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eBeam Initiative Annual Survey Results

Photomask Japan 2021

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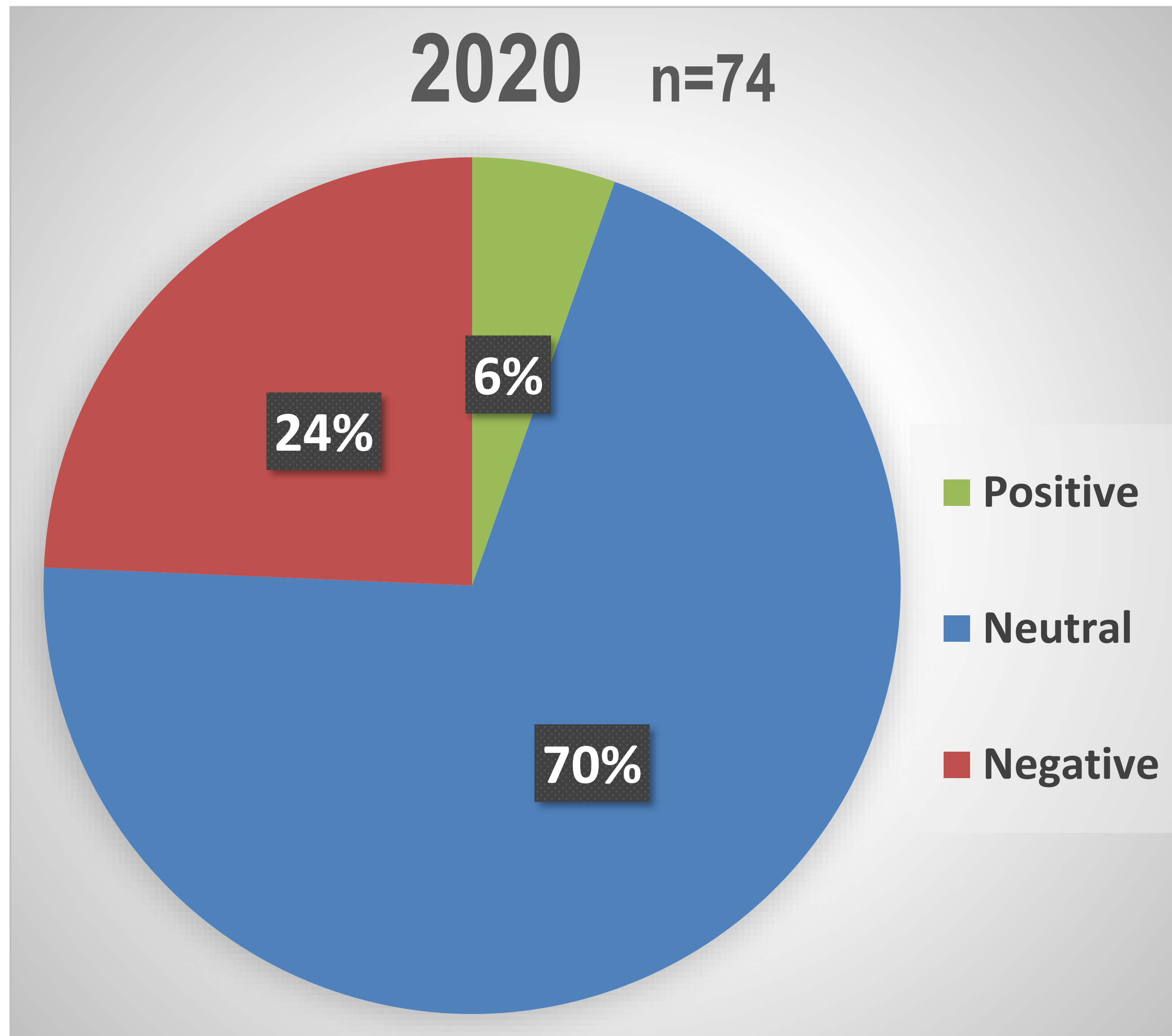
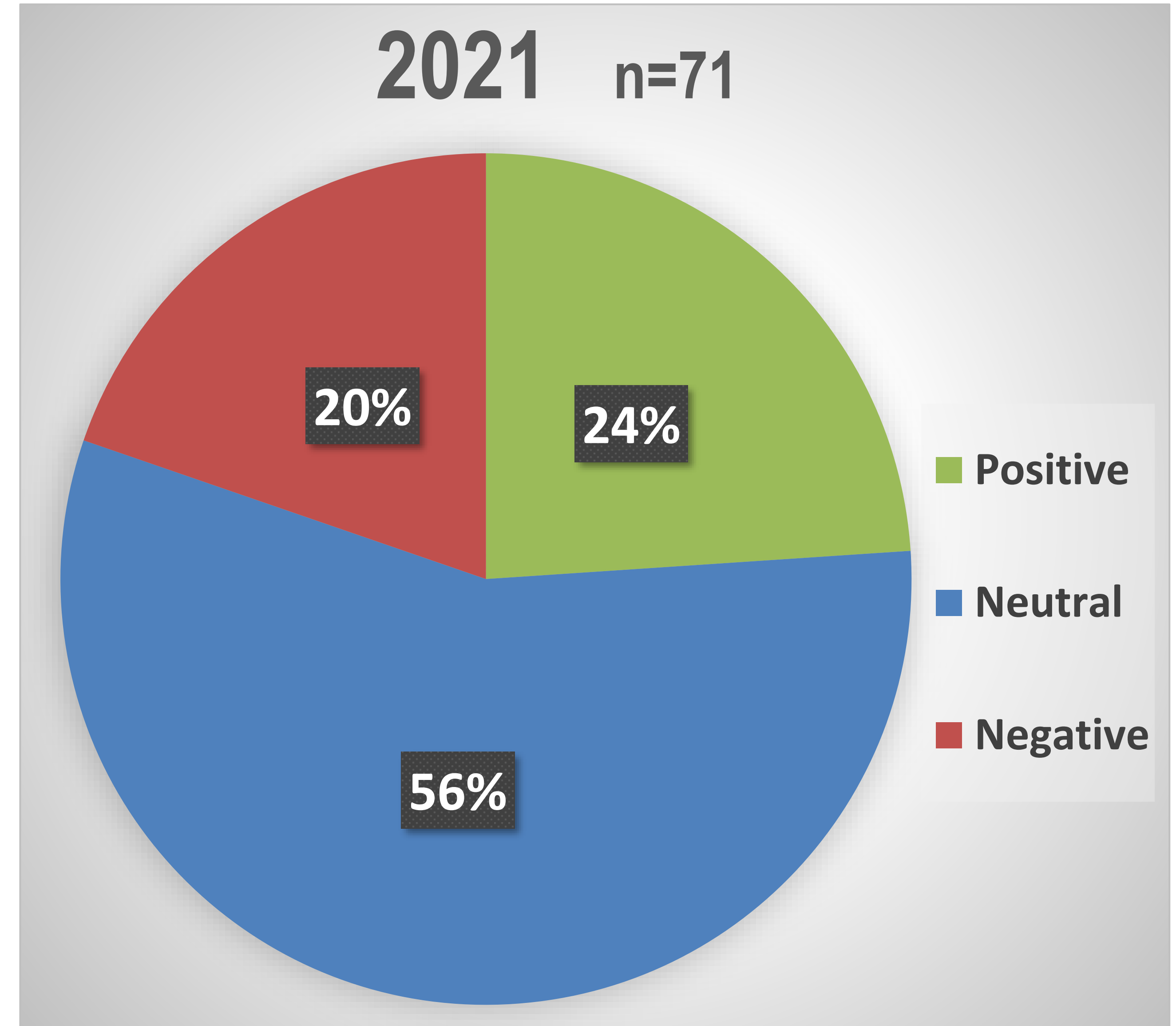
Survey Says Net Neutral COVID-19 Business Impact

