Beam

Initiative

eBeam Initiative

Design for E-beam: Getting the Best Wafers Without the Exploding Mask Cost

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Managing Sponsor, eBeam Initiative

Higher Mask Cost : the Greatest Concern for Designers

Global Semiconductor Alliance 12/6/2007:
What is the biggest challenge to overcome as your company moves from one process node to the next?

Challenge	Share
Other	9%
Test costs	0%
Packaging costs	2%
Semiconductor IP quality	6%
Semiconductor IP cost and availability	13%
Inadequate EDA tools for increasing complexity	10%
Increased design complexity	26%
Higher-mask costs	34%

Source : Global Semiconductor Alliance

The Challenge: Mask Economics Must Work!

Normalized cost

14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0

32 nm
45 nm
65 nm
90 nm
130 nm
150 nm

2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020

Year

Normalized Mask Set Costs Over Time

Courtesy of Toppan Photomasks, Inc.

Direct-Write or Mask? Either Way, E-beam Writes All Chips!

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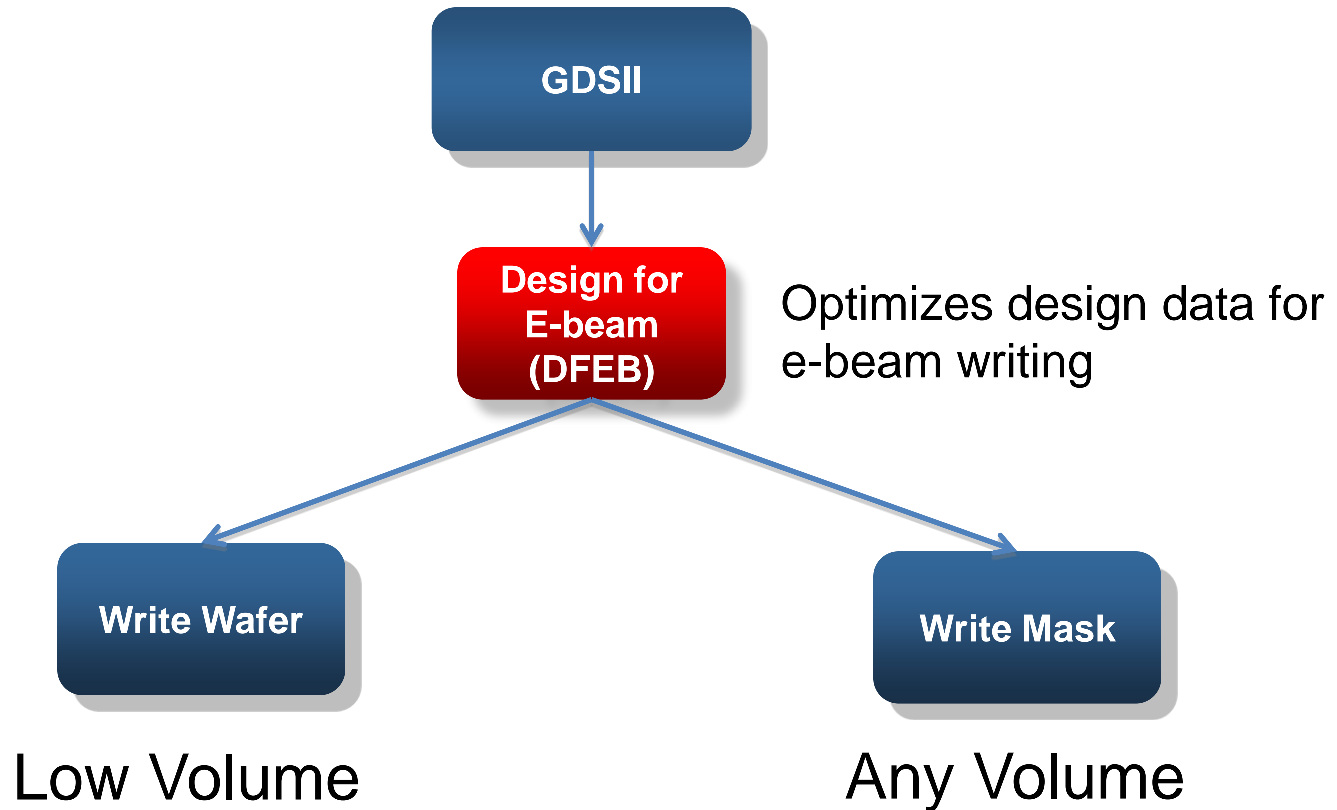
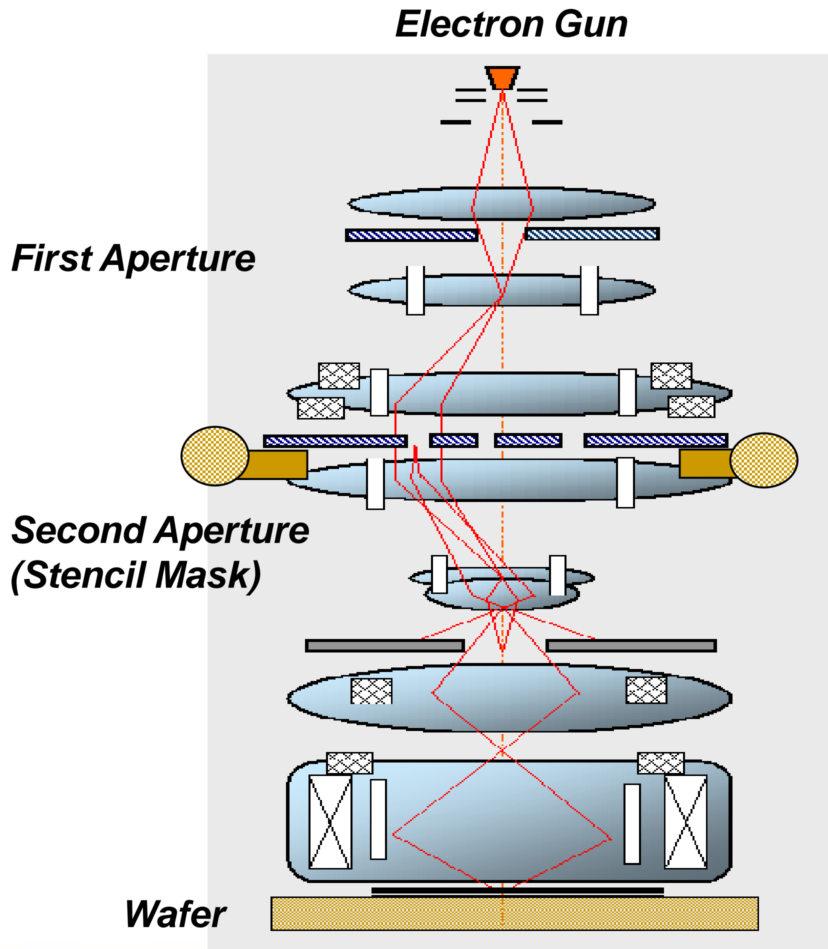


