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Study of aging behaviour on 193nm Phase Shift Masks

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ABSTRACT

Chrome migration or aging phenomenon is known for 193nm binary photomasks since a few years. 193nm irradiations and time generate an oxide growth on chrome sidewalls and then cause a non-uniform increase of critical dimensions (CD)[1],[2],[3],[4]. If not prevented or detected early enough, wafer fabs are likely to face process drifts, defectivity issues and even lower yield on wafers in the worst cases. Fortunately, some solutions have been put in place in the industry. A standard cleaning and repel service at the maskshop has been demonstrated as efficient to remove the grown materials and get the mask CD back on target. Some detection methods have been already described in literature, such as wafer CD intrafield monitoring (ACLV)[1], giving reliable results but also consuming additional SEM time with less precision than direct reticle measurement. Another approach is to monitor the CD uniformity directly on the photomask, concurrently with defect inspection for regular requalification to production for wafer fabs[5]. This enables ultimately to trigger the preventive cleanings rather than on predefined thresholds.

However, may the 193nm Phase Shift Masks (PSM) be impacted too? In other words, should wafer fabs pay attention to this form of aging? Indeed, some publications[6],[7],[8] report a growth of SiO$_2$, leading to the development of a high duration MoSi (modification of MoSi composition).
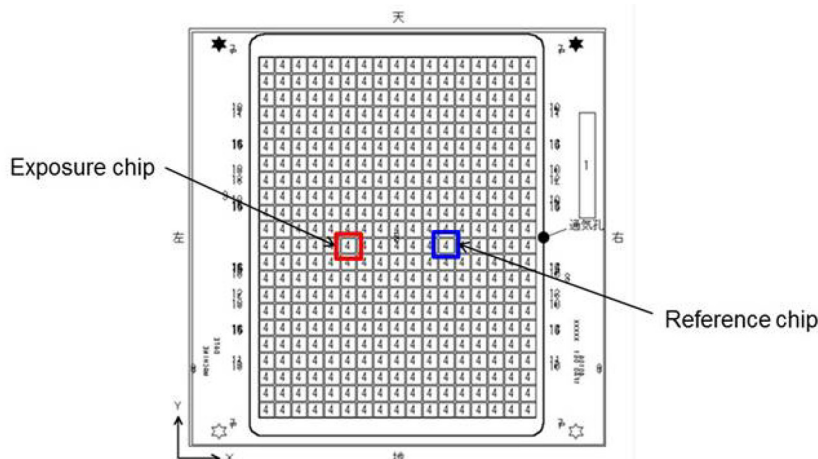
Figure 2.1: Two dice written on test mask.

SPIE.

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EDITORIAL

Get a Lot More for Your Money on that Next Generation Equipment Purchase

Michael D. Archuletta, RAVE LLC

When was the last time you had a roadmap strategy meeting with one of your key equipment suppliers?

In other words, how much information do you normally share (good and bad)? How many process improvement projects do you conduct that include your tool vendor in the reported results? How many of your tool vendors know the process recipes you use or the specifics of how you use the tool in production? How often do you modify a tool to improve its use without notifying the supplier? How often do you demand revolutionary performance improvements from your equipment suppliers without giving a clear description of why each specification improvement is necessary? What is your involvement in industry-wide technology standards forums that create comprehensive roadmaps for the different equipment disciplines?

Most industry partners are really good about this and religiously cooperative with their suppliers. But, it never hurts to be reminded about the importance and value of "team spirit." Technology advancement and equipment evolution go hand-in-hand. You can't have one without the other. For each new technology node, system performance specifications must be clearly delineated and the trade-offs between critical process parameters need to be understood and prioritized. Meaningful new test vehicles should be jointly designed with metrology protocols defined and agreed. Otherwise, precious time and millions of dollars can be lost chasing the wrong things in the wrong order. When tool suppliers are forced to develop innovations on their own, with limited input, customers can expect the tool technology to be disproportionately expensive, late to market and lacking critical performance capabilities.

Add to this, the list of Photomask manufacturers and equipment suppliers that drop out of the mask industry each year. The equation is simple. Over the last ten years, the average cost to develop a new tool generation has tripled. By the way, equipment prices have done the same. An equipment generation that cost $6-8M to develop in 2005, now approaches $12-24M to develop today. Amortize that R&D ROI over a shrinking number of customers. In 2005, the maximum number of tools of a given generation expected to sell in a niche market like the Photomask Industry was 10-20 units. Today that number can be as low as 6 tools. Equipment suppliers that don't capture 80% of the market, never recoup their investment and can't create the income necessary to afford the next development cycle.

When it comes to advanced manufacturing equipment technology, getting the performance capabilities and specifications right the first time is paramount. This is not an indictment of technology information sharing habits, but rather a gentle reminder that active collaboration always accomplishes more, faster and a lower ultimate cost. Keep in mind, proprietary technology and competitive secrets do not need to be divulged. There is much relevant and important information that can be exchanged without "giving away the store." Truth is, equipment vendors don't mind being asked for extraordinary capabilities and tight performance specifications. What drives equipment makers crazy are demands without cooperative input and sufficient clarity on what, when and why something is needed for the succeeding generation of process technology.

