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2017 Mask maker survey conducted by the eBeam Initiative

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ABSTRACT

Captive and merchant mask makers participated in an anonymous survey in the summer of 2017 to capture the profile of the mask industry for the period of July 2016 through June 2017. A mask industry survey has been conducted for the 15th time in the past 16 years. Sematech ran the mask industry survey for 13 years through 2013. In 2015, the eBeam Initiative invested in reviving a subset of the survey called the Mask Maker Survey. The eBeam Initiative's third Mask Maker Survey in 2017 covers a number of questions related to the profile of the mask industry, from overall number of masks to pattern generation type. The survey addresses questions about data preparation, writing and delivery times. Mask yields and returns are captured along with a new question on the usage of mask process correction (MPC) by ground rules. The eBeam Initiative also conducts an annual Perceptions Survey of mask industry luminaries.

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

1. INTRODUCTION

For the past three 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 are included in the main program of the SPIE Photomask Technology and EUV Conference.

The content of the survey repeats nearly all the questions from the 2016 survey in order to provide trend analysis. However, this year's data represented a considerable increase in the number of mask reported (~118%) so the year-to-year comparisons needed some additional care in reporting. 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 other cases, a different weighted average was used to look at trend that differed for leading-edge masks. The Leading Edge Weighted Average, where utilized, was computed by averaging each company response multiplied by that company's percentage share of <45nm ground rule masks reported.

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.

Fourteen mask shops were invited to participate in the 2017 survey and ten participated: Advanced Mask Technology Center (AMTC), Dai Nippon Printing (DNP), GLOBALFOUNDRIES, Intel, Photronics DNP Semiconductor 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.

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2. RESULTS

2.1 Masks Reported by Ground Rule

For the 12 months ending June 2017, there were 463,792 masks that were reported to have been delivered by the 10 participating companies and Figure 1 shows the breakdown by ground rule as reported by the participants. This is in contrast to 212,956 masks reported in the 2016 survey, also shown in Figure, which is an increase of approximately 118%. As a result of this large increase in reported masks, the analysis of the data has been handled with care. Weighted analysis based on leading edge nodes below 45nm ground rules was used where noted to either counter what would be a misleading trend or to gain insight on the leading-edge trends. The breakdown of masks below 45nm is included in Figure 1. Leading Edge Weighted Average or LE Weighted Average is computed by averaging each company response multiplied by that company's percentage share of <45nm ground rule masks reported.
All other weighted average analysis used in this report is based on volume.

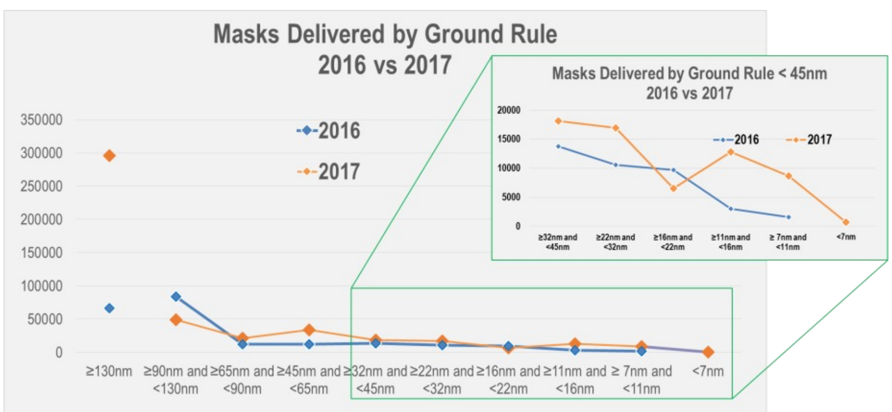

Figure 1: Historical mask shipments by ground rule

2.2 Masks Delivered by Type and Substrate

There were 1041 EUV masks reported in the 2017 survey versus 382 EUV masks in the 2016 survey. The 2017 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)

