EUV Lithography at Insertion and Beyond

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Technology and Manufacturing Group
Intel Corporation
Acknowledgements

Kenny Toh for help with Rigorous EM modeling
Robert Bristol and Mark Phillips for fruitful discussion and comments
Outline

Intel Technology Cadence

EUV HVM Insertion
- Timing
- Method
- Tooling
- Materials
- Priorities

EUV beyond Insertion

Conclusions
# Intel Technology Cadence

<table>
<thead>
<tr>
<th>Process Name</th>
<th>P1266</th>
<th>P1268</th>
<th>P1270</th>
<th>P1272</th>
<th>P1274</th>
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<tbody>
<tr>
<td>Lithography</td>
<td>45nm</td>
<td>32nm</td>
<td>22nm</td>
<td>14nm</td>
<td>10nm</td>
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<td>1&lt;sup&gt;st&lt;/sup&gt; Production Year</td>
<td>2007</td>
<td>2009</td>
<td>2011</td>
<td>2013</td>
<td>2015</td>
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</tbody>
</table>

Intel continues introducing a new technology generation every 2 years.

*Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi*
2X Area density Scaling at Intel - Last 10 Years

Bitcell Area (\(\mu m^2\))

- 90nm: 193
- 65nm: 193
- 45nm: 193
- 32nm: 193i
- 22nm: 193i

22nm SRAM Test Chip
- 364 MBit array
- ~3B Transistors
- 3d Gen high-k Metal Gate

Intel IDF 09/2009

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
Cost per Transistor Trend sustained with TriGate and 193i Pitch Divided Lithography
22nm node HVM Litho – 193i

Half Pitch (nm)

\[ HP = k_1 \frac{\lambda}{NA} \]

- g-line (435)
- i-line (365)
- DUV (248)
- 193i

- EUV
- E-beam
- DSA
- NIL

22nm 2011
14nm 2013
10nm 2015
7nm 2017
HVM Start

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
14nm HVM Litho – 193i

Half Pitch (nm)

\[ HP = k_1 \frac{\lambda}{NA} \]

22nm 2009
14nm 2011
10nm 2013
7nm 2015

Dev. Start

435 (g-line, k1=0.4))
365 (i-line, k1=0.4)
248 (DUV, k1=0.4)
193 (dry/immersion, k1=0.3)
13.5 (EUV, k1=0.4))

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
**EUV HVM Insertion Method**

**Complementary**

**Definition:**
1. *completing*: completing something else
2. *making whole*: making a pair or whole

*MSN Encarta dictionary*

---

**Step 1.** Use mature High Throughput 193i with Pitch Division to define CD Critical parts of layout by patterning continuous gratings.

**Complement** Step 1 by Step 2

**Step 2.** Use High Resolution High Throughput Imaging to break continuity of gratings defined in Step 1.

---

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
40nm Pitch Example

**ArF Only Patterning**

1 193i w/PD to form gratings + 4 193i Masks/Exposures to form Pattern = 5 Mask 5 Exposures

**Complementary Patterning**

CD, LWR <2nm 3s

1 Mask/1 193i Expose + 1 Mask/1 EUV Expose

1 193i w/PD to form gratings Total + 1 EUV Masks/Exposure 2 Masks/2 Exposures

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
193i Allows for better LWR Starting Control then EUVL

Images in 193i Resist with 1.35NA
Pitch = 84nm, LWR 3σ=1.6nm
40nm Pitch Example - ArFi Can do Cuts (with 4 masks)

On Target – Upsized
10nm/long side
13nm/short side

To be followed by chem trim
10nm/side

<table>
<thead>
<tr>
<th>Location</th>
<th>MEEF</th>
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<td>3.05</td>
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<tr>
<td>short side bottom</td>
<td>2.97</td>
</tr>
<tr>
<td>long side left</td>
<td>1.42</td>
</tr>
<tr>
<td>long side right</td>
<td>1.73</td>
</tr>
<tr>
<td>long side top</td>
<td>2.54</td>
</tr>
<tr>
<td>long side bottom</td>
<td>2.04</td>
</tr>
</tbody>
</table>

