eBeam Initiative

2019-2020 Mask Maker Survey Results

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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

Ground rule	Data label	n
≥130nm	296,365	n=8
≥90nm and <130nm	57,286	n=8
≥65nm and <90nm	45,923	n=8
≥45nm and <65nm	44,141	n=8
≥32nm and <45nm	27,425	n=7
≥22nm and <32nm	30,680	n=8
≥16nm and <22nm	17,135	n=9
≥11nm and <16nm	16,472	n=5
≥ 7nm and <11nm	13,786	n=6
≥5nm and <7nm	7,995	n=2
<5nm	1,625	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?

Masks per Mask Set Data was Inconclusive

Insufficient number of respondents for 7-11nm to report

Masks Per Mask Set by Ground Rule

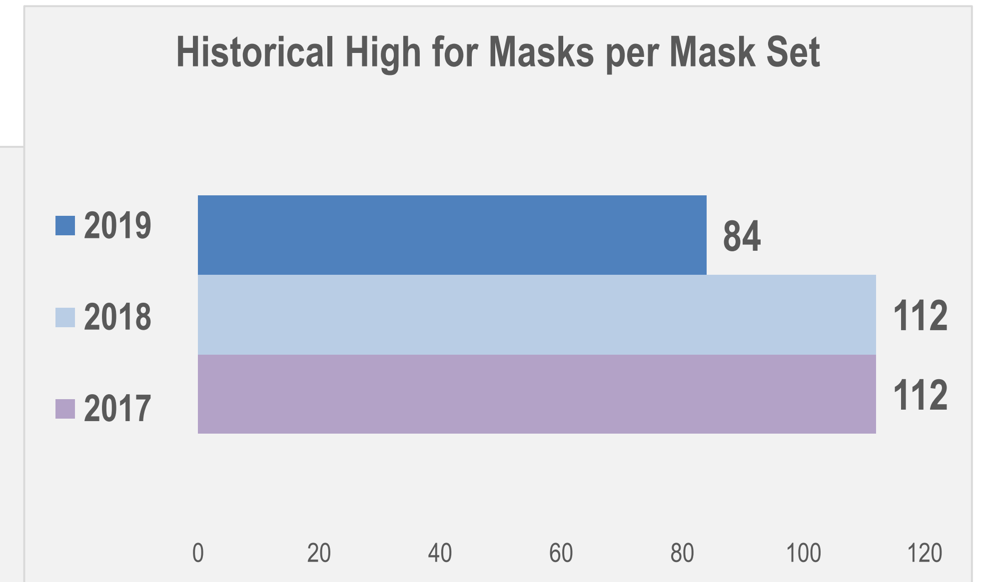
2020 Weighted Avg (n=8)

Avg # Masks/Mask Set

Ground Rule	≥130nm	≥90nm and <130nm	≥65nm and <90nm	≥45nm and <65nm	≥32nm and <45nm	≥22nm and <32nm	≥16nm and <22nm	≥11nm and <16nm
2020 Weighted Avg	21	35	37	40	43	47	59	64
n	n=7	n=7	n=7	n=7	n=6	n=7	n=5	n=7

