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2018 mask makers' survey conducted by the eBeam Initiative

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2018 Mask makers' survey conducted by the eBeam Initiative

Aki Fujimura^a, Jan Willis^b

^aD2S, Inc., 4040 Moorpark Ave., Suite 250, San Jose, CA USA 95117; ^beBeam Initiative

ABSTRACT

Captive and merchant mask makers participated in an anonymous survey in the summer of 2018 to capture the profile of the mask industry for the period of July 2017 through June 2018. The eBeam Initiative's fourth Mask Makers' Survey in 2018 covers a number of questions related to the profile of the mask industry, from overall number of masks to pattern generation type. The survey respondents – the same 10 captive and merchant photomask manufacturers who participated in last year's survey – reported a 27% overall increase in mask output this year as compared to last. Increases were reported in numbers of masks produced at every ground rule, but $\geq 5\text{nm}$ and $< 7\text{nm}$, $\geq 16\text{nm}$ and $< 22\text{nm}$, and $\geq 65\text{nm}$ and $< 90\text{nm}$ were particularly pronounced in percentage increases year over year. Respondents reported that lasers wrote 74% of the masks they produced this past year. Overall mask yields have remained steady at 94% over the last two years. The eBeam Initiative also conducts an annual Perceptions Survey of mask industry luminaries which can be found at www.ebeam.org.

Keywords: mask industry, photomask, mask yield, mask data preparation, eBeam, multi-beam, EUV, MPC

1. INTRODUCTION

For the past four years, the eBeam Initiative has sponsored a survey that aims to enhance the level of understanding of the unique and critical issues faced by the mask industry. Results from this annual survey are used to provide a snapshot of the mask industry during a given year as well as highlight long term trends. In past years, the survey results were presented at the eBeam Initiative reception along with its annual Perceptions Survey results. Beginning in 2017, the results were included in the main program of the SPIE Photomask Technology and EUV Conference.

The survey includes input from both merchant and captive (in-house) mask shops from around the world to provide an objective assessment of the industry. Each year's survey covers the past 12 months from July of the previous year to June of the current year. The survey is prepared by the eBeam Initiative and administered by David Powell, Inc. to protect the information as well as preserve participant anonymity. The content of the survey repeats nearly all the questions from the 2017 survey in order to provide trend analysis. In some cases, a straight forward weighted average analysis was used to look at the trends, computed by averaging each company response multiplied by that company's percentage share of all reported masks in a particular category.

The ten participating mask shops in the 2018 survey were: Advanced Mask Technology Center (AMTC), Dai Nippon Printing (DNP), GLOBALFOUNDRIES, Intel, Photronics DNP Mask Corp (PDMC), Photronics, Samsung, Semiconductor Manufacturing International Co. (SMIC), Taiwan Mask Shop (TMC) and Toppan Photomasks, Inc. The survey should not be considered as "complete" or totally comprehensive.

2. RESULTS

2.1 Masks Reported by Ground Rule

For the 12 months ending June 2018, there were 587,233 masks that were reported to have been delivered by the 10 participating companies. Figure 1 shows the breakdown by ground rule as reported by the participants. This is in contrast to 463,792 masks reported in the 2017 survey, also shown in Figure 1, which was an increase of 27%. The breakdown of masks below 45nm is upper right in Figure 1. Figure 2 includes the % change in masks by ground rule and Figure 3 includes the difference in the number of masks by ground rule for 2018 vs 2017. Note that for masks grater or equal to 130nm in ground rules, the year-over-year increase in percentage was less than others at 8%, but represented over 25,000 in increase in the number of masks.