Direct-Write Character Projection Production Use at e-Shuttle

Picture Courtesy of e-Shuttle, Inc.

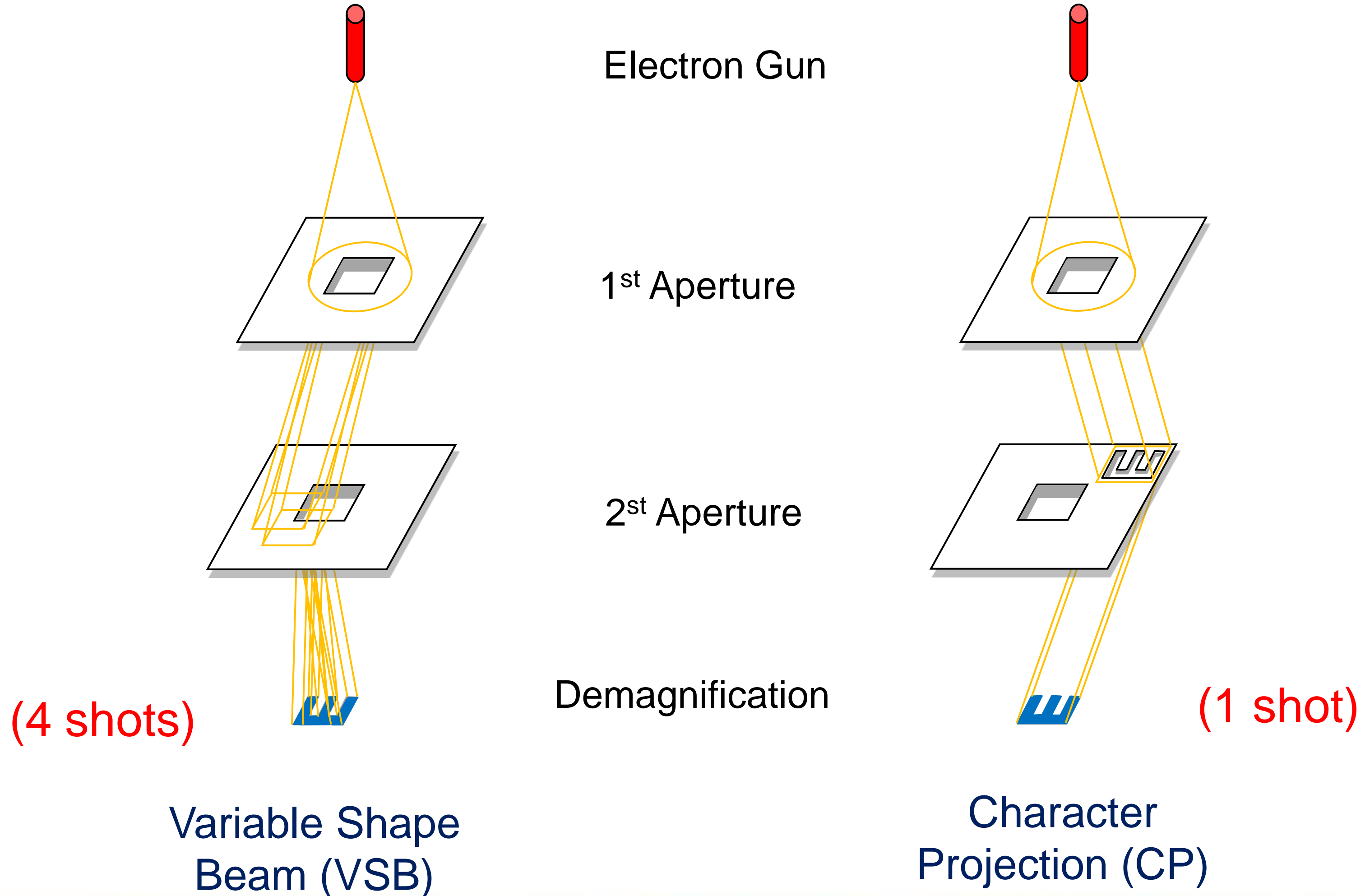
Today’s E-beam Lithography



- 50kV E-beam drills great holes!
- E-beam doesn’t have depth of focus (DOF) problems like light
- E-beam is very accurate compared to light
- Write time is the challenge