Blue Mask

DOF (+ 60) contours
- On target
- Positive defocus
- Negative defocus

MEEF contours
- On target
- MEEF up
- MEEF down

Print Larger

SMO+ILT Mask

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
40nm Pitch Example - *ArFi Can do Cuts* (with 4 masks + Print Bias and Shrink)

On Target – Upsized
- 10nm/long side
- 13nm/short side

To be followed by chem trim
- 10nm/side

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Print Larger

SMO+ILT Mask

**Blue Mask**

**DOF (± 60) contours**
- On target
- Positive defocus
- Negative defocus

**Blue Mask**

**MEEF contours**
- On target
- Meef up
- Meef down
Edge Placement Error might be an issue with multiple pitch divided steps

That’s how enlarged grating cuts are suppose to go on the wafer if placement and dimensions of all 4 cuts exposed in 4 separate exposures are ideal.
Edge Placement Error might be an issue with multiple pitch divided steps

That’s how next interconnect and vias are suppose to go on the wafer if placement and dimensions of next layer interconnect and vias grating are ideal.
Edge Placement Error might be an issue with multiple pitch divided steps

That’s what happens if some exposure steps introduce 5-7nm overlay errors
Edge Placement Error might be an issue with multiple pitch divided steps

That’s what happen if some exposure steps introduce 5-7nm overlay errors and OPC imperfections, Defocus, Dose instability add to Edge Placement Error (EPE) resulting in yield loss.
Edge Placement Error might be an issue with multiple pitch divided steps

Combining divided exposures in one will help minimize one of major contribution to EPE budget.

EPE improvement is one of key benefits we expect for EUV to bring to future technologies
EUV HVM Insertion

In addition to widely discussed EUV infrastructure issues following capabilities have to be present in support of EPE and Yield requirements for EUV HVM Insertion at Intel:

Tooling  - Sophisticated OPC
Materials  - Stochastics Suppression
EUV is complex PSM (Thick) Mask. Fast Thick Mask Tooling needed for OPC.

Thick Mask Vertical: Near Field E-Field

Big Imin and Imax Deltas
EUV is complex PSM (Thick) Mask. Fast Thick Mask Tooling needed for OPC

Significant 3D EPE due to: mask source angular dependencies (EPE - Slot position dependent), narrow DOF (Pitch dependent BF), poor PW for semi-isolated features

Thick Mask Vertical: Near Field E-Field

Big Imin and Imax Deltas

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
EUV HVM Insertion
Need for Sophisticated OPC

I. INTRODUCTION

In this discussion, we show that the masking layer does not behave like a simple binary filter but rather that the illuminating radiation is diffracted and propagates in the multilayer in a very complex way before being reflected out of the mask, affecting the system imaging.

Imaging properties of the extreme ultraviolet mask

B. S. Bollepalli, M. Khan, and F. Cerrina

Image EPE is multivariate function of 3D EUV mask scattering, i.e.:
- features placement and dimensions through field (slot) are source shape and mask tone and pitch and feature size dependent

3D nature of EM reflection/absorption/scattering on EUV Mask will require Fast and Accurate non-Kirchhoff approach for EUV OPC modeling and corrections

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
EUV HVM Insertion
Need for Sophisticated OPC

All features are on the same mask and need to be printed at the same time.
All dimensions in nm

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
# Simulation Conditions

<table>
<thead>
<tr>
<th>Simulator</th>
<th>Intel’s Rigurous EM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation Model</td>
<td>Vector, FDTD</td>
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<tr>
<td>Imaging</td>
<td>NA=0.33, X-Dipole 0.9/0.2</td>
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<tr>
<td>Wavelength</td>
<td>13.5nm</td>
</tr>
<tr>
<td>CRAO</td>
<td>6 deg</td>
</tr>
<tr>
<td>Aberrations, Flare, OOB</td>
<td>All 0</td>
</tr>
<tr>
<td>Mask Absorber</td>
<td>n=0.9394; k=0.0410</td>
</tr>
<tr>
<td>Multilayer Si</td>
<td>n=0.9988; k=0.0018</td>
</tr>
<tr>
<td>Intermix Layer</td>
<td>n=0.9691, k=0.0044</td>
</tr>
<tr>
<td>Multilayer Mo</td>
<td>n=0.9235; k=0.0065</td>
</tr>
<tr>
<td>Edge Placement</td>
<td>Mask Tone Specific Threshold</td>
</tr>
</tbody>
</table>
EUV HVM Insertion
Need for Sophisticated OPC Sensitivity Study