By 2021, 24% positive vs 20% negative predictions

What business impact do you think COVID-19 will have on (2020, 2021) total mask revenues?





66% Say EUV Positive for 2020 Mask Revenues

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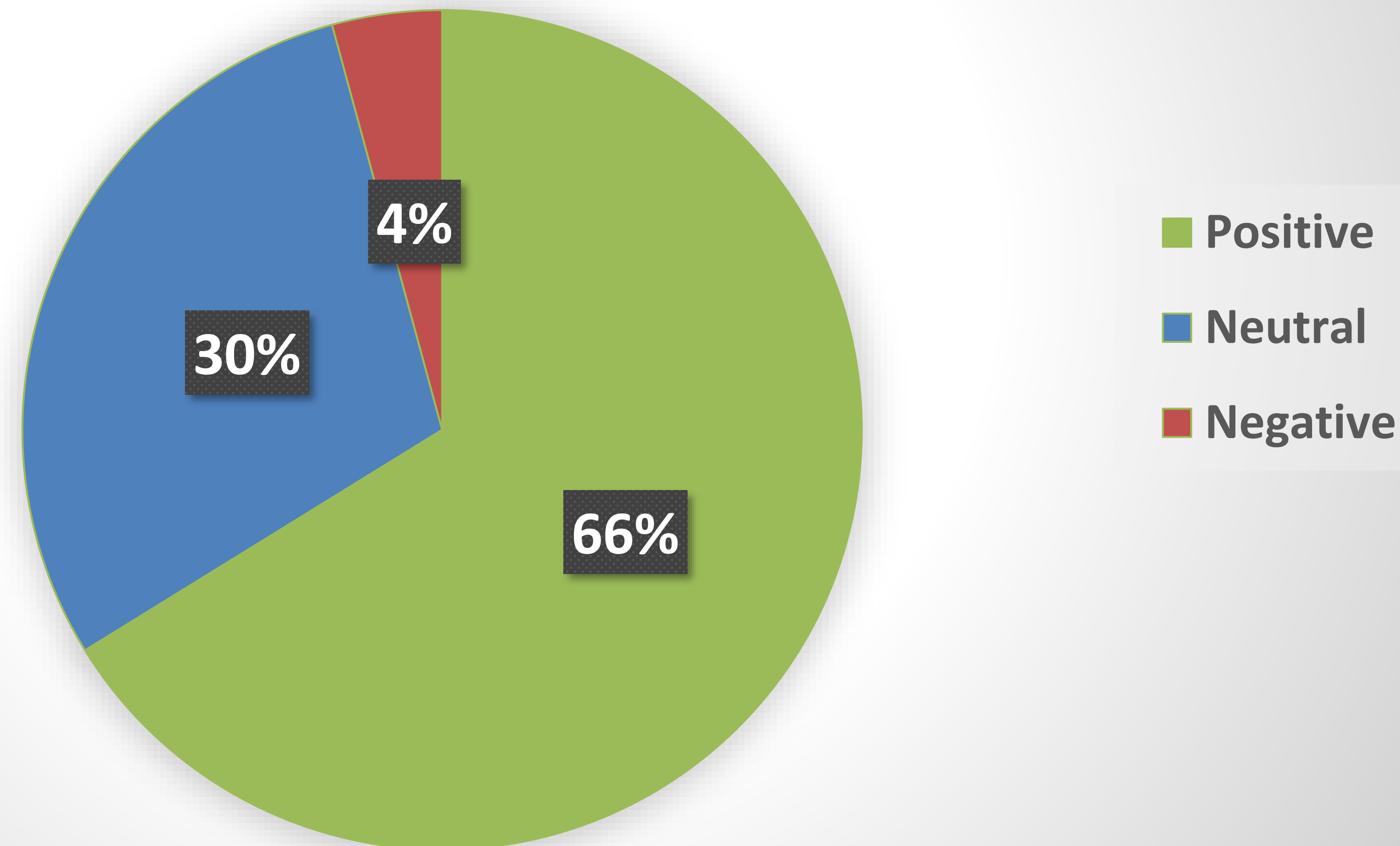
There are fewer masks per wafer with EUV, but each EUV mask is more expensive. Net of all effects, how will the increased use of EUV contribute to the size of total 2020 mask revenues? n=71



55% Say EUV Pellicles for HVM by End of 2022

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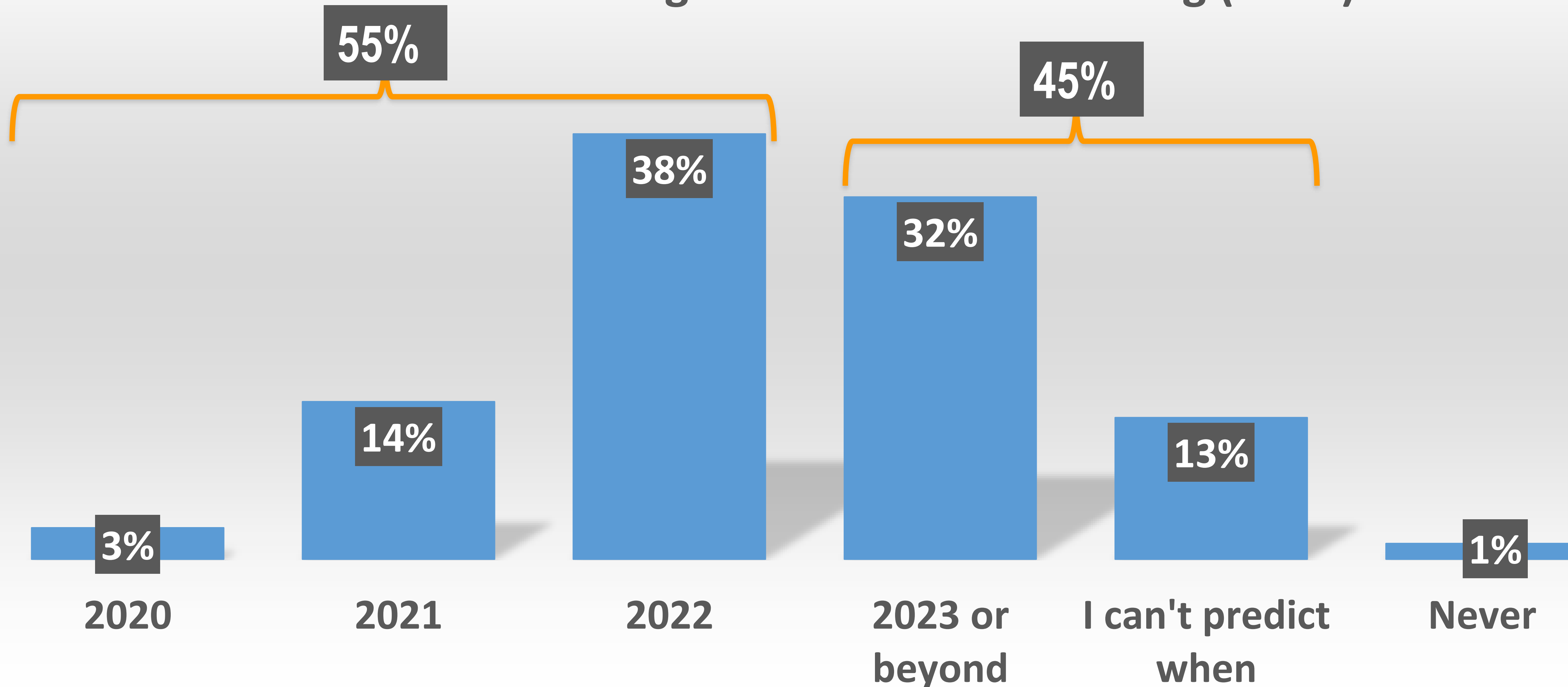

