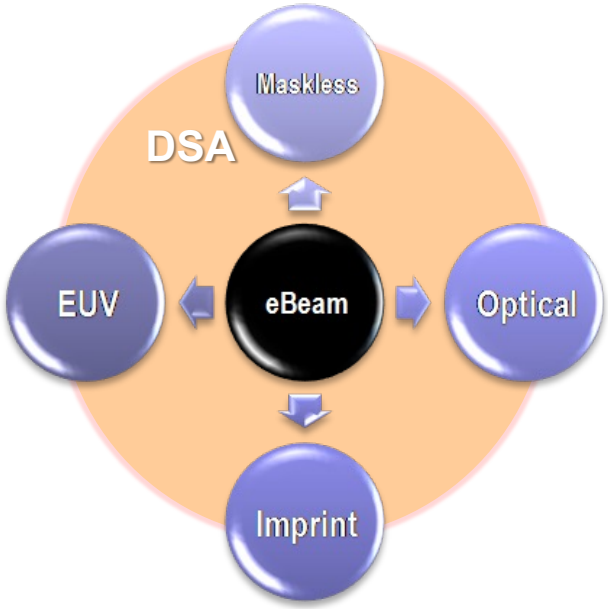
2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024



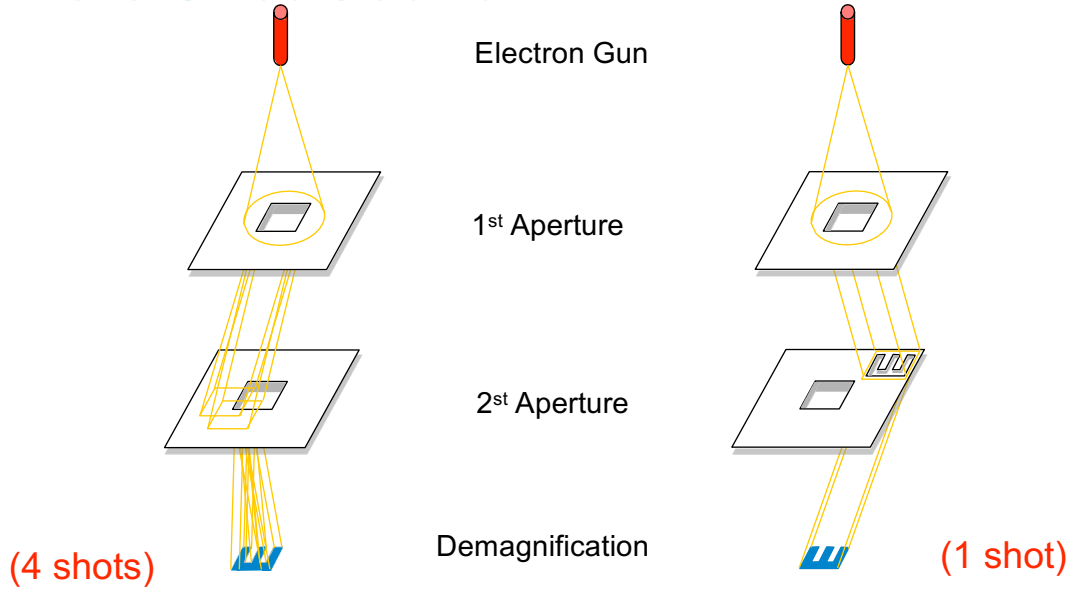
eBeam Writes All Chips

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



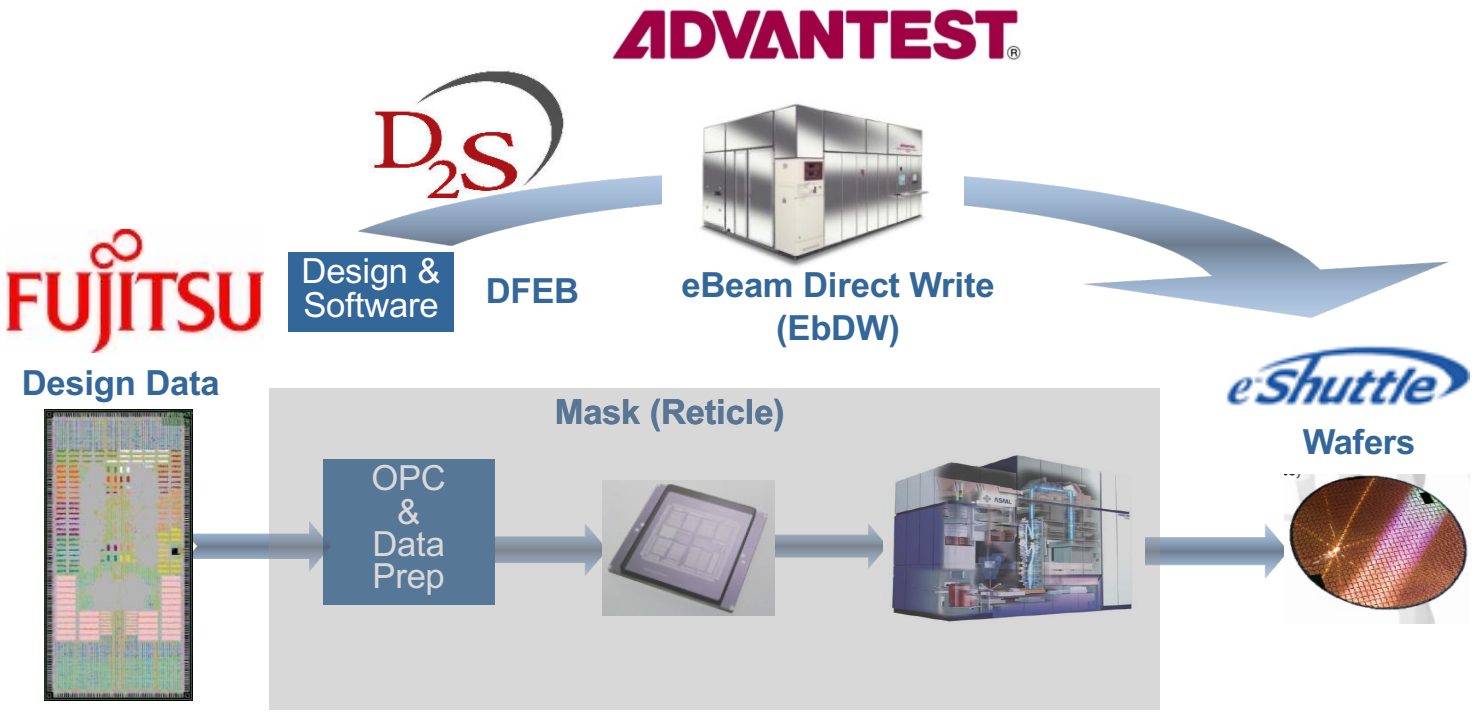
Character Projection Lowers Shot Count



Drawing Courtesy of Hitachi High-Technologies

October 2008

Collaboration to prove DFEB benefits

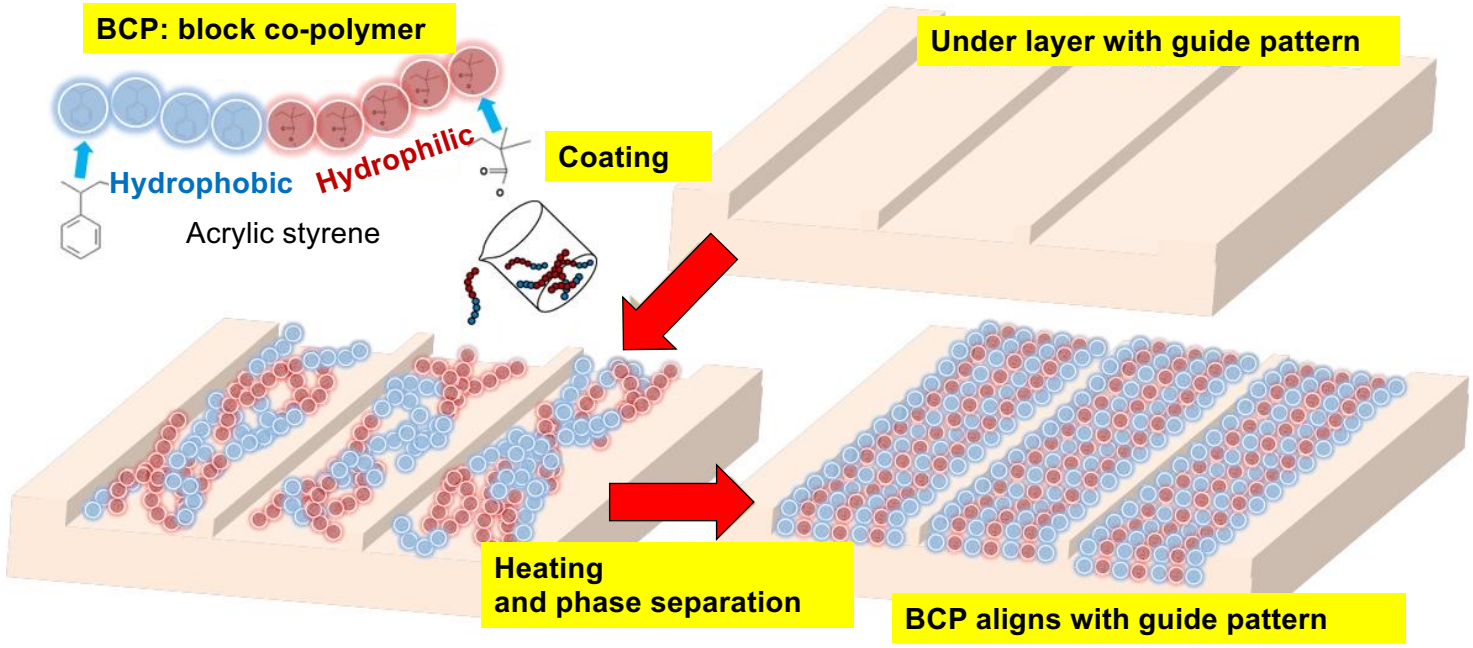


Presented by Fujitsu at the Launch of the eBeam Initiative
SPIE 2009 eBeam Initiative Lunch