Drawing Courtesy of Advantest

Character Projection Lowers Shot Count



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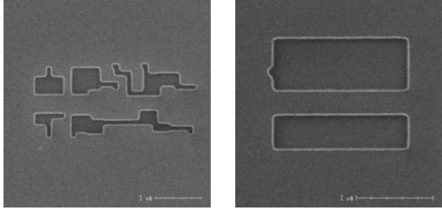
Drawing Courtesy of Hitachi High-Technologies

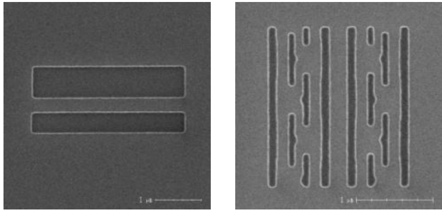
DFEB Character Exposure Results

All images obtained by one CP shot

65nm LP

Active





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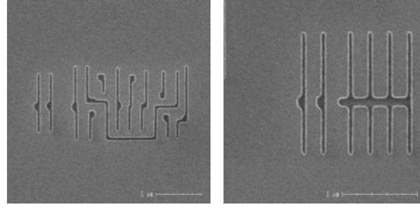
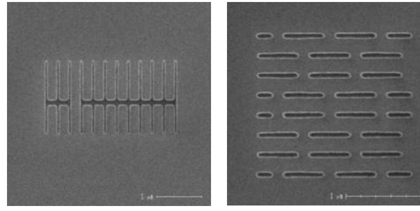
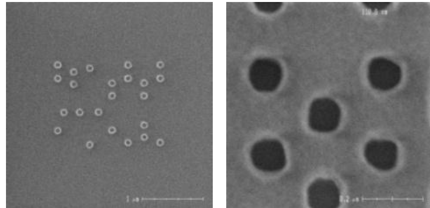
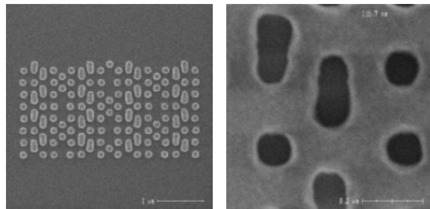


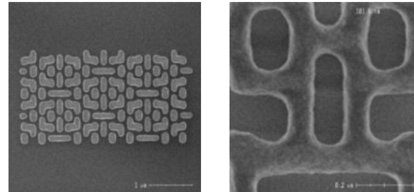


Contact

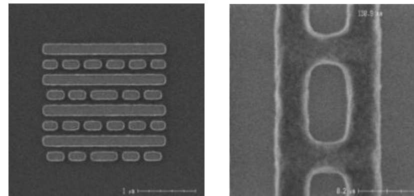




Metal-1

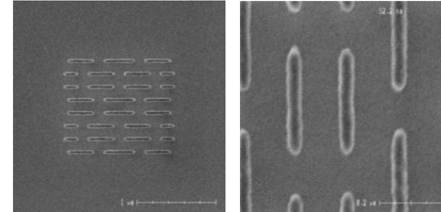


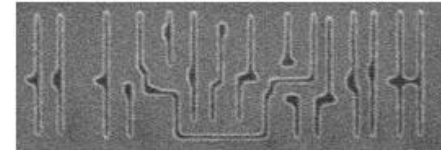
Metal-2

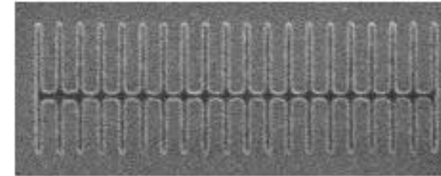


45nm proto

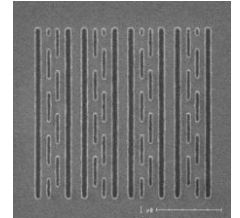
Gate





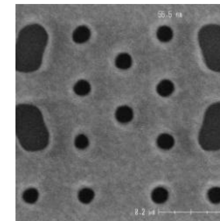


Active



SRAM

Contact



SRAM

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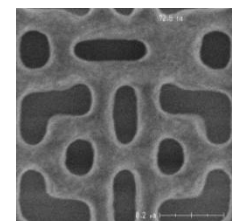

SRAM

EIPBN, 2009
Courtesy Fujitsu Ltd, e-Shuttle, Inc., Advantest Corp. and D2S, Inc.

DFEB Makes Maskless Low-Volume SoCs Practical

DFEB optimizes for shot count at the design stage to reduce residue VSB to achieve 10-25X reduction

Comparison Source: D2S, Inc. Computer simulation of e-beam write time on a particular test case (speed up is dependent on aperture size and utilization %)