74% Agree Actinic Inspection for EUV HVM by 2023

48% eBeam multi-beam mask inspection, 51% eBeam multi-beam wafer inspection

Regarding EUV mask pattern inspection, please indicate your level of agreement with the following statements:
n=69

Statement	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
Actinic inspection will be used in the mask shop for EUV high volume manufacturing (HVM) by 2023	23%	51%	13%	11%	1%
eBeam multi-beam inspection will be used in the mask shop for EUV HVM by 2023	9%	39%	23%	27%	3%
eBeam multi-beam inspection of wafers will be used for the purpose of mask inspection for EUV HVM by 2023	9%	42%	25%	22%	3%

74%
48%
51%

EUV is Driving Multi-Beam Writer Purchases

Survey participants ranked six reasons

Q: Please rank the primary reasons for purchasing multi-beam mask writers. Note in the answers below, precision refers to CD uniformity as well as placement accuracy. n=77

#1 : More throughput for EUV Masks

1 2 3 4 5 6

N/A=8%

#2 : More precision required for EUV Masks

1 2 3 4 5 6

N/A=9%

#3 : Curvilinear inverse lithography technology (ILT) for 193i

1 2 3 4 5 6

N/A=8%

#4 : Curvilinear inverse lithography technology (ILT) for EUV

1 2 3 4 5 6

N/A=10%

#5 : More precision required for leading-edge 193i masks

1 2 3 4 5 6

N/A=10%

#6 : More throughput for 193i masks

1 2 3 4 5 6

N/A=12%

Note: 1-6 on X-axis indicate % of respondents that ranked that question as that ordinal number

84% Say ILT in Use Today

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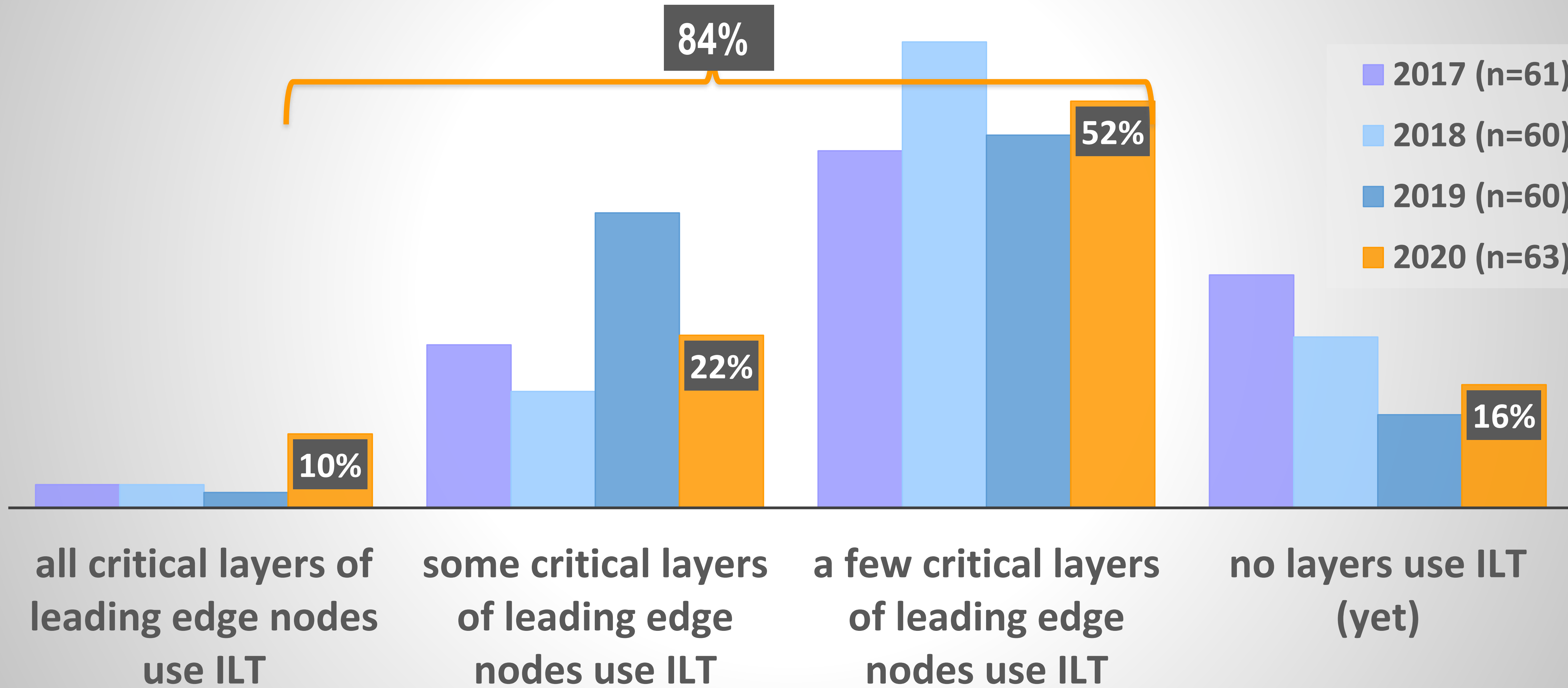