2009: Announcing DFEB technology Collaboration

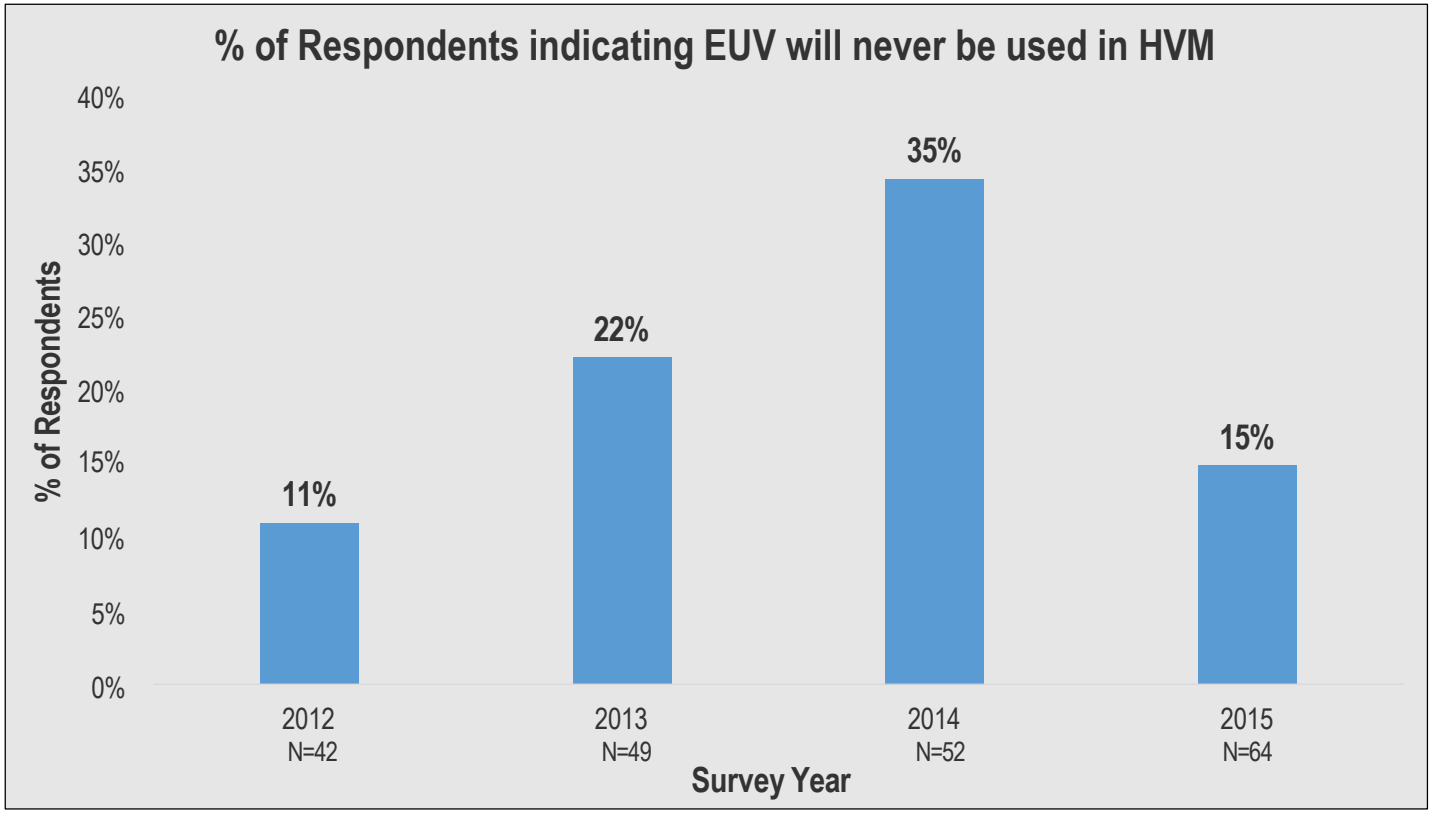
DSAL *(Directed Self Assembly Lithography)*

Lithography of using self-organization phenomenon of polymer



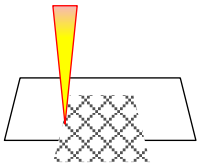
Optimism in EUV Increased vs 2014

Respondents answering "Never" down to 15%



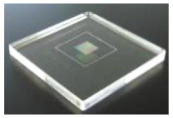
NIL template strategy

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



EB writing

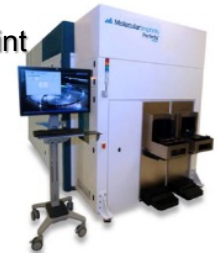
Master



High quality master template

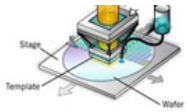
Replica

Imprint



Multiple replica templates

Replica templates used as stamps for wafer lithography



Wafer imprint

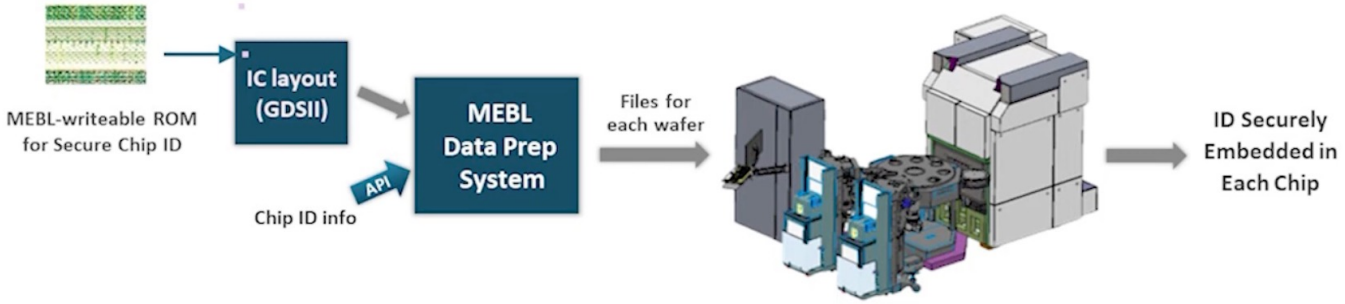
DNP

Presented by Naoya Hayashi, DNP
eBeam Initiative Luncheon at SPIE 2016

Secure Chip ID 1: – MEBL Is the Only Litho Capable

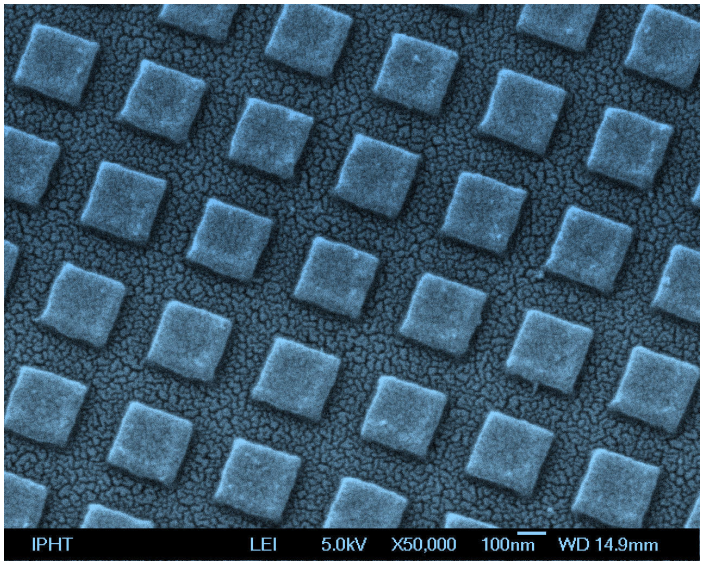
How MEBL hardcode unique data in each chip:

- Data pertaining to Chip ID is incorporated in the DPS through the API
- Chip ID info becomes part of the data to be written on wafer
- Throughput for embedding chip ID is more than **> 25 wafers/hour per chamber**

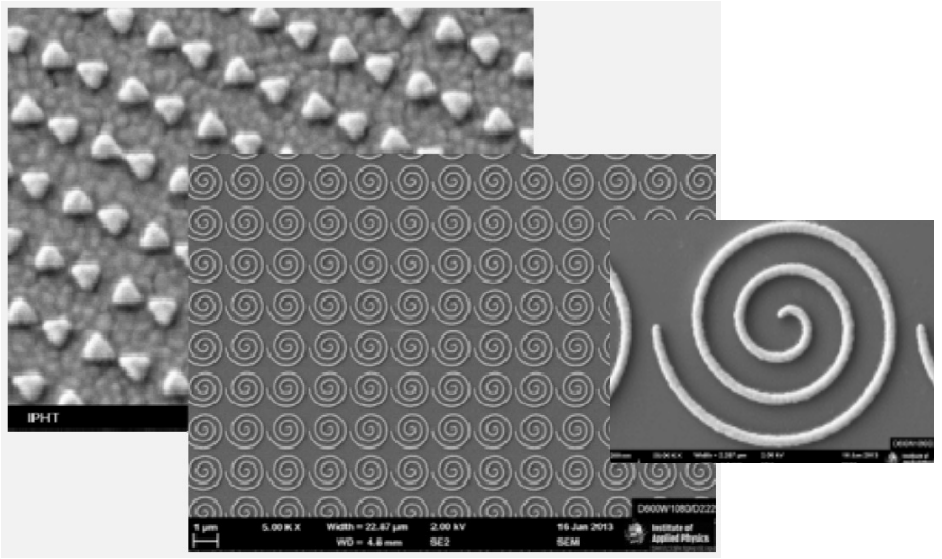


Presented by Dr. David Lam, Multibeam Corp. at eBeam Initiative Lunch SPIE 2023

Application Example 3:
Metamaterials: Small Structures + High Fidelity + Large Areas