So, keep participating in those industry consensus and standards forums. And when a key equipment supplier asks for a roadmap exchange, a joint development project, a tool design or performance review, share as much as you can. You'll get a lot more for your money on that next generation equipment purchase.
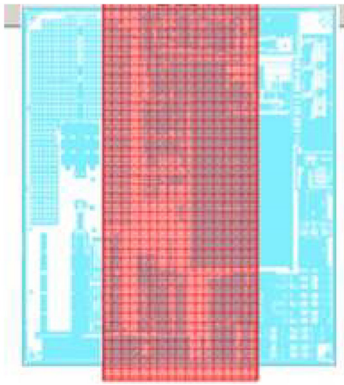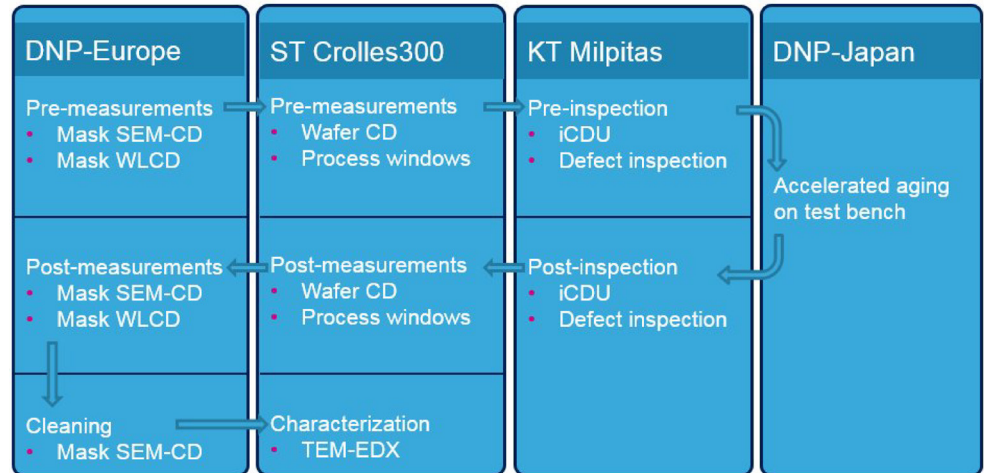
Figure 2.2: Exposure slit in test bench.

Figure 2.3: Experimental flow at a glance.

This study will characterize the aging behaviour on a 193nm PSM contact hole layer, 40nm logic technology node.

During this study, the aging phenomenon has been accelerated with the use of a test bench, to reach a CD increase up to 11nm after a cumulated exposure dose of 10kJ/cm² (equivalent to exposures of >32,000 wafers 300mm). Two dice were compared, one kept as reference without any exposure, whereas the other die was aged on the accelerated test bench.

Exhaustive characterization has been performed, with CD measurements on the mask and on wafers, evaluation of lithography process windows for usual patterns and most critical features (Optical Proximity Correction hotspots). It appears that despite a consistent CD increase on the mask, the impact on wafer can be neglected, at least at this amount of exposures. Aerial CD were also analysed through a Zeiss WLCD™ to enable a prediction of wafer impact.

An advanced inspection tool (KLA-Tencor X5.2 model) has been challenged as an inline monitoring method to detect the aging degradation on PSM. The Intensity Critical Dimension Uniformity option (iCDU™) was firstly developed to provide feed-forward CDU maps for scanners intrafield corrections, from arrayed dense structures on memory masks. Due to layout complexity and differing feature types, CDU monitoring on logic masks used to pose unique challenges. CDU monitoring on logic masks is now available, the latest Delta-Die and Delta-Time options gives all the needed information, as shown in this paper. In this study, iCDU has demonstrated its ability to catch a slight degradation of CD uniformity.

In the end, this study shows evidences that standard cleanings used in maskshops cannot recover the mask back to its original CD. Finally, Transmission Electron Microscopy (TEM) was used to confirm the chemical nature of the grown material on sidewalls. TEM cuts provide a comparison between a production mask (aging over many years in production) and the test mask (accelerated aging on a test bench).

1. Introduction

For many years, the semiconductor industry used to face a few main mechanisms of yield losses, like haze growth on patterns or pellicle darkening. However, new second-order failure mechanisms appeared after the major ones were put under control in wafer fabs. Indeed, wafer fabs are still learning, even on mature technologies like binary or PSM. When 193nm binary reticles were used on layers with very critical CD, chrome migration or aging phenomenon could no longer be neglected and thus must be taken into consideration. 193nm irradiations and time generate an oxide growth on chrome sidewalls and then cause a non-uniform increase of CD[1],[2],[3,][4] with radial signatures. If not prevented or detected early enough, wafer fabs are likely to face process drifts, defectivity issues and even lower yield on wafers in the worst cases. Fortunately, a standard cleaning and repel service at the maskshop has been demonstrated as efficient to remove the grown materials and get the mask CD back on target. Inline monitoring was key to advisedly trigger preventive cleanings. Therefore new detection methods have been found, such as wafer CD intrafield monitoring (ACLV)[1], giving reliable results but also consuming additional SEM time with less precision than direct measurement on reticle. Another approach is to monitor the CD uniformity directly on the photomask, concurrently with defect inspection for regular requalification to production for wafer fabs thanks to iCDU option available on the advanced inspection system KLA Tencor X5.2[5]. This enables ultimately to trigger the preventive cleanings rather than on predefined thresholds.

Aging of 193nm binary reticles became a main concern for wafer fabs, so that innovative solutions were put in place to get rid of this weakness of binary reticles. New blanks were introduced by suppliers, with high durability to irradiations. Another approach to prevent from any trouble, was to improve the mask manufacturing process in maskshops, in order to make the reticle more resistant to future oxidation. A simpler solution was to switch from binary blanks to PSM blanks, because PSM were supposed to be less sensitive to oxidation growth, as reported in a few publications[6],[7],[8]. Aging on PSM is described as a slow oxidation of MoSi, leading SiO_2 growth on sidewalls. As SiO_h is expected to be more or less transparent to exposure light, is the aging on PSM still likely to cause troubles for wafer fabs?