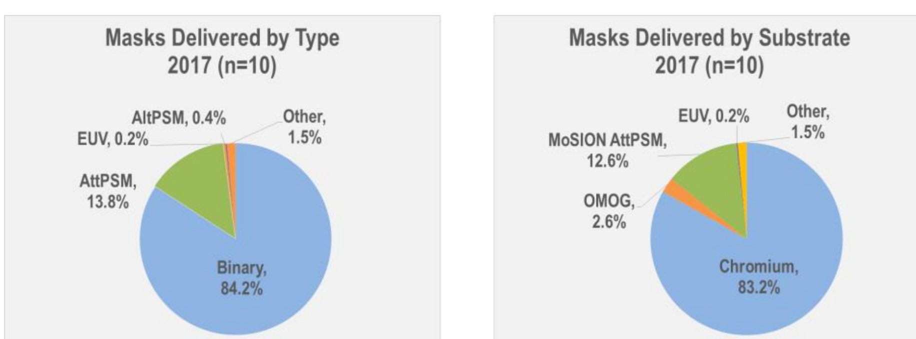

Figure 2: 2017 mask shipments by type and by substrate

2.3 Pattern Generation Type

2017 survey participants didn't report any multi-beam masks yet. Variable Shaped Beam (VSB) eBeam pattern generation was used on ~29% of the masks shipments reported. The 2017 question asked was:
What was the percentage written by the following pattern generation? (eBeam (VSB), eBeam (multi-beam), eBeam (raster), LASER, Other)

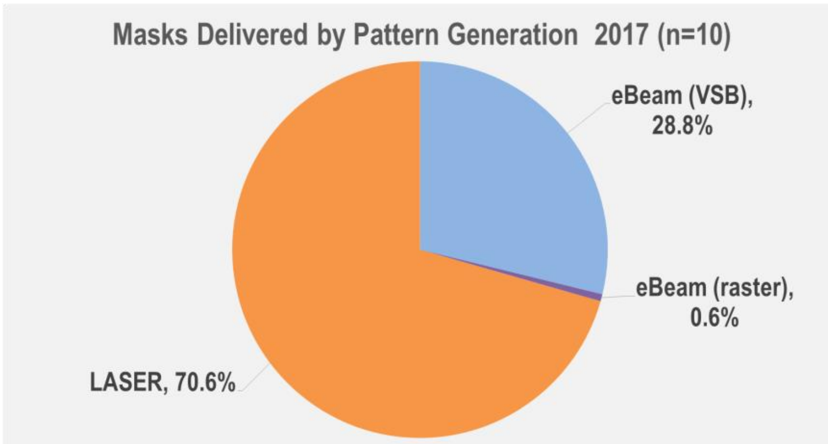

Figure 3: 2017 mask shipments by ground rule

2.4 Etch

Dry etch and wet etch continue to be 50-50, however, applying the Leading Edge Weighted Average, the leading edge is correlated more with dry etch. The 2017 question asked was: What was the percentage by…? (Wet Etch, Dry Etch)

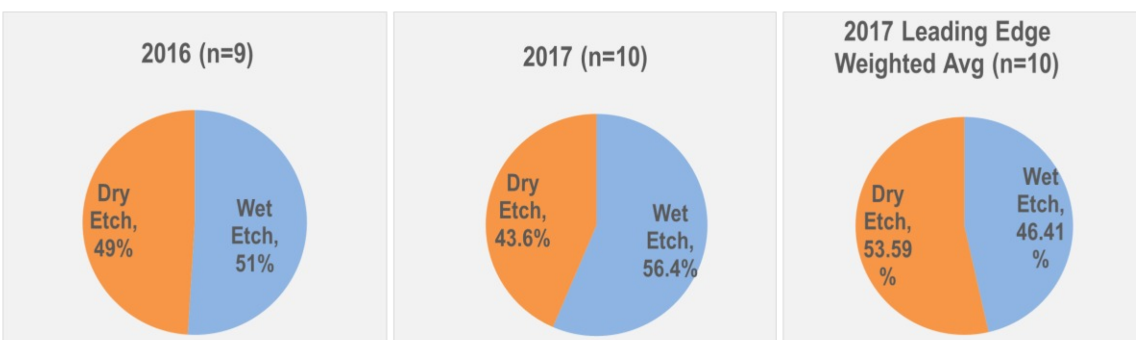

Figure 4: Historical shipments by etch and 2017 Leading Edge Weighted Average analysis

2.5 Average Write Time

Overall average mask write times are consistent from 2016 to 2017. However, in 2017, the question was enhanced to report the average mask write by writer type. When looking at VSB weighted average write times, the results are higher at 6.8 hours. The 2017 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)