Plasmonic Nanostructures



Bow Tie & Spiral Arrays

Source: IPHT Jena, Germany

Presented by Matthias Slodowski, Vistec, SPIE-AL 2024

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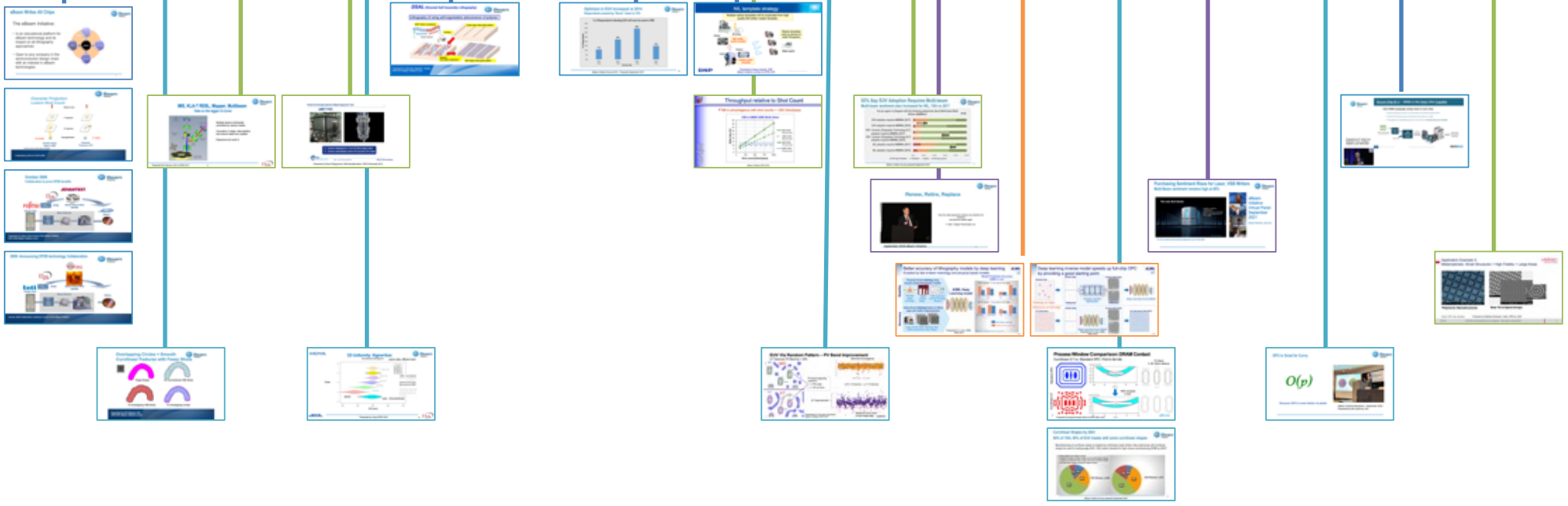
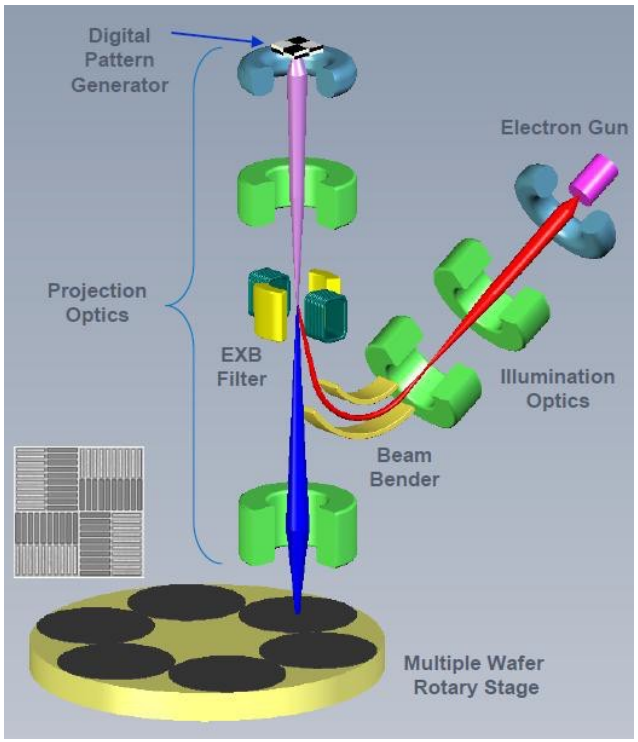


IMS, KLA-T REBL, Mapper, Multibeam

Take on the bigger S-Curve



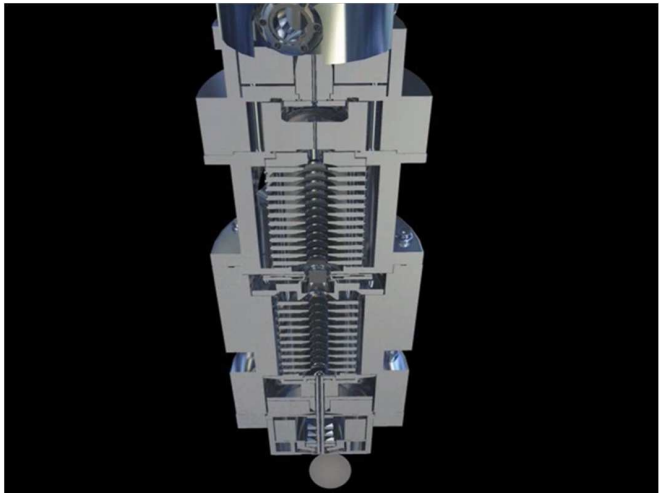
Multiple beams individually controlled by various means

Innovation in stage, data pipeline and column taken as a system

Expensive but worth it

Proof-of-Concept electron Mask Exposure Tool

eMET POC

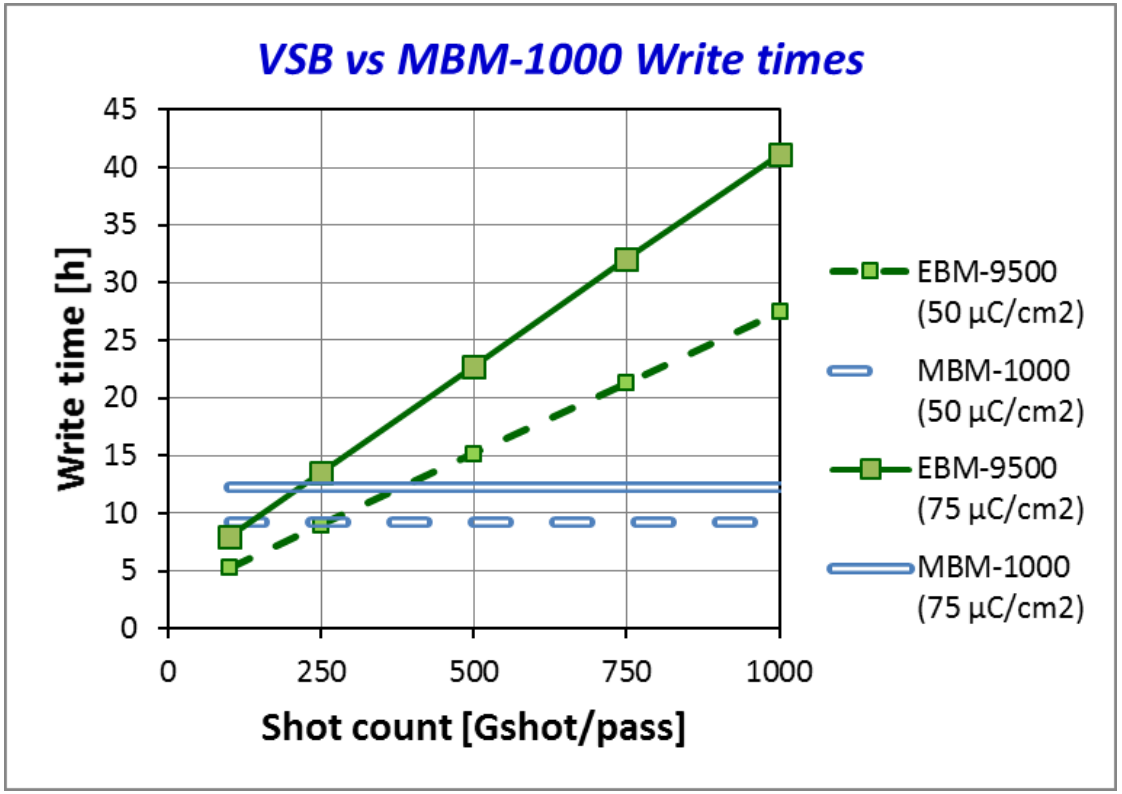


- 0 Column designed for 11nm HP (8nm logic) node
- 0 Column extendibility to 8nm HP and 6nm HP nodes