This study will fully assess the impact for wafer fabs of the aging phenomenon on PSM. A 193nm PSM contact layer from 40nm logic technology node will be characterized by SEM-CD and WLCD on mask, wafer CD, iCDU results and TEM-EDX chemical analysis, before and after an accelerated aging of a test mask. The experimental flow is described in the next chapter. In the end, experimental results will be compared with real production
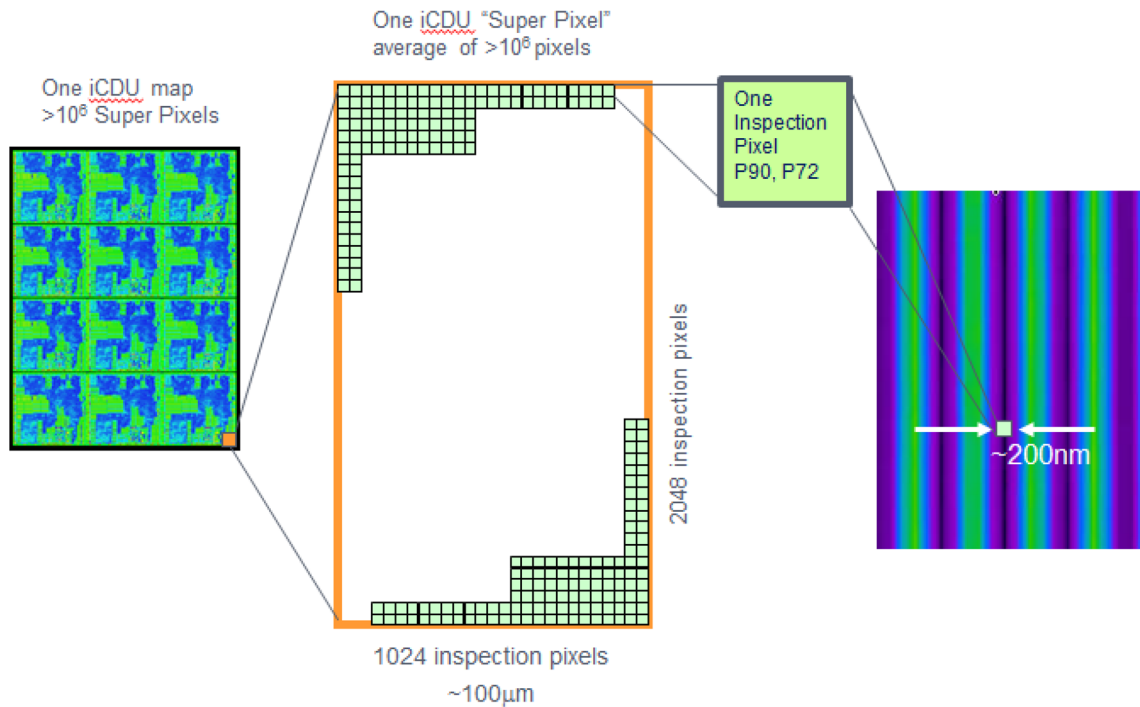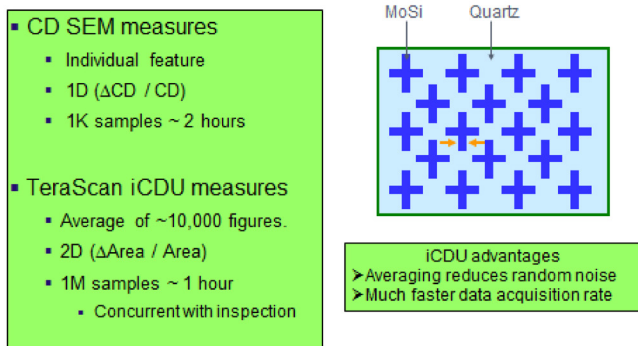
BREWS
N • E • W • S

One iCDU map
>10⁶ Super Pixels

One iCDU "Super Pixel"
average of >10⁶ pixels

One
Inspection
Pixel
P90, P72

2048 inspection pixels

~200nm

1024 inspection pixels
~100μm

Figure 3.1: Sub region Super Pixel.

- CD SEM measures
  - Individual feature
  - 1D (ΔCD / CD)
  - 1K samples ~ 2 hours
- TeraScan iCDU measures
  - Average of ~10,000 figures.
  - 2D ($\Delta Area$ / Area)
  - 1M samples ~ 1 hour
    - Concurrent with inspection

MoSi   Quartz

iCDU advantages
➤ Averaging reduces random noise
➤ Much faster data acquisition rate

Figure 3.2: Comparison of SEMCD measurement to iCDU measurement.

Table X1. Observed SEMCD Shift in the Exposed Area.

	Pattern K [EXP]		
	SEM CD Shift (nm)		
	after $5kJ/cm^2$	from 5kJ to $10kJ/cm^2$	after $10kJ/cm^2$
Average	-6.3	-4.1	-10.4
Max	-4.0	-1.3	-7.6
Min	-8.5	-7.0	-12.1
Range	4.4	5.7	4.6
3Sigma	3.9	4.8	3.7

reticles, to assess the methodology of the study and the validity of the results.