75

n<3 for <11nm

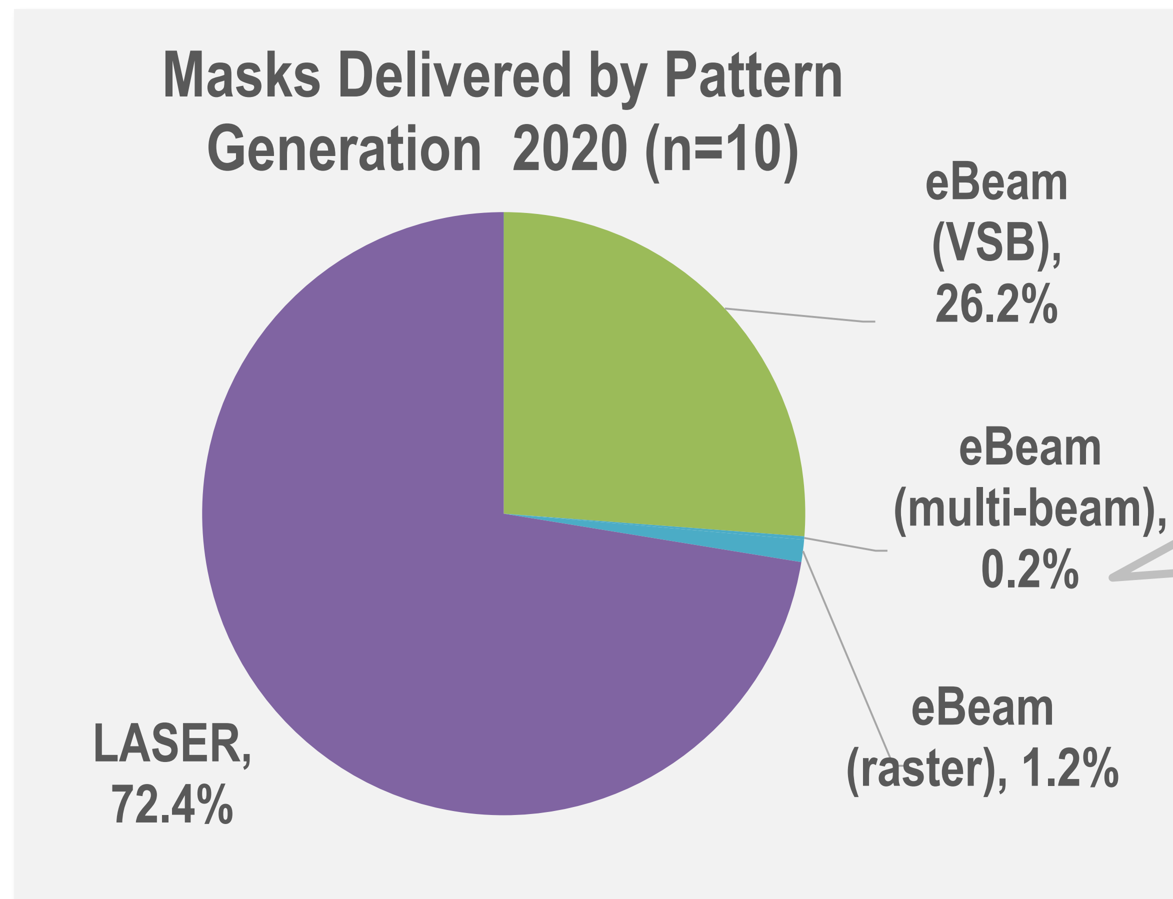


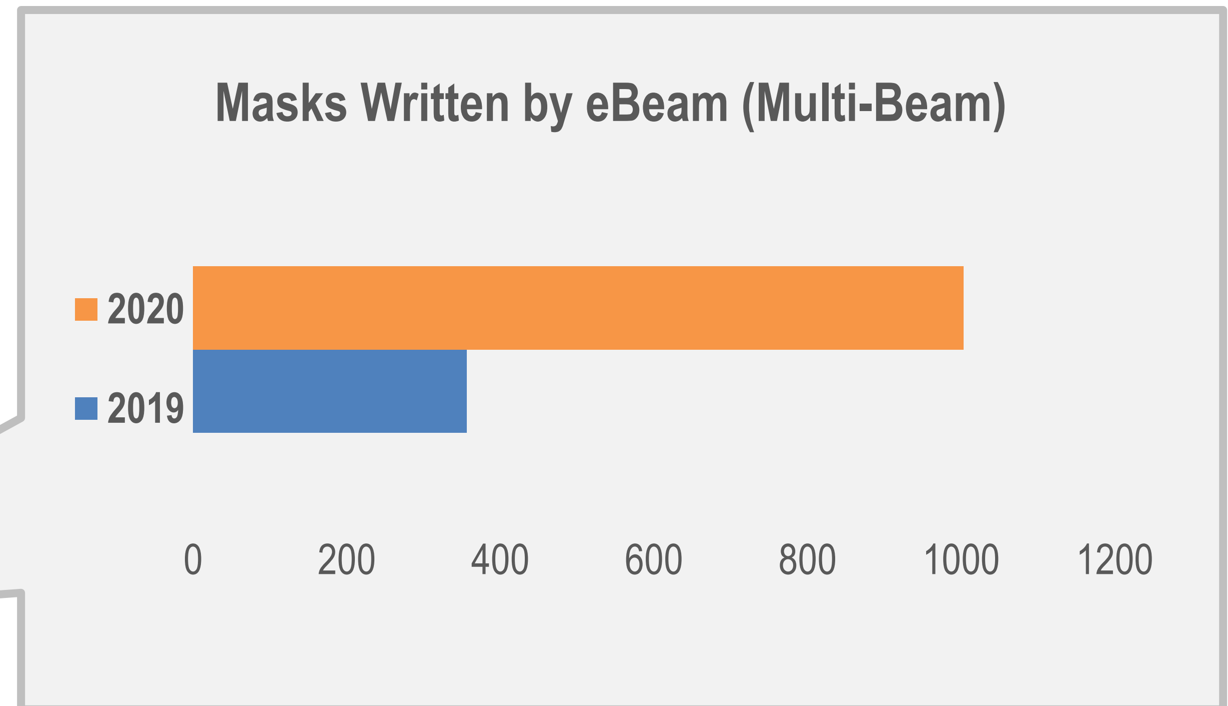
In these years, we had sufficient number of responding companies to report 7-11nm

Q: What was the average # of masks per mask set 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.

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

1st Time to Report Avg Multi-Beam Write Time

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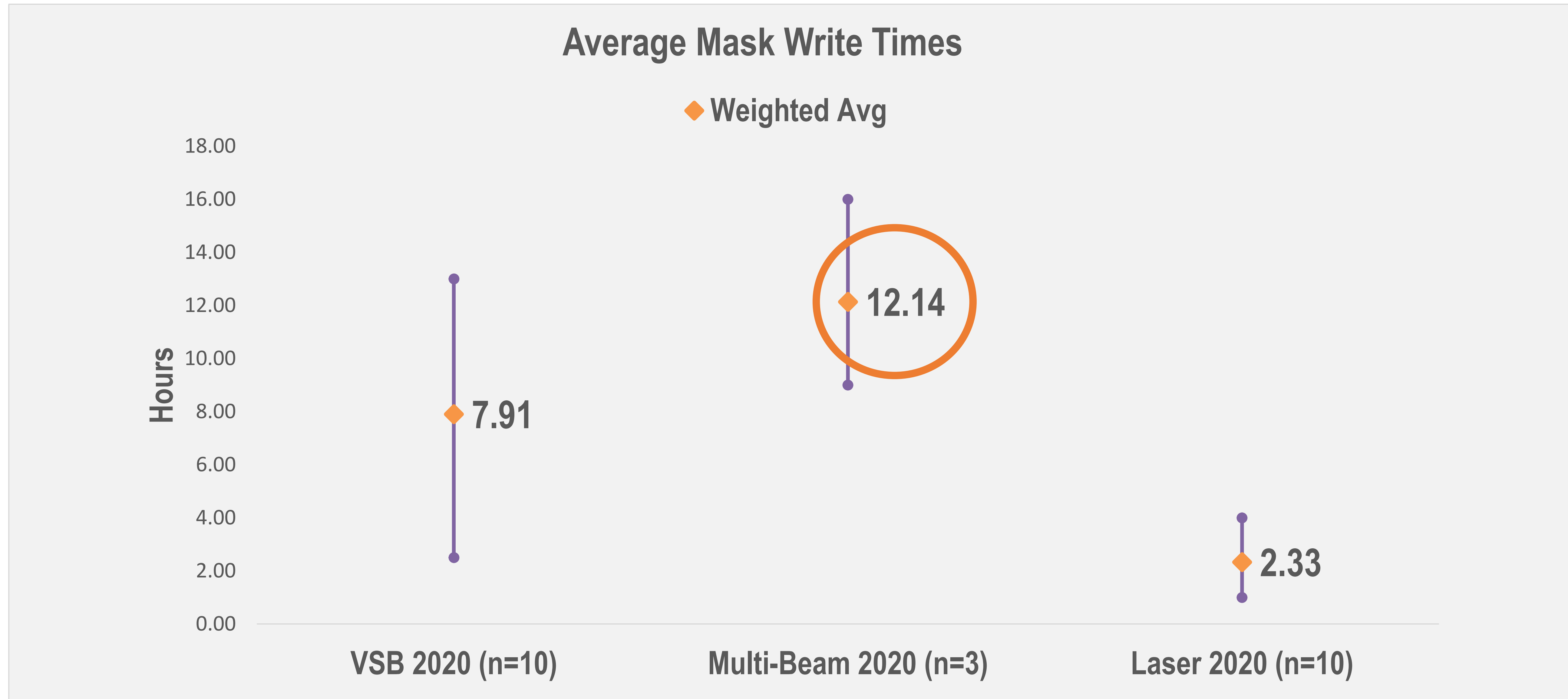

Q: What was the average write time for each type of pattern generation*?

For Weighted Avg, each response of each writer type is weighted by percentage share of that company of total reported masks of that type.

Longest Write Time Reported is VSB ~57 Hours

~30 hour longest Multi-Beam Write Time Reported (n=3)

Note: n=10 for 2020 are different 10 companies than n=10 for 2019, 2018

Q: What was the longest write time for each type of pattern generation?