Presented by Elmar Platzgummer, IMS Nanofabrication, SPIE Photomask 2012

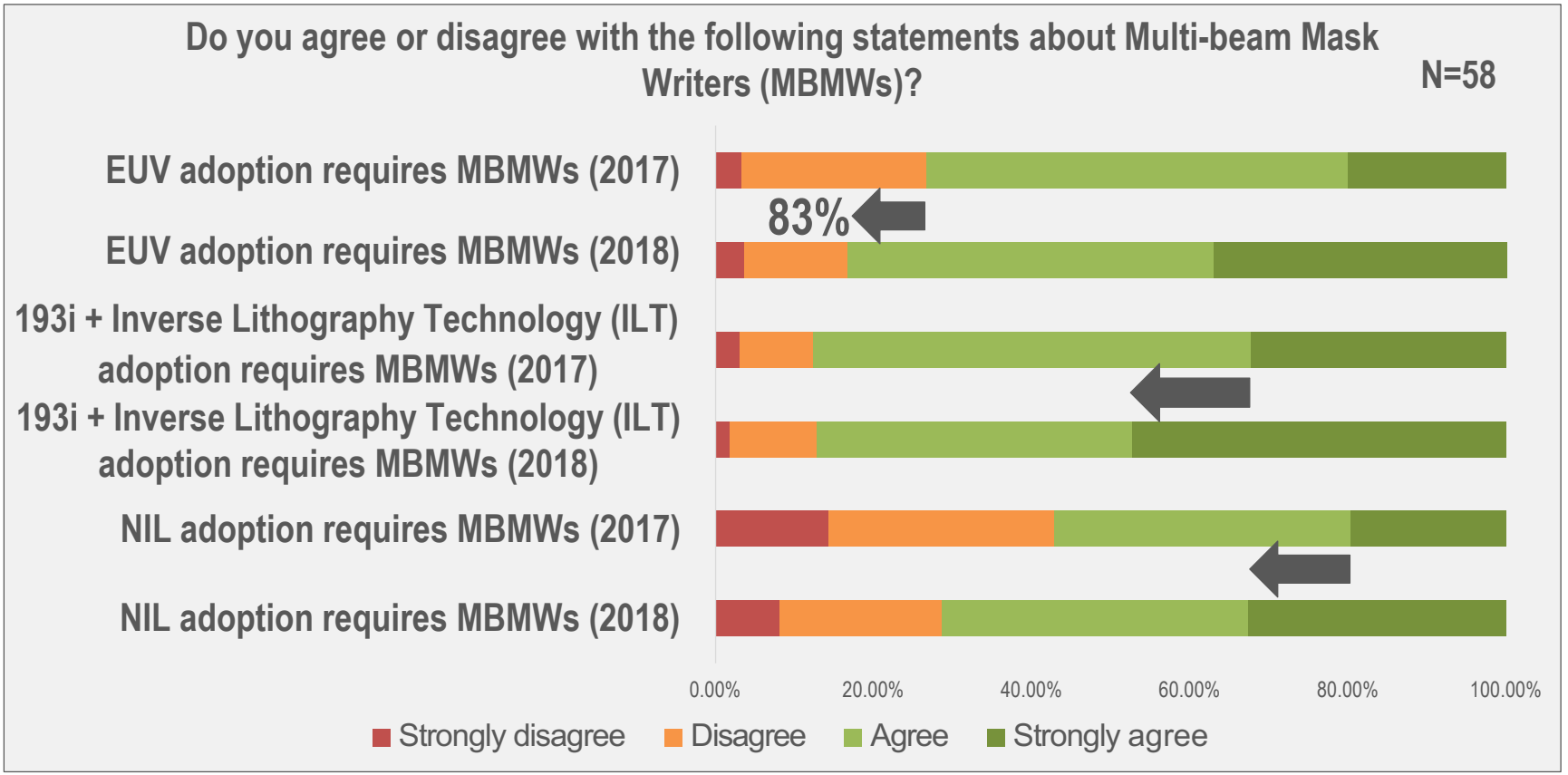
Throughput relative to Shot Count

- MB is advantageous with shot counts > ~200 Gshot/pass.



83% Say EUV Adoption Requires Multi-beam

Multi-beam sentiment also increased for NIL, 193i vs 2017



eBeam Initiative Survey presented September 2018

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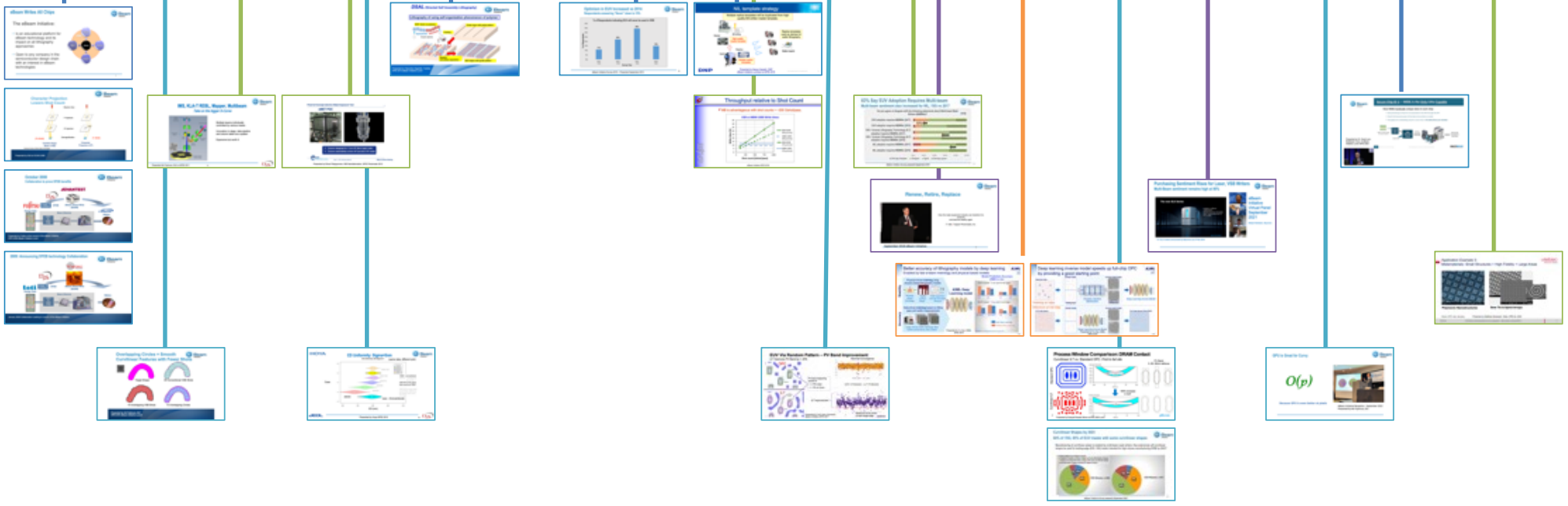


Renew, Retire, Replace

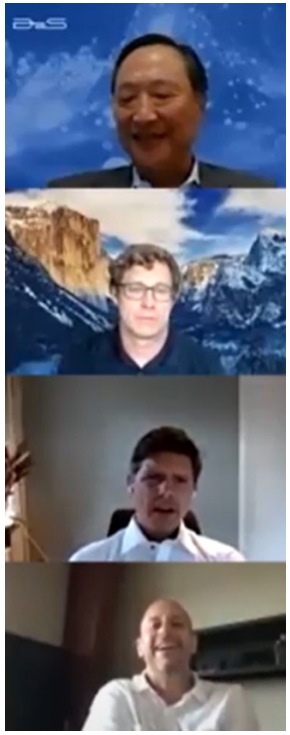
How the mask equipment industry can transform its products
and become healthy again

F. Kalk | Toppan Photomasks, Inc.

Purchasing Sentiment Rises for Laser, VSB Writers

Multi-Beam sentiment remains high at 90%

* 51 SLX orders announced by Mycronic as of Feb 2024



eBeam Initiative Virtual Panel September 2021

Mikael Wahlsten, Mycronic

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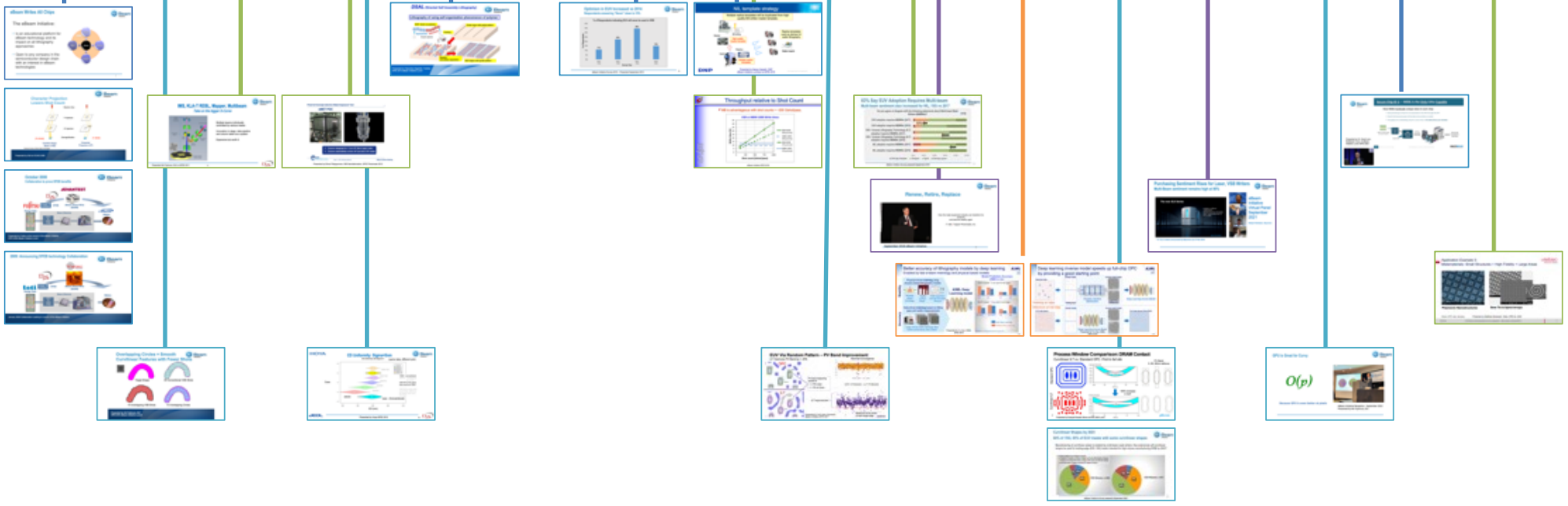
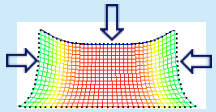


Better accuracy of lithography models by deep learning

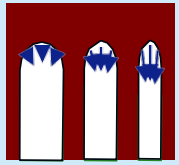
Enabled by fast e-beam metrology and physical based models

Stability

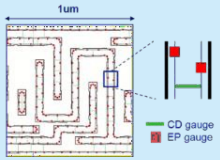
Physical driven **training** using physics based lithography models