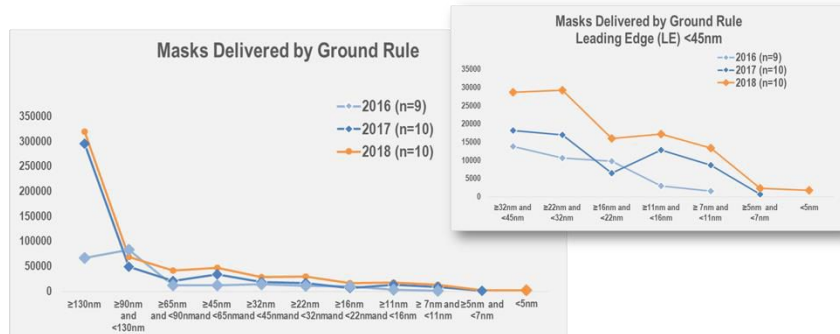


Figure 1: Historical mask shipments by ground rule 2016-2018 and below 45nm

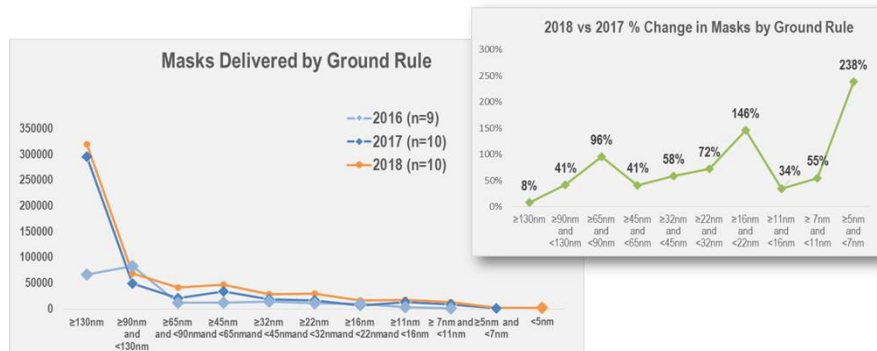


Figure 2: Historical mask shipments by ground rule 2016-2018 and by % change for 2018 vs 2017

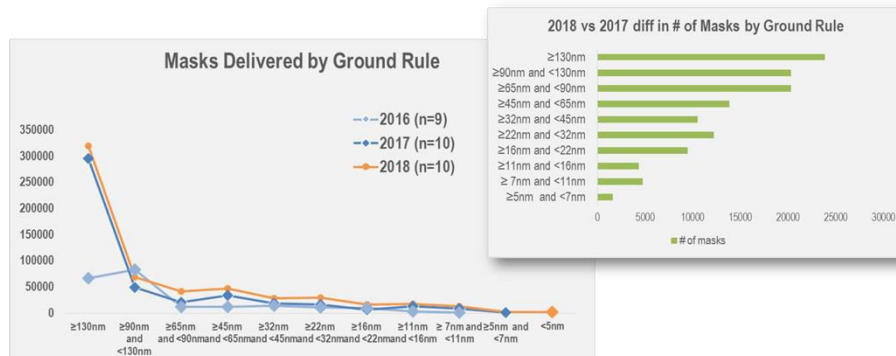


Figure 3: Historical mask shipments by ground rule 2016-2018 and by difference in # for 2018 vs 2017

2.2 Masks Delivered by Type and Substrate

There were 2185 EUV masks (0.4% of the total) reported in the 2018 survey as shown in the left pie chart in Figure 4. The questions asked were: What was the percentage by...? (Binary, AttPSM, AltPSM, EUV, Other) What was the percentage by substrate type? (Chromium, OMOG, MoSION AttPSM, EUV, Other)

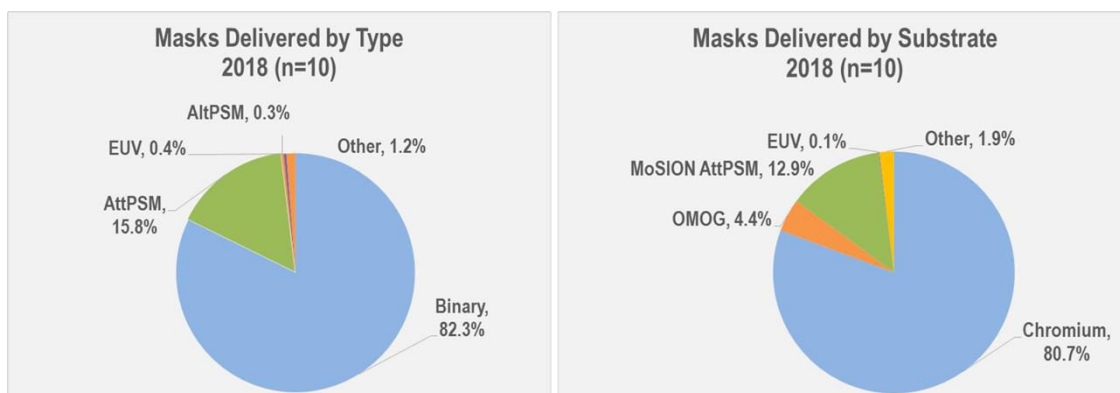


Figure 4: 2018 mask shipments by type and by substrate

2.3 Pattern Generation Type

Lasers were used to write 74% of the masks in 2018 as reported by the participants as shown in Figure 5. Variable Shaped Beam (VSB) eBeam pattern generation was used on 25% of the mask shipments reported. The question asked was: What was the percentage written by the following pattern generation? (eBeam (VSB), eBeam (multi-beam), eBeam (raster), LASER, Other)