1. Size up features to improve contrast and stochastics until MEEF=3
2. Use Kirchhoff to find starting mask OPC dimensions
3. Use Rigorous EM modeling to run near field/far field imaging around starting OPC dimensions to find correct mask sizing
4. Define common focus and dose threshold for all features
5. Characterize slot position EPE sensitivities for all features
6. Characterize focus dependent EPE sensitivities for all features

Assess both Dark field and Bright field sensitivities.
EUV HVM Insertion
Need for Sophisticated OPC

Example 2

<table>
<thead>
<tr>
<th></th>
<th>W</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPC (Ideal Mask)</td>
<td>18</td>
<td>23</td>
</tr>
<tr>
<td>OPC (Thick Mask)</td>
<td>14</td>
<td>27</td>
</tr>
<tr>
<td>Target</td>
<td>22</td>
<td>30</td>
</tr>
</tbody>
</table>
Example2 (blue) : Dark Field, Aerial Image with OPC, CRAO along x-axis

Contrast = 0.846

$\Phi=0$ Slot Center (Blue Solid line)

CRAO along x-axis
Threshold $\rightarrow 0.05$
for $\phi=0$ we get,
$CD_x = 22$
$CD_y = 29.3$

$\Phi=25$, Slot Edge (Red dashed line)
Example 2 (blue): Dark Field, Aerial Image with OPC, CRAO along x-axis

Threshold $\rightarrow 0.05$

for $\phi=0$ we get,

$CD_x = 22$

$CD_y = 29.3$

Contrast $= 0.846$

$\Phi=0$ Slot Center
(Blue Solid line)

CRAO along x-axis

Threshold $\rightarrow 0.05$

$\Phi=25$, Slot Edge
(Red dashed line)

$\Delta CD_x = 0.5$

$\Delta CD_y = 0.9$

3D mask effect

Geometric
Shadow effect

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
Through-Slit 3D Mask EPE effects are source shape, mask tone, feature pitch and feature size dependent.

Slit Edge-Center CD Delta

- Example 1
- Example 1B
- Example 2
- Example 2 - Isolated
- Example 3
- Example 4A
- Example 4B
- Example 4B (annular)
- Example 4C

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Example2 (blue): Dark Field, Through focus results

\[ \Delta CD(x) = CD(x, \text{focus}) - CD(x, \text{focus}=0) \]

\[ \Delta CD(y) = CD(y, \text{focus}) - CD(y, \text{focus}=0) \]

Image Contrast

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3D Mask dependent EPE Changes through Focus are Tone, Pitch and Feature size specific and significant for most features

Example1 (Blue) : Through focus contour

This feature

Bright Field

Dark Field
3D Mask dependent EPE Changes through Focus are Tone, Pitch and Feature size specific and significant for most features.

Example 1B (blue): Through focus contours

Measurement made on this feature

Bright Field

Dark Field

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Through-Focus 3D Mask EPE effects are source shape, mask tone, feature pitch and feature size Dependent

![DCD thru-focus graph]

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Interaction of oblique EUV Radiation with 3D geometries formed by reflective and absorptive layers of EUV Mask leads to complex near field phase and amplitude behavior of reflected EUV radiation.

Complexity of referred interaction manifest itself in properties usually associated with phase shifted masks: $I_{\text{min}}$ lower than $I_{\text{min}}$ for “thin mask”, sizable “Best Focus” shifts between different features and pitches and strong dependence on radiation source choice.

Referred dependencies, if not corrected, will result in Edge Placement Errors that will consume exceedingly large portion of CD Control Budget.