Physical Resist Shrinkage



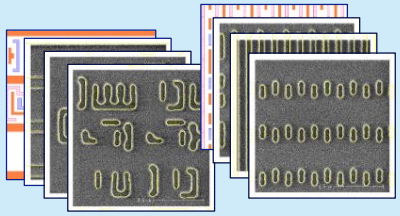
Resist surface stress



Data expansion through simulated contours

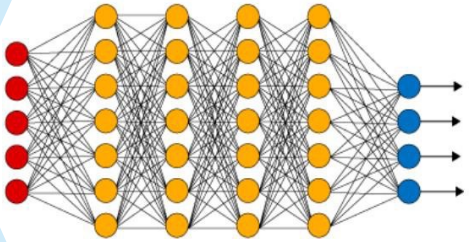
Accuracy

Data-driven **training** based on fitting spec and wafer measurements



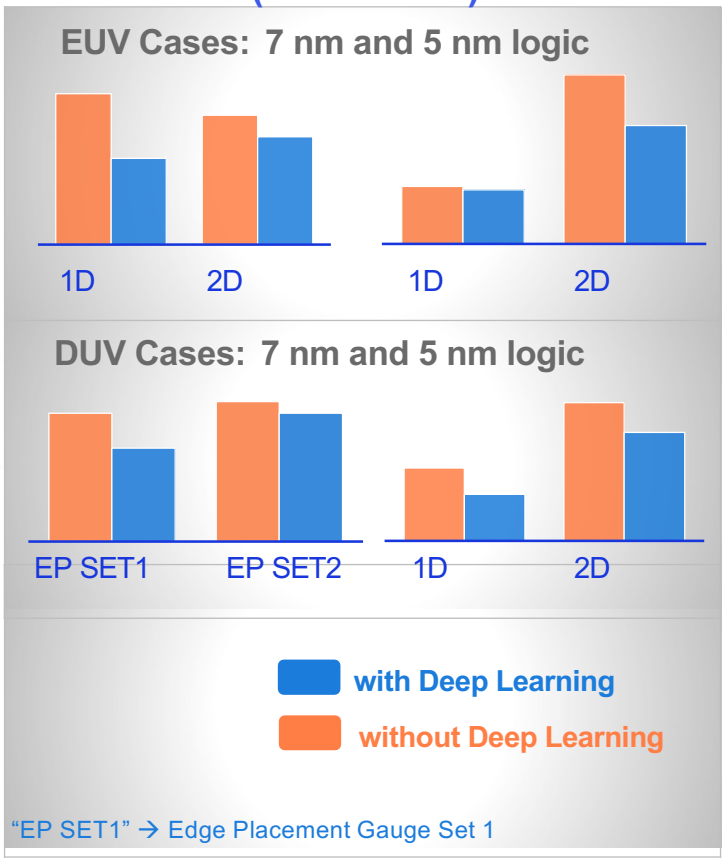
Large volume wafer metrology data, further enhanced by fast e-beam

ASML Deep Learning model



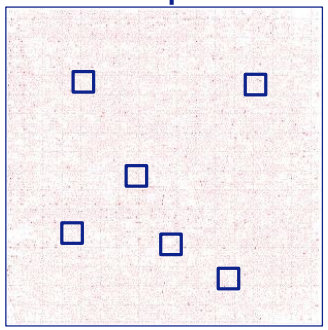
Presented by Yu Cao, ASML
SPIE 2019

Model Prediction Accuracy (RMS in nm)



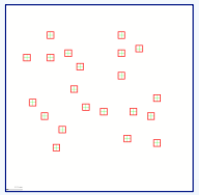
Deep learning inverse model speeds up full-chip OPC by providing a good starting point

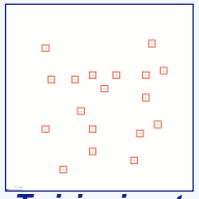
Selected clips



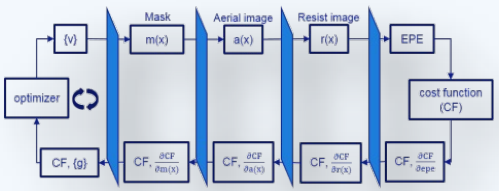
Training *on clips*

Design target



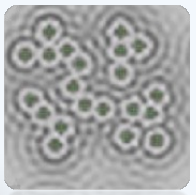


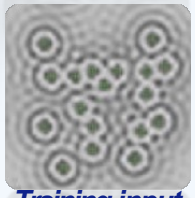
Training input



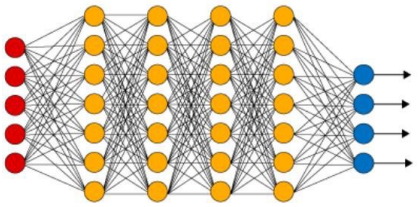
Complex, Iterative Optimization

Inverse mask image





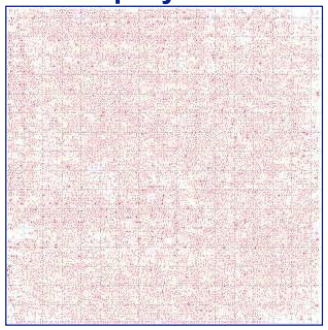
Training input



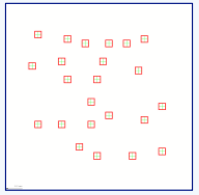
Deep Learning Inverse Model

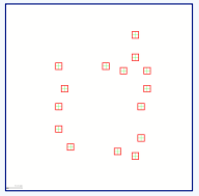
Inference *on full chip*

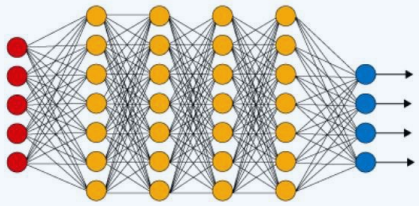
Full chip layout



Design target



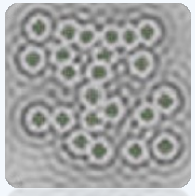


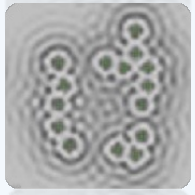


Deep Learning Inverse Model

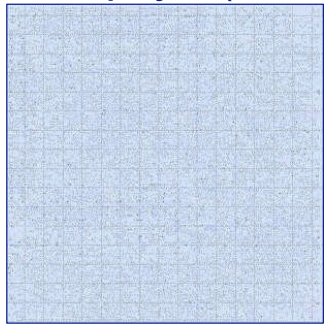
Presented by Yu Cao, ASML
SPIE 2019

Inverse mask image





Full chip layout (Post-OPC)



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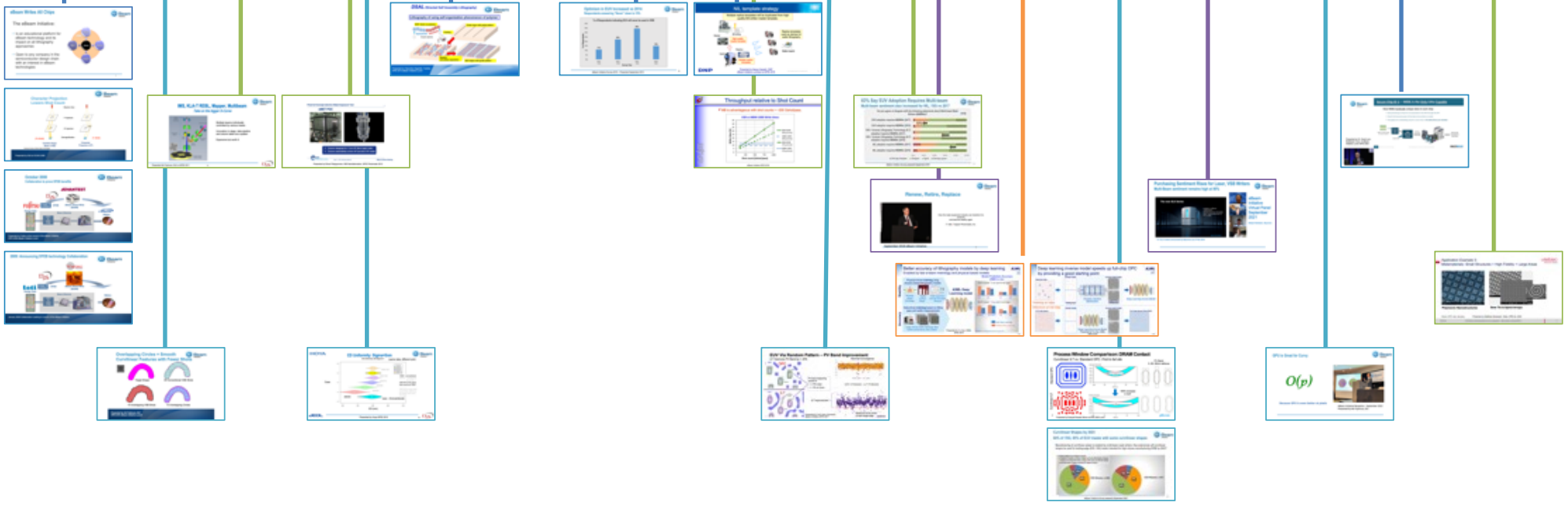
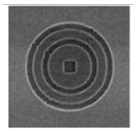
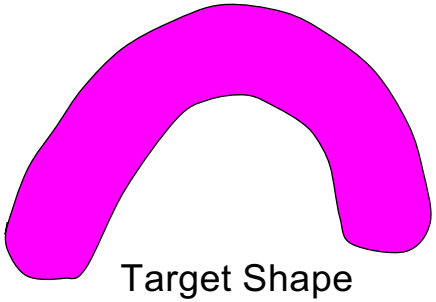
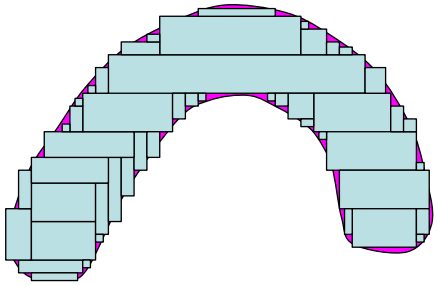