Curvilinear Shapes Predicted for EUV

94% of 193i, 85% of EUV masks with some curvilinear by 2023

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?

	193i Masks n=68	EUV Masks n=61
entire reticles of curvilinear shapes	12%	6%
a hybrid of mostly curvilinear shapes and some Manhattan shapes	20%	33%
a hybrid of mostly Manhattan shapes with some curvilinear shapes	62%	46%
only Manhattan shapes including 45 degree shapes	6%	15%

Multi-Beam and EUV Trends Becoming Visible

- **Thank you to 10 participating companies in 2020 Mask Makers Survey:**
  - AMTC, DNP, HOYA, Intel, Micron, Photronics (incl PDMC), Samsung, SMIC, TMC, Toppan
  - Independently collected by David Powell, Inc.

- **Not the same participating companies as last year so yearly comparisons inconclusive in most cases**

- **Collected data "for the last 12 months (July 2019 to June 2020)"**

- **Survey slides available at www.ebeam.org**

558,834 Masks Delivered by 10 Companies

Masks Delivered by Ground Rule

2019 (n=11)
2020 (n=10)

350000
300000
250000
200000
150000
100000
50000
0

296,365
57,286
45,923
44,141
27,425
30,680
17,135
16,472
13,786
7,995
1,625

≥130nm	≥90nm and <130nm	≥65nm and <90nm	≥45nm and <65nm	≥32nm and <45nm	≥22nm and <32nm	≥16nm and <22nm	≥11nm and <16nm	≥ 7nm and <11nm	≥5nm and <7nm	<5nm
n=8	n=8	n=8	n=8	n=7	n=8	n=9	n=5	n=6	n=2	n=2

Masks Delivered by Ground Rule
Leading Edge (LE) <45nm

2019 (n=11)
2020 (n=10)