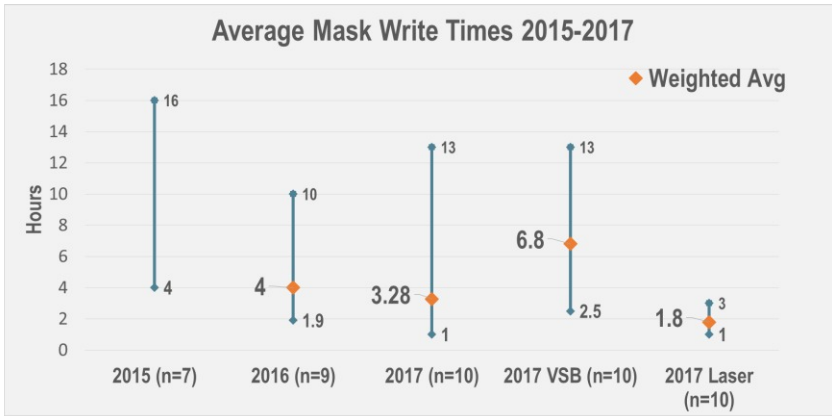

Figure 5: Historical average mask write times and 2017 average write times by writer type

2.6 Longest Write Times

The longest reported mask write time was 60 hours for VSB writers and 18.4 hours for laser writers. It was the first year that the longest write time was reported by writer type. In 2016, the longest write time reported was 48 hours and 72 hours in 2015. The 2017 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)

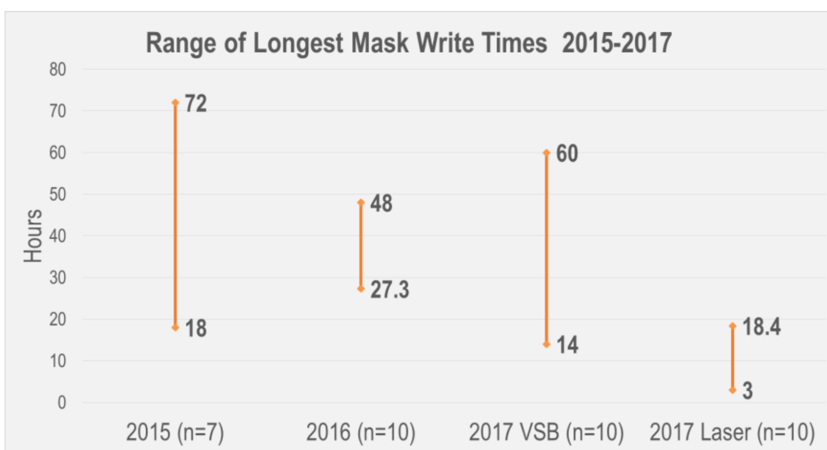

Figure 6: Historical range of longest mask write times reported

2.7 Largest Data Volume

In 2017, the largest data volume was reported by writer type for the first time. For VSB writers, the range of the largest data volume was 100GB up to 2.2TB with the weighted average of 0.94TB. For laser writers, the range was 500kB up to 30GB, with the weighted average of 8GB. The 2017 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)

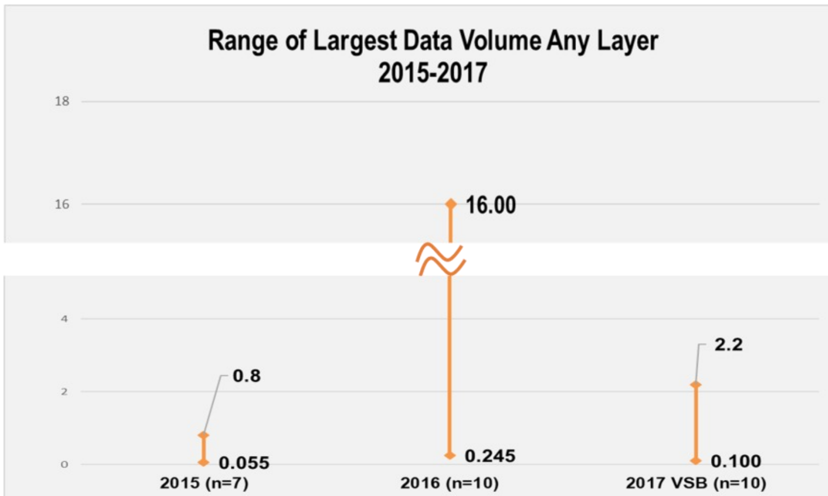

Figure 7: Historical range of largest data volume reported

2.8 Turnaround Time

In 2017, mask turnaround time (TAT) weighted average by ground rule was worse at the leading edge as expected. The longest TAT reported was 21 days. The 2017 question asked was: What was your average Turn-Around-Time (TAT) by Ground Rules in the past year?