Many High-Priced Designs, More with Uncertain Volumes

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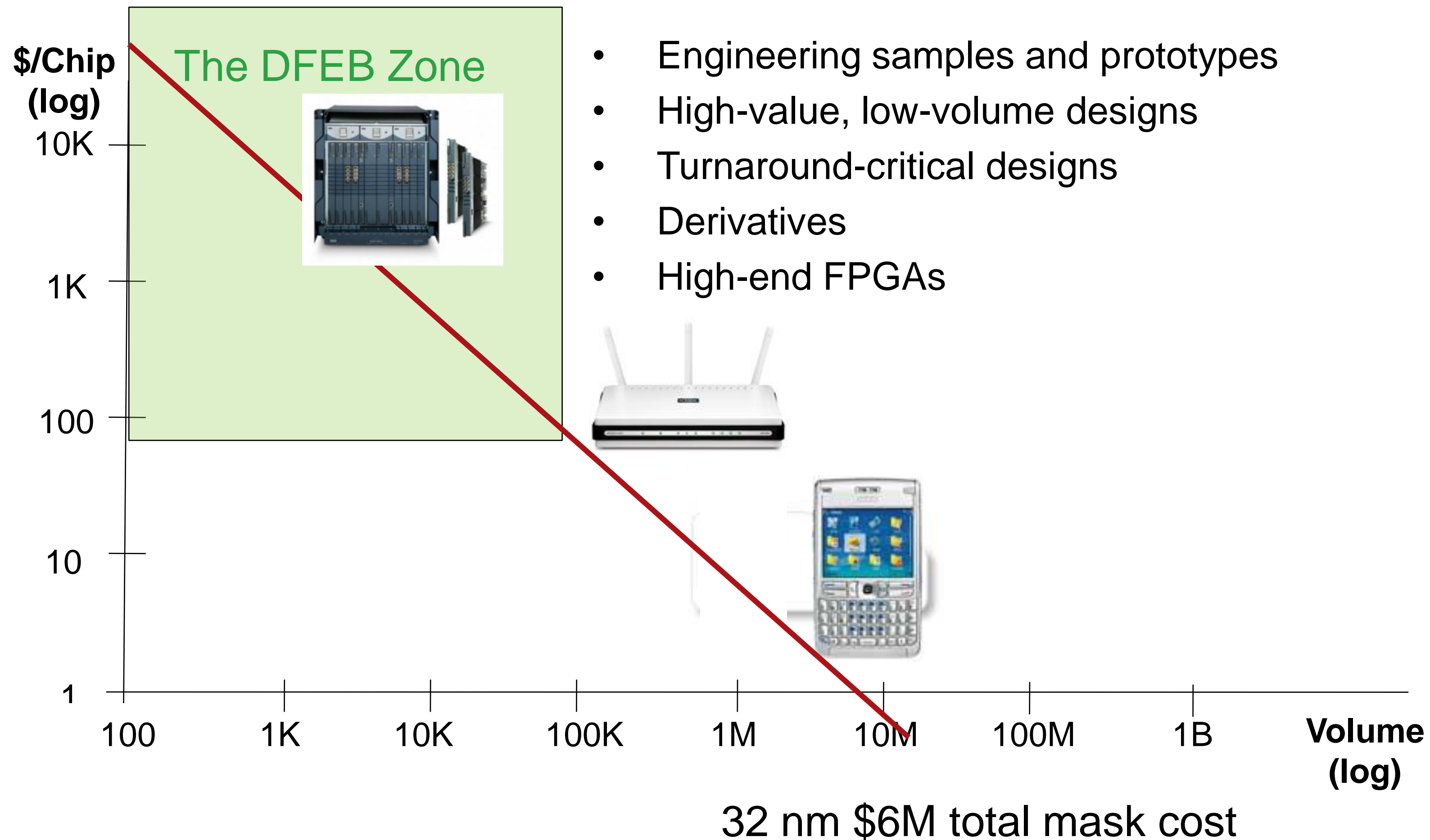


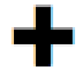
32 nm $6M total mask cost

Lithography for 22nm and Beyond

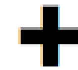
- Light
  - Today : 193i w/multiple patterning masks
  - Future : EUV (Extreme Ultra-Violet)
- Nano-imprint
- Electron Beam (E-beam) Lithography
  - Today : Shaped Beam and Character Projection
  - Future:
    - Multiple-beam E-beam
    - Multi-columned, single-beam
    - Multi-shaped beam (MSB)

Multi-Shaped Beam (MSB)

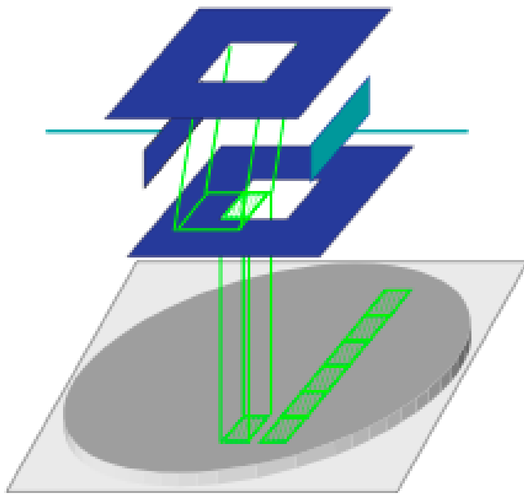
Single Shaped Beam (SSB)

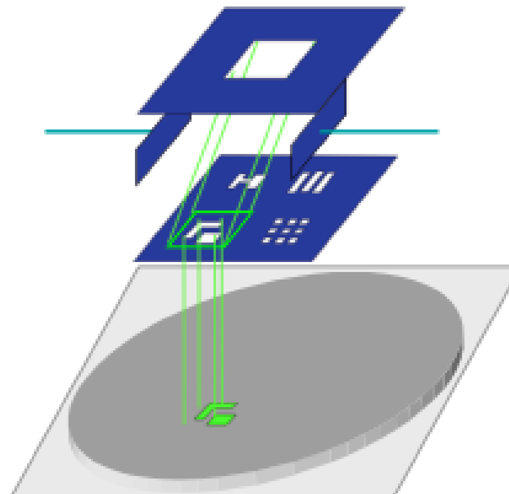


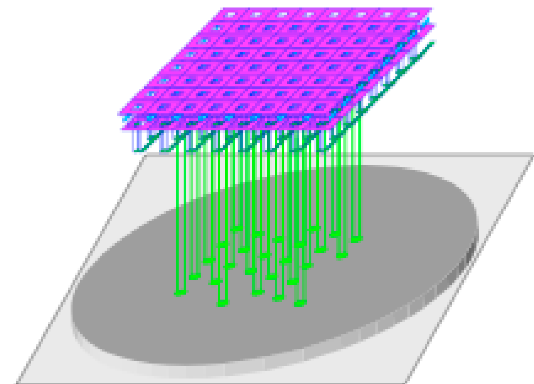
SB - Cell Projection (SB – CP)