Median for Largest VSB Data Volume is 1.1 TB

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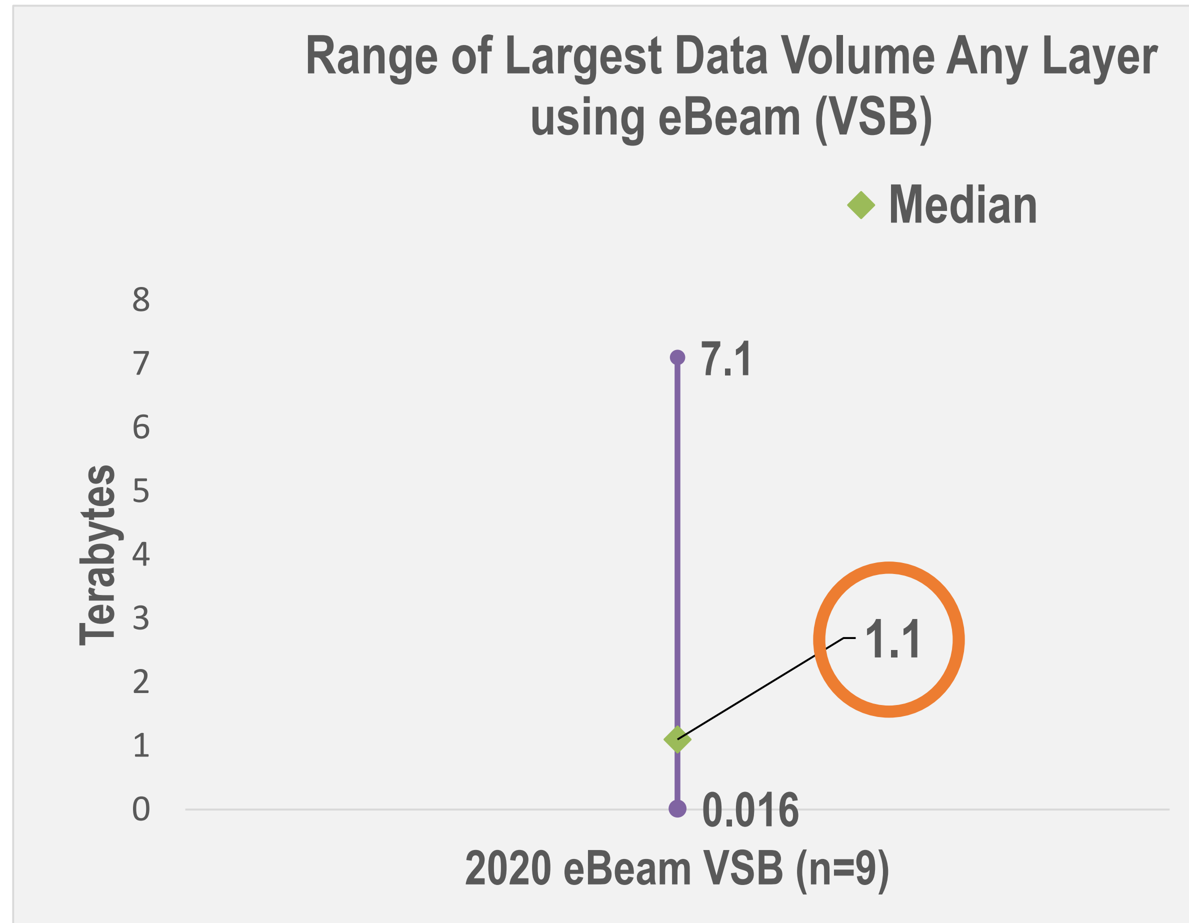

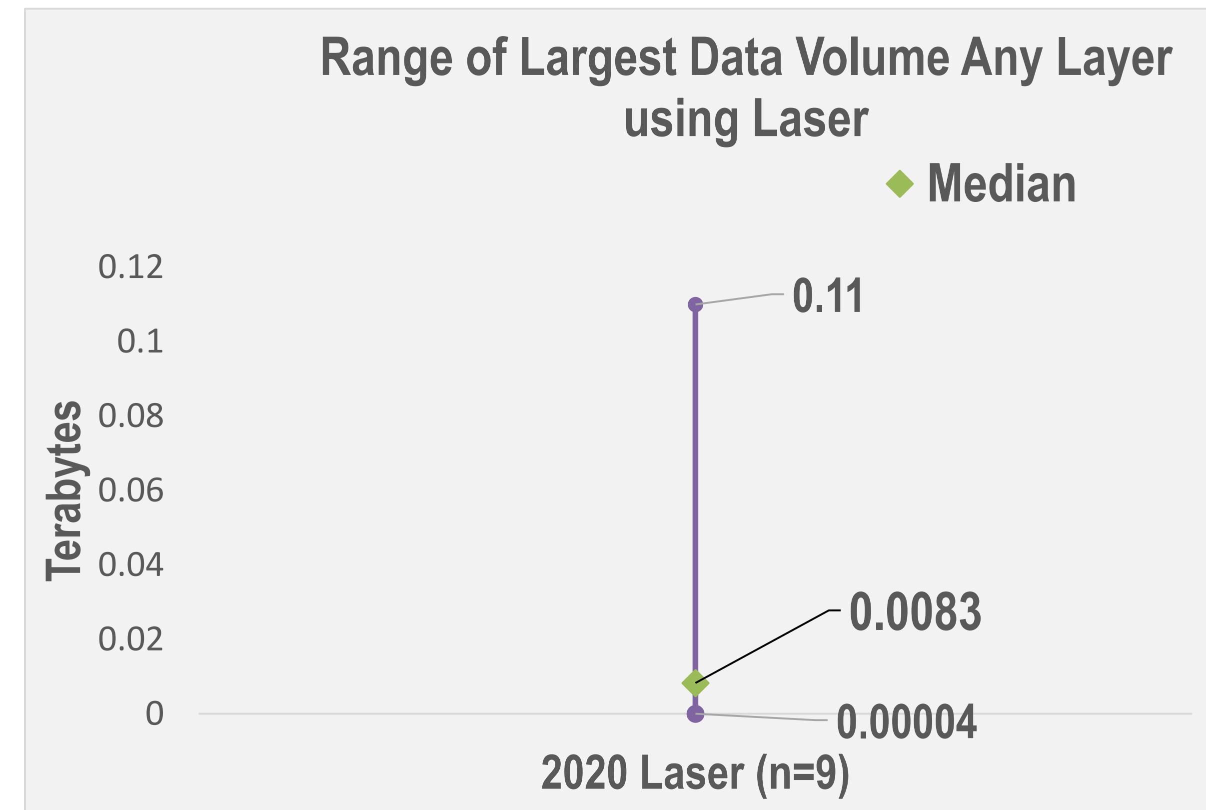

Q: What was the largest data volume for any mask level for each type of pattern generation?