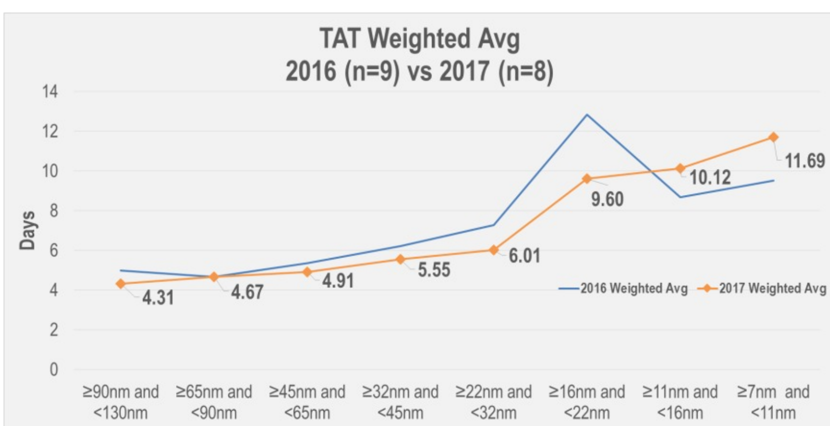

Figure 8: Historical TAT Weighted Average

2.9 Number of Masks per Mask Set

In 2017, the largest number of masks per mask set was 112. The 2017 question asked was: What was your average number of masks per mask set by Ground Rules in the past year?

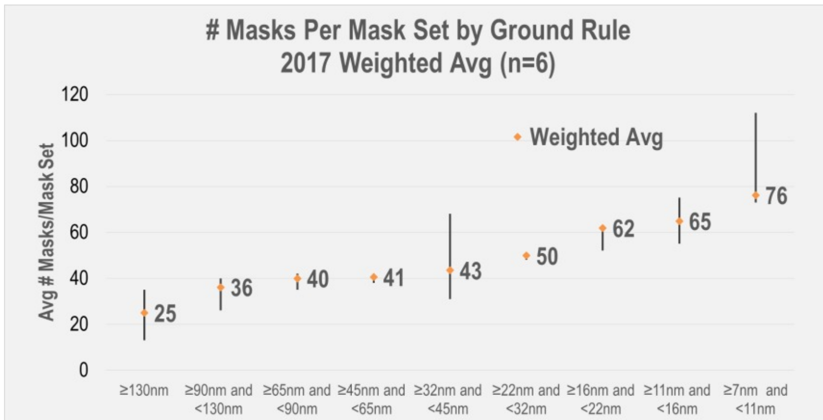

Figure 9: # of Masks per Mask Set by Ground Rule in 2017

2.10 Average Number of Defects by Mask Type

In 2017, the average number of defects per mask by mask type increased for opaque and other mask types. When looking at the LE Weighting results shown in blue in Figure 10, the average # of defects per mask increased for clear masks as well. The 2017 question asked was: What was the average number of defects per mask for July 2016-June 2017? (Clear, Opaque, Other)

