Mask Industry Assessment: 2003

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ABSTRACT

Microelectronics industry leaders routinely name mask technology and mask supply issues of cost and cycle time as top issues of concern. A survey was initiated in 2002 with support from International SEMATECH (ISMT) and administered by SEMI North America to gather information about the mask industry as an objective assessment of its overall condition.[1] This paper presents the results of the second annual survey which is an enhanced version of the inaugural survey building upon its strengths and improving the weak points. The original survey was designed with the input of member company mask technologists, merchant mask suppliers, and industry equipment makers. The assessment is intended to be used as a baseline for the mask industry and the microelectronics industry to gain a perspective on the technical and business status of the critical mask industry. An objective is to create a valuable reference to identify strengths and opportunities and to guide investments on critical-path issues. As subsequent years are added, historical profiles can also be created.
This assessment includes inputs from ten major global merchant and captive mask manufacturers representing approximately 80% of the global mask market (using revenue as the measure) and making this the most comprehensive mask industry survey ever. The participating companies are: Compugraphics, Dai Nippon Printing, Dupont Photomask, Hoya, IBM, Infineon, Intel, Taiwan Mask Company, Toppan, and TSMC.

Questions are grouped into five categories: General Business Profile Information; Data Processing; Yields and Yield loss Mechanisms; Delivery Time; and Returns and Services. Within each category are a multitude of questions that create a detailed profile of both the business and technical status of the mask industry.

Keywords: Mask industry, photomask, industry, mask yield, photomask yield, mask quality, photomask quality

1. INTRODUCTION

International SEMATECH initiated a survey of the mask industry in 2002 intending to enhance the level of understanding of the unique and critical issues associated with the photomask industry[1]. The desire is to make the survey an annual event from which a substantial and valuable reference database can be built over time to aid in identifying past trends and validating future projections. A very similar survey had been done annually for seven years but was suspended after 1999 for lack of support for the expenses to conduct it. The results from those past surveys were published as SPIE papers and presented at BACUS and were found to provide valuable insights for both mask makers and mask users.[2,3] The 2003 survey is nominally the same as last year's but with some important changes that address observations made last year. In this way, the survey will continue to evolve and respond to needs so that its value to the mask community is maximized. Questions are grouped into five categories: General Business Profile Information; Data Processing; Yields and Yield loss Mechanisms; Delivery Time; and Returns and Services. Within each category are a multitude of questions that create a detailed profile of both the business and technical status of the critical mask industry.

More specifically, the major attributes changed or preserved from the 2002 survey were:

- The total number of question line items in the collection spreadsheet was reduced by removal of the requirement for data to be reported by calendar quarter. Since the 2002 survey revealed no substantially interesting insights from the quarterly division of data, in the 2003 version a simplified summary of the last 12 months was requested.
- The yield loss summary from 2002 showed that defects accounted for an average half of all yield losses. The 2003 survey attempts to partition this overwhelming yield loss contributor with additional questions about the types of defect losses. This resulted in the addition of three yield loss categories to the survey. In 2002, the defect-related yield loss categories were: soft defects and hard defects. In the 2003 survey, the defect categories have a finer granularity: excessive quantity of hard defects, excessive quantity of soft

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defects, OPC-related hard defects, un-repairable hard clear defects, and un-repairable hard opaque defects. This successfully partitioned the defect yield loss data into smaller components bringing the largest single component yield loss element from 50% in 2002 to 28% in 2003.

- A category for "incorrect pellicle mounted" was added to the Returns section.
- The Data Processing section is preserved as in 2002 with information on design file size and data preparation time since this continues to grow as a significant component of cost and cycle time. Detailed questions on mask types were preserved including phase-shift and OPC to reflect the explosion in demand for these advanced reticle types. Information on fabrication processes and tools is again included to reflect the introduction of more dry etching, and higher energy e-beam and shaped-beam pattern generators at the high-end.
- The other major survey sections, General Business Profile Information, Data Processing, Delivery Time, and Returns and Services, were preserved in format as 2002 but with minor attribute name changes to enhance clarity.

2. ASSESSMENT APPROACH

The survey was sent by hardcopy mail to all mask-makers listed in the 2002 edition of the Mask-Makers Handbook.[4] There were ten respondents to the survey and all are major commercial or captive mask fabricators representing an excellent cross-section of the industry. This participation rate is significantly better than 2002 which garnered only seven participants. The survey participants this year were (in alphabetical order): Compugraphics, Dai Nippon Printing (DNP), Dupont Photomasks, Hoya, IBM (captive), Infineon (captive), Intel (captive), Taiwan Mask Company, Toppan, and TSMC (Taiwan Semiconductor Manufacturing Corporation, captive).

The survey was divided into five major sections:

1. General Mask Profile Information
This section seeks to establish a general description of the basic elements of the mask business: technology ground-rule categories, application types (logic, memory, uP, etc.), mask types by glass size (PSM, binary, OPC), magnification distribution, and distribution of fabrication methods used for patterning, etch, metrology, inspection, repair, plus pellicle types.

2. Data Processing
This section requests data on file size and data preparation time average, maximum, and 95th percentile of each respondent's distribution. The 95Th percentile is requested to help discern what file sizes are truly representative of the norm without having extraordinarily large, anomalous files over-weighted in the analysis.

3. Yields and Yield Loss Mechanisms
Overall yield by glass size and mask type (binary, phase-shifting method) is given. Fifteen yield loss mechanisms are offered to create an industry Pareto chart.

4. Delivery Time
Data on average delivery time and time for the first three layers of a new mask set are collected by four different mask type categories: binary, binary with moderate to aggressive OPC, EPSM, and APSM.

5. Mask Returns
This section collects data on mask returns according to nine categories. A subsection assesses "mask maintenance" services provided with categorization into seven service categories.

The complete set of questions posed is given in Appendix A.