2. Experimental Flow

In order to complete this study in a reasonable time frame, as many years would be necessary to achieve a satisfying degradation of a real production mask, the aging phenomenon has been accelerated on a 193nm test bench. Considering the limited size of exposure spot, only 2 dice were written on the test mask for comparison: one die kept as a reference without any exposure, whereas the test die has been exposed on the test bench (Fig 2.1).

Despite the small size of the chip, only the middle stripe has been exposed. Chip size is 5.7mm x 5.7mm but exposure area is 3mm x 6mm (Fig 2.2). The full experimental flow is described in Fig 2.3 below.

After mask manufacturing in DNP-E, the two dice have been measured with a SEM-CD. Aerial CD has been evaluated thanks to Zeiss WLCD under scanner relevant illumination conditions, in order to estimate the impact on wafer.

This test mask has been exposed in STMicroelectronics Crolles300 on a 193nm immersion scanner. Then wafers have been fully characterized with SEM-CD on specific metrology targets at minimum design rules as well as on most critical OPC hotspots. Process windows have been also evaluated.

KLA Tencor in Milpitas inspected the test mask on a X5.2 system with a pixel 72nm, to get the initial iCDU map before aging.

Accelerated aging has been performed on a 193nm test bench, with a cumulated exposure dose of $10kJ/cm^2$ (theoretically equivalent to exposures of >32,000 wafers 300mm). The characteristics of the test bench were chosen to be comparable with the exposure conditions of a wafer scanner (even if not the same).

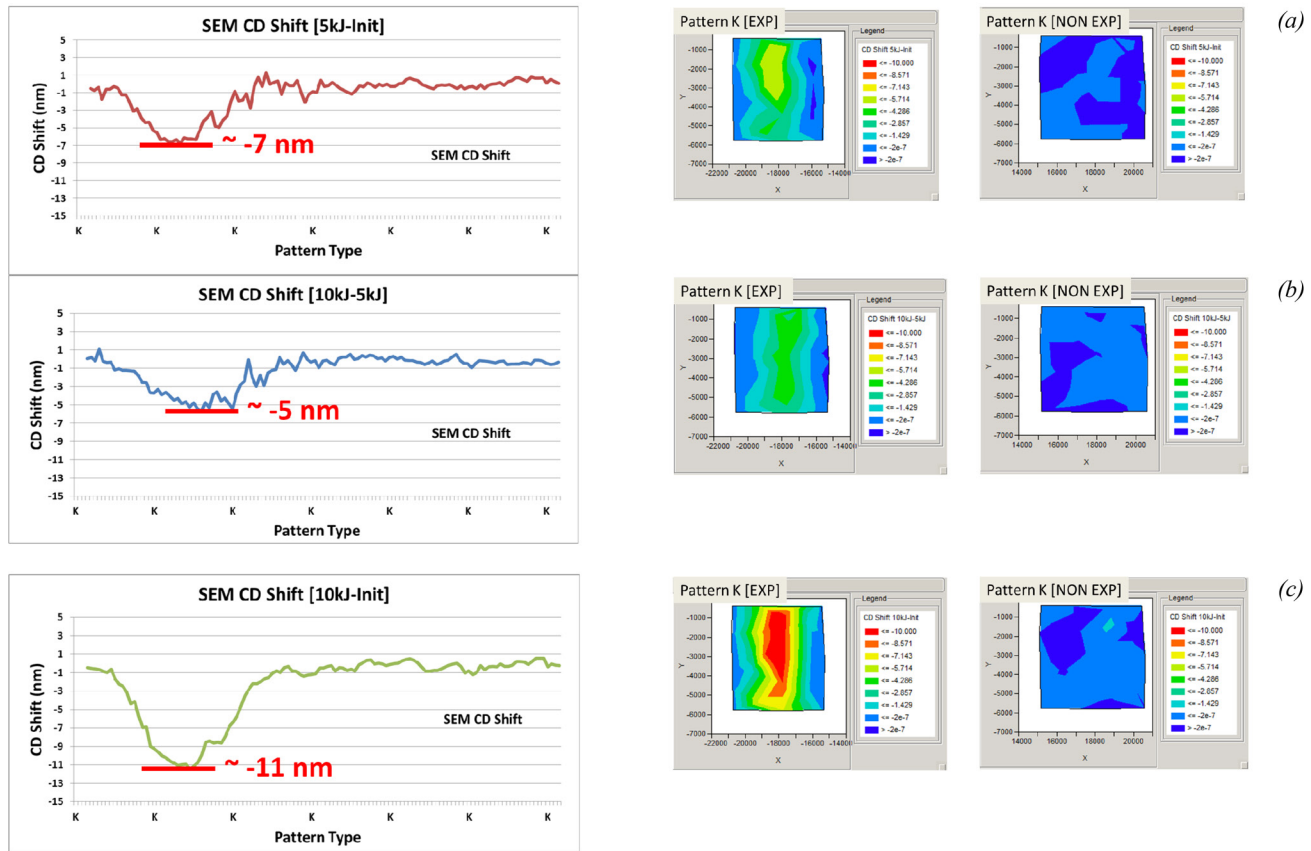In order to determine the exact evolution of the aging phenom-

Figure 4.1.1: SEM-CD shift after the 5kJ/cm^2 (a), between 5 and 10kJ/cm^2 (b) and the overall change after 10kJ/cm^2 (c).

enon, an intermediate check of Mask CD and WLCD was made after the first 5kJ/cm^2.

After the accelerated aging, same set of measurements on wafer and on mask have been done again, to enable the comparison after – before.

In addition, a standard cleaning (production flow for repel service) has been applied, to evaluate its ability to recover the CD on a PSM.