Multi Shaped Beam (MSB)







Drawing Courtesy of Vistec

Multi-Source/Single-Column: MCC System with 16CCs

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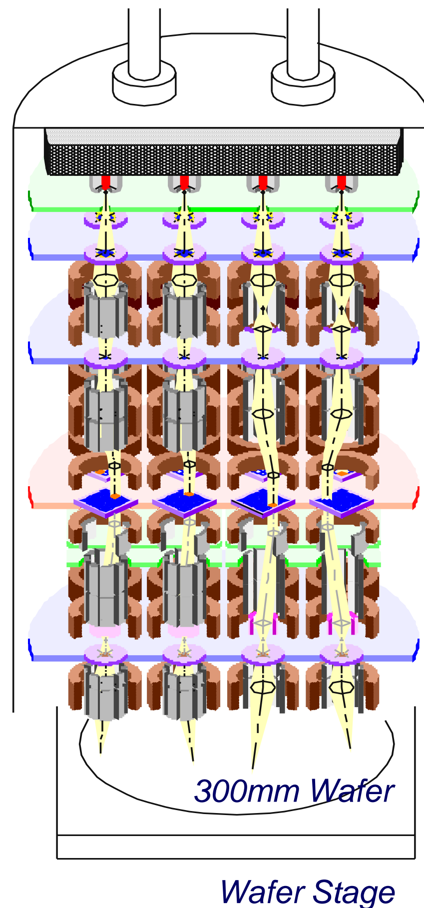

Electron Gun (4x4)

Blanking Deflectors

Rectangular Apertures (4x4)

Pre. Mask Deflector

CP Aperture Masks (on separated stage)

Post Mask Deflectors

Round Apertures

Major Deflector (100x100 um)

Minor Deflector (10x10 um)