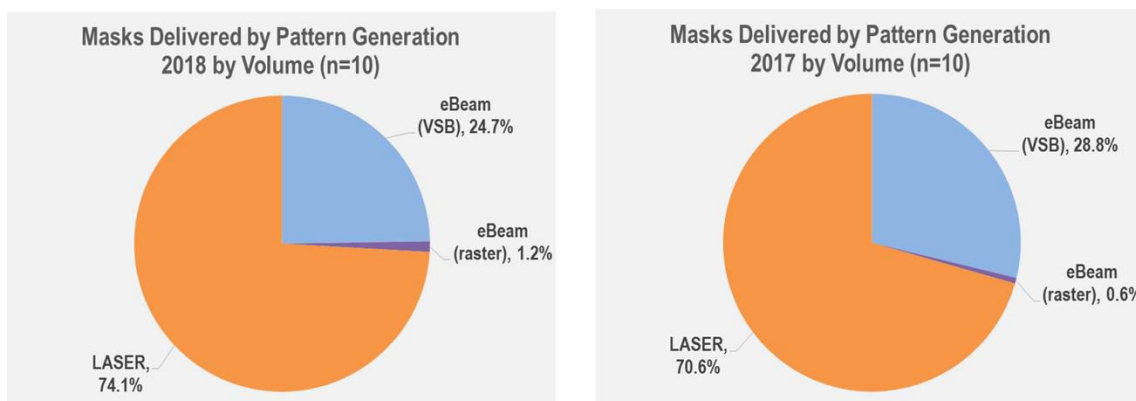


Figure 5: 2018 vs 2017 mask shipments by pattern generation type

2.4 Etch

Wet etch usage increased slightly to 60.5% as reported in 2018 and shown in Figure 6. The question asked was: What was the percentage by...? (Wet Etch, Dry Etch)

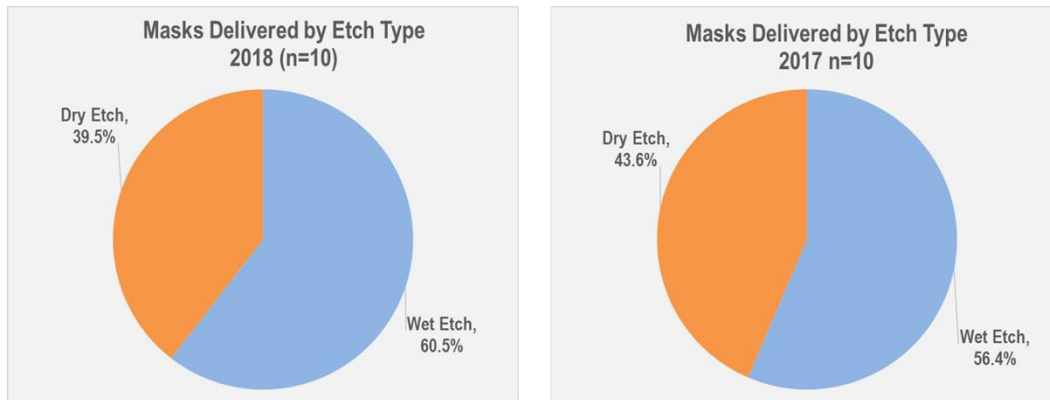


Figure 6: 2018 vs 2017 shipments by etch type

2.5 Average Write Time

Average write time for VSB writers increased from 6.8 hours in the 2017 survey to 8.3 hours in 2018 (>20% increase) as shown in Figure 7. Average write time for laser writers increased from 1.8 hours to 2.07 hours also shown in Figure 7. The question asked was: What was the average write time over the past 12 months (July 2016-June 2017) for each type of pattern generation? (eBeam (VSB), eBeam (multi-beam), eBeam (raster), LASER, Other) Results are reported when $n > 2$.