In the end, the mask has been cut and characterized by TEM-EDX, so that degraded sidewalls were observed and the chemical nature of the grown material was determined.

3. Description of iCDU

iCDU stands for "intensity Critical-Dimension-Uniformity". This is a data gathering and analysis feature that yields data on the state of the intensity based, transmitted (T) and reflected (R) light, uniformity on a photomask. The processing starts with a standard photomask inspection with focus on specific sub-regions of the photomask. These sub-regions form an iCDU "Super Pixel" which contains 1024 inspection pixels x 2048 inspection pixels. With an inspection pixel size of 72 nm or 90 nm it is on the order of 100μm x 200μm in size. Fig 3.1 demonstrates the principle of a Super pixel.

For each sub region the transmitted and reflected light intensity are summed separately. It should be noted that this operation runs concurrently with the defect inspection and there is no additional time required beyond the standard photomask inspection for this application. For memory photomasks, where the same pattern is repeated over essentially the entire photomask, one would expect that the intensity values would be the same for each sub-region.

However, if a CD variation causes the patterns to grow in a region, it would locally decrease the transmitted light intensity and increase the reflected light intensity. This is the principle behind iCDU. Note that both transmitted and reflected light provid signal for the CD variation (although of opposite sign), but tend to have different noise sources. Hence, both T and R fields can be used to help isolate the true CD errors.

Compared to SEMCD measurements this method has the advantage of averaging over more than 10^6 pixels which reduces the random pattern noise in the measurements and is much faster than a SEMCD measurement as shown in Fig 3.2. Output resolution on the scale of 100μm provides good averaging and finely spaced measurement points. It will not find very small (50 μm or smaller) defective CD regions, but those will generally be caught by traditional defect inspection (Die-to-die, Die-to-Database or STARlight 2) itself.

The iCDU applications have traditionally been restricted to memory photomasks with repeating pattern. However, they need not be restricted in that manner. The key requirement is that the intensity difference is taken between regions that contain the same pattern. In that case the difference in intensity should be caused by a change in CD rather than a difference in local design. For the current application, an intensity map at one point in time (for example at incoming quality inspection when the photomask has been certified by the photomask supplier) was taken and used as the reference map. Then another map is taken after the photomask has been subjected to processes that are likely to induce a change in the photomask and referred to as the test map. Using
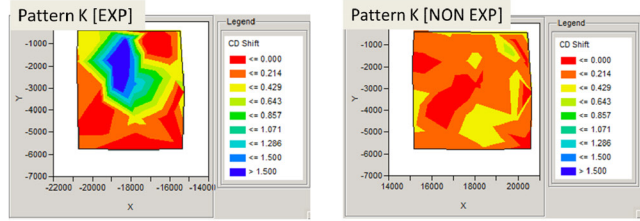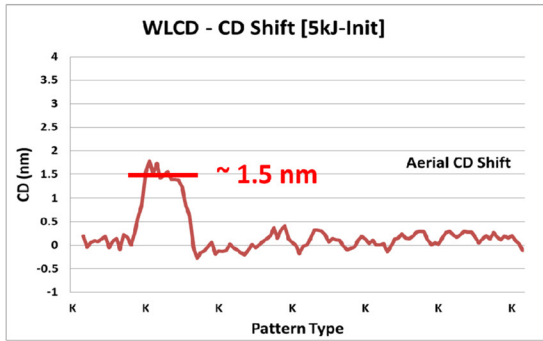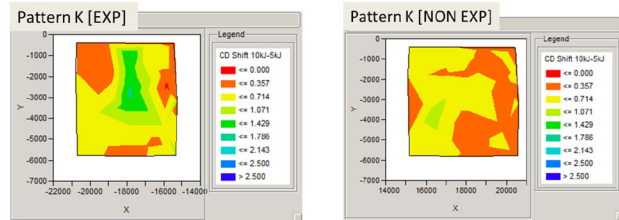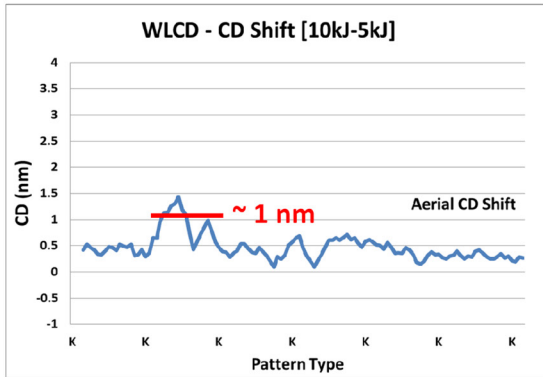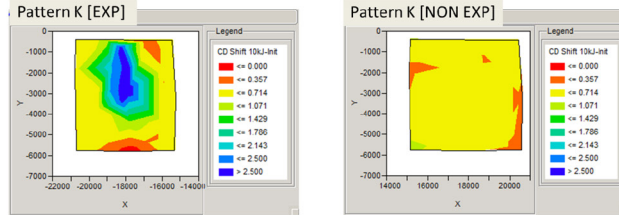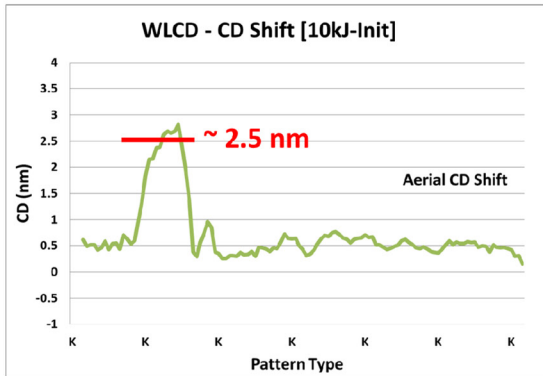
Figure 4.1.2. WLCD CD shift after the 5kJ/cm² (a), between 5 and 10kJ/cm² (b) and the overall change after 10kJ/cm² (c).