David Powell Consulting, the same company that had been contracted for last year's survey, were again the focal point for data collection. Participant identification markings were removed by David Powell Consulting to make the raw data anonymous and then were forwarded to the author. Data were requested from survey participants for the 12 month period from July 1, 2002 through June 30, 2003. The data were loaded into a spreadsheet and summarized for lowest, highest, and average values then graphically displayed as appropriate for the data. Respondents receive a

CD-ROM with complete summary data (beyond the scope of this paper) for further analysis as an incentive for participation.
The intention of International SEMATECH is to continue sponsoring the survey as an annual event. Drawing from the continuing experience, the survey will continue to evolve in scope and clarity. The author invites critique and suggestions from the industry including mask users so as to maximize the utility and value of the survey. These comments will be forwarded to the author of the next survey summary.

3. DATA

The following plots in Appendix B summarize the key observations that can be drawn from the data. Please recognize that although the survey had ten participants, all being major players in the industry, the data cannot be considered "complete" and totally comprehensive. Using financial data from public documents, the respondents cumulatively represent approximately 80% of the industry on a revenue basis (adjusted for approximations of captive mask fabrication open-market value). Please be careful interpreting the comparisons drawn between the 2002 and 2003 surveys since the 2002 survey represents a considerably narrower sample of the overall industry.

Some summary observations drawn from the data are:

- Logic designs are driving the majority of mask volume accounting for approximately 61% of the total, down from 70% last year.
- Although the advanced mask technologies for sub-130nm node technologies get the most attention in technical conferences and publications, only 3% of mask volume is attributable to this still-developing segment and nearly half of all masks are still built to a 500nm or larger design node.
- Even with the ever-growing use of phase-shifting masks, binary masks still represent 95% of the total volume in this group of respondents.
- Six-inch blank usage outstrips five-inch by a factor of 3.4 to 1. All other glass sizes represent 7% of the total.
- 5X magnification printing accounts for just under half of the mask volume, with 4X at 38% and 1X still holding 12% of total volume.
- Design data file sizes are averaging 1.5 GB (double last year's 0.7 GB value) with a maximum observed of 76 GB (4x last year's 18 GB maximum input).
- Data preparation CPU processing times averaged 6.5 hours or 4 times higher than last year, with a maximum observed of 360 hours!
- Yields for binary masks are fairly consistent among the respondents in the low 90s% but show significant variation for phase-shift likely due to the variance of experience between mask fabs. Phase shift mask average yields vary between the 40% and 90% levels with attenuated averaging 67% and alternating at 58%. Both represent substantial increases over last year's data which were 40% and 49% average for attenuated and alternating respectively. However, as is especially important to bear in mind for yield data, the group of respondents are different in 2003 vs. 2002.
- The major process-related yield loss mechanism continues to be defects accounting cumulatively (hard and soft, all types) for about 60% of yield loss. However, administrative and manufacturing errors combined account for a startling 18% of yield losses, the same as reported last year, while CD control accounts for about 16%.
- Delivery times are averaging 5-7 days for binary masks (range is for simple binary to aggressive OPC), much better than the 6-9 days reported last year. Attenuated PSMs average 11 days compared to 14 days reported last year. Alternating PSMs continue to have a distinctively longer lead-time running 23 days compared to 30 days reported last year but, based upon a relatively small volume representing less than 1% of total shipments.
- Mask returns represent about 0.2% of production volume and the reasons are not substantially different from last year. The largest return reason is data preparation errors at 19.5% reflecting the increasing nominal datafile sizes and design complexity. The next three largest contributors are soft-defects, "other reasons", and "administrative errors" in roughly even proportions of about 17% each. The "other reasons" category is new this year and needs to be partitioned more finely in the next survey.
- Mask maintenance service is dominated by damaged pellicle replacement at 63% and particles under the pellicle accounting for about 17% of the maintenance volume.

The detailed data plots for key questions are given in Appendix B.

4. CONCLUSIONS

The survey overall was a success in capturing ten major industry players who are dominant suppliers in the industry cumulatively representing approximately 80% of global mask revenue. The data, although not able to illustrate a "complete" portrayal of the industry, are still valid for extracting some interesting observations summarized in Section 3 and graphically presented in Appendix B. These observations will only be enhanced in value as the history and trends are created over time.

Defects continue to be the overwhelming source of yield loss and, therefore, a major influence on cost and delivery time. This year's survey added significant new information to discern the types of defects. Un-repairable opaque and clear defects account for 43% of yield loss making improved ability to repair defects with high spatial resolution and to reconstruct large areas as possibly the single most opportune area to improve mask yield. Soft defects trail at 3.5% of yield loss indicating that cleaning processes are performing fairly well. OPC-related defects (e.g., missing serifs or broken sub-resolution scatter bars) are only 2.1% commensurate with the 19% portion of all masks that have any OPC at all. Continued implementation of SMIF-type micro-environment containment and improved handling practices for key defect-sensitive process sectors should provide benefit as defenses against defects.

Remarkably, the second largest yield detractor is not process related but is human error in manufacturing and administrative operations. At nearly 17% combined, this may indicate the need for more automation in the input and handling of production control information from order entry through recipe loading and specification dispositioning.

CD control is the second largest process yield detractor at 16% indicating that the patterning sector including pattern generation, develop, and transfer have opportunity for improvement. It could be interesting to probe this further by partitioning the issue with more questions in the next survey.

Data preparation times vary greatly between respondents reflective of the different business foci: some dealing heavily in simple, commodity binary masks and others having significant complex, vertex-rich, fine grid designs in their portfolio. The average data prep time for all responses was 6.5 hours but the range was 30 minutes to 28 hours roughly commensurate with data volume variation. The average preparation time was a reasonable 1.6 hours with a 95^{th} percentile number at 19.3 hours. The component of preparation time attributable to hardware and software performance may be resolved in some cases without invention but simply an upgrade investment.

Data file sizes vary considerably too of course for the same reasons as preparation times with the average at 1.5 GB but individual respondent means range from 40 MB to 7.7 GB! The maximum file size reported was 76 GB. SEMI introduced the new OASIS data format October 2003 which is reportedly up to 60% more compact than GDSII. Hopefully, this effort will be embraced and other data formats and more efficient hierarchical data preparation algorithms being developed will keep the continuing data volume explosion in check.

