Mask Industry is Ready for Curvilinear ILT
A Decade of ILT!

6
Papers

2
Foundries

1
Memory

1
Mask shop
A Decade of ILT!

Fast Inverse Lithography Technology

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6
Papers

2
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Mask shop
ILT Adopted as the Way Forward

>200 Papers

Today

ILT expertise proliferated 2014 panel 2016 panel

Officially announced
Is the Entire Mask Supply Chain Ready for Curvilinear ILT Masks?

Mask Data Preparation → Mask Writing → Mask Metrology → Mask Inspection → Mask Review → Mask Repair
Big Changes Are Coming in Litho and Mask …

ILT Mask Patterns: Here Today

B.G. Kim, et al., BACUS, 2012

Multi-beam Mask Writing: 2017-2018

Source: NuFlare Technology

EUV Mask Production: 2018

Source: Barrett Research Group
68% Say Multi-beam HVM by end of 2018
2016 eBeam Initiative Survey

By the end of which year do you believe that multi-beam technology will be used for high volume manufacturing mask writing?

<table>
<thead>
<tr>
<th>Year</th>
<th>2014 (n=51)</th>
<th>2015 (n=61)</th>
<th>2016 (n=69)</th>
<th>2019 or later</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Respondents</td>
<td>4%</td>
<td>29%</td>
<td>35%</td>
<td>32%</td>
</tr>
</tbody>
</table>
EUV Pessimism is the Lowest in 5 Years
Only 6% Responded with “Never” in 2016

% of Respondents indicating EUV will never be used in HVM

<table>
<thead>
<tr>
<th>Survey Year</th>
<th>% of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012 (n=42)</td>
<td>11%</td>
</tr>
<tr>
<td>2013 (n=49)</td>
<td>22%</td>
</tr>
<tr>
<td>2014 (n=52)</td>
<td>35%</td>
</tr>
<tr>
<td>2015 (n=64)</td>
<td>15%</td>
</tr>
<tr>
<td>2016 (n=73)</td>
<td>6%</td>
</tr>
</tbody>
</table>

Source: 2016 eBeam Initiative Perceptions Survey www.ebeam.org
Multi-beam Provides Constant Write Time

Multi-beam has the shot count advantage > ~200 Gshot/pass

Source: NuFlare Technology, eBeam Initiative SPIE lunch 2016
Multi-beam is Great for Curvilinear ILT

Multi-beam exposure without loss of TPT

D2S note: Written on IMS alpha machine
But VSB, Multi-beam Will Co-exist for Years

What percentage of new mask writers purchased worldwide will be multi-beam writers in each year?

Source: 2016 eBeam Initiative Perceptions Survey www.ebeam.org
Is the Entire Mask Supply Chain Ready for Curvilinear ILT Masks?

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✔ ✔
The New ILT World Calls for New CD Metrology: Mask and Wafer!
The New ILT World Calls for New CD Metrology: Mask and Wafer!
Simulation Can Provide Aerial Image from High-Resolution SEM Image

SEM Contour Extraction

Aerial Image Simulation
The New ILT World Calls for New CD Metrology: Mask and Wafer!

GPU = Real-time for mask + wafer
Is the Entire Mask Supply Chain Ready for Curvilinear ILT Masks?

Mask Data Preparation ✔

Mask Writing ✔

Mask Metrology ✔

Mask Inspection

Mask Review

Mask Repair
Mask Inspection Tools Adding Aerial Image Inspection Mode

KT Teron™ 630

Selectable imaging modes to provide the necessary signal-to-noise ratio (SNR) to ensure defect-free 1Xnm generation reticles, whether optical reticles with complex OPC or EUV reticles (Source: KT website)

Applied AERA™4

Designed to emulate a scanner, the Aera4 system delivers superior first-time inspection success rate over other high-resolution inspection systems on advanced masks, including those with aggressive OPC, such as inverse lithography. (Source: AMAT website)
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✔ ✔ ✔ ✔
Simulation and Aerial-based Defect Review Has been Used in Production For Years

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✔ ✔ ✔ ✔ ✔
2D Mask Repair, Simulation-based Mask Repair Verification Used in Production For Years

Expanding the Applications of Computational Lithography & Inspection (CLI) in Mask Inspection, Metrology, Review, and Repair

Linyong Pang, Danping Peng, Peter Hu, Dongxue Chen, Lin He, Ying Li, Chris Clifford, Vikram Tolani
Luminescent Technologies, Inc. 2471 East Bayshore Road, Suite 600, Palo Alto, CA 94303, USA

2D Mask Repair, Simulation-based Mask Repair Verification Used in Production For Years

In-situ Repair Qualification by Applying Computational Metrology and Inspection (CMI) Technologies

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The Entire Mask Supply Chain is Ready for Curvilinear ILT Masks

Mask Data Preparation
- MB & handle CL
- MRC
- MDP: OLS
- MV

Mask Writing
- VSB: Overlapped shots
- Multi-beam

Mask Metrology
- Contour and EPE
- Wafer Plane Analysis

Mask Inspection
- Contour based
- MPI and WPI

Mask Review
- AIMS
- AIA: D2D, D2DB

Mask Repair
- Reference Pattern Generation