Accurate and Fast Approximation of Rigorous EM modeling and corresponding model calibration procedures are necessary to provide EUVL OPC support for HVM Insertion.
EUV HVM Insertion – Materials Stochastics Suppression

Given actual and expected 193i and EUV Tools respective Productivity one have to conclude that NXE33XX must have TPT>100wph at HVM insertion.
EUV HVM Insertion
Materials Requirements

Cuts and Vias

Desired

Mn Cuts OL >0

Mn+1, Vn OL & Stochastics >0

Mn Cuts Stochastics >0

Mn+1

Mn Cuts OL >0

Mn

Mn Cuts OL >0

Mn Cuts Stochastics >0

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EUV HVM Insertion - Materials
Stochastics Suppression

EUV Cuts and Vias

193i Cuts and Vias

EPE (EUV/193i OL) ≤ EPE (N*193i/193i)
EPE EUV Stochastics ≥ EPE 193i Stochastic
Assuming everything else = We would want at EUV Insertion
EPE EUV (OL, Stochastics) < EPE 193i (OL, Stochastics)
EUV HVM Insertion - Materials
Stochastics Suppression

EUV Cuts and Vias

- Mn Cuts OL >0
- Mn+1, Vn OL&Stochastics >0
- Mn Cuts Stochastics >0

193i Cuts and Vias

- 5nm
- 10nm

EPE (EUV/193i OL) ≤ EPE (N*193i/193i)
EPE EUV Stochastics ≥ EPE 193i Stochastic
Assuming everything else = We would want at EUV Insertion
EPE EUV (OL, Stochastics) < EPE 193i (OL, Stochastics)
EUV HVM Insertion - Materials
Stochastics Suppression

EPE (EUV/193i OL) ≤ EPE (N*193i/193i)
EPE EUV Stochastics ≥ EPE 193i Stochastic
Assuming everything else = We would want at EUV Insertion
EPE EUV (OL, Stochastics) < EPE 193i (OL, Stochastics)

Given 5nm EPE limit what does it mean for EUV Stochastics?

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
EUV HVM Insertion - Materials
Stochastics Suppression

\[ EPE_{\text{all}} = EPE_{\text{OL}} \pm \frac{1}{2} \text{CD3}\sigma \]
\[ |EPE_{\text{all}}| = EPE_{\text{OL}} + \frac{1}{2} \text{CD3}\sigma \]

\( \text{CD3}\sigma = f(\text{resist stochastics, focus and dose errors, OPC residuals, mask errors with MEEFs, Etch Biases, etc, etc, etc}) \)

Assuming for simplicity for EUV:

\( \sigma(\text{resist stochastics}) = \sigma(\text{focus and dose errors, OPC residuals, mask errors with MEEFs, Etch Biases, etc, etc, etc}) \)

\[ |EPE_{\text{all}}| = EPE_{\text{OL}} + \frac{1}{2} \text{CD3}\sigma = EPE_{\text{OL}} + \frac{1}{2}\text{CD3}\sigma(2\text{resist stochastics}) \]

or, keeping it simple,

\[ |EPE_{\text{all}}| = EPE_{\text{OL}} + \text{CD3}\sigma(\text{resist stochastics}) = 5\text{nm} \]

Assuming EUV/193i \( EPE_{\text{OL}} = 2\text{nm} \)

\( \text{CD3}\sigma_{\text{EUV}}(\text{resist stochastics}) = 5\text{nm} - EPE_{\text{OL}} = 5\text{nm} - 2\text{nm} = 3\text{nm} \)
EUV HVM Insertion - Materials Stochastics Suppression

Figure 8. Comparison of $\sigma_{\text{image}}$ Booyang plots for NXE:3100 conventional vs. Quasar illumination. Litho targets are 1:1 Contacts at 54 nm pitch, IMEC setup POR.

EUV resist performance: current assessment for $\text{sub-22 nm half-pitch patterning on NXE:3300}$


Proc. of SPIE Vol. 8322, 83221J · © 2012 SPIE

$\text{CD}3\sigma_{\text{EUV}}(\text{resist stochastics}) = 3\text{nm} = \text{CD}3\sigma(\text{focus and dose errors, OPC residuals, mask errors, Etch Biases etc, etc, etc})$ will be very tough

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
### EUV HVM Insertion - Materials Stochastics Suppression