Delivery times show a predictable trend of variation between mask types with binary averaging 5.5 days, binary with significant OPC complexity at 7.2 days, then attenuated at 11.1 days and alternating at 23.4 days. The variation between suppliers is difficult to analyze considering the variance in design complexity between the various mask type categories and the variance in experience with the more advanced mask types. Although binary mask delivery time has been essentially flat for years in the surveys, attenuated PSM shows improvement. Considering the difference in raw process time for attenuated PSMs is only about 30% more, the data indicate there should be opportunity for further delivery time reduction for attenuated PSMs.

Mask returns are dominated by human-related errors with the combination of data preparation and administrative errors accounting for at least 36% of the total. As stated in the case of initial yield loss, automation of data processing and handling and order entry should improve on this performance. Soft defects accounted for 16.5% of returns indicating some opportunity for automation of the critical pellicle mounting sector. Incorrect pellicles being mounted account for just under 10% of returns which seems inexcusable.

Hopefully these benchmark data and interpretations discussed above will provide inspiration for further analysis and deeper thought on the issues and stimulate innovation to improve performance in the crucial areas.

ACKNOWLEDGEMENTS

The author thanks the participating companies heartily for their spirit of competition with cooperation in assembling this valuable analysis of the industry.

The author thanks Ronda Wall and Dan Tracy at SEMI North America for co-sponsoring the survey as in the past and administering the actual mailings and collection of data with Dede Adams at the consulting firm David Powell Consulting, Inc.

Financial reference data were provided by Ted Berg of Lehman Brothers and I appreciate his continued generosity in sharing information regarding the mask industry.

REFERENCES

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2. B.J. Grenon, "1999 Mask Industry Quality Assessment", Proc. SPIE 15th Annual Symposium on Photomask Technology and Management BACUS, **Vol. 3873**, pp. 162-174,
3. E. Gonzalez-La'O, "1998 Mask Industry Quality Assessment", Proc. SPIE 14th Annual Symposium on Photomask Technology and Management BACUS, **Vol. 3546**, pp. 10-29, 1998
4. B.J. Grenon, Mask Makers Data Book, 2002 Edition, published by Grenon Consulting, Inc., 2002

APPENDIX A: Survey Questions

1.0 General Mask Profile Information
The ground-rule categories are based on the ITRS 2001 edition definition at 1X. All magnification reticles can be combined for these questions. Please ensure the total of all categories adds to 100%.

1.1 Percentage of overall mask shipments that fit into the following nominal feature groundrule categories. (Next 7 lines should add to 100%)

- 1.1.1 >= 500nm groundrule
- 1.1.2 >= 350 < 500nm
- 1.1.3 >= 250 < 350nm
- 1.1.4 >= 180 < 250nm
- 1.1.5 >= 130 < 180nm
- 1.1.6 >= 100 < 130nm
- 1.1.7 <100nm groundrule

Please categorize your designs into the categories as best as possible. "Memory" is meant to be chips that are pure memory designs. "Logic" or "System-on-chip" designs having substantial memory portions should not be considered "memory". Please ensure the total of all categories adds to 100%.

1.2 Percentage of overall mask shipments that fit into the following application categories. (Next 6 lines should add to 100%)

- 1.2.1 Memory
- 1.2.2 Logic
- 1.2.3 Microprocessor
- 1.2.4 RF/mixed-signal
- 1.2.5 System on a chip
- 1.2.6 Other

Please note that question 1.3 asks for number of units while questions 1.3.1-1.3.4 ask for each category as a percentage of the total.

1.3 Total number of units of total shipped: (integer quantity)

1.3.1 6 inch glass: percentage of total shipments (should equal sum of next 3 lines)

1.3.1.1 Binary
1.3.1.2 Attenuated PSM
1.3.1.3 Alternating PSM
1.3.2 5 inch glass: percentage of total shipments (should equal sum of next 3 lines)
1.3.2.1 Binary
1.3.2.2 Attenuated PSM
1.3.2.3 Alternating PSM
1.3.3 All other sizes of glass: percentage of total shipments
1.3.4 Magnification: percentage of total (Next 4 lines should add to 100%)
1.3.3.1 1X
1.3.3.2 4X
1.3.3.3 5X
1.3.3.4 All other magnifications

Please note that sections1.4.x.x asks for answers expressed again as a percentage of total shipments. Please ensure each subsection 1.4.x adds to 100%.
1.4 Percentage of total shipments: (Each sub-section 1.4.1 - 1.4.7 should add to 100%)
Guidance is given for each OPC category but please use your best judgment in categorizing the OPC type into one of the four choices.
1.4 Percentage of total shipments: (Next 4 lines should add to 100%)
1.4.1.1 Without OPC
1.4.1.2 Simple OPC - serifs
1.4.1.3 Moderate OPC - rules based
1.4.1.4 Aggressive OPC - model based or scattering bars
(Next 6 lines should add to 100%)
1.4.2.1 Laser patterned
1.4.2.2 Vector shaped e-beam patterned: <50 kV
1.4.2.3 Vector shaped e-beam patterned: > = 50 kV
1.4.2.4 Raster or vector spot e-beam patterned: <50 kV
1.4.2.5 Raster or vector spot e-beam patterned: > = 50 kV
1.4.2.6 Other patterning method
(Next 2 lines should add to 100%)
1.4.3.1 Wet etched
1.4.3.2 Dry etched
(Next 5 lines should add to 100%)
1.4.4.1 Optical CD measurement MUV
1.4.4.2 Optical CD measurement DUV
1.4.4.3 SEM CD measurement
1.4.4.4 Other CD measurement technique
1.4.4.5 No CD measurement
(Next 4 lines should add to 100%)
1.4.5.1 Die:die inspection
1.4.5.2 Die: database inspection
1.4.5.3 Both die:die and die:database inspection
1.4.5.4 No inspection
(Next 4 lines should add to 100%)
1.4.6.1 Laser repair
1.4.6.2 FIB repair
1.4.6.3 Mechanical (nano-shaping) repair
1.4.6.4 No repair
(Next 4 lines should add to 100%)
1.4.7.1 Teflon-based pellicle
1.4.7.2 Nitrocellulose pellicle
1.4.7.3 Other material
1.4.7.4 No pellicle

2.0 Data Processing
Please use units of megabytes for questions 2.1-2.3

2.1 Average of distribution of incoming data file sizes after all data manipulations are completed (OPC, kerf merge, test sites merge, proximity correction)

We ask for the 95th percentile here to eliminate the influence of anomalously large datasets that do not represent the state of the nominal case.