Table X2. Observed WLCD CD Shift in the Exposed Area.

Pattern K [EXP]			
WLCD CD Shift (nm)			
	after 5kJ/cm²	from 5kJ to 10kJ/cm²	after 10kJ/cm²
Average	1.4	0.9	2.3
Max	2.2	1.6	3.3
Min	0.6	0.0	0.7
Range	1.6	1.6	2.7
3Sigma	1.6	1.7	2.1

the reference recipe during subsequent inspections, the reference and test can be subtracted point-by-point and result in a map that shows uniformity changes (T and R) without pattern effects even on a random logic photomask.

This feature can readily apply to photomask re-qualification in the wafer fab to identify changes in the photomask from impacts such as Chrome Migration or clean process, which can induce CD changes, exposure related irradiation damage like crystal growth and other impacts such as pellicle degradation or backside film growth. The last two examples aren't pattern changes, but the change in transmission uniformity can effectively produce a CD uniformity variation on the printed wafer.
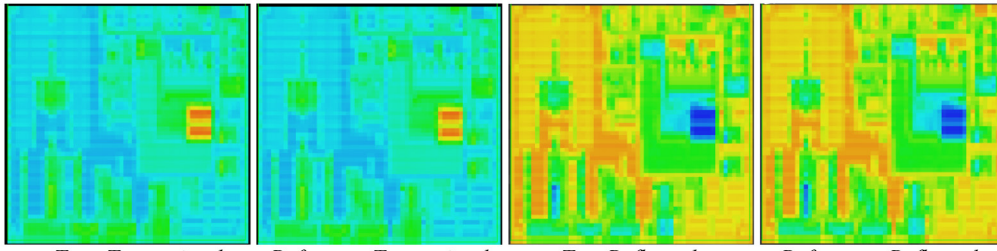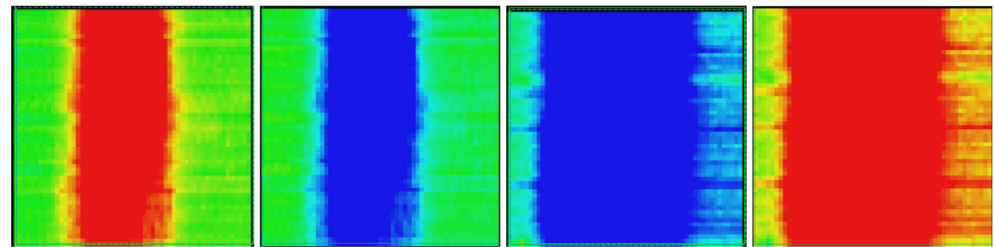
| Test Transmitted | Reference Transmitted | Test Reflected | Reference Reflected |

Figure 4.2.1: **Raw Intensity Pre-Aging,** (Transmitted scaled to 35-65 Gray Scale, Reflected scaled to 125-250 Gray Scale).
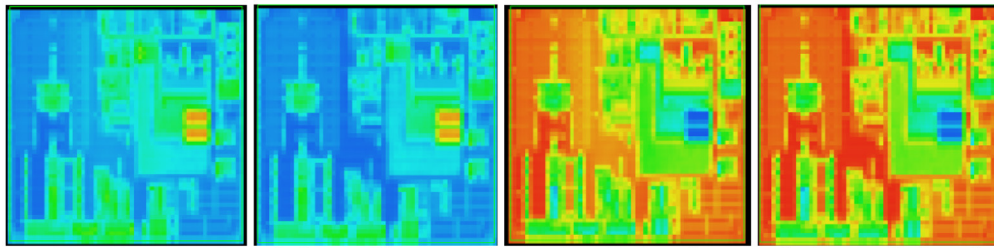
| Test Transmitted | Reference Transmitted | Test Reflected | Reference Reflected |

Figure 4.2.2: **Raw Intensity Post-Aging,** (Transmitted scaled to 35-65 Gray Scale, Reflected scaled to 125-250 Gray Scale).
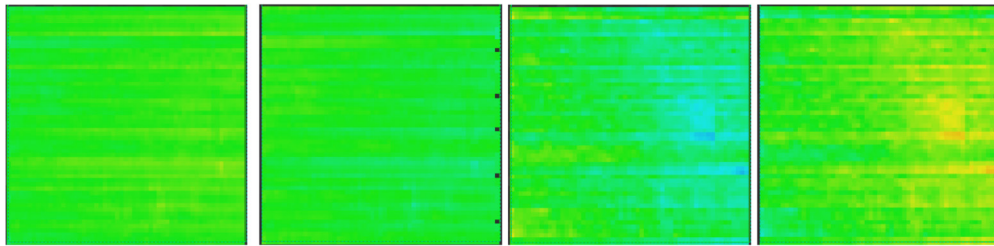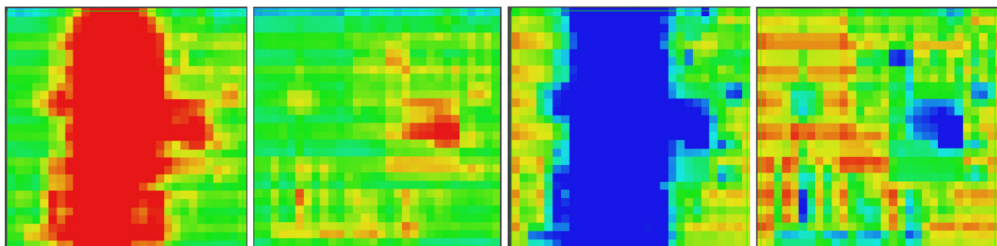

| Test Transmitted | Reference Transmitted | Test Reflected | Reference Reflected |