<table>
<thead>
<tr>
<th>Protecting group size</th>
<th>Resist A</th>
<th>Resist B</th>
<th>Resist C</th>
<th>Resist D</th>
<th>Resist E</th>
<th>Resist F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protecting group ratio</td>
<td>Bulky</td>
<td>Bulky</td>
<td>Bulky</td>
<td>Small</td>
<td>Small</td>
<td>Small</td>
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<tr>
<td>Sensitivity</td>
<td>46.0mJ</td>
<td>55.9mJ</td>
<td>61.4mJ</td>
<td>53.2mJ</td>
<td>54.5mJ</td>
<td>56.1mJ</td>
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<tr>
<td>CDU</td>
<td>9.7nm</td>
<td>5.8nm</td>
<td>3.6nm</td>
<td>Overdose</td>
<td>Overdose</td>
<td>3.8nm</td>
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<td>35nm CH</td>
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<tr>
<td>Sensitivity</td>
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<td>60.1mJ</td>
<td>70.6mJ</td>
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<td>59.5mJ</td>
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<tr>
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</table>

Table 2. CDU values and sensitivity for different protective group ratios at 30nm HP and 35nm HP contact hole patterns. All six samples were exposed on the AMET using annular illumination. Process conditions are the same.

**Key Parameters of EUV Resists for Contact Hole Applications**

Kyoungyong Cho 1, Hiroki Nakagawa 2, Ken Maruyama 2, Makoto Shimizu 3, Tooru Kimura 3, Yoshi Hishiro 2,

1 SEMATECH, 257 Fuller Road, Albany NY 12203  
2 JSR Micro, Inc., 1280 North Mathilda Avenue, Sunnyvale, CA 94809  
3 JSR Corporation, 100 Kawajiri-cho, Yokkaichi, Mie, 510-8552, Japan
In 2003, Lee, Bristol and Bjorkholm using photon shot noise statistics considerations only, derived formula for required incoming Dose ($D_{inc}$) to print all of $Z$ contacts size $S$ (nm) with Probability (Yield) $Y\%$ within Exposure Dose variation defined by exposure latitude $EL = 2\Delta N/N_0$ where $\Delta N = n\sigma$), assuming ratio of incoming radiation to absorbed by resist is given by $\alpha$ and quantum efficiency of photons producing species resulting in solubility change is given by $\varepsilon$. Plot on the right shows relation between $n$ and Yield for large contact arrays.

To print good all of $n*10^{10}$ $(3*1.4*10^9*2^n)$ contacts on 98% of the wafers require $n=7$ for $2\Delta N$ absorbed EUV photons (Ivy Bridge (22nm) has $1.4*10^9$ Transistors, assume 3 Contacts/Transistor.)

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
In 2003, Lee, Bristol and Bjorkholm using photon shot noise statistics considerations only, derived formula for required incoming Dose ($D_{inc}$) to print all of Z contacts size S (nm) with Probability (Yield) Y% within Exposure Dose variation defined by exposure latitude $EL = 2\Delta N/N_0$ where $\Delta N = n\sigma$, assuming ratio of incoming radiation to absorbed by resist is given by $\alpha$ and quantum efficiency of photons producing species resulting in solubility change is given by $\varepsilon$.

Plot on the right shows Dose needed to print good all $n*10^{10}$ contacts with 98% probability for EUV ($\varepsilon=2$) with $EL=5\%$ and rather generous absorption $\alpha=0.5$

$D_{inc} = Dose to Print (mj/cm^2), Photon stats Only!$

$n=7$
$\alpha=0.5$
$\varepsilon=2$
$EL=5\%$

Shot noise and process window study for printing small contact holes using EUV Lithography

EUV HVM Insertion - Materials
Stochastics Suppression

\[ CD3\sigma_{EUV}(\text{resist stochastics}) = 3\text{nm} = CD3\sigma (\text{Photon, } e^- \text{ Acid, Develop stats}) \]

\[ D_{inc} = \text{Dose to Print (mJ/cm}^2)\), Photon stats Only! \]

Contact Size (nm)

\[ D_{inc} \geq \frac{1.88}{\alpha \cdot \epsilon} \left[ \frac{2n}{EL \cdot S} \right]^2 \text{mJ/cm}^2 \]

\[ n=7 \quad \alpha=0.5 \quad \epsilon=2 \quad EL=5\% \]