2.2 95th percentile of distribution of incoming data file sizes after all data manipulations are completed (OPC, kerf merge, test sites merge, proximity correction)

2.3 Maximum data file size observed

Please use units of hours including all operations to prepare the data (CPU hours, administrative, engineering, checking etc.)

2.4 Average of distribution of data file preparation times (preparation to go from incoming design data to pattern generator-ready data).

2.5 95th percentile of distribution of data file preparation times (preparation to go from incoming design data to pattern generator-ready data).

2.6 Maximum data file preparation time observed

3.0 Yield

Overall yields: 3.1 + 3.2 + 3.3 should sum to 100%

- 3.1 6 inch glass overall yield:
  - 3.1.1 Binary
  - 3.1.2 Attenuated PSM
  - 3.1.3 Alternating PSM
- 3.2 5 inch glass overall yield:
  - 3.2.1 Binary
  - 3.2.2 Attenuated PSM
  - 3.2.3 Alternating PSM
- 3.3 All other sizes of glass: overall yield

For reticles that are lost to yield for more than one reason, please choose one primary yield loss reason for each loss. Using this method, the total yield losses should add to 100% even if overall yield loss for all reticles is, for example, 20%.

Definitions:

Hard defect: any undesigned or unintentional material on or in the mask blank which cannot be removed or corrected by conventional cleaning techniques. Examples: absorber flake, protrusion, intrusion, bridge, pinhole, erosion, and missing anti-reflective coating.

Soft defect: chemical residue, particle, or foreign material on the mask surface which is generally removable by conventional cleaning techniques. Examples: contamination, particles, chemical droplet, water-spot, crystalline residue, and haze.

Yield Loss Mechanisms: 3.3.1-3.3.15 should sum to 100%

3.4 Percentage of total yield losses due to each reason 3.3.1- 3.3.15 (should add to 100%):

- 3.4.1 Excessive quantity of hard defects (not OPC related)
- 3.4.2 OPC-related hard defect (missing serifs, assist bars defect, etc.)
- 3.4.3 Unrepairable clear hard defect(s) (not OPC related)
- 3.4.4 Unrepairable opaque hard defect(s) (not OPC related)
- 3.4.5 Soft defects (not pellicle mount related)
- 3.4.6 CD mean-to-nominal
- 3.4.7 CD uniformity
- 3.4.8 Image placement
- 3.4.9 Phase error mean-to-nominal
- 3.4.10 Phase error uniformity
- 3.4.11 OPC-related losses (missing serifs, assist bars defect or out of CD spec)
- 3.4.12 Pellicle Mounting error
- 3.4.13 Post-pellicle mount, soft defects after mount
- 3.4.14 Administrative error (order entry, dataprepation software or human error)
- 3.4.15 Manufacturing error (procedural, wrong recipe, software or human error)

Please use units of days for sections 4.x with 0.1 day accuracy.

4.0 Delivery Time

Delivery times in days for each mask type for two cases each:

4.1 Case 1: Average per mask for first three layers of a given mask set

- 4.1.1 Binary (days)
- 4.1.2 Binary with moderate or aggressive OPC (days)
- 4.1.3 Attenuated PSM (days)
- 4.1.4 Alternating PSM (days)

4.2 Case 2: Average overall for this type of mask

- 4.2.1 Binary
- 4.2.2 Binary with moderate or aggressive OPC
- 4.2.3 Attenuated PSM
- 4.2.4 Alternating PSM

5.0 Returns

Mask Returns refers to masks that are returned to the Mask Fab by a customer for a quality problem that existed at time of shipment. Sometimes these issues are controversial, for example, in the case of damage. Please use your best judgement to complete this section.

Please note that the total of all mask return reasons should add to 100%. For reticles that are returned for more than one reason, please choose one primary return reason. Using this method, the return should add to 100%.

5.1 Mask Returns overall for all mask types: (percentage of total shipments)

Percentage of total returns for: (next 9 lines should add to 100%)

- 5.1.1 Hard defects (chrome, opaque, clear, ESD-induced)
- 5.1.2 Soft defects (foreign material, stains)
- 5.1.3 Hard defect: bad repair
- 5.1.4 Data preparation error (order entry error, job deck error, kerf array merge error)
- 5.1.5 CD out-of-specification
- 5.1.6 Image placement out-of-specification
- 5.1.7 Administrative human error
- 5.1.8 Wrong pellicle
- 5.1.9 Other reasons

Mask Maintenance Service refers to masks returned from customers for reasons other than manufacturing defects or warranty issues. For example, customer handling damage or contamination or accidental pellicle breakage.