Overlapping Circles = Smooth Curvilinear Features with Fewer Shots

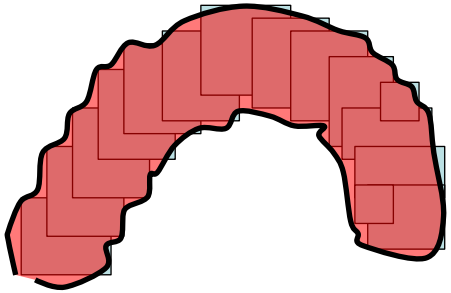




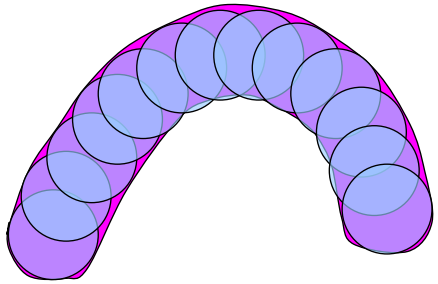
Target Shape



40 Conventional VSB Shots



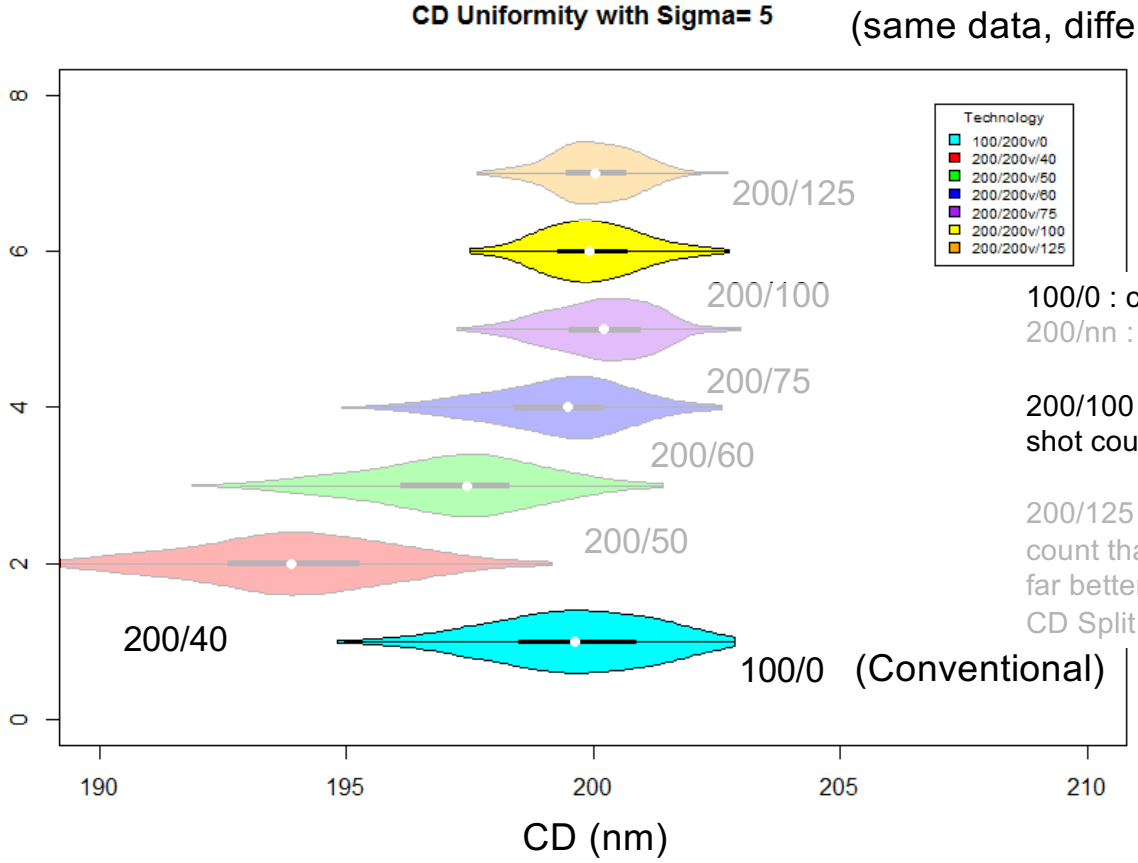
15 Overlapping VSB Shots



13 Overlapping Circles

CD Uniformity: Sigma=5nm

(same data, different plot)



Case

100/0 : conventional

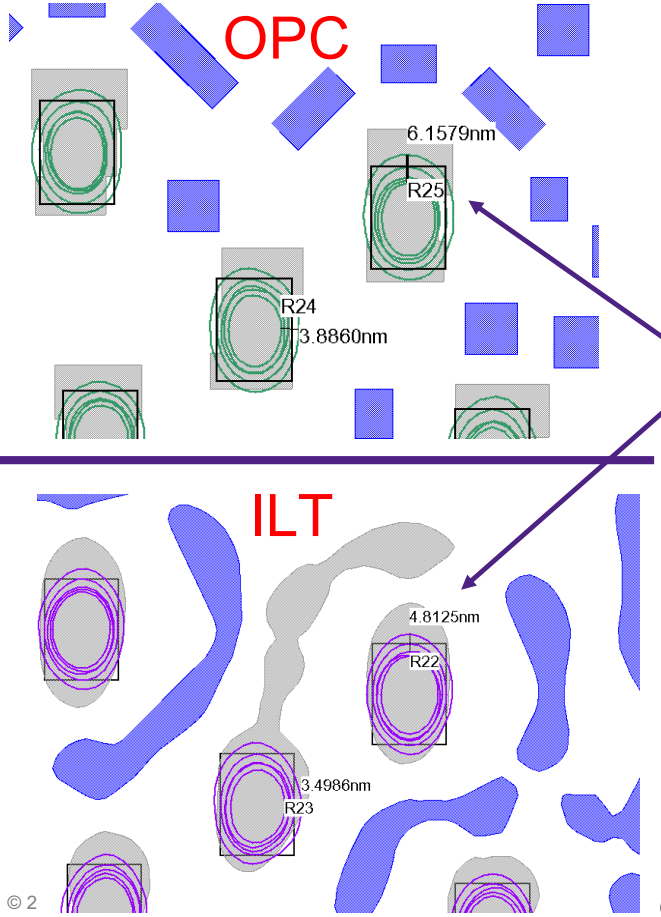
200/nn : overlapping by nn-nm

200/100 is the same shot count as 100/0

200/125 is more shot count than 100/0 but far better CDU from CD Split

EUV Via Random Pattern – PV Band Improvement

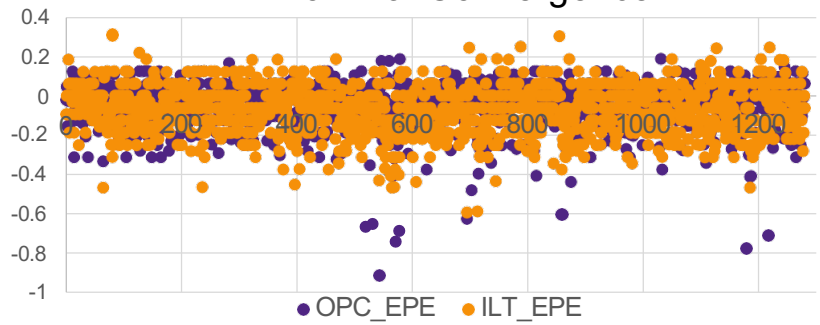
ILT Improves PV Band by > 20%



PV band measuring spread of

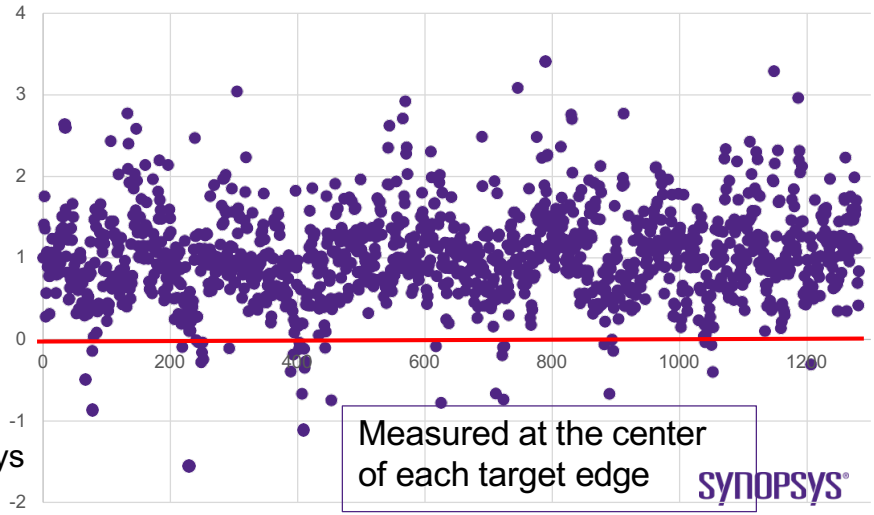
- +/-15% dose
- +/- 50 nm focus

Nominal Convergence



OPC PVBAND - ILT PVBAND

ILT Improvement



Measured at the center of each target edge

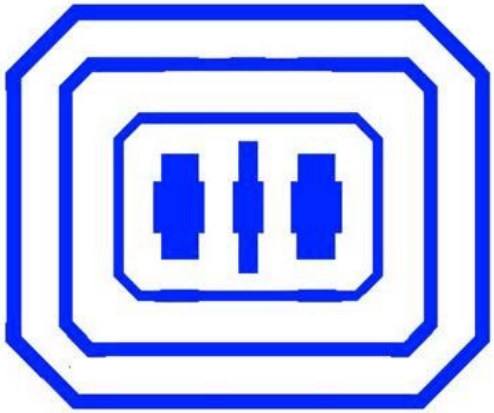
Presented by Tom Cecil, Synopsys
eBeam Initiative SPIE 2017