Drawing Courtesy of Advantest

MCC-POC System

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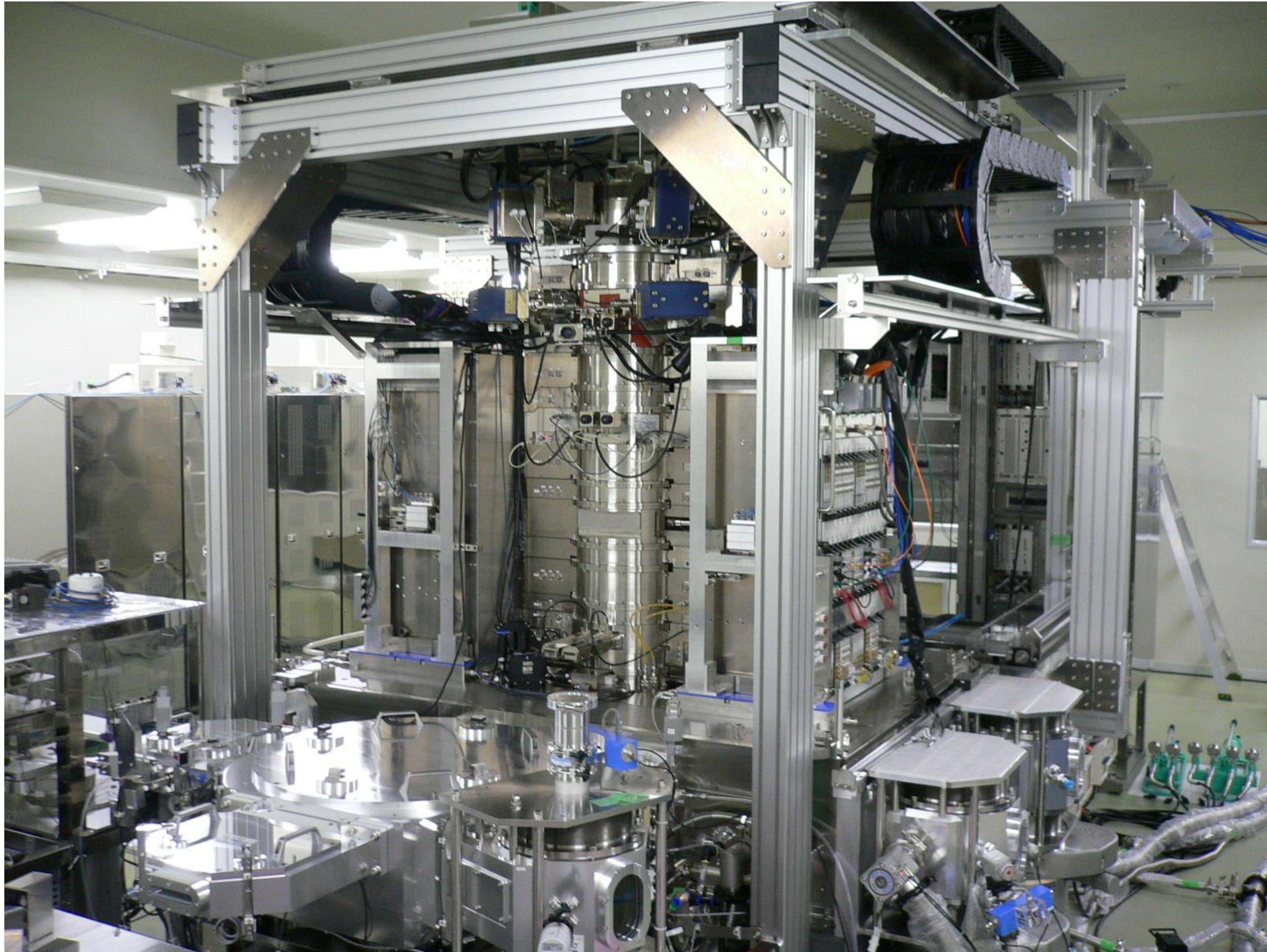
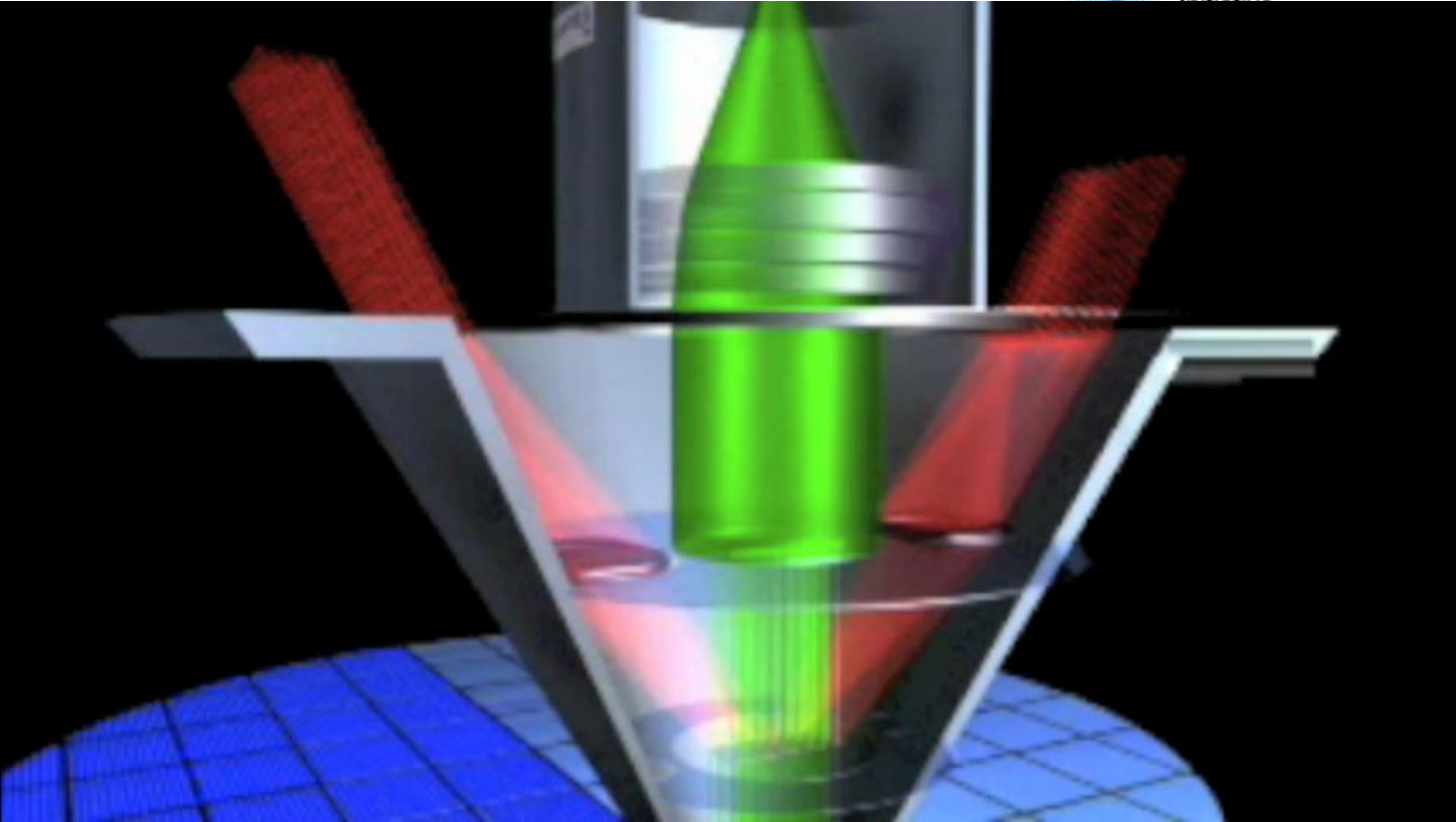