Figure 4.2.3: **Delta-Die Pre-Aging,** (Scaled to -0.5 to +0.5 Gray Scale; Die mean normalized to 0).

| Test Transmitted | Reference Transmitted | Test Reflected | Reference Reflected |

Figure 4.2.4: **Delta-Die Post-Aging,** (Scaled to -0.5 to +0.5 Gray Scale; Die mean normalized to 0).

| Test Transmitted | Reference Transmitted | Test Reflected | Reference Reflected |

Figure 4.2.5: **Delta-Time Post-Aging,** (Transmitted scaled to -+/- 1.0 Gray Scale, Reflected +/- 4.0 GS; Normalized to Test Die Mean).
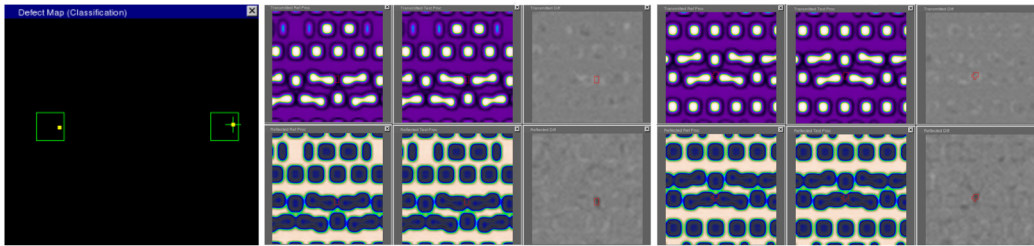
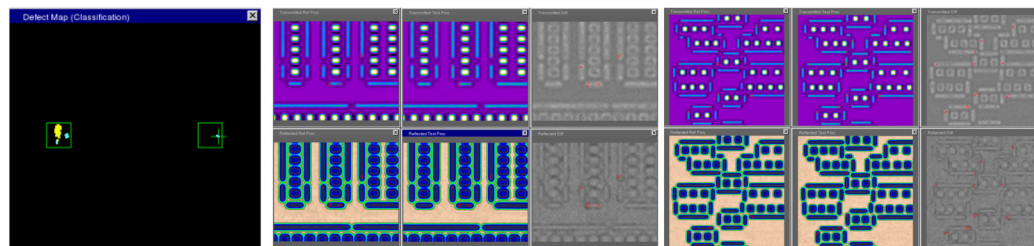*Figure 4.2.6: Two marginal defects detected in pre-aging inspection.*

Figure 4.2.7: Examples of the 385 defects found in post-aging die-die inspection.

4. Experimental Results

4.1. Photomask CD results in mask shop

SEMCD Results

The full characterization of the Mask CD with SEM-CD was performed at four levels: at mask making, after an exposure on the test bench of 5kJ/cm², after the full exposure of 10kJ/cm² and after a final repell cleaning.

In Fig 4.1.1 we reported the evolution of the observed SEM-CD shift and the footprint of the variation at 5kJ/cm², the changes happened between 5 and 10kJ/cm² and the results at 10kJ/cm².

It is clear how the CD shift is limited to the exposed slit: the CD shift map matches the exposure slit position of Fig.2.2, while the Non-Exposed area remain unchanged along the whole experiment.

The initial exposure at 5kJ/cm² generated an initial reduction of the size of holes close to 7nm. The following 5kJ/cm² exposure determined a further reduction of about 5nm, showing a general slowing down of the growth rate. It is the symptom of the shielding effect of the material already grown, which reduces the speed of the oxide formation at the surface of the features.

The overall exposure of 10kJ/cm² induced a SEM-CD shift of about 11nm.

The final cleaning performed on the mask didn't affect at all the Mask CD and the only observed variation correspond to the measurement tool noise. For this reason we don't report info here.

The SEM-CD shift observed into the exposed area is summarized in the table X1.

WLCD Results

The dice on the mask were also evaluated by Zeiss WLCD™ at the same steps as reported for the SEM measures.

The WLCD CD shifts confirm the change observed by the SEM measures. The whole set of data is reported in Fig.4.1.2.

The simulation produces holes smaller after the exposure due to the material growth.

The first 5kJ/cm² induces a change of about 1.5nm, the following 5kJ/cm² of about 1nm only. Even for the WLCD measures, we see a reduction of the material growth rate during the second 5kJ/cm² exposure. The overall change is about 2.5nm.

The WLCD CD shifts observed into the exposed area are summarized in the table X2.

4.2. Results and Discussion of iCDU

As stated in Section 3, iCDU data collection was performed in parallel with the defect inspection of the test mask pre- and post-aging. Figures 4.2.1 and 4.2.2 below show the raw data collected with iCDU algorithm. The mean of the transmitted and reflected results will be used to calculate intensity changes in.

Pre-aging, the iCDU uniformity, as determined by Delta-Die option shows good quality results, with Transmitted 3 sigma at 0.3% of transmitted mean, and Reflected 3 sigma at 0.16% of reflected mean. Note that the different patterns on the device are not an issue for Delta-Die, which performs averaging and then subtraction of correlated points on each die, regardless of the intensity value changing due to different patterns.