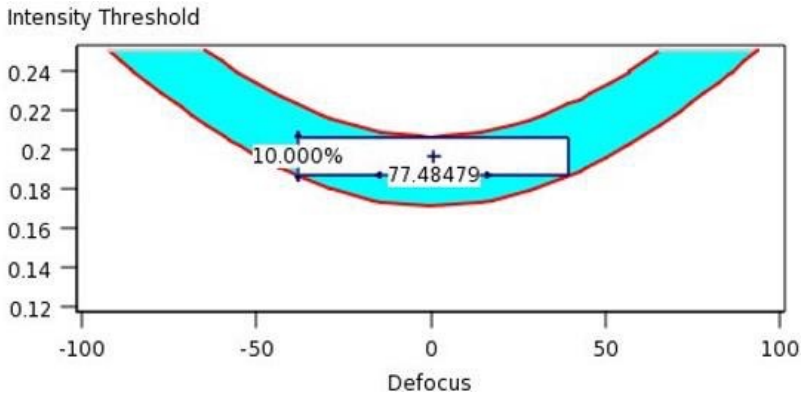
SYNOPSYS®

Process Window Comparison: DRAM Contact

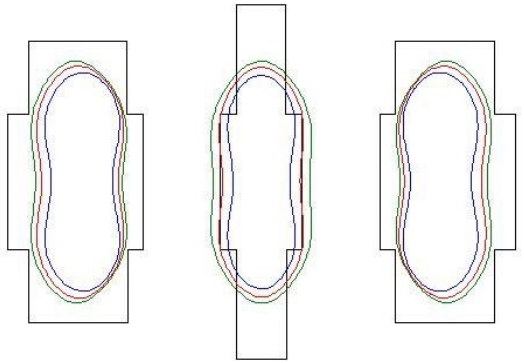
Curvilinear ILT vs. Standard OPC: *First to fail site*

Standard OPC

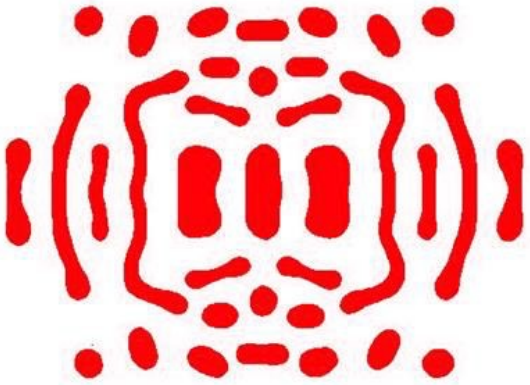




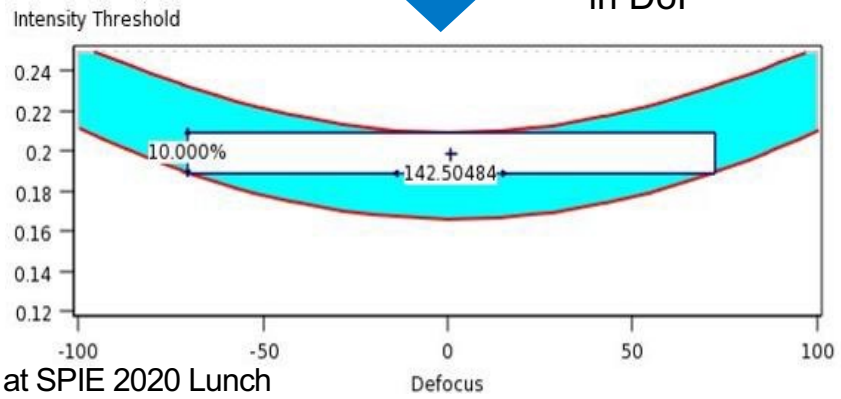
PV Band
0, 60, 90nm defocus

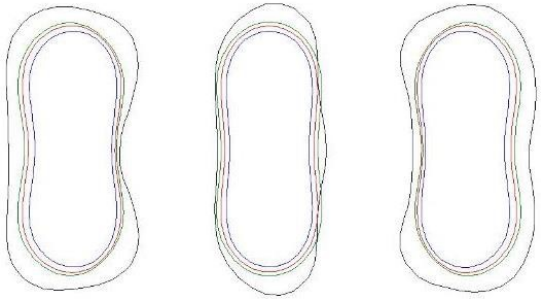


Curvilinear ILT



~85% increase in DoF





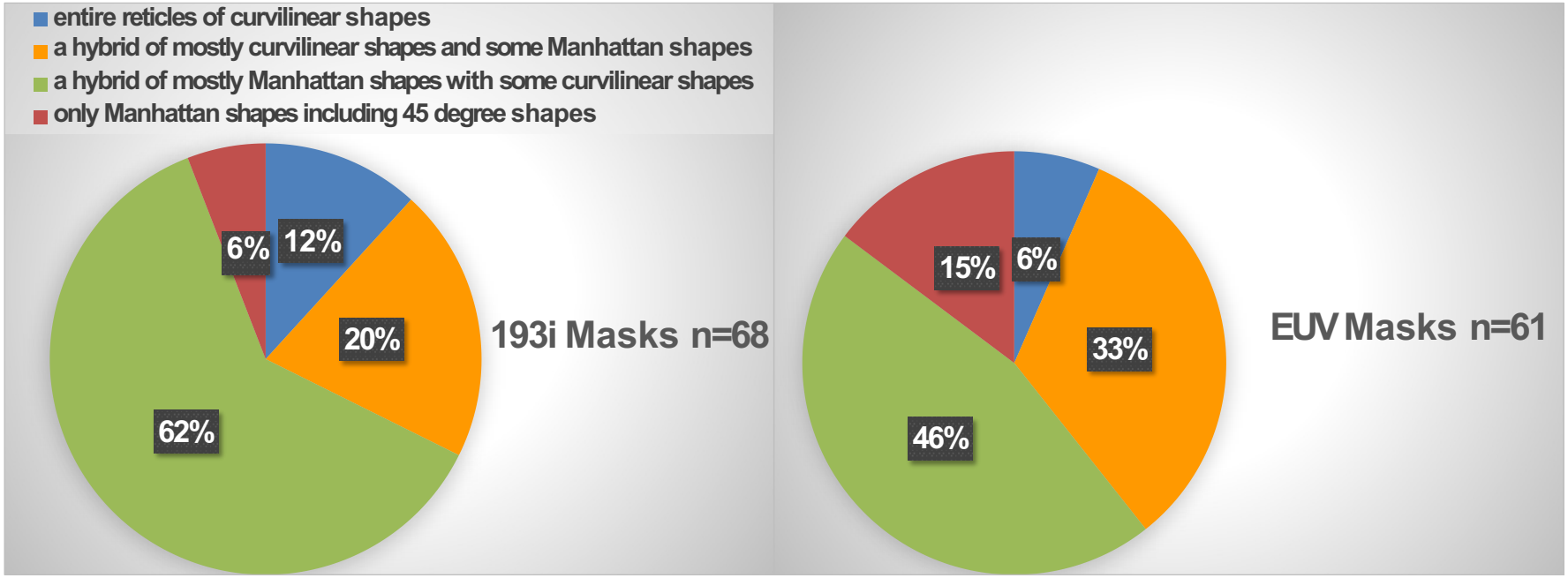
Presented by Ezequiel Russell, Micron at SPIE 2020 Lunch

Micron

Curvilinear Shapes by 2023

94% of 193i, 85% of EUV masks with some curvilinear shapes

Manufacturing of curvilinear masks is enabled by multi-beam mask writers. How extensively will curvilinear shapes be used for leading-edge (EUV, 193i) masks intended for high volume manufacturing (HVM) by 2023?



eBeam Initiative Survey presented September 2020

GPU is Great for Curvy

$$O(p)$$

Because GPU is even better at pixels

eBeam Initiative Reception - September 2022
Presented by Aki Fujimura, D2S

Thank You for Your Contributions over 15 Years!

Frank Abboud
Ajay Barawal
Peter Buck
Tom Cecil
Gek Soon Chua
Tom Faure
Yuri Granik
Colin Harris
Matt Hettermann
Franklin Kalk
Byung Gook Kim
Christof Klein
David Lam
Hans Loescher
Chris Mack
Seiji Nagahara
Noriaki Nakayamada
Leo Pang
Jan Hendrik Peters
Christophe Pierrat
Praveen Raghavan
Ezequiel Russell
Steffen Schulze
Vivek Singh
Chris Spence
Vikram Tolani
Markus Waiblinger
Yuichiro Yamazaki