Courtesy of Advantest

MAPPER



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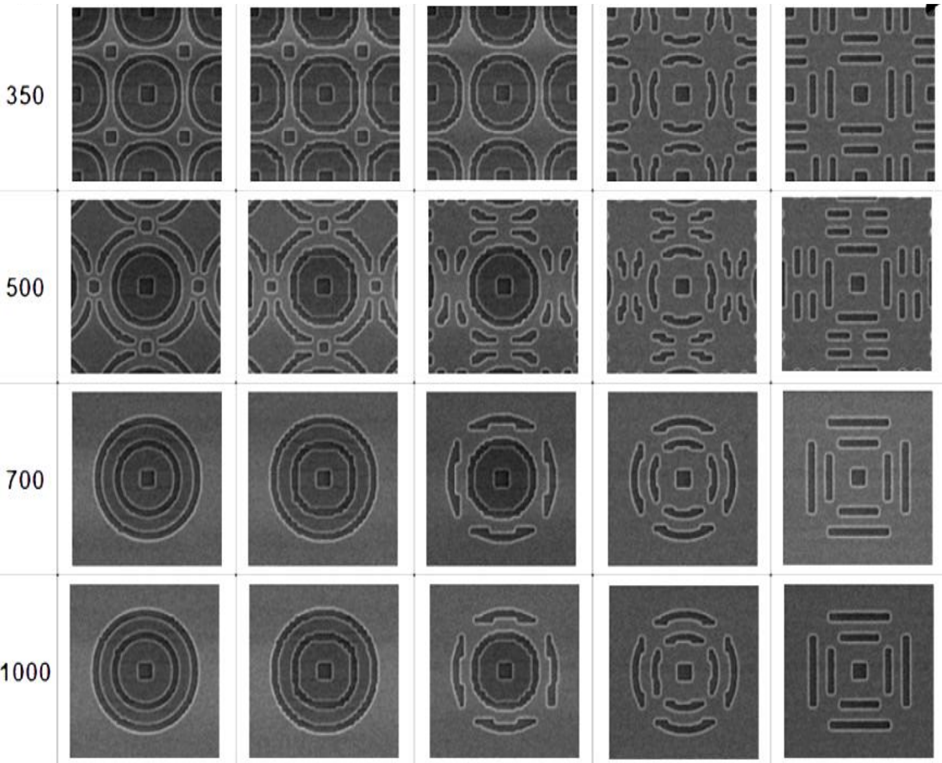
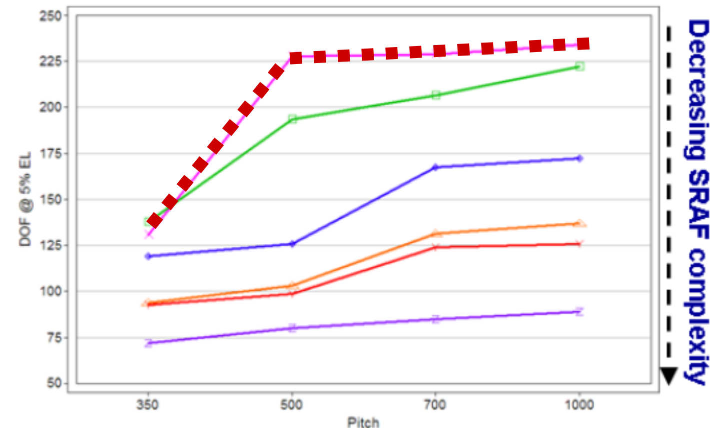
At 22nm 193i
Good Wafers = High Mask Cost

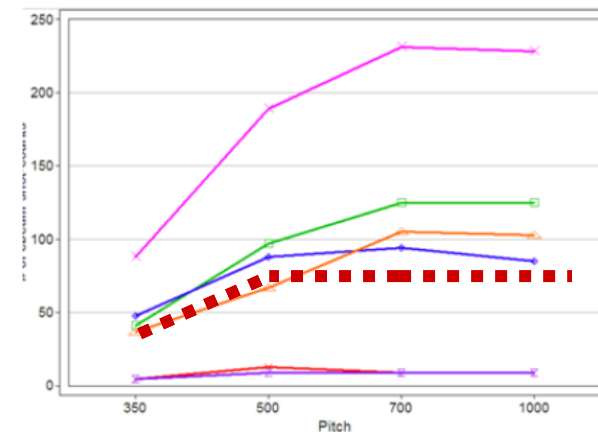


OPC A: standard OPC

DOF @ 5%EL

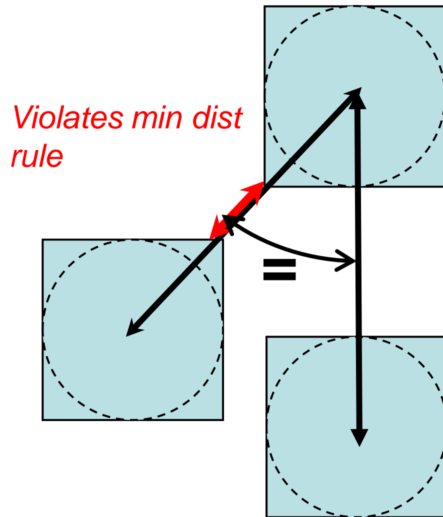


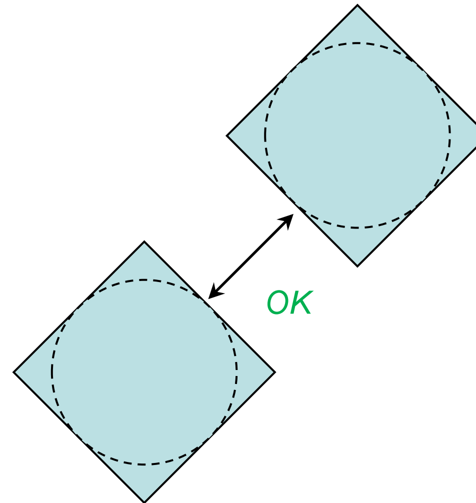
# of eBeam Shot-counts

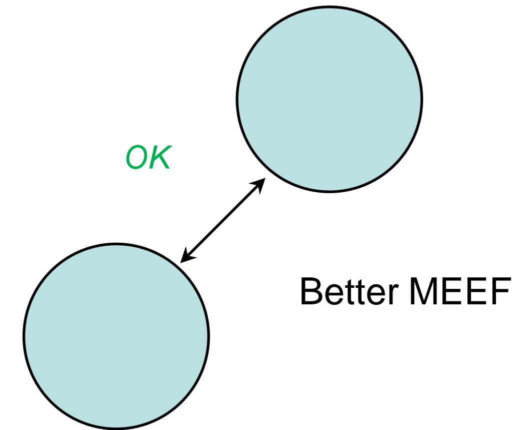


Samsung study : Ref: Byung-Gook Kim, et al., PMJ 2009.