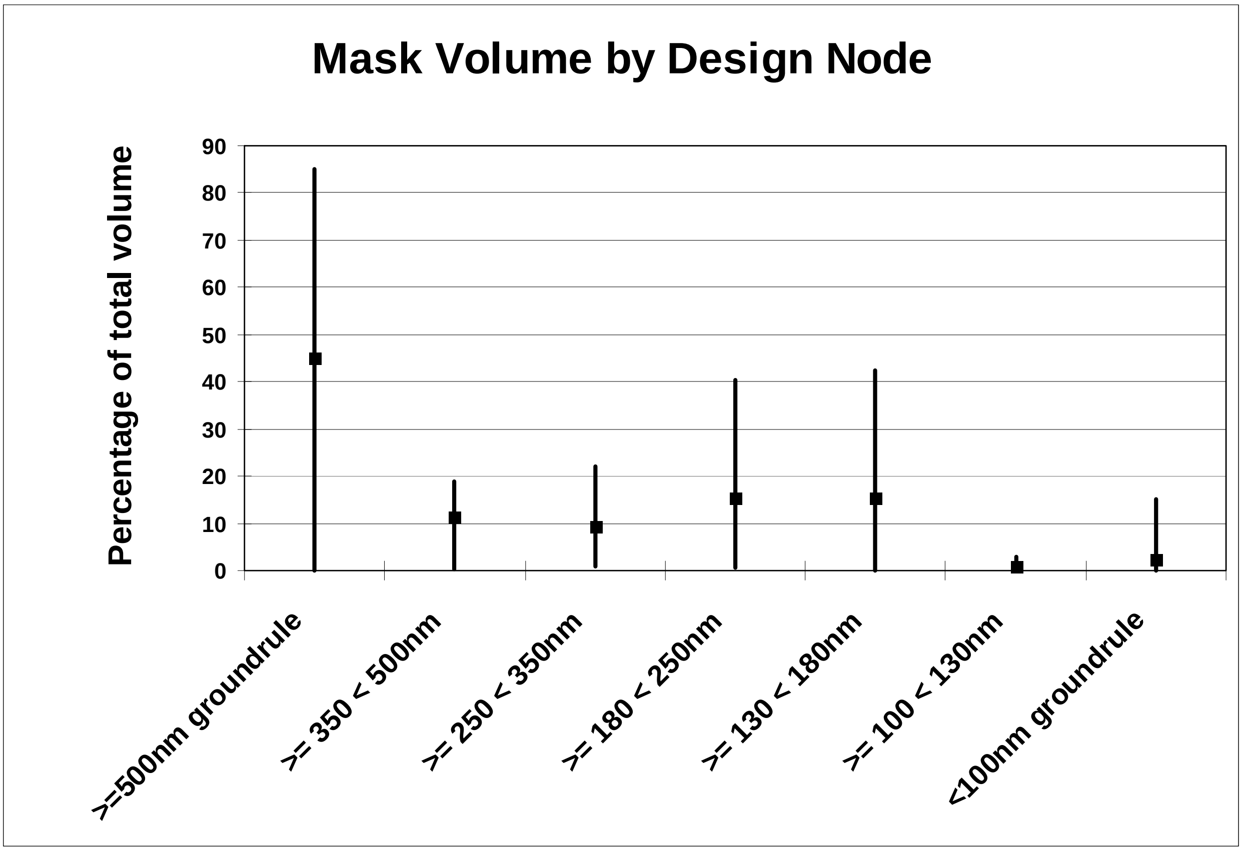
Please note that the total of all mask maintenance reasons should add to 100%. For reticles that are serviced for more than one reason, please choose one primary return reason. Using this method, the maintenance reasons should add to 100%.

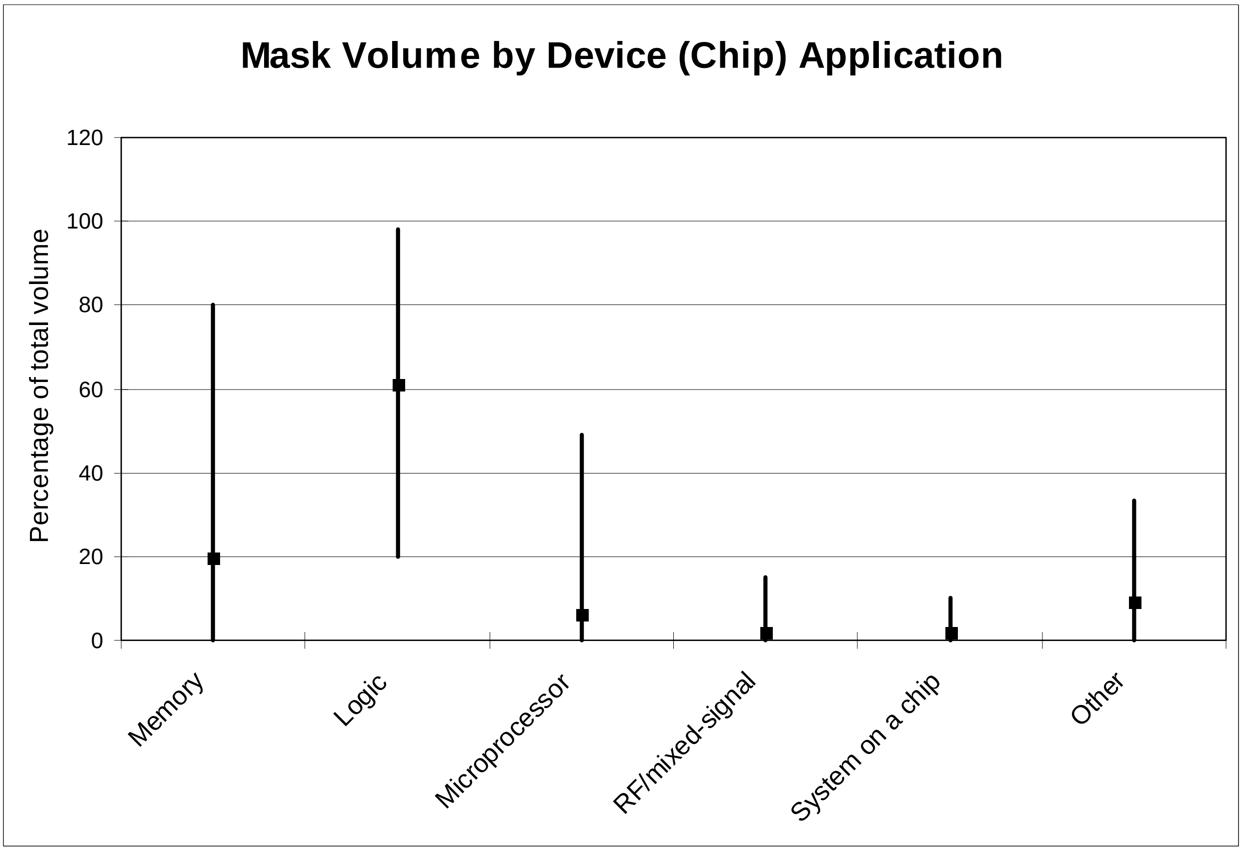
5.2 Mask Maintenance Service: (percentage of total shipments submitted a service)