Ofer Adan
Jèrôme Belledent
Christian Bürgel
John Chen
Hugh Durdan
Donis Flagello
Mike Green
Naoya Hayashi
Tatsuhiko Higashiki
Takashi Kamikubo
David Kim
Tadashi Komagata
Harry Levinson
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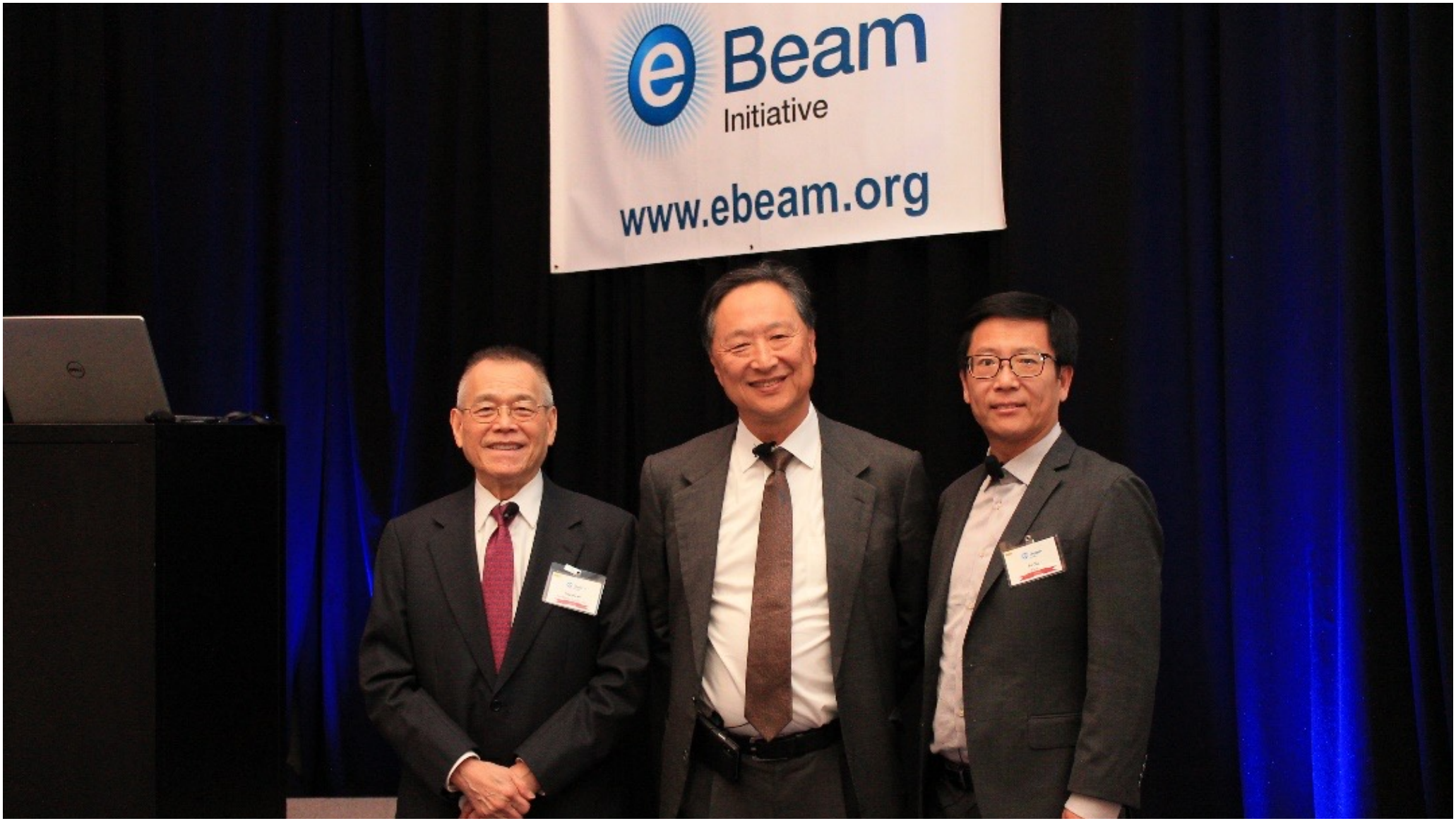
Yasutoshi Nakagawa
Bob Pack
Ryan Pearman
John Petersen
Elmar Platzgummer
Jed Rankin
Emile Sahouria
Abhishek Shendre
Matthias Slodowski
Ines Stolberg
Haruo Tsuchikawa
Sterling Watson

Sergey Babin
Ingo Bork
Yu Cao
Jin Choi
Klaus Edinger
Emily Gallagher
Brian Grenon
Mike Hermes
C.U. Jeon
Kokoro Kato
Yasuki Kimura
Thomas Kurian
Timothy Lin
Shinchi Machida
Greg McIntyre
Takayuki Nakamura
Laurent Pain
Danping Peng
Hans Pfeiffer – RIP
Chris Progler
Doug Resnick
Glen Scheid
Mark Sheppard
Mike Smayling – RIP
Steve Teig
Mikael Wahlsten
Jim Wiley

Aki Fujimura, Co-founder
Jan Willis, Co-founder

eBeam Initiative Staff:
Geena Dabadghav
Janet Greene
Angie Kellen
David Moreno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Chris Progler
Photronics
Glen Scheid
Micron Technology


NEC


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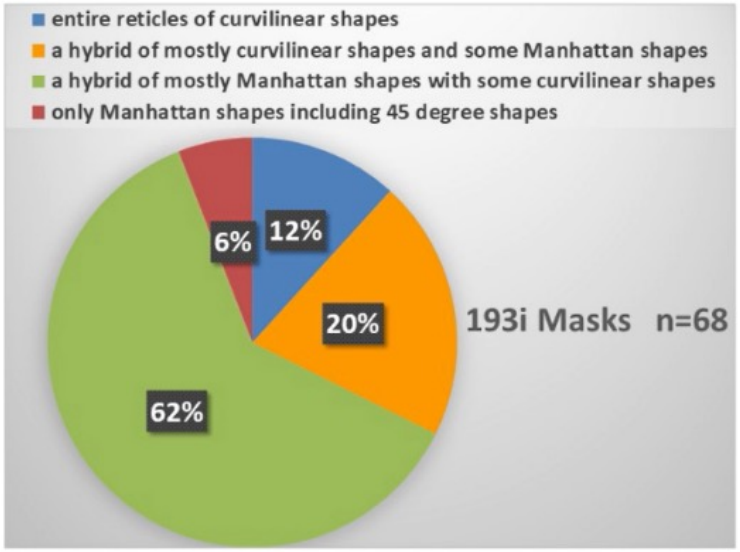
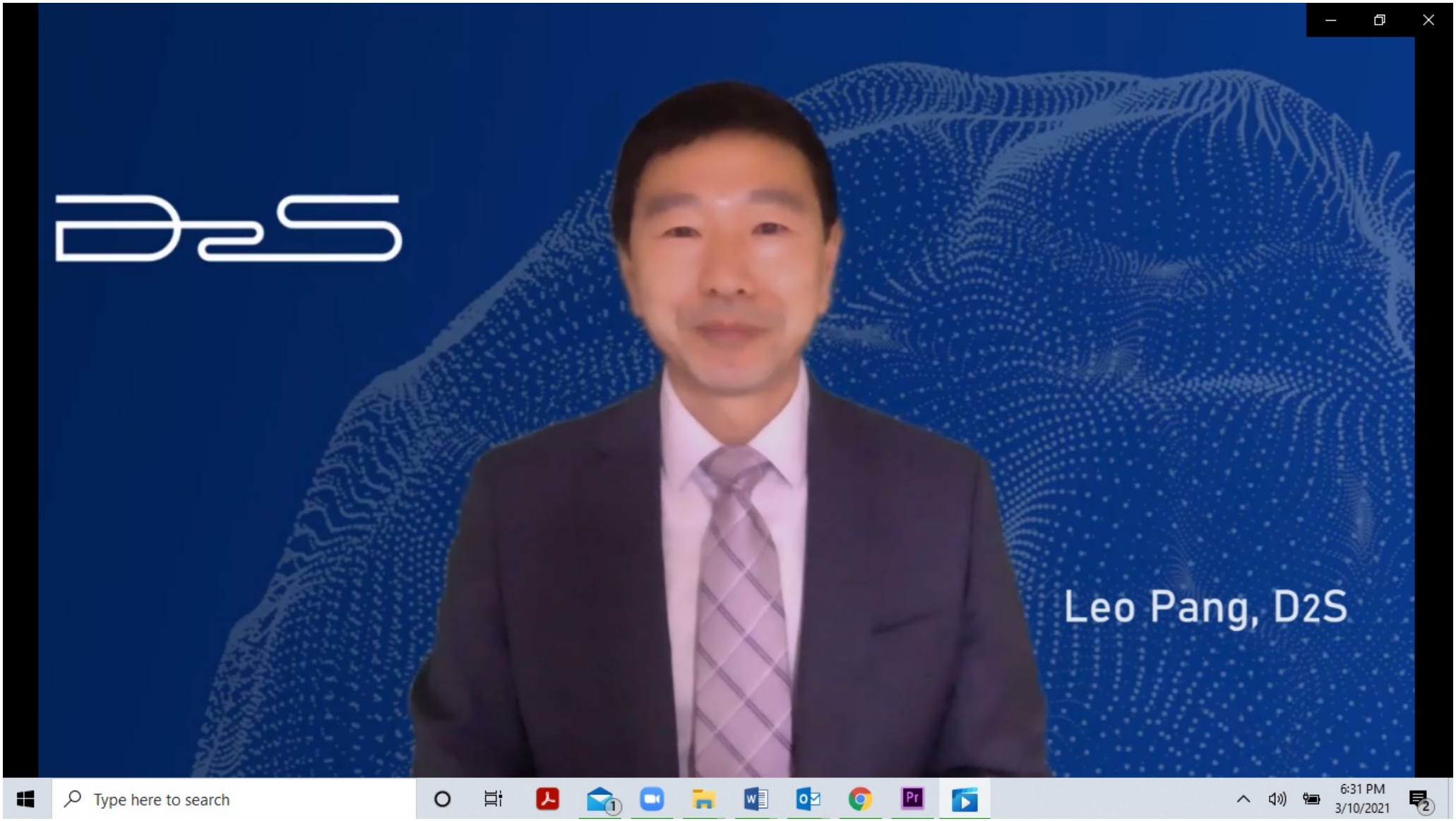
Initiative
Naoya Hayashi,
DNP Honorary Fellow
Ezequiel Russell,
Micron

94% say 193i Masks with Some Curvilinear Shapes by 2023
According to 2020 Luminaries Survey Prediction

eBeam Initiative

Manufacturing of curvilinear masks is enabled by multi-beam mask writers. How extensively will curvilinear shapes be used for leading-edge (EUV, 193i) masks intended for high volume manufacturing (HVM) by 2023?




D2S
Leo Pang, D2S
Type here to search
6:31 PM
3/10/2021


FELLOW


EXIT


RESERVED


ZEISS
Dr. Markus Waiblinger
Product Manager ebeam repair system MeRiT®


Beam


Klaus Edinger
ZEISS
Brian Grenon


Beam
Initiative
CEBL Results
(single-column proof of concept)
Advantest / TEL
(SPIE 2012)
Leti / Tela Innovations
(SPIE 2012)


SPEAKER


Beam
Christian Burgel
ANITC
Franklin Kalk
Aki Fujimura
D2S

Collaboration Already Underway

- **Fujitsu, e-Shuttle and D2S to Prove DFEB Design and Manufacturing**
- **65-nm low-power test chip**
- **Announced October 2008**

Pictured are (left to right) ***Dr. Haruo Tsuchikawa****, President of e-Shuttle,* ***Hiroyuki Asahida****, Director of Marketing at Fujitsu Microelectronics, and* ***Aki Fujimura,*** *Chairman and CEO of D2S.*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