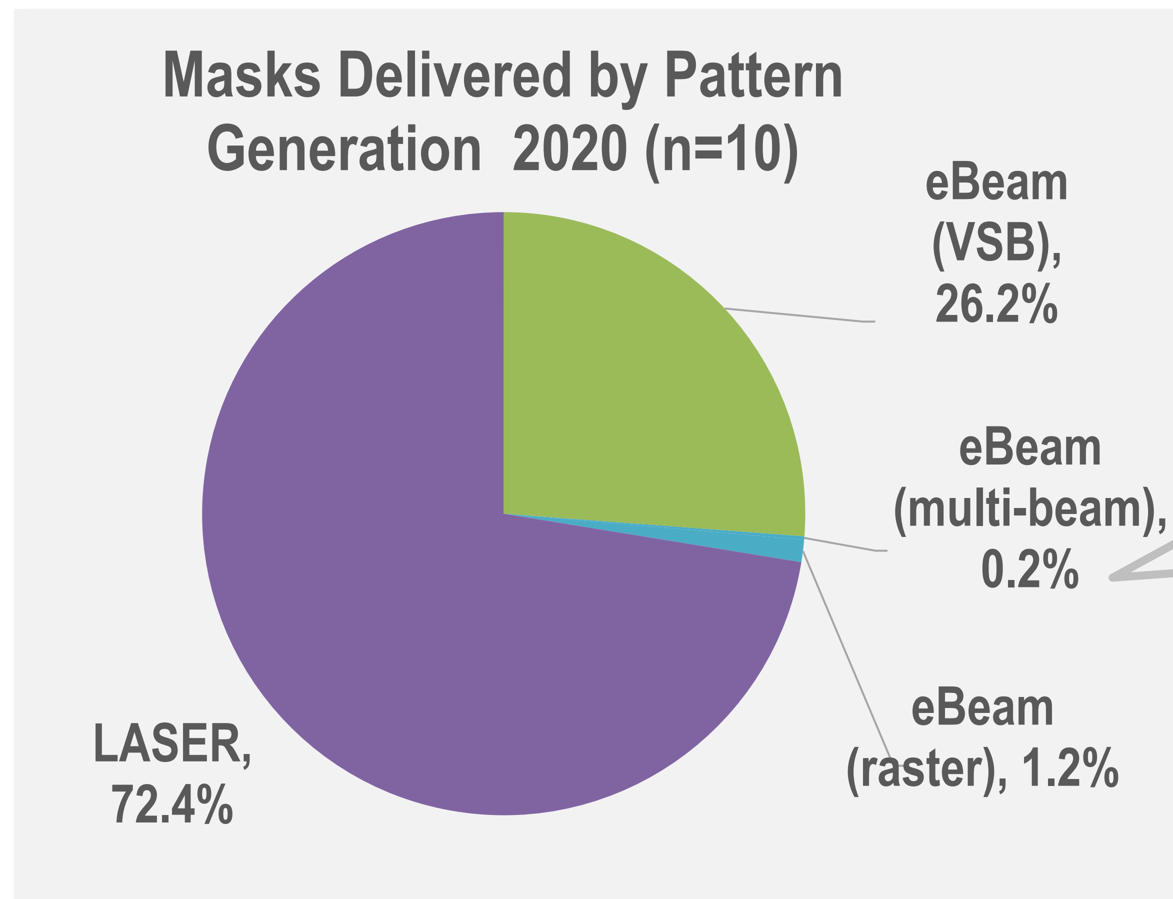
35000
30000
25000
20000
15000
10000
5000
0

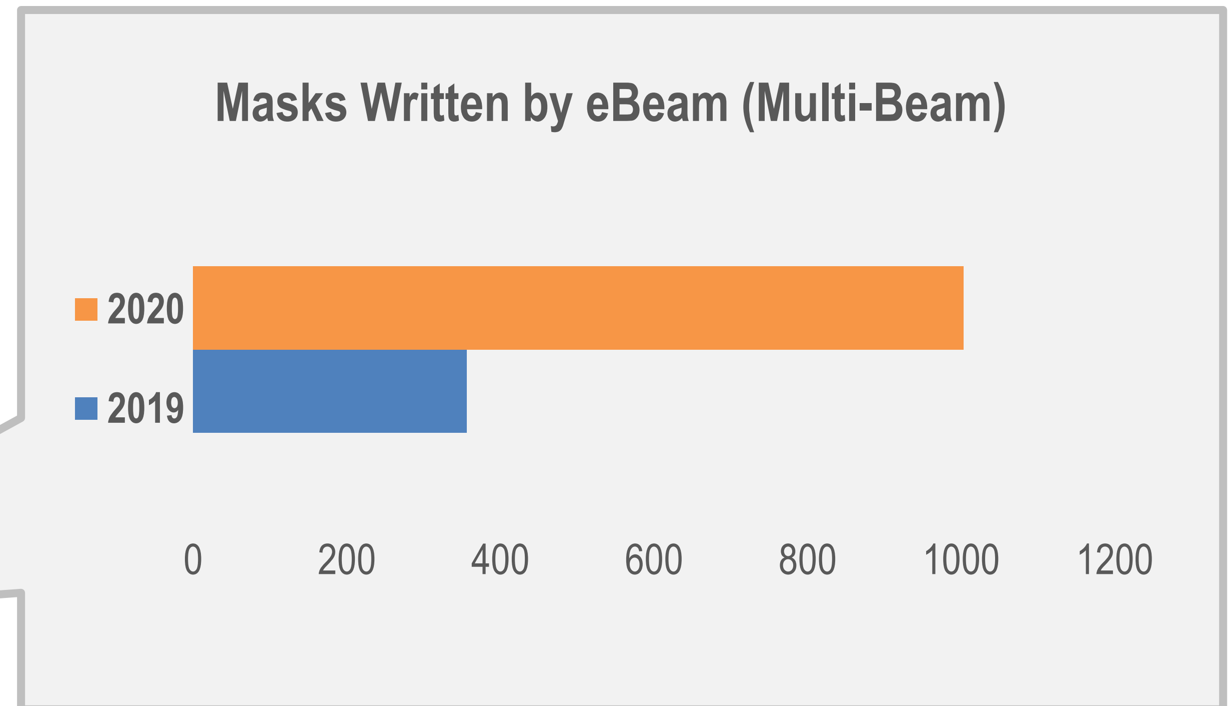
≥32nm and <45nm
≥22nm and <32nm
≥16nm and <22nm
≥11nm and <16nm
≥ 7nm and <11nm
≥5nm and <7nm
<5nm

Q: What was the number of masks delivered?