1629 EUV Masks Reported in 2020 Survey*

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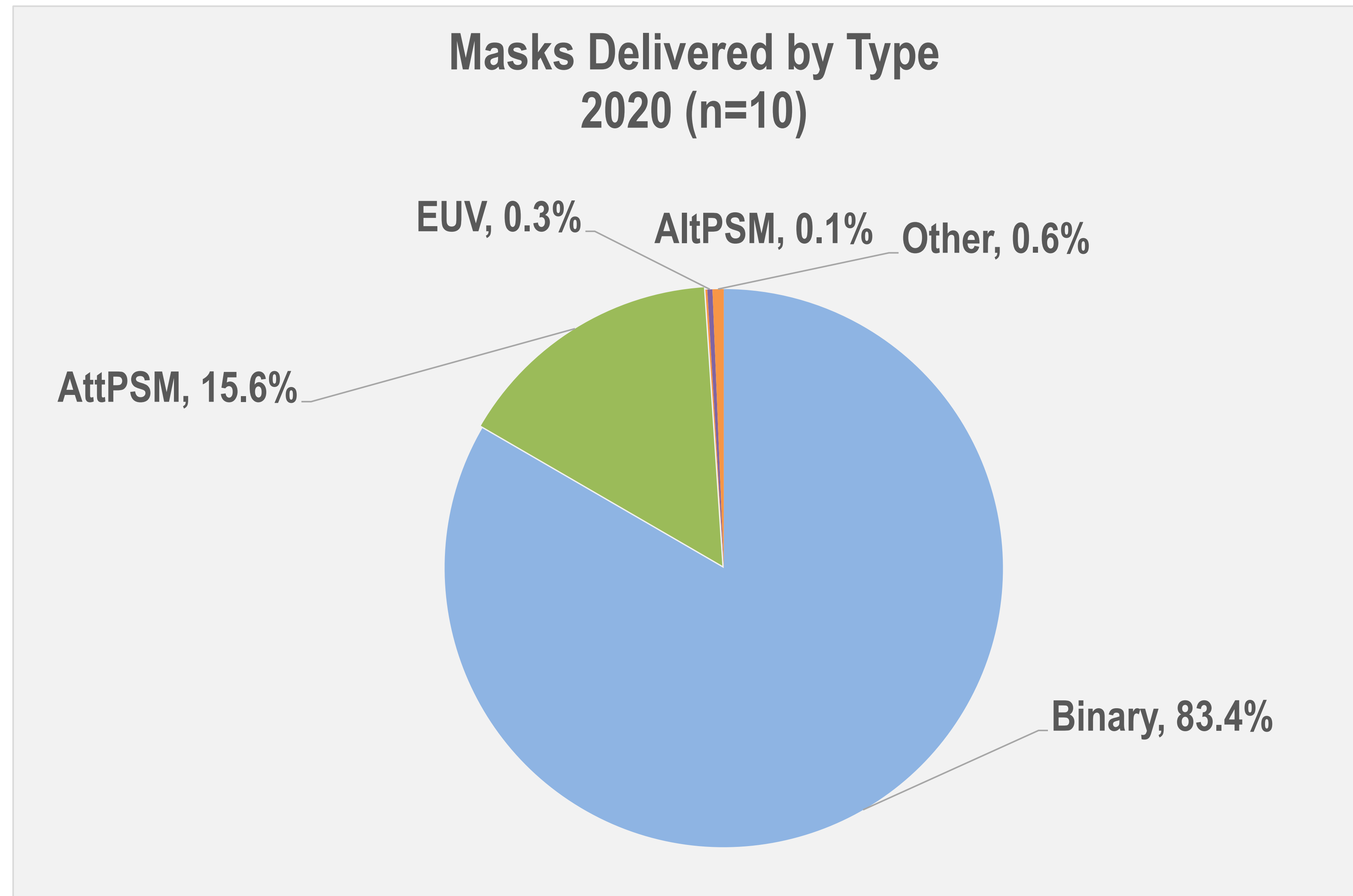

Q: What was the % by…?
Binary, AttPSM, AltPSM, EUV, Other

* Yearly comparisons inconclusive due to participant change

Highest Dose Resist Used is More for EUV Masks

EUV Median was 61.3 µC/cm2

Highest Dose Resist Used
193i and EUV (µC/cm2)

◆ Median

µC/cm2

300
250
200
150
100
50
0

	193i 2019 (n=8)	193i 2020 (n=8)	EUV 2019 (n=5)	EUV 2020 (n=4)
Max	100	68.6	240	240
Median	43	43	115	61.3
Min	31	30	31	31

Q: In the past year, what was the highest dose resist used in production for each category?

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%		

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

* Yearly comparisons inconclusive due to participant change

Clear Defect of Absorber Affecting EUV Yield

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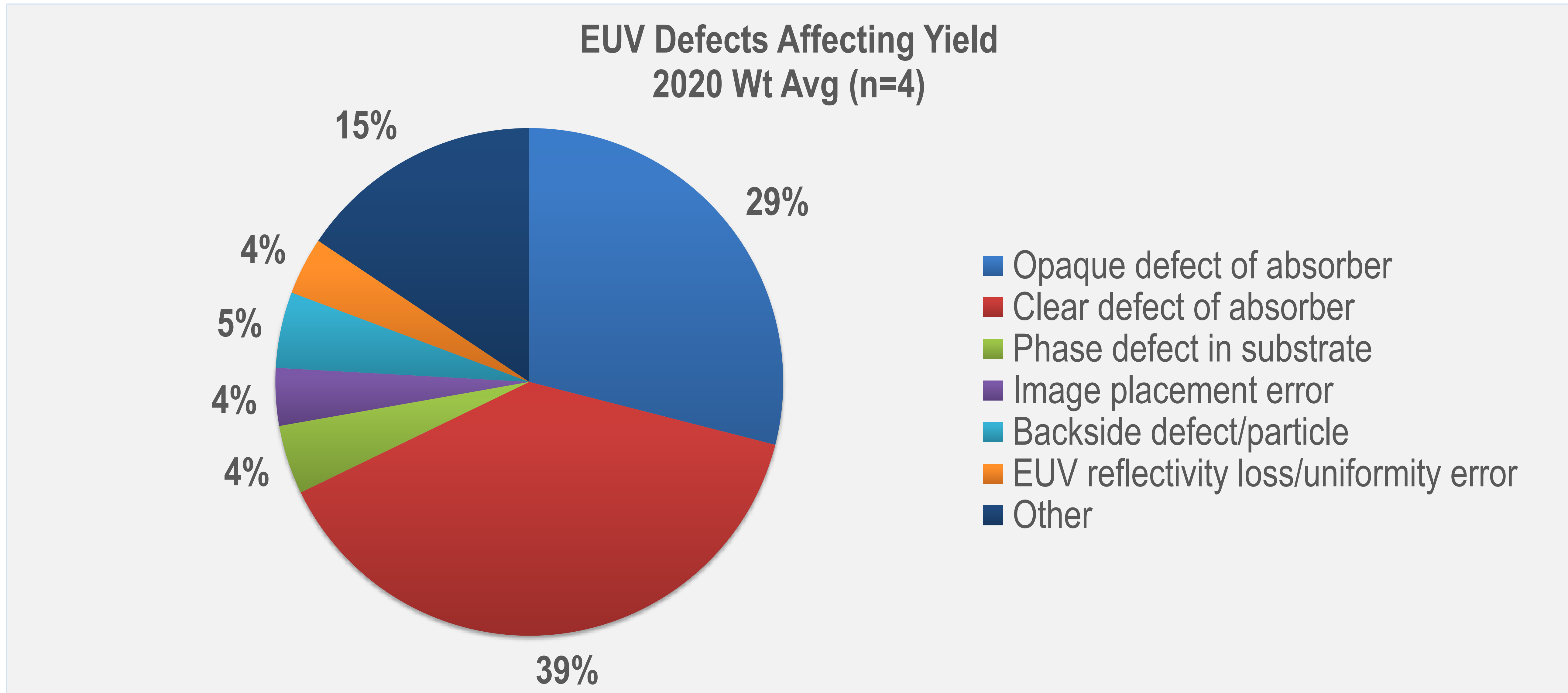