Percentage of total services for: (Next 7 lines should add to 100%)

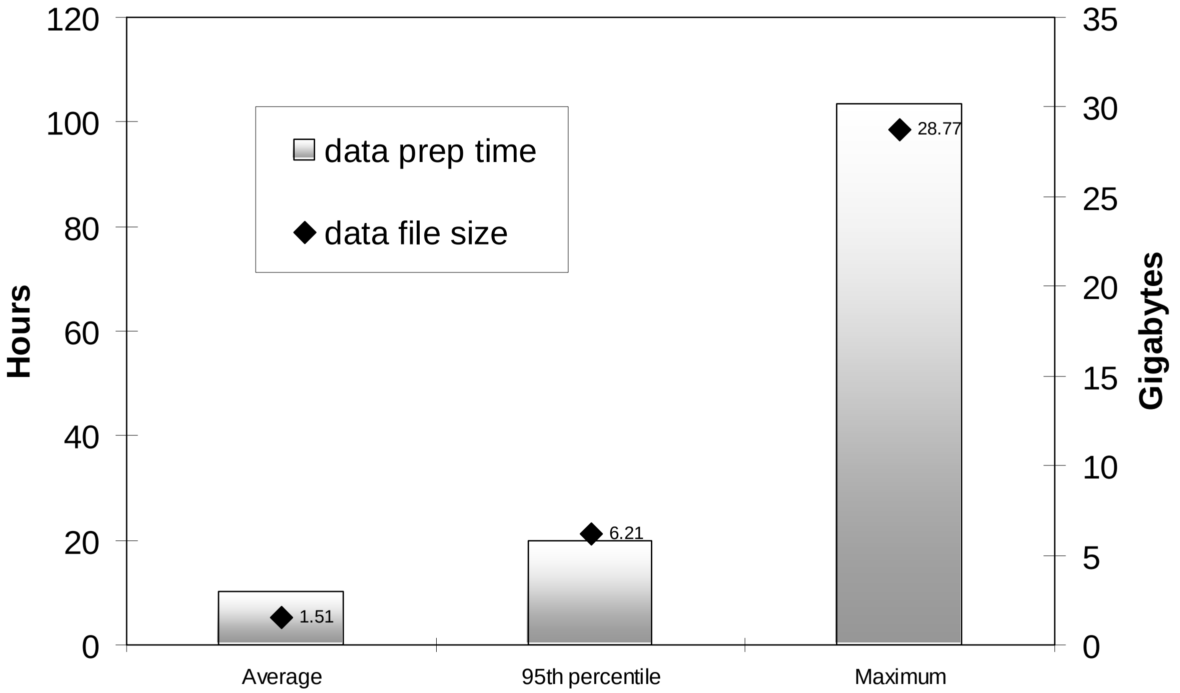
- 5.2.1 Damaged pellicle
- 5.2.2 Particles under pellicle
- 5.2.3 Exposure-induced degradation - 248nm
- 5.2.4 Exposure-induced degradation - 193nm
- 5.2.5 Non-removable particles
- 5.2.6 Scratch, chip, or other physical mask damage
- 5.2.7 Other reasons

APPENDIX B: Survey Data Plots

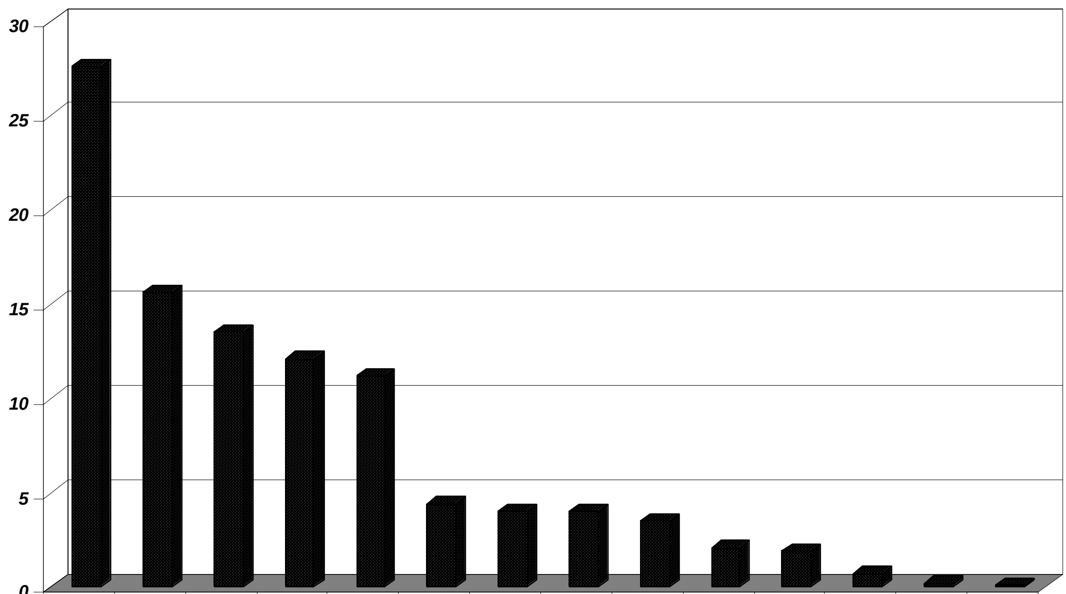

Mask Volume by Design Node
Percentage of total volume
90
80
70
60
50
40
30
20
10
0
>=500nm groundrule
>= 350 < 500nm
>= 250 < 350nm
>= 180 < 250nm
>= 130 < 180nm
>= 100 < 130nm
<100nm groundrule