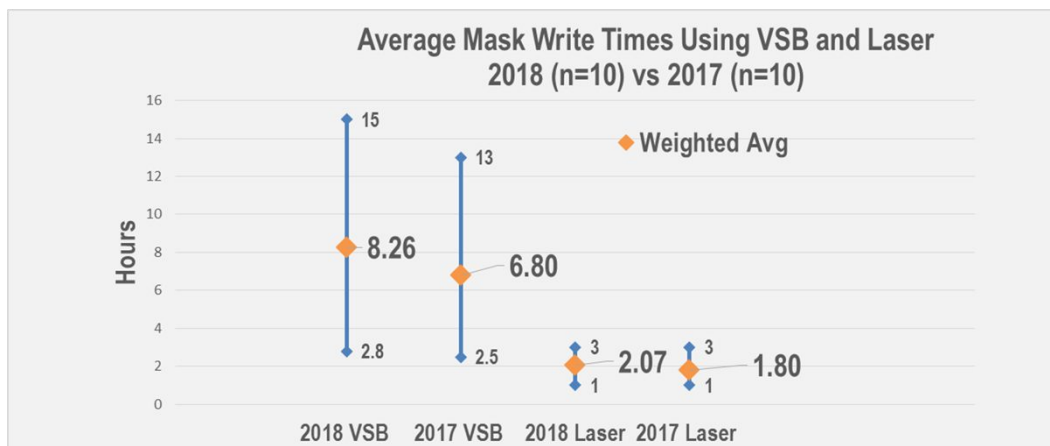


Figure 7: 2018 vs 2017 average mask write times by writer type

2.6 Longest Write Times

The longest reported mask write time in 2018 was 40.23 hours for VSB eBeam and 19.4 hours for laser as shown in Figure 8. The question asked was: What was the longest write time over the past 12 months for each type of pattern generation? (eBeam (VSB), eBeam (multi-beam), eBeam(raster), LASER, Other)

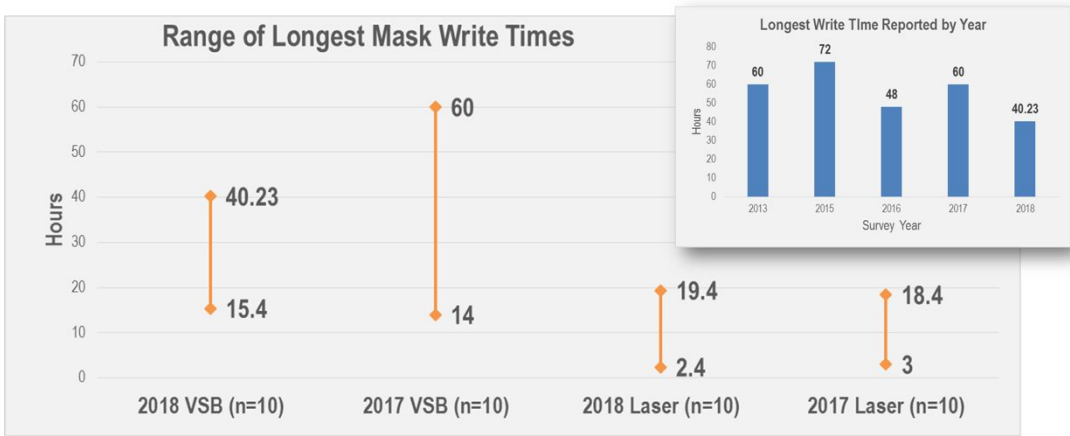


Figure 8: Range of longest mask write times by writer type for 2018 vs 2017 and historical longest reported

2.7 Largest Data Volume

For VSB writers, the range of the largest data volume reported in 2018 increased to 3.2 TeraBytes (TB) from 2.2 TB in 2017 with the weighted average of 1.23 TB for 2018 as shown in Figure 9. For laser writers, the range reported increased in 2018 to 240 GigaBytes (GB) up from 30 GB in 2017, with the weighted average of 19 GB in 2018 also shown in Figure 9. The question asked was: What was the largest data volume for any mask level for each type of pattern generation over the past 12 months? (eBeam (VSB), eBeam (multi-beam), eBeam (raster), LASER, Other) Results are reported when n > 2.