Q: Percentage of the total number of masks in the preceding question by Ground Rules of the critical layers?

Multi-Beam Masks More than Doubled





Q: What was the % written by the following pattern generation?
eBeam (VSB), eBeam (multi-beam), eBeam (raster), LASER, Other

94.2% Mask Yield Reported*

EUV Mask Yield Reported was 91%

Mask Yield 2020

2020 | 2019 | 2018

All Masks (n=10) — 94.2%

EUV (n=4) — 91%

AltPSM (n=4) — 87%

AttPSM (n=10) — 89%

Binary (n=10) — 96%

0.0% 10.0% 20.0% 30.0% 40.0% 50.0% 60.0% 70.0% 80.0% 90.0% 100.0%

Q: What was your overall mask yield? Q: What was your percent mask yield by category?

* Yearly comparisons inconclusive due to participant change

TAT Increasing at Smaller Ground Rules

Mask Shops that do Leading Edge May Tend to be Faster

TAT Weighted Avg

◆ 2020 Wt Avg (n=9 before excl outliers)

Ground Rule	n	Days
≥130nm	n=7	2.84
≥90nm and <130nm	n=7	3.82
≥65nm and <90nm	n=7	4.68
≥45nm and <65nm	n=7	4.83
≥32nm and <45nm	n=6	5.11
≥22nm and <32nm	n=7	6.31
≥16nm and <22nm	n=5	8.43
≥11nm and <16nm	n=8	9.73
≥ 7nm and <11nm	n=5	7.53

Days (0.00–25.00)

n<3 for <7nm

Normalized Average of TAT Change as Ground Rules shrink (n=8)

Ground rules on the x-axis: ≥130nm; ≥90nm and <130nm; ≥65nm and <90nm; ≥45nm and <65nm; ≥32nm and <45nm; ≥22nm and <32nm; ≥16nm and <22nm; ≥11nm and <16nm; ≥7nm and <11nm. The y-axis runs from 0.00 to 1.40.

"Normalized average" takes a ratio of a company's response to that company's response for ≥11nm and <16nm and then averages for all companies that responded for that ground rule.

Q: What was your average Turn-Around-Time (TAT) per mask for critical layer masks by Ground Rules in the past year? (Please note, this question is only asking about critical layer masks, not the average of all masks.)

Weighted Average is computed by averaging each company response of each category multiplied by that company's percentage share of reported masks of that category.

Mask Data Prep Time More Than Doubled <32nm

Avg Mask Data Prep Time

◆ 2020 Wt Avg

Hours

Ground Rules	n	2020 Wt Avg (hours)
≥130nm	n=7	3.44
≥90nm and <130nm	n=7	3.16
≥65nm and <90nm	n=7	2.22
≥45nm and <65nm	n=6	6.85
≥32nm and <45nm	n=7	8.98
≥22nm and <32nm	n=7	7.96
≥16nm and <22nm	n=8	22.64
≥11nm and <16nm	n=6	18.90
≥ 7nm and <11nm	n=3	17.26

n<3 for <7nm

Normalized Average of MDP Time Change as Ground Rules shrink (n=6)