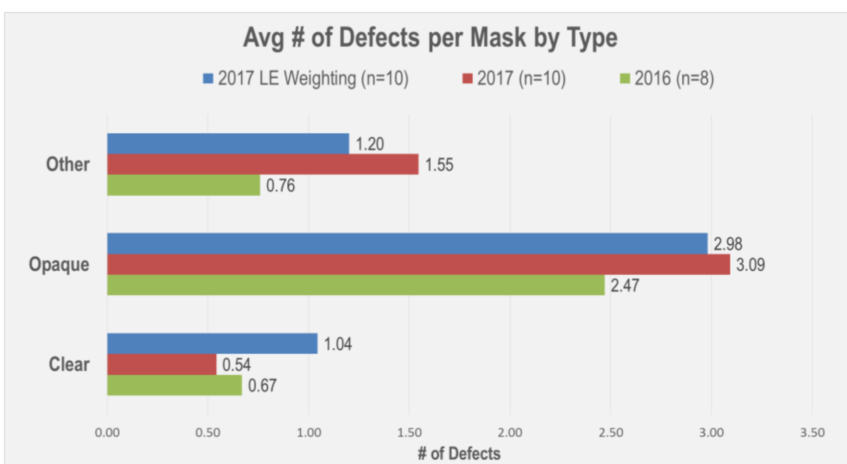

Figure 10: Historical average # of defects per mask by mask type

2.11 Mask Repair by Type

In 2017, looking at the LE Weighted Average helps identify that eBeam and nanomachining are increasing in usage for mask repair in the leading edge as shown in blue in Figure 11. The 2017 question was: What was the percentage of masks repaired by….? (No Repair, eBeam, LASER, Nanomachining, FIB)

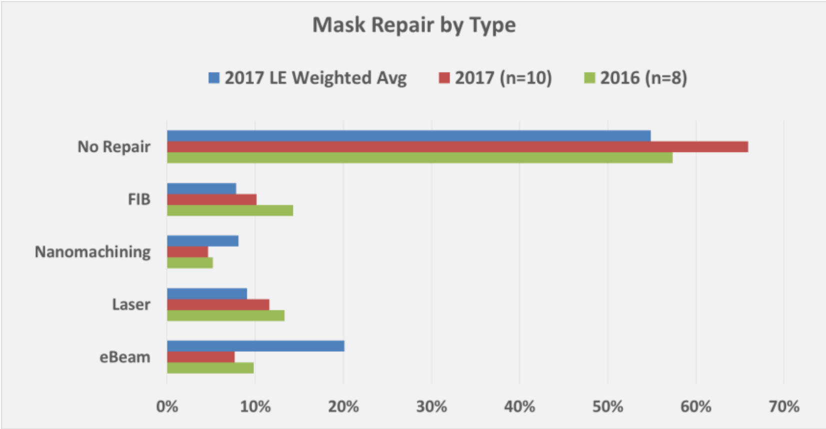

Figure 11: Historical mask repair by type

2.12 Mask Returns

Data prep errors were the number one identified source of mask returns according to the 2017 survey. Only 0.31% of masks are returned according to the 2017 survey. The 2017 question asked was: Of the masks returned from the fab, what percentage were attributed to the following causes? (Soft Defects, Hard Defects, Data prep errors, Bad repair, Wrong Pellicle/Damage, Haze, Other)

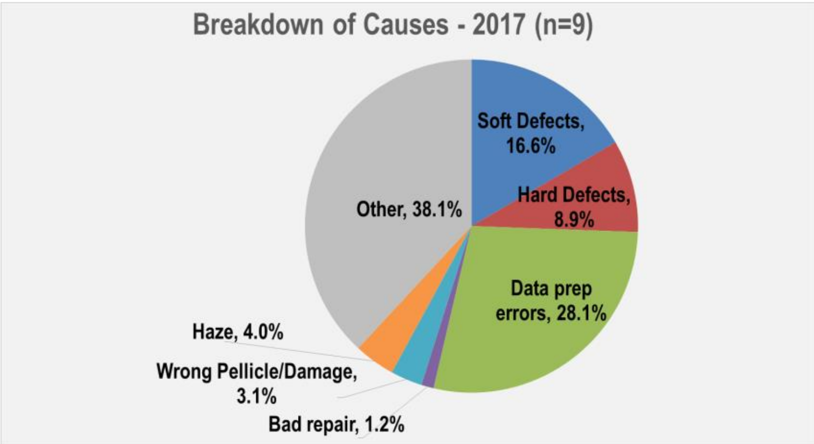

Figure 12: Causes of Mask Returns in 2017

2.13 Mask Yield

In 2017, mask yield was reported by mask type. Mask yield overall was 94.8%. The 2017 questions asked were: What was your overall percent mask yield for July 2016-June 2017? What was your percent mask yield by category for July 2016-June 2017? (Binary, AttPSM, AltPSM, EUV)