Mask Volume by Device (Chip) Application
Percentage of total volume
120
100
80
60
40
20
0
Memory
Logic
Microprocessor
RF/mixed-signal
System on a chip
Other

Design Data Size and Prep Time

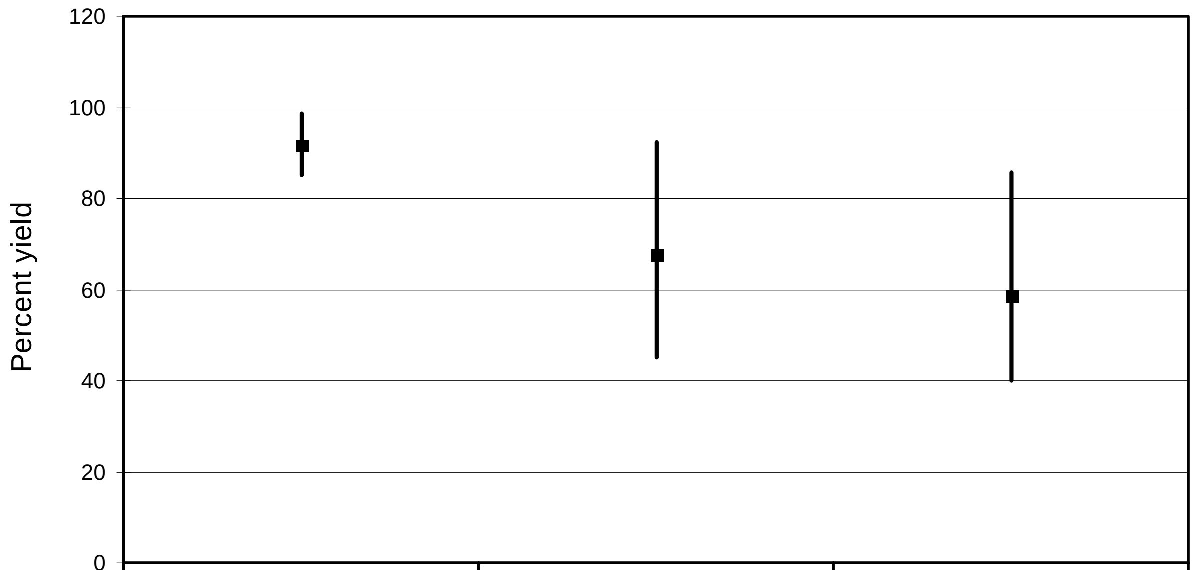


Yield Loss Reasons



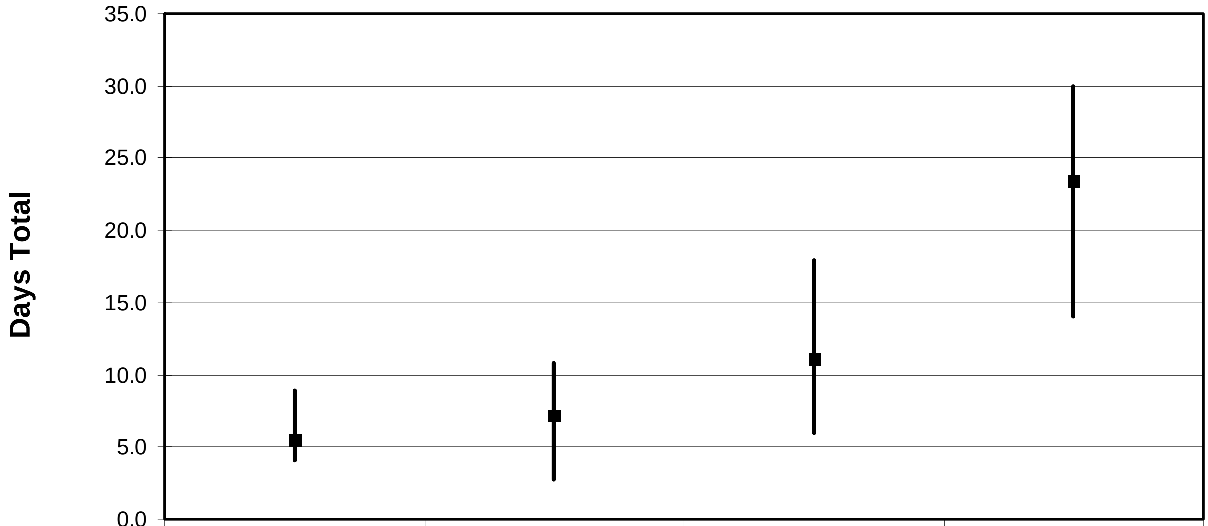
	Unrepairable opague	Unrepairable clear	Manufacturing error	CD Mean-to-Nominal	Excessive hard defects	Image Placement error	CD Uniformity	Administrative error	Soft defects	OPC-related defects	Post-pellicle mount	Phase angle mean-to-	Phase angle uniformi	Pellicle mounting error
■ Yield loss percent	27.6	15.6	13.5	12.1	11.2	4.4	4	4	3.5	2.1	1.9	0.7	0.2	0.1