Y axis: 0.000, 0.500, 1.000, 1.500, 2.000, 2.500

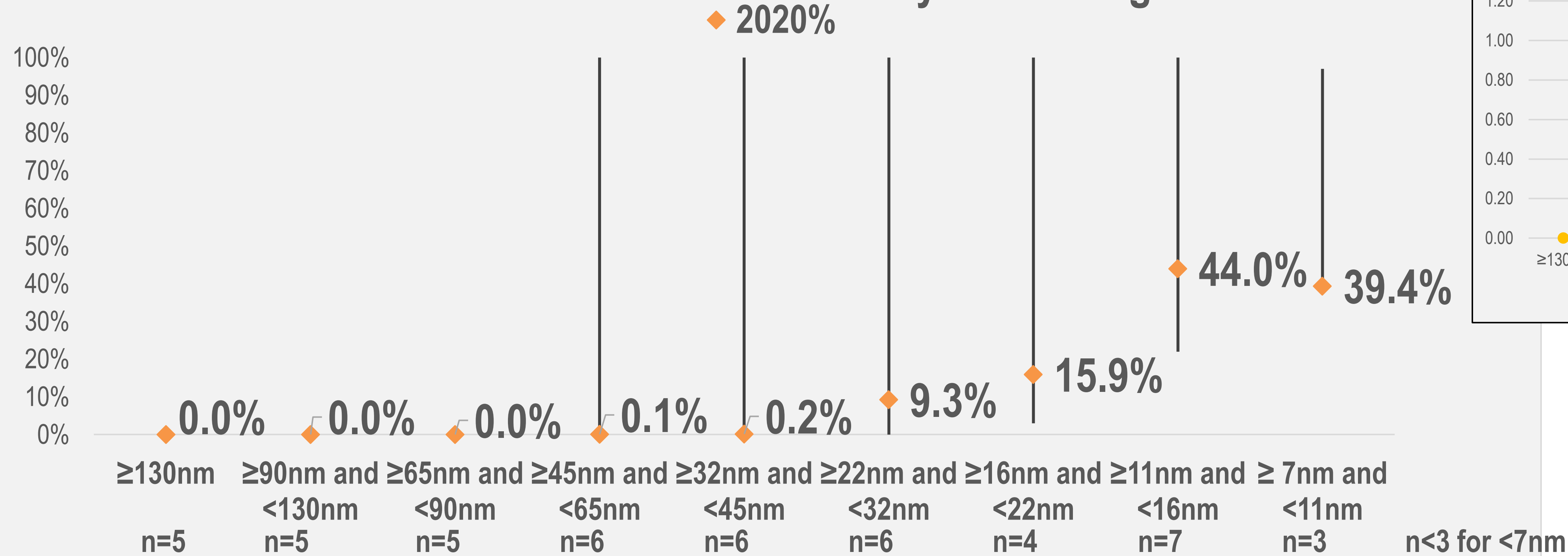
X axis: ≥130nm; ≥90nm and <130nm; ≥65nm and <90nm; ≥45nm and <65nm; ≥32nm and <45nm; ≥22nm and <32nm; ≥16nm and <22nm; ≥11nm and <16nm; ≥7nm and <11nm

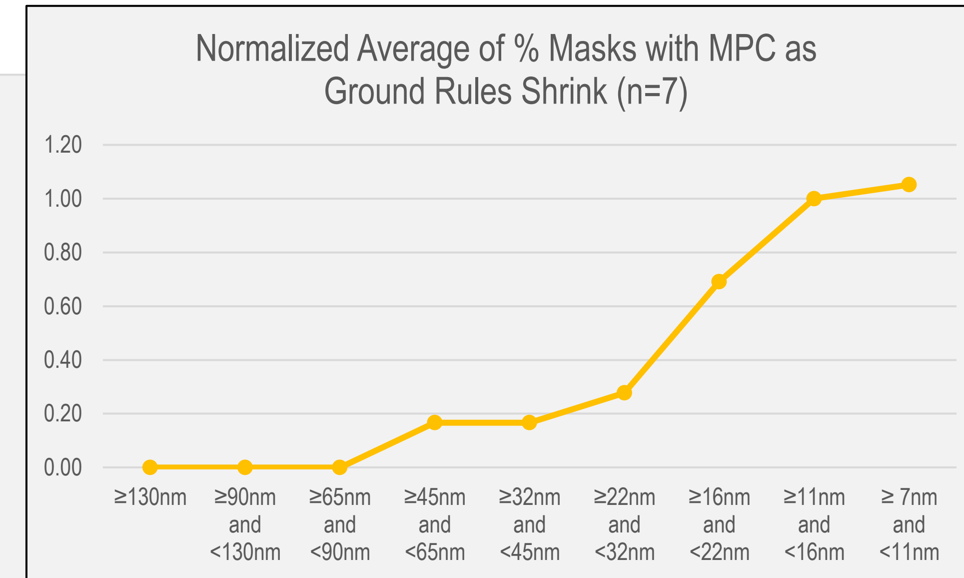
"Normalized average" takes a ratio of a company's response to that company's response for ≥11nm and <16nm and then averages for all companies that responded for that ground rule.

Q: What was the average data prep time (starting point defined as RET output) by Ground Rules?

Weighted Average is computed by averaging each company response of each category multiplied by that company's percentage share of reported masks of that category.

MPC Usage Increasing at Leading Edge Nodes





"Normalized average" takes a ratio of a company's response to that company's response for ≥11nm and <16nm and then averages for all companies that responded for that ground rule.

Revised Q: What percentage of critical layer masks by Ground Rules had Mask Process Correction (MPC) applied in the past year? (Please note, this question is only asking about critcial layer masks, not the percentage of all masks. MPC is defined as offline manipulation of geometry and/or dose of mask shapes during mask data preparation of the specified mask shapes received from OPC/ILT in order to more reliably manufacture the specified mask shapes on the physical mask or to maintian site-to-site compatibility. PEC, LEC, FEC, and other corrections performed by the writer are not considered MPC. But if, for example, EUV mid-range correction is performed offline during mask data preparation instead of using the inline writer capability, then this should be considered MPC.)

Exciting Times in the Photomask Industry

- Growing market
- EUV
- Multi-beam
- Curvilinear

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