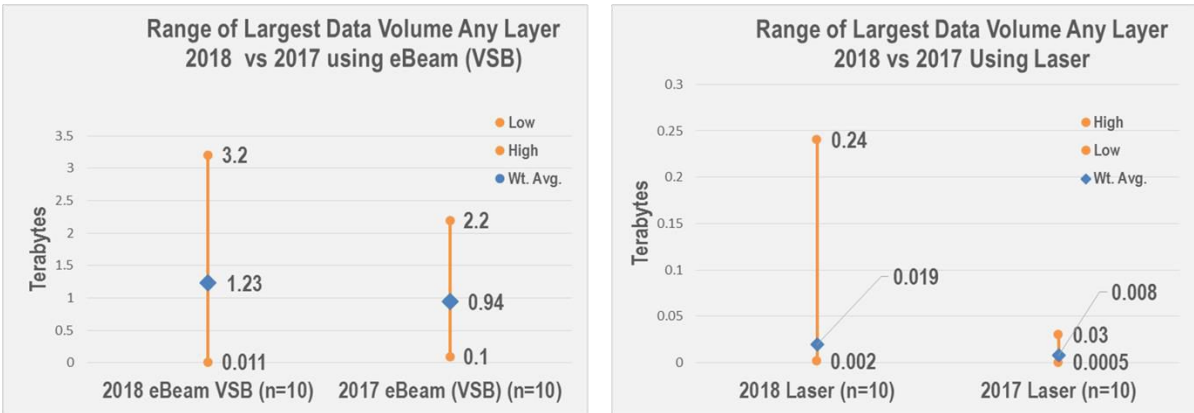


Figure 9: 2018 vs 2017 range of largest data volume and weighted average reported for VSB and Laser writers

2.8 Turnaround Time

No improvement in turnaround time was reported by respondents to the 2018 mask makers’ survey. The trend continues where every year, the smallest ground rules (most leading edge) takes substantially longer turnaround times for the masks than the previous generation. Ground rules above and including 130nm have an average turnaround time of 3.2 days, while those below and including 7nm need 11.7 days as shown in Figure 10. The question asked was: What was your average Turn-Around-Time (TAT) by Ground Rules in the past year?



Figure 10: Historical TAT Weighted Average

2.9 Number of Masks per Mask Set

In 2018, the largest number of masks per mask set was 112. The 2018 results reported followed the same pattern of results reported in 2017 as shown in Figure 11. The question asked was: What was your average number of masks per mask set by Ground Rules of the critical layers?

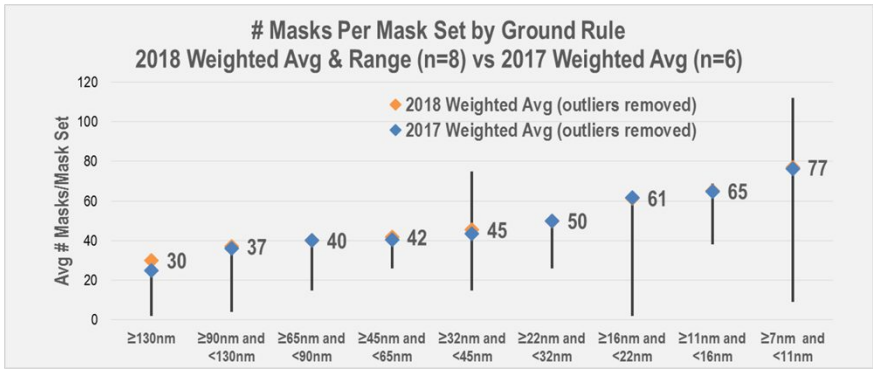


Figure 11: # of Masks per Mask Set by Ground Rule 2018 vs 2017

2.10 Average Number of Defects by Mask Type

In 2018, the average number of defects per mask by mask type reported increased for opaque to 3.36 and for clear to 1.10 while decreasing to 0.55 for other mask types as shown in Figure 12. The question asked was: What was the average number of defects per mask? (Clear, Opaque, Other)