NEW Q: For EUV mask in the past year, what defects affected the yield by category?

For All Masks, More Opaque than Clear Defects*

Avg # of Defects per Mask by Type

	2020 (n=9)	2019 (n=10)	2018 (n=10)
Other	0.53	0.20	0.55
Opaque	3.89	3.18	3.36
Clear	1.17	1.62	1.10

Avg # of Defects (axis: 0.00 – 4.50)

Q: What was the average number of defects per mask?

* Yearly comparisons inconclusive due to participant change

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.

Chromium is Dominant Substrate at 81.2%

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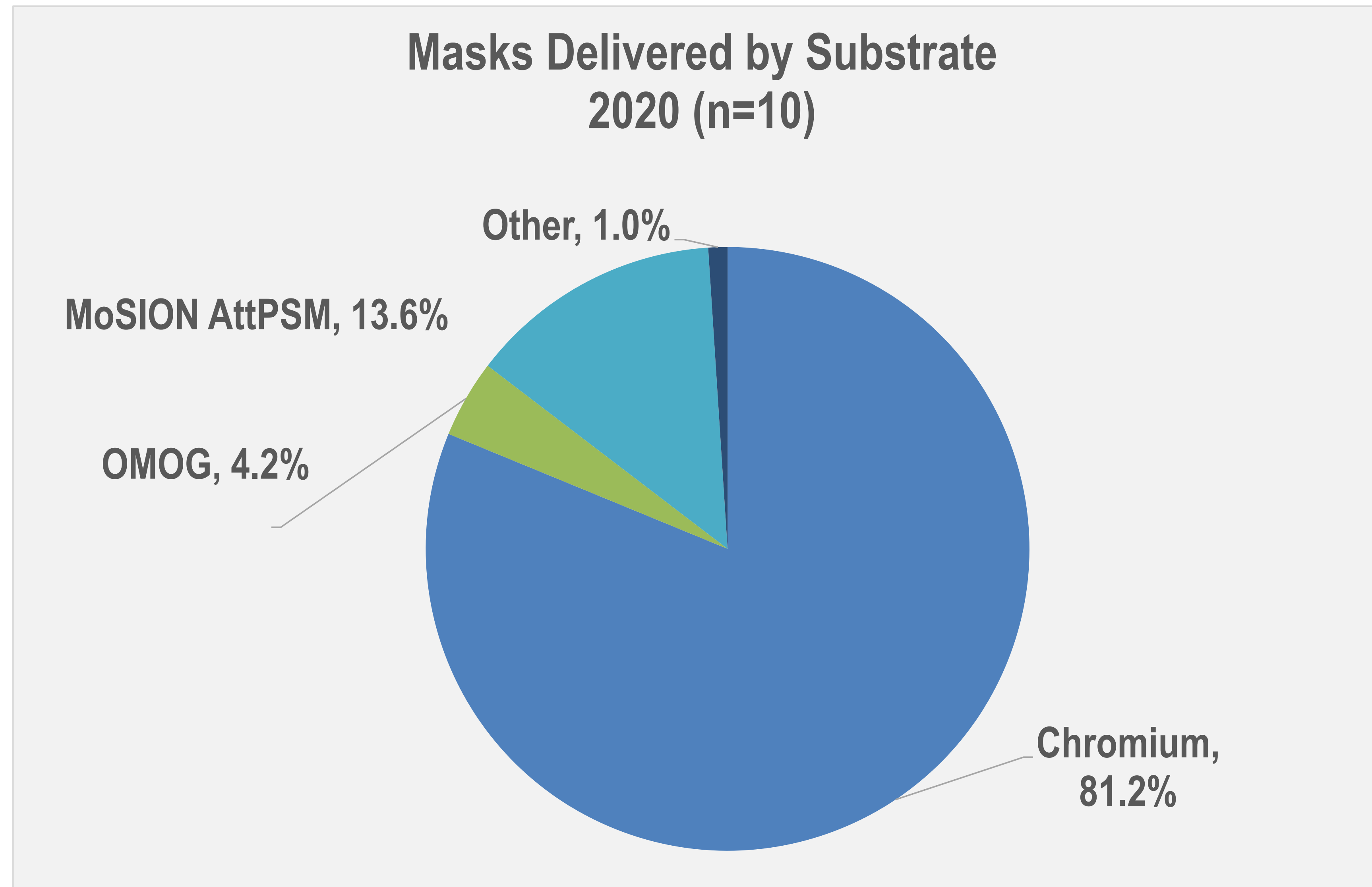

Revised Q: What was the % by substrate type?
Chromium, OMOG, MoSION AttPSM, Other