Comparison of EUV and e-Beam Lithographic Technologies for Sub 22nm Node Patterning
James Cameron et al
Proc. of SPIE Vol. 8322 83222F-1

1

Shot noise and process window study for printing small contact holes using EUV Lithography
Sang H. Lee, Robert Bristol, John Bjorkholm

Yan Borodovsky, Intel, 2012
EUV HVM Insertion - Materials
Stochastics Suppression

\[ CD3\sigma_{\text{EUV}}(\text{resist stochastics}) = 3\text{nm} = CD3\sigma(\text{Photon, } e^-\text{ Acid, Develop stats}) \]

- Comparison of EUV and e-Beam Lithographic Technologies for Sub 22nm Node Patterning
  James Cameron et al. Proc. of SPIE Vol. 8322 83222F-1

- D\text{inc} = \text{Dose to Print (mJ/cm}^2\text{), Photon stats Only!}

- \( n=7 \)
- \( \alpha=0.5 \)
- \( \varepsilon=2 \)
- \( \text{EL}=5\% \)

- Shot noise and process window study for printing small contact holes using EUV Lithography

Yan Borodovsky, Intel, 2012
EUV HVM Insertion - Materials Stochastics Suppression

\[ CD3\sigma_{EUV}(\text{resist stochastics}) = 3\text{nm} = CD3\sigma (\text{Photon, e\textsuperscript{-} Acid, Develop stats}) \]

Comparison of EUV and e-Beam Lithographic Technologies for Sub 22nm Node Patterning
James Cameron et al 2012

\[ D_{inc} = \text{Dose to Print (mj/cm\textsuperscript{2})}, \text{ Photon stats Only!} \]

2013-2014

Contact Size (nm)

\[ n=7 \]
\[ \alpha=0.5 \]
\[ \varepsilon=2 \]
\[ EL=5\% \]

Shot noise and process window study for printing small contact holes using EUV Lithography
EUV HVM Insertion - Materials
Stochastics Suppression

\[ D_{inc} > 60 \text{mj/cm}^2 \]
EUV HVM Insertion - Materials
Stochastics Suppression

$D_{inc} > 60 \text{mj/cm}^2$

$D_{inc} > 60 \text{mj/cm} = \text{EUV Source Power at IF } \geq 1,000 \text{W at HVM Insertion}$

Yan Borodovsky, Intel, 2012 International Workshop on EUV Lithography, Maui, Hi
Re-target EUV Source Power Requirements for HVM Insertion

Shot noise statistics alone leads to conclusion that source in-band average power needed to expose resist capable to meet HVM Contacts and Cuts patterning requirements might need to exceed 1,000W at Intermediate Focus (IF).

While this is 4X of current source power targeted for EUV tools in 2013-2014 it is hard to expect 4X power gain during next several years through incremental improvement of existing designs.

New ideas and focused effort is necessary to enable concept, design and implementation of such source in relatively short time.

Having 1,000W average in-band power at IF source will enable resist vendors and their customers develop and select resist materials from large array of polymer and inorganic materials that already demonstrated properties close to required at suggested Exposure doses range for both Complementary and traditional lithography approaches.
Beyond Insertion

In my opinion it is critical for EUV HVM introduction to attain 100wph productivity with resists capable to limit impact of stochastic effects to CD3σ<3nm for contacts ~20nm diameter.

This most probably will require sources 4X more powerful then currently under development.

There is no benefit in developing higher resolution EUVL through NA>0.33 or λ=6.8nm unless resist stochastics effects can be reduced ~2X from current best CAR platforms levels

Priority for the resources and research dollars, euros, yens, wons and rubles available for “beyond Insertion” R&D projects should be speedy development of realistic solutions for 13.5nm Source capable of 1kW in-band Power at IF.
Conclusion

Significant OPC infrastructure development will be necessary to overcome EUV 3D Mask effects.

EUV source power targets need to be revised upwards (≥1kW average in-band @IF) to meet future Complementary Lithography and Contacts patterning technology needs.

Significant progress had been made to achieve EUV Pilot Capabilities, let's make sure opportunity for HVM insertion will not be missed.
Thank you for your attention