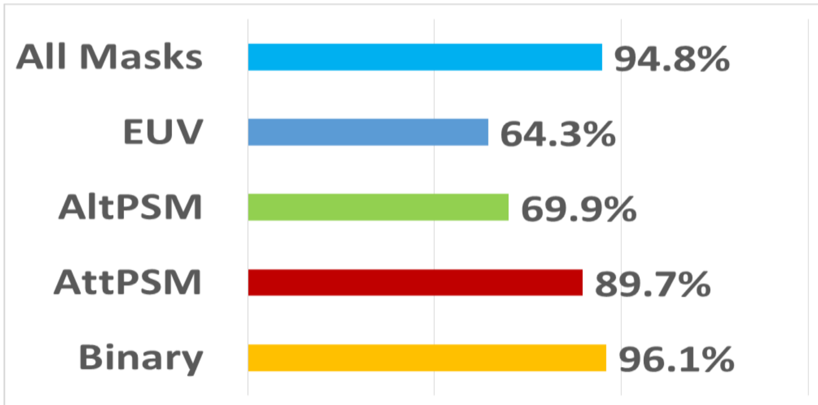

Figure 13: Mask yield by mask type

2.14 Data Preparation

The weighted average for data prep time is greater at leading edge nodes as shown in green in Figure 14. The starting point for data preparation was defined as RET output. Figure 14 also shows in orange the weighted average after outliers in the data were removed, which then follows the expected pattern of average data prep time increasing as you move to a smaller ground rule starting with 130nm. The 2017 question asked was: What was the average data prep time (starting point defined as RET output) by Ground Rules?

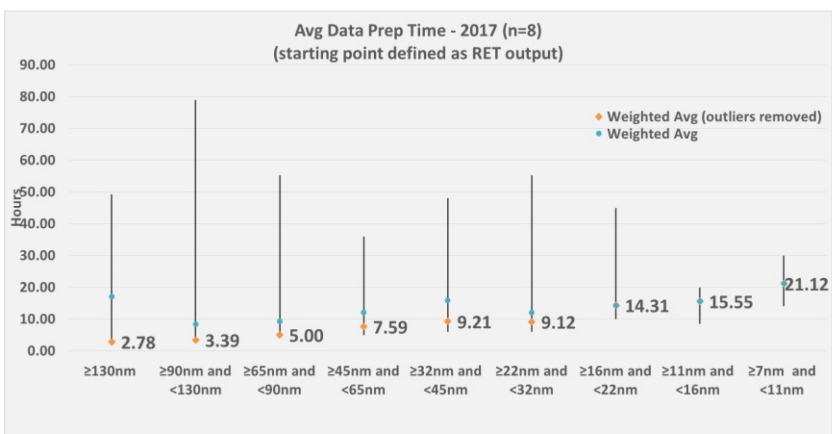

Figure 14: Data preparation time by ground rule

2.15 Mask Process Correction (MPC)

In a new question for 2017, MPC increased at leading-edge nodes and appears to be a new requirement. The 2017 question asked was: What % of masks by ground rules had Mask Process Correction (MPC) applied?

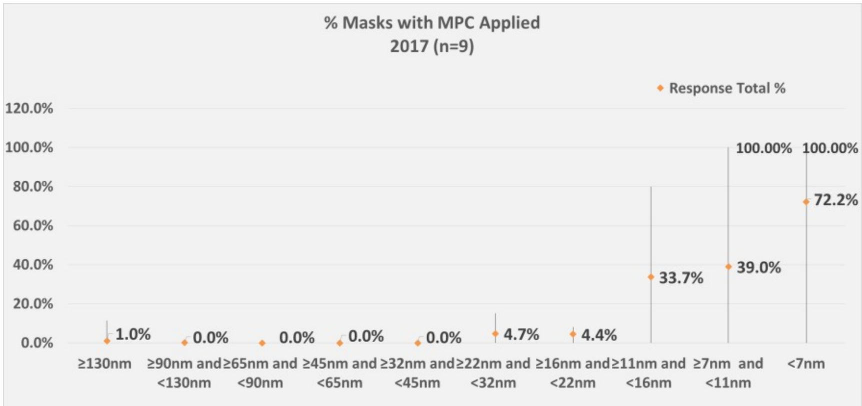

Figure 15: % of masks using MPC by ground rule

3. ACKNOWLEDGEMENTS

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- Dede Adams at David Powell, Inc. for administering the survey.