85 Luminaries Participated in the 12th Annual Survey
Representing 47 different companies in July 2023

What part of the semiconductor ecosystem is your primary focus?

- Chip design: 9%
- EDA/IP: 4%
- Mask manufacturing: 5%
- Equipment: 1%
- Materials: 12%
- Chip manufacturing: 23%
- Services: 41%
- Research: 5%
Luminaries Confident in High-NA EUV and Curvilinear Masks
12th Annual Luminaries Survey - July 2023

• Luminaries remain confident in broad High-NA EUV adoption by 2028

• Confidence doubled in leading-edge mask shops handling curvilinear mask demand

• Curvilinear masks aren’t just for EUV

• Luminaries are more confident about 2023 mask revenues than SEMI
83% Say 2023 Mask Revenues Increase or Stay the Same
While SEMI predicts a 3% contraction for 2023

According to SEMI's 2022 Photomask Characterization Study, the worldwide semiconductor photomask market achieved its tenth consecutive year of growth in 2022 amounting to $5.5 billion. A contraction of 3% is projected by SEMI in 2023 due to the macroeconomic headwinds and the overall semiconductor industry slowdown.
82% Predict High-NA EUV First HVM Usage by 2027
Similar to last year

When will High-NA EUV first be used for high volume manufacturing (HVM)? Choose one.
Broad High-NA EUV Adoption to Ramp Up by 2028
80% say by 2028 or before, same as last year

When will there be broad high volume manufacturing (HVM) adoption of High-NA EUV by more than one company? Please choose one.

- 2025 OR BEFORE: 10% (2022), 13% (2023)
- 2026: 3% (2022), 15% (2023)
- 2027: 39% (2022), 37% (2023)
- 2028: 19% (2022), 25% (2023)
- 2029 OR BEYOND: 19% (2022), 19% (2023)
- NEVER: 1% (2022), 1% (2023)

80%
New: SRAFs in the 4X dimension for High-NA EUV masks will need to be smaller. What will be the required minimum dimension (on mask) that mask shops need to manufacture for HVM production using High-NA EUV?

- > 30 nm: 5%
- 25 nm < and ≤ 30 nm: 23%
- 20 nm < and ≤ 25 nm: 33%
- 15 nm < and ≤ 20 nm: 38%
- ≤ 15 nm: 71%
No Agreement on Larger High-NA EUV Mask Size
New question may have been confusing

New: Please indicate your level of agreement or disagreement with the following statements:

High-NA EUV masks will be larger in dimensions. (n=74)

- 4% Strongly agree
- 27% Agree
- 34% Neither agree or disagree
- 23% Disagree
- 12% Strongly disagree
95% Agree Multi-Beam Mask Writers Needed for EUV
82% agree they are more accurate/precise vs leading-edge VSB

New: Please indicate your level of agreement or disagreement with the following statements:

Multi-beam mask writers are more accurate/precise as compared to leading-edge VSB writers. (n=78)
- 82% Agree
- 44% Strongly agree
- 38% Agree
- 15% Neither agree or disagree
- 3% Strongly disagree

Multi-beam mask writers are needed to write EUV masks, whether for Manhattan or curvilinear shapes. (n=83)
- 95% Agree
- 53% Strongly agree
- 42% Agree
- 2% Neither agree or disagree
- 2% Strongly disagree
75% Say 2-3 EUV Masks Needed If No Pellicle
25% think 4 or more, some much more

New: On the average overall for the whole industry, for EUV masks without pellicles, how many masks will be produced per exposure layer of a mask design this year?

| 10 or more | 7% |
| 6-9        | 4% |
| 4-5        | 14% |
| 2-3        | 75% |

Responses (n=56)
Half Say ≥ 90% Transmission Rate to Use EUV Pellicle
Wide range expressed by other half of respondents

New: At what one-way transmission rate do you think most of .33 NA EUV high volume manufacturing (HVM) masks will end up with pellicles on them? You can answer by sliding the bar or inputting a number in the box.

Responses (n=83)
Note: this question did not have an option to say “no opinion”
Two respondents didn’t complete this question.
EUV Masks Inspected by Actinic to Double in 3 Years
Survey says it will double to >60% by 2026

By 2023
New: What percentage of .33 NA EUV high volume manufacturing (HVM) production masks will be inspected in the mask shop using actinic inspection this year (2023)?
n=67

- 39% 0-20%
- 34% 21-40%
- 18% 41-60%
- 4% 61-80%
- 4% 81-100%

By 2026
New: What percentage of .33 NA EUV high volume manufacturing (HVM) production masks will be inspected in the mask shop using actinic inspection this year (2026)?
n=68

- 31% 0-20%
- 16% 21-40%
- 15% 41-60%
- 31% 61-80%
- 7% 81-100%
Majority Say All of EUV Mask Making is More Expensive
86% say EUV blanks, 47% say EUV inspection equipment >2X cost of 193i

<table>
<thead>
<tr>
<th>New: How much more expensive is EUV versus 193i leading-edge mask equipment, materials and software?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheaper</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>OPC/ILT software and hardware (n=61)</td>
</tr>
<tr>
<td>MDP/MPC software and hardware (n=62)</td>
</tr>
<tr>
<td>Mask repair (n=68)</td>
</tr>
<tr>
<td>Mask inspection (n=74)</td>
</tr>
<tr>
<td>Mask writers (n=74)</td>
</tr>
<tr>
<td>Mask resist (n=64)</td>
</tr>
<tr>
<td>Mask blanks (n=70)</td>
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<td></td>
</tr>
</tbody>
</table>
New: What do you predict will happen to overall investment in equipment purchase for 193i only over the next 3 years?