36% of the Reported Masks used Dry Etch

Correlates to leading edge masks

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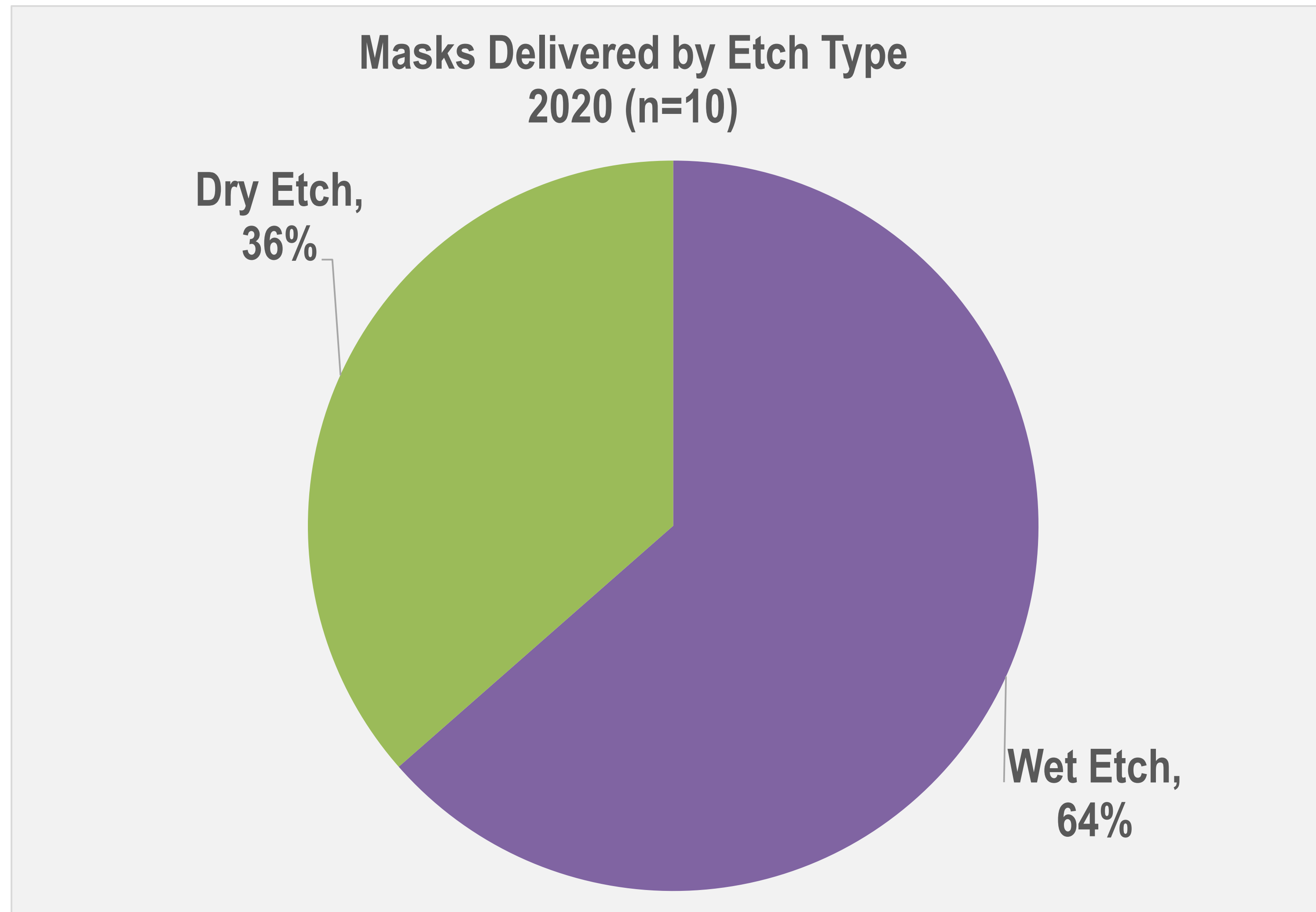
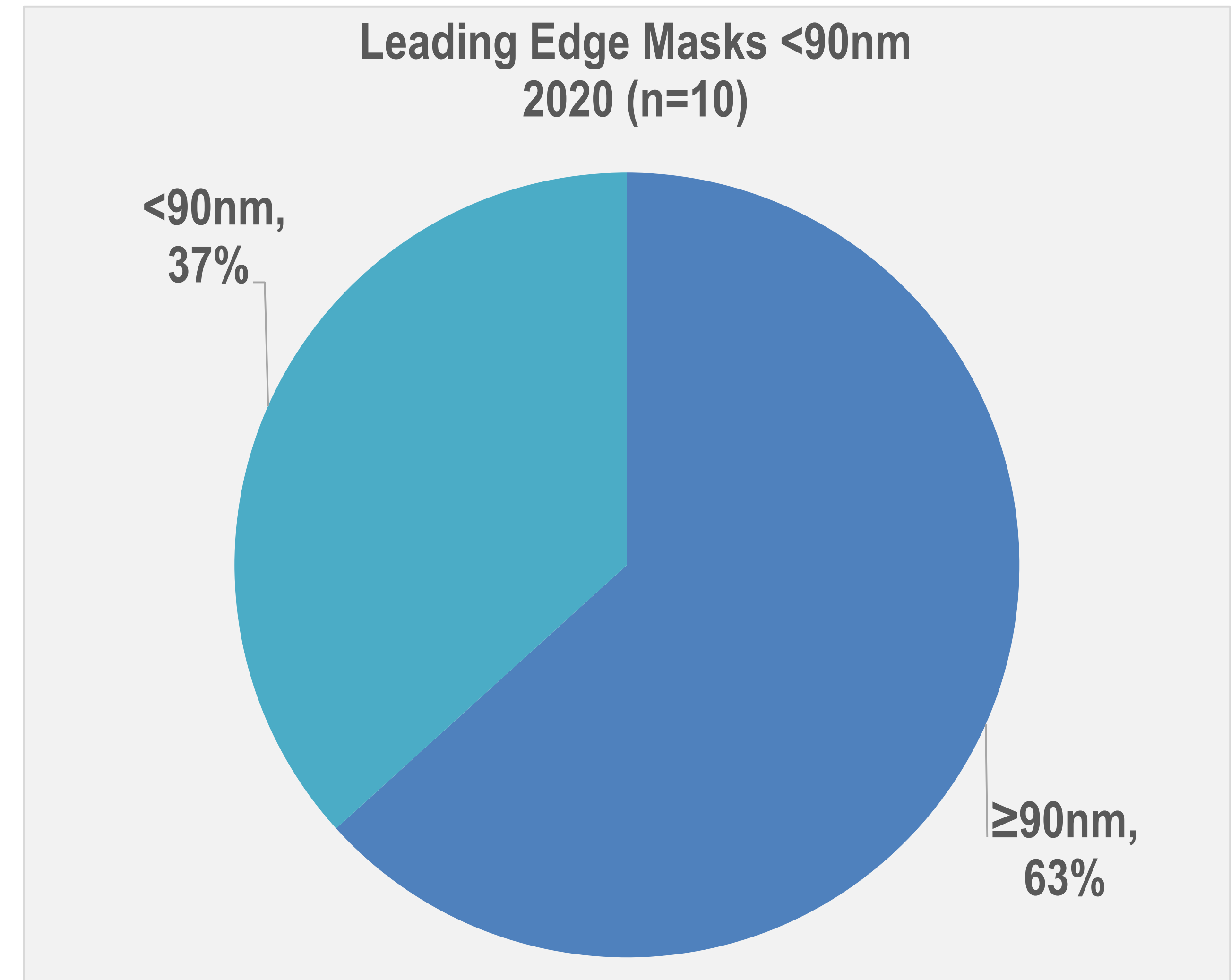
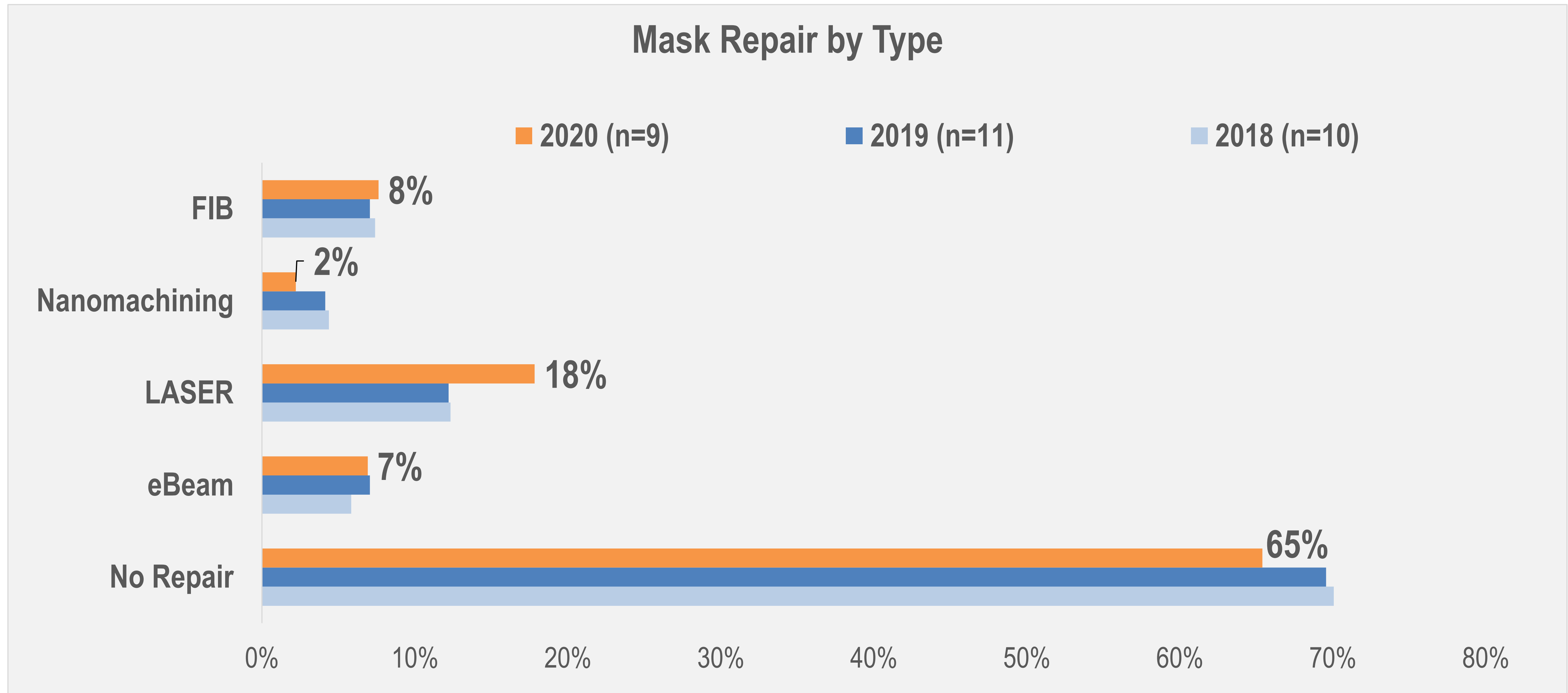