Overall Yields by Mask Type



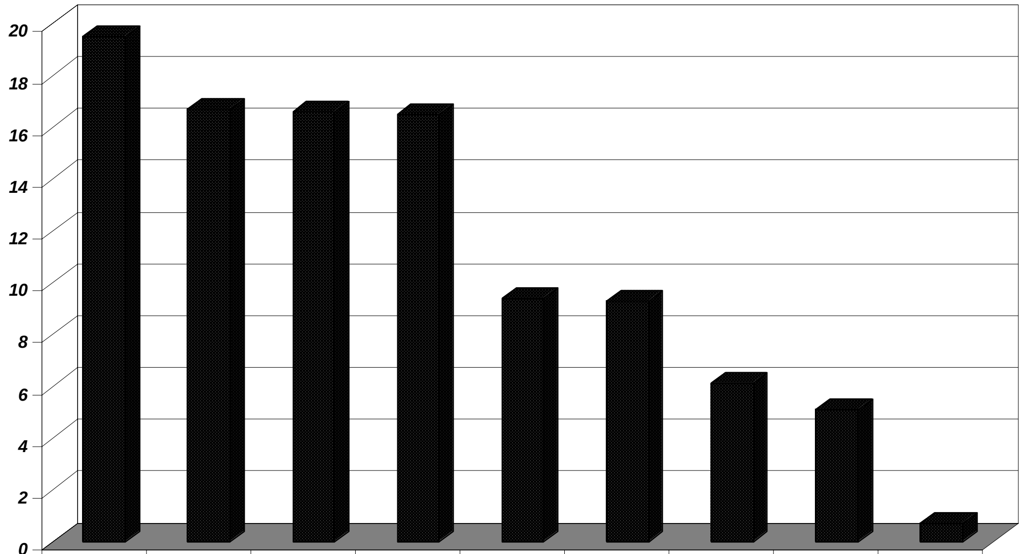
	Binary	Attenuated PSM	Alternating PSM
max	98.5	92.4	85.7
min	85.0	45.0	40.0
average	91.6	67.6	58.5

Delivery Time



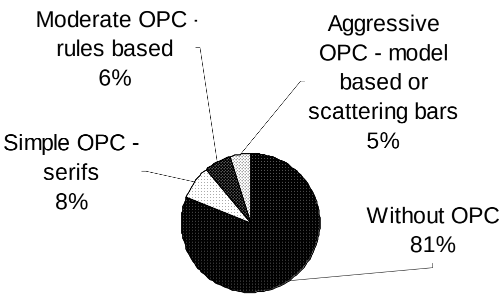
	Binary (days)	Binary with moderate or aggressive OPC (days)	Attenuated PSM (days)	Alternating PSM (days)
Longest	8.9	10.8	17.9	30.0
Shortest	4.1	2.8	6.0	14.0
■ Average	5.5	7.2	11.1	23.4

Mask Return Reasons

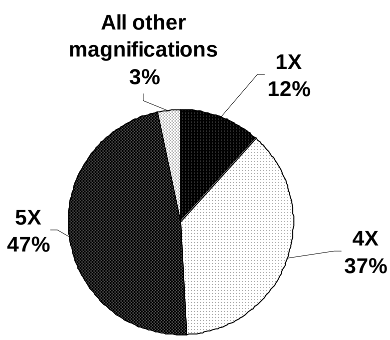


	Data prep	Other reasons	Administr ative human	Soft defects	Wrong pellicle	Hard defects	CD	Bad repair	Image placement
Percent of returns	19.5	16.7	16.6	16.5	9.4	9.3	6.1	5.1	0.7

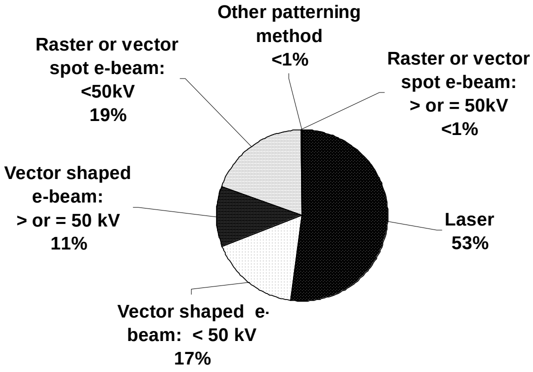
Mask Volume by OPC Level



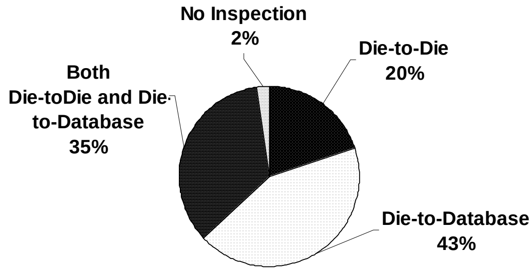
Magnification



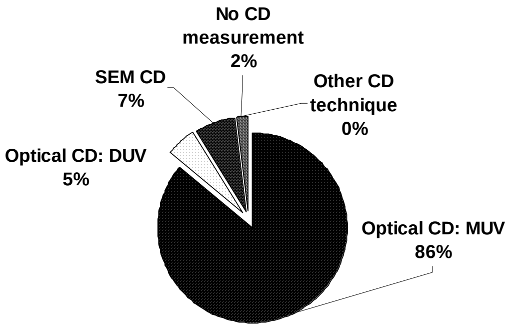
Patterning Method



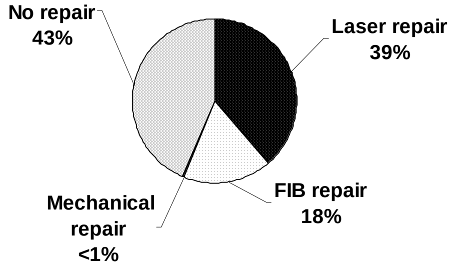
Inspection Modes



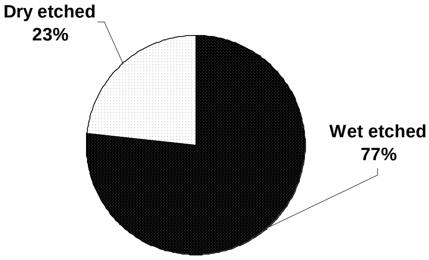
CD Metrology



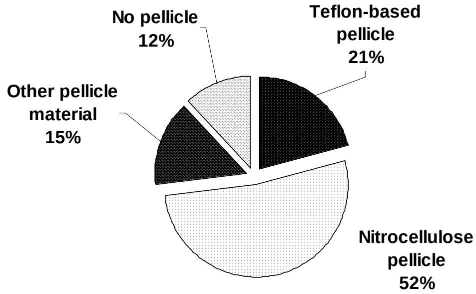
Repair Process



Attenuator Etch Process



Pellicle Type



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