- Mask inspection tools (n=81):
  - Increase: 63%
  - Stay about the same: 36%
  - Decrease: 1%

- eBeam multi-beam mask writers (n=79):
  - Increase: 77%
  - Stay about the same: 19%
  - Decrease: 4%

- eBeam VSB mask writers (n=80):
  - Increase: 31%
  - Stay about the same: 41%
  - Decrease: 28%

- Laser mask writers (n=78):
  - Increase: 41%
  - Stay about the same: 41%
  - Decrease: 18%
Deep Learning Perception No Longer Shifting Into Future
56% say 2024 or before this year and 58% last year

In the mask industry, when will capabilities based on deep learning become a competitive advantage for any step in the mask making process?

- 2021 or before: 7%
- 2022: 15%
- 2023: 35%
- 2024 or beyond: 31%
- Never: 2%

- 2021 n=73

- 2022 or before: 11%
- 2023: 22%
- 2024: 25%
- 2025 and beyond: 38%
- Never: 3%

- 2022 n=63

- 2021 or before: 7%
- 2022: 15%
- 2023: 34%
- 2024: 19%
- 2025 and beyond: 25%
- Never: 2%

- 2023 n=77
New: "Non-EUV leading edge for the industry" is a node at which fabs using 193i lithography reaches a practical limit of economic viability. Which logic node is that today (2023) and in 7 years (2030)?

<table>
<thead>
<tr>
<th>Node Range</th>
<th>2023 (n=78)</th>
<th>2030 (n=77)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;28nm</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>&gt;20nm and ≤28nm</td>
<td>4%</td>
<td>3%</td>
</tr>
<tr>
<td>&gt;14nm and ≤20nm</td>
<td>8%</td>
<td>1%</td>
</tr>
<tr>
<td>&gt;11nm and ≤14nm</td>
<td>19%</td>
<td>25%</td>
</tr>
<tr>
<td>&gt;7nm and ≤11nm</td>
<td></td>
<td>41%</td>
</tr>
<tr>
<td>&gt;5nm and ≤7nm</td>
<td></td>
<td>39%</td>
</tr>
<tr>
<td>≤5nm</td>
<td></td>
<td>23%</td>
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<td>4%</td>
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</tbody>
</table>

"Non-EUV Leading Edge” Node Ranges >5nm to ≤ 14nm
Survey Predicts Curvilinear ILT for 193i as well as EUV
70% agree useful for 193i, 75% agree needed for 2nm .33 NA EUV

New: Please indicate your level of agreement or disagreement with the following statements:

Curvilinear ILT is useful for 193i for non-EUV leading-edge nodes. (n=80)

- Strongly agree: 70%
- Agree: 24%
- Neither agree or disagree: 24%
- Disagree: 6%

Curvilinear ILT is needed for 2nm logic with .33 NA EUV at least for hot spots. (n=77)

- Strongly agree: 26%
- Agree: 49%
- Neither agree or disagree: 18%
- Disagree: 5%
- Strongly disagree: 1%
Survey Trend is Towards More Critical Layers Using ILT
46% say “some critical layers” in 2023 vs 46% said a “few” in 2022

How broadly is inverse lithography (ILT) used for production chips today (2023)?

- All critical layers of leading edge nodes use ILT: 46%
- Some critical layers of leading edge nodes use ILT: 11%
- A few critical layers of leading edge nodes use ILT: 39%
- No layers use ILT (yet): 3%
No Major Change in Curvilinear Mask Making Concerns

Please rank your biggest concerns in producing masks with curvilinear* shapes. n≥71

#1: Mask shop software infrastructure
#2: Mask Inspection
#3: Mask Metrology
#4: ILT software
#5: Access to Multi-beam Mask Writers
#6: Mask Repair

Note: 1-6 on X-axis indicate # of respondents that ranked that question as that ordinal number with 1 = highest

N/A=14%
N/A=13%
N/A=14%
N/A=13%
N/A=16%
N/A=15%

*The survey question included “Curvilinear shapes can be piecewise linear polygons of some resolution, Bezier, B-spline or other curved-edge descriptions, but excludes shapes that only contain Manhattan or 45-degree straight edges.”
Confidence Doubled in Handling Curvilinear Mask Demand
87% say leading-edge mask shops can handle at least limited number

Are the concerns in HVM of masks containing curvilinear features insurmountable for the leading-edge mask shops by end of 2023? Please select the statement you agree with most about the curvilinear capability of leading-edge mask shops by the end of 2023

- They have no problem with such masks.
- They can handle as many such masks as there is demand.
- They can handle some limited number of such masks.
- They can handle a very few special cases of such masks, but not yet in general.
- The concerns are insurmountable for now.

2022 (n=70) 2023 (n=74)

- 1% 1%
- 9% 1%
- 16% 32%
- 51% 54%
- 12% 23%

87%
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• Luminaries remain confident in broad High-NA EUV adoption by 2028: 80% of Luminaries surveyed say more than one company will adopt High-NA EUV by 2028, same as last year.

• Confidence doubled in leading-edge mask shops handling curvilinear mask demand: 32% said they can handle the demand vs 16% last year; while 87% of Luminaries say leading-edge mask shops can handle at least a limited number.

• Curvilinear masks aren’t just for EUV: 70% of Luminaries say curvilinear masks are useful for non-EUV leading edge nodes.

• Luminaries are more confident than SEMI about 2023 mask revenues: 83% of Luminaries say 2023 mask revenues will increase (30%) or stay the same (53%) despite SEMI forecasting a contraction of 3%.
Thank you to those who participated in the survey!

Luminaries survey results available on www.ebeam.org