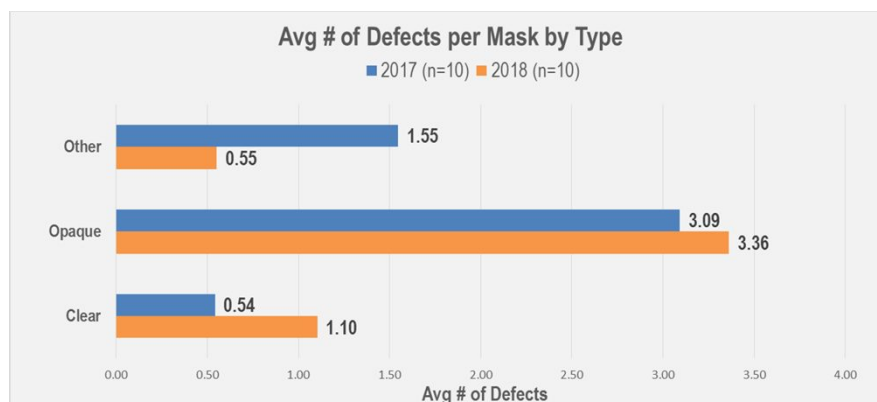


Figure 12: Average # of defects per mask by mask type 2018 vs 2017

2.11 Mask Repair by Type

In 2018, mask repair was either unchanged or slightly down by type of repair from what was reported for 2017. “No repair” on masks as reported increased to 70% from 66% as shown in Figure 13. The question was: What was the percentage of masks repaired by....? (No Repair, eBeam, LASER, Nanomachining, FIB)

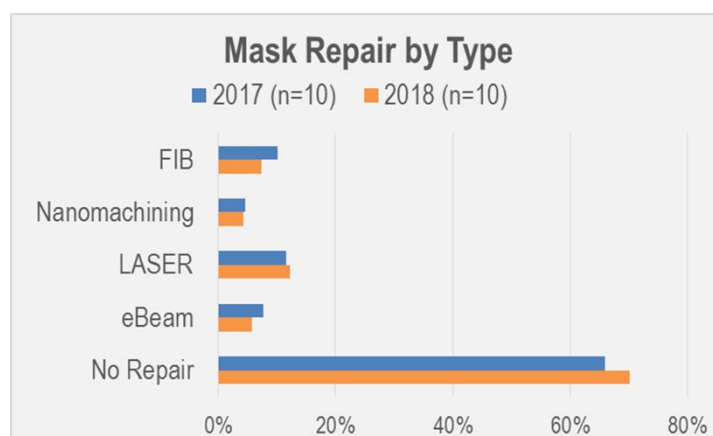


Figure 13: Mask repair by type 2018 vs 2017

2.12 Mask Returns

2018 survey results reported that 0.4% of masks were returned from the fab vs 0.31% reported in the 2017 survey. The question asked was: What percentage of the masks were returned from the fab? In a separate question which was modified in 2018 to include different answer choices than 2017, Soft and Hard defects were the highest reported cause of masks returned from the fab as shown in Figure 14. The 2018 question asked was: Of the masks returned from the fab, what percentage were attributed to the following causes? (Soft Defects, Hard Defects, Mask data prep errors, OPC/ILT errors, Bad repair, Wrong Pellicle/Damage, Haze, Other)

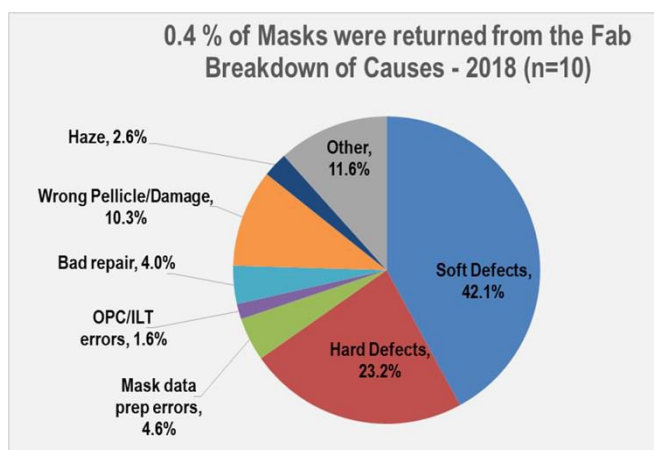


Figure 14: Causes of Mask Returns in 2018

2.13 Mask Yield

Mask yield overall was reported at 93.8% vs 94.8% reported in 2017. For EUV masks, the reported yield increased in 2018 to 72.2% from 64.3% reported in 2017. The questions asked were: What was your overall percent mask yield? What was your percent mask yield by category? (Binary, AttPSM, AltPSM, EUV)