Circles are Better for Design AND Manufacturing







Printing Circles as Characters

Dose provided:

16.0 uC/cm2 19.7 uC/cm2 24.3 uC/cm2

Shot diameter = 118

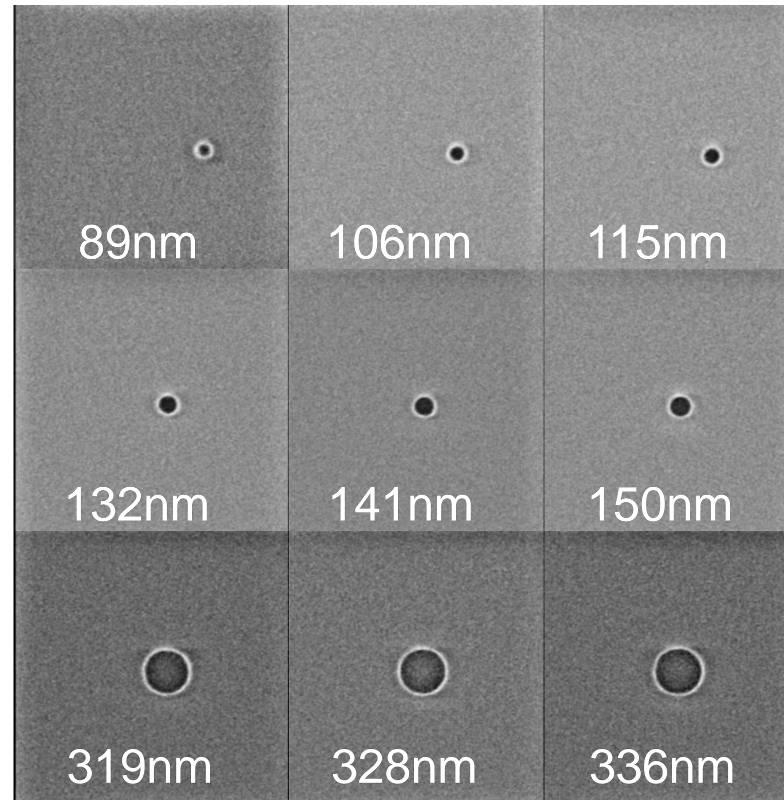
Hole Diameter on mask (measured)

Shot Diameter = 142

Hole Diameter on mask (measured)

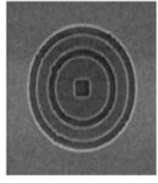
Shot Diameter = 334

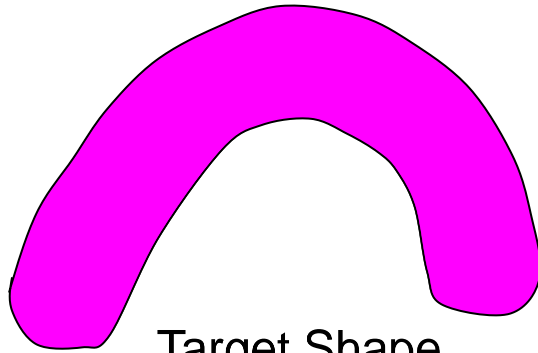
Hole Diameter on mask (measured)



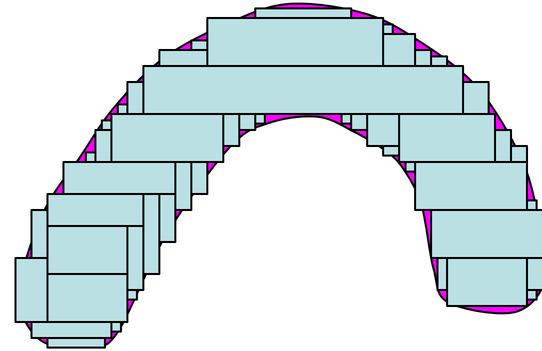
Courtesy JEOL, Ltd.
Patents pending, D2S, Inc.

Overlapping Circles = Smooth Curvilinear Features with Fewer Shots

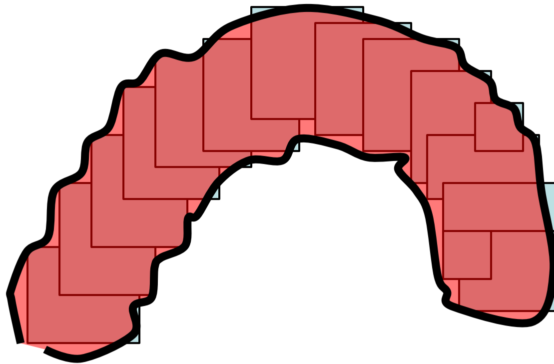




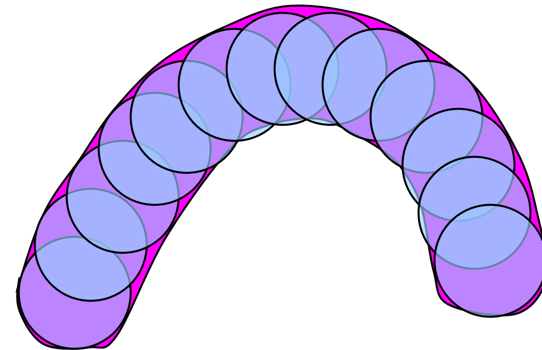
Target Shape



40 Conventional VSB Shots



15 Overlapping VSB Shots



13 Overlapping Circles

Patents pending, D2S, Inc.

Smooth Curves with Practical Write Times through DFEB

Shots Used

Resist Exposed Images

Simulated Mask Shape

Courtesy Luminescent, Inc. and JEOL, Ltd.
Patents pending, D2S, Inc.

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