Q: What was the percentage by…? Wet Etch, Dry Etch

65% of Masks "No Repair"*

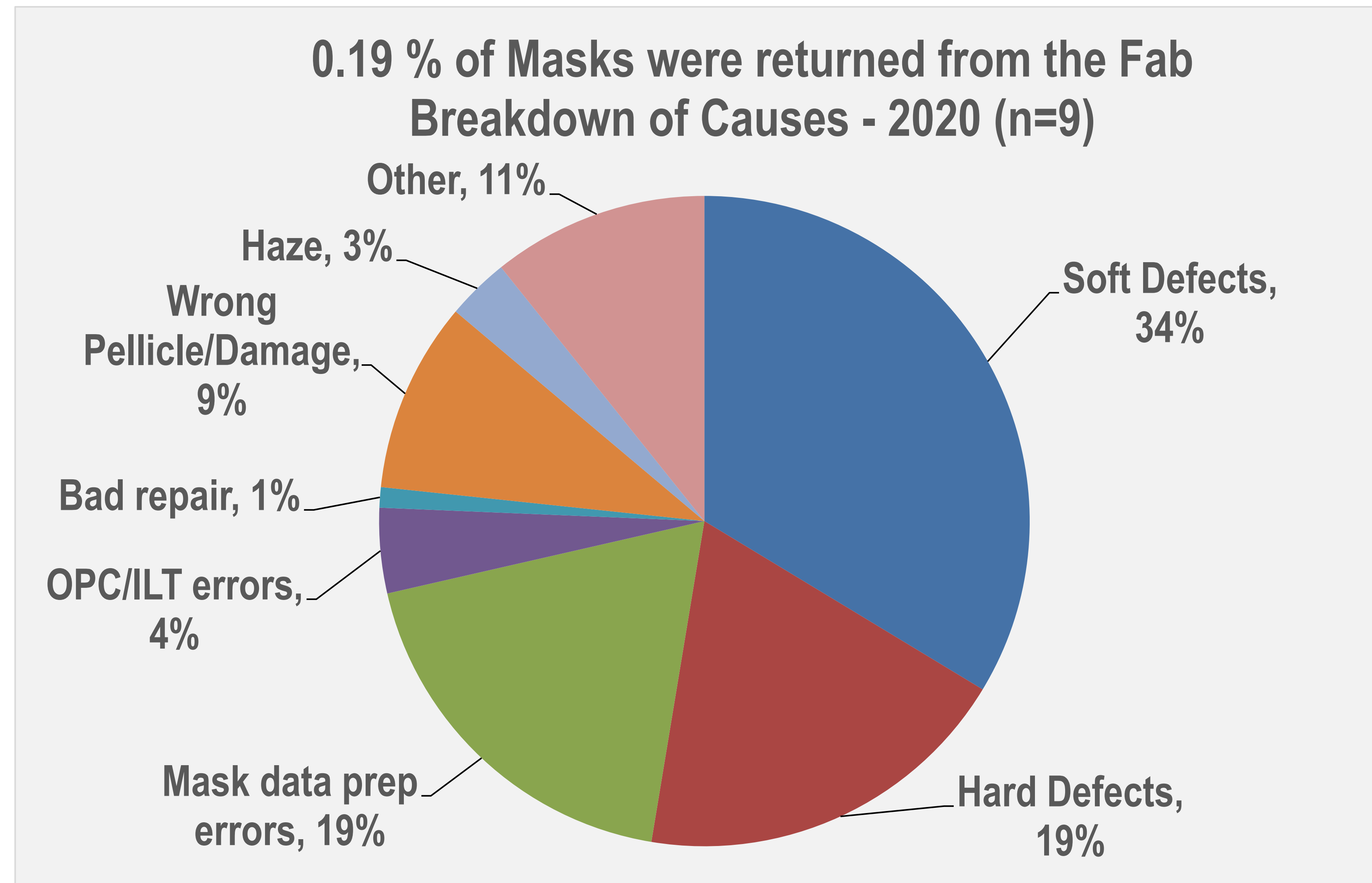


Q: What was the percentage of masks repaired by…No Repair, eBeam, LASER, Nanomachining, FIB

* Yearly comparisons inconclusive due to participant change

Soft & Hard Defects More than Half of Returns

0.19% of Masks returned from the fab



Q: What percentage of masks were returned from the fab?