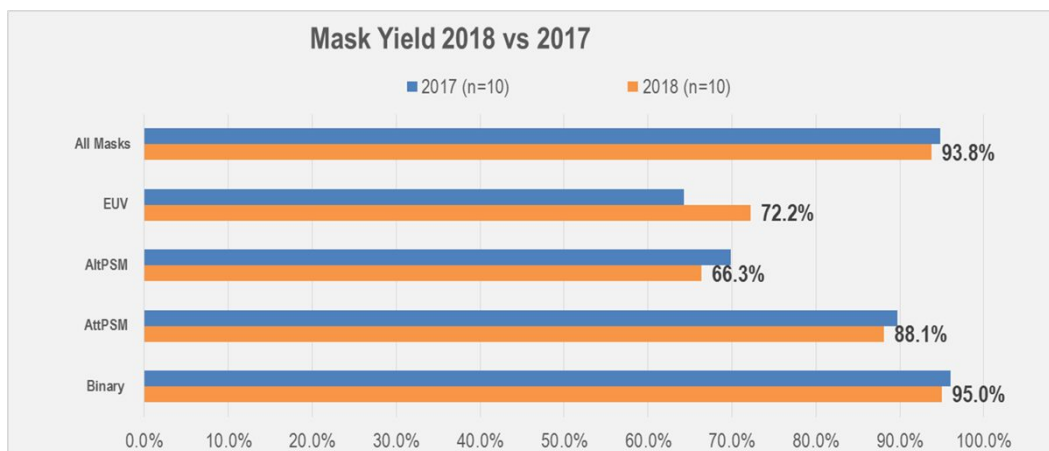


Figure 15: Mask yield by mask type 2018 vs 2017

2.14 Data Preparation

The 2018 reported weighted average for data preparation time substantially increased at leading edge nodes below 16nm as shown in Figure 16. The starting point for data preparation was defined as RET output. The question asked was: What was the average data prep time (starting point defined as RET output) per mask for critical layer masks by Ground Rules?

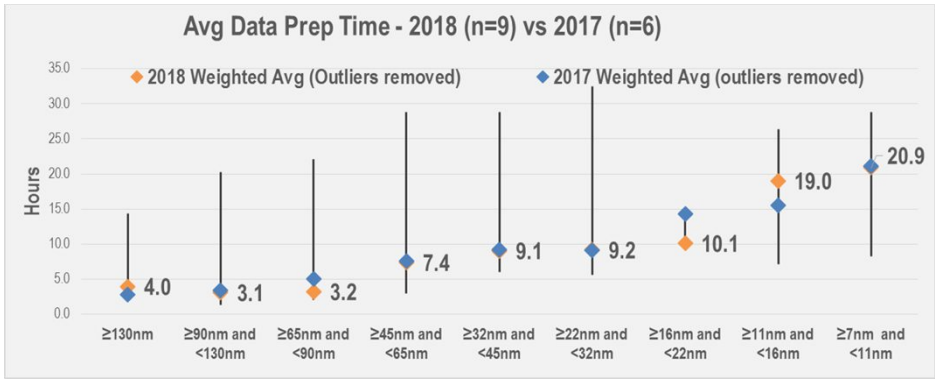


Figure 16: Data preparation time by ground rule 2018 vs 2017

2.15 Mask Process Correction (MPC)

The % of masks using MPC increased at leading-edge nodes for the second year in a row as shown in Figure 17, indicating a potential new requirement at <16nm. The question was first asked in 2017: What % of masks by ground rules had Mask Process Correction (MPC) applied?

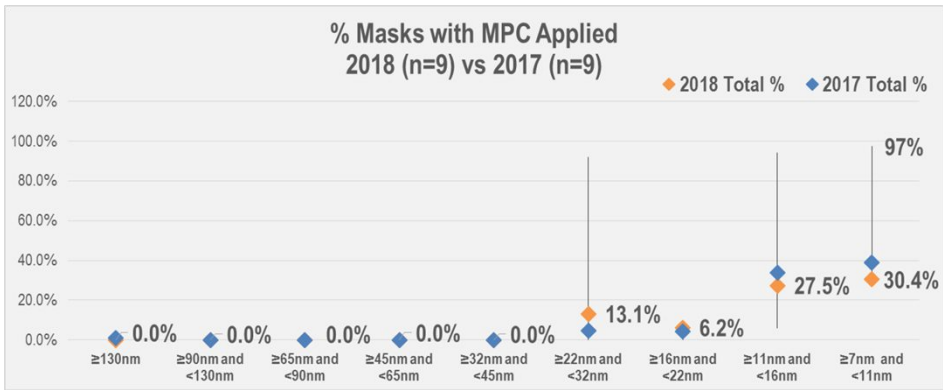


Figure 17: % of masks using MPC by ground rule 2018 vs 2017

3. ACKNOWLEDGEMENTS

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