Q: Of the masks returned from the fab, what percentage were attributed to the following causes?

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)

Days

25.00
20.00
15.00
10.00
5.00
0.00

Ground Rule	≥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
TAT (days)	2.84	3.82	4.68	4.83	5.11	6.31	8.43	9.73	7.53
n	n=7	n=7	n=7	n=7	n=6	n=7	n=5	n=8	n=5

n<3 for <7nm

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

1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00

≥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 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

Ground Rule	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

Hours: 0.00, 10.00, 20.00, 30.00, 40.00, 50.00, 60.00

n<3 for <7nm

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

0.000, 0.500, 1.000, 1.500, 2.000, 2.500

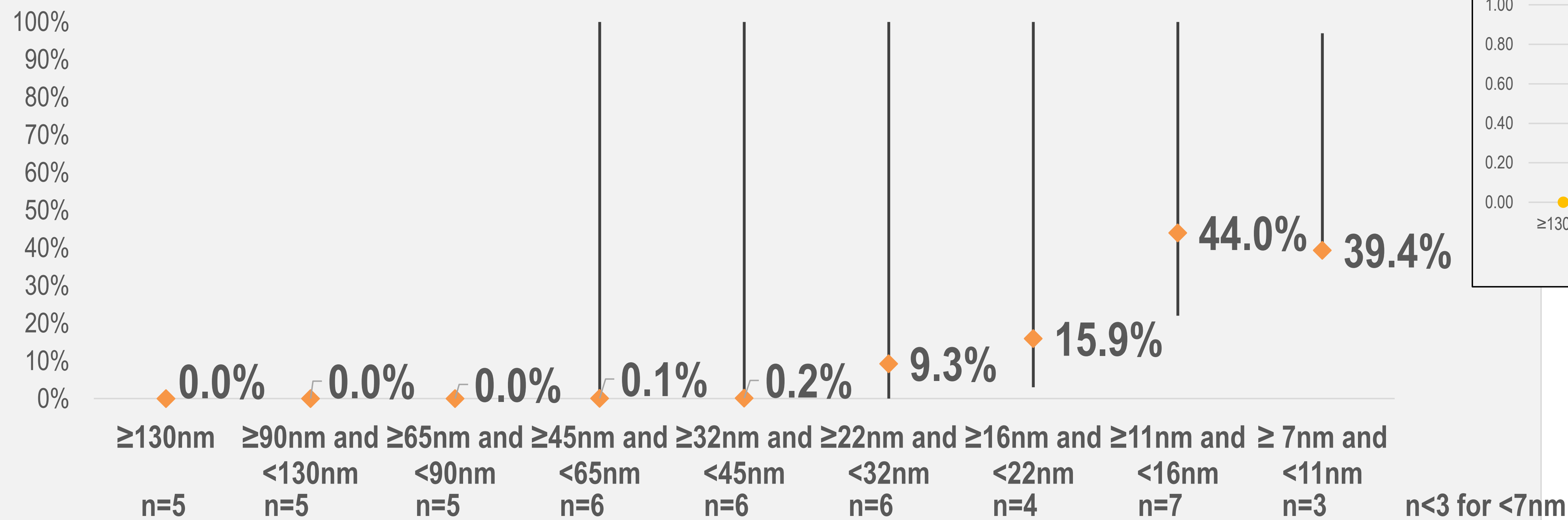
≥130nm, ≥90nm and <130nm, ≥65nm and <90nm, ≥45nm and <65nm, ≥32nm and <45nm, ≥22nm and <32nm, ≥16nm and <22nm, ≥11nm and <16nm, ≥7nm and <11nm

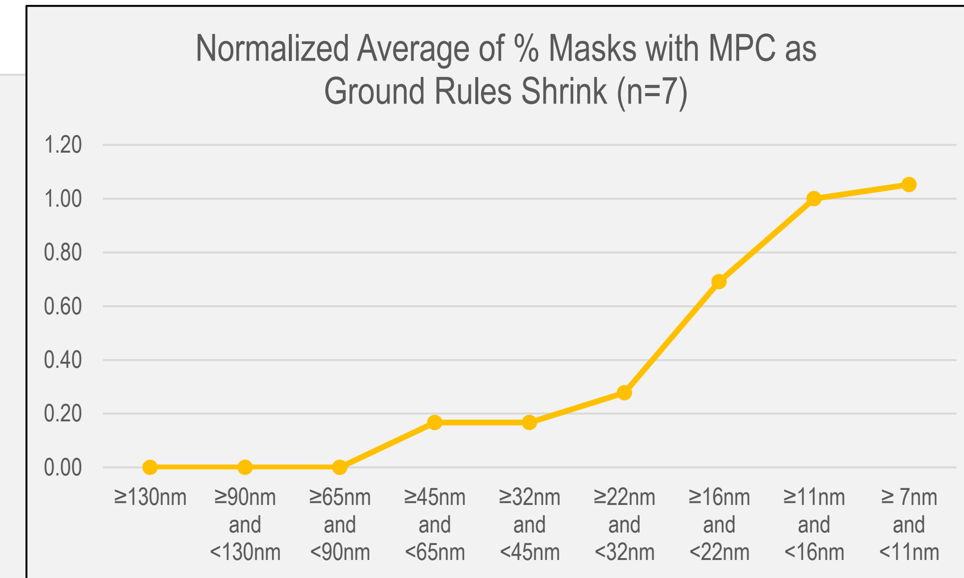
"Normalized average" takes a ratio of a company's response to that company's response for ≥11nm and <16nm and then averages for all companies that responded for that ground rule.

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.)

Multi-Beam and EUV Trends Becoming Visible

- 558,834 masks reported by 10 different companies than last year
- Masks written with Multi-Beam Mask Writers more than doubled
- EUV mask yield reported at 91%
- MPC usage increasing at leading edge nodes

PDFs, Videos, and Panel Discussion at www.ebeam.org