Table 4.2.1: 3 sigma uniformity as measured by iCDU Delta-Die and Delta-Time.

	Pre-Aging	Post-Aging		
	Delta-Die	Delta-Die	Delta-Time Test Die	Delta-Time Ref Die
Transmitted	0.29%	4.1%	6.7%	2.8%
Reeflected	0.16%	4.8%	7.1%	3.0%

Exposures-induced CD shift on wafer
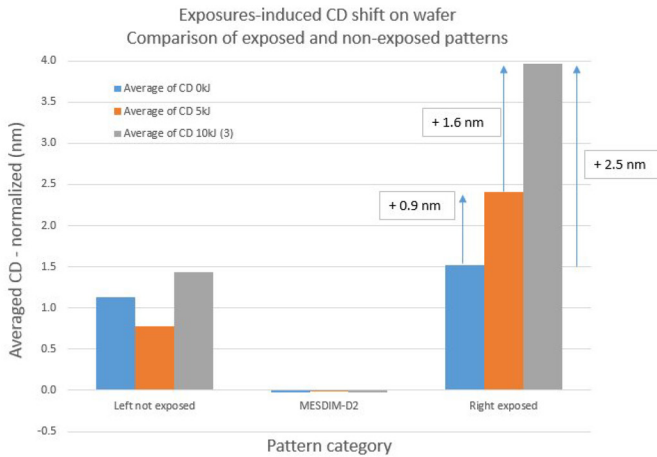Comparison of exposed and non-exposed patterns

Figure 4.3.1: Normalized CD on wafers after 10kJ/cm² exposures Normalization of MESDIM feature.
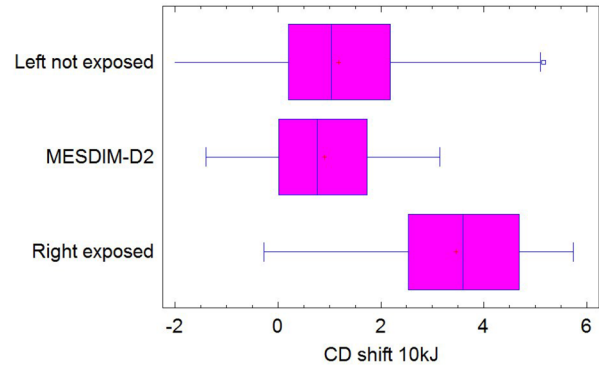

Box-and-Whisker Plot

Figure 4.3.2: Normalized CD on wafers after 10kJ/cm² exposures Normalization of MESDIM feature.

Post-aging, the non-uniformity increases by a factor of > 10x, Delta-Die results show transmitted 3sigma at 4.1% of transmitted mean, and reflected 3 sigma at 4.8% of mean. It should be noted that Delta-Die option creates an average of all dice on the mask. Since this experiment only contains one reference and and one test die, the defective (aged) area is evenly distributed as a positive error in one die and a negative error in the other die. Had the inspection covered all 374 die on the mask, the error signal of the aged die would appear as the only area of deviation from the all dice mean.

Utilizing the Delta-Time option in Fig 4.2.5, with the pre-aging inspection as the reference, we can see that the test die change in uniformity is much greater than the change in the reference die. The test die 3 sigma is 6.7% transmitted and 7.1% reflected, while the reference has changed slightly, the 3 sigma is $< \frac{1}{2}$ of the aged area, at 2.8% transmitted and 3.0% reflected. The reference area would still be acceptable for uniformity quality, where the aged area would not be.

In conclusion, refer to the table 4.2.1 below for 3 sigma uniformity summary results.

A brief discussion of the defects captured in pre- and post-aging inspections. The inspections were run in Die-Die mode using 72nm pixel with a moderate sensitivity settings (~75-80% of maximum settings). The pre-aging inspection found 2 defects, which are small and would not be lithographically significant, refer to Figure 4.2.6.

The post-aging result, using the same inspection recipe, detected 385 total defects. Of these, 35 could be called marginal pattern defects and 350 defects in SRAF sizing, almost all of which occured in the accelerated aging exposure area. The defect signature shows a difference in both transmitted and reflected intensity, particularly at the ends of small assist features. Two examples are shown in figure 4.2.7 below.

While these defects in themselves are marginal in that they fall on assist features, the fact that they are clustered in one area, and occur on a mask that was previously virtually defect-free, is a warning that the sidewalls have been damaged in this area of the plate.
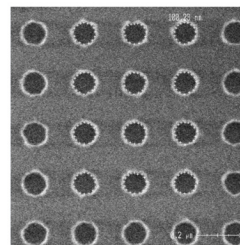

Figure 4.3.3: SEM top view picture of metrology targets.

4.3. Waferprint

According to the results presented in Fig 4.3.1, despite a measurement uncertainty of about +/- 0.5 nm, the accelerated aging caused a consistent CD shift of + 2.5nm after 10kJ/cm². This shift is exactly the same as predicted by WLCD. ANOVA analysis confirms a statistically significant difference of CD shift between exposed and non-exposed areas (Fig 4.3.2). intrafield CD results.

Wafer CD Shift on Metrology Target
Fig 4.3.3 shows a SEM top view picture of the metrology patterns, with averaged measures in the field of view. Those metrology targets are spread all over the field: "MESDIM-D2" is the metrology target used for regulation loops, "Left not exposed" is the reference die, and "Right.

Process Window Variation on Critical Features
Knowing from metrology targets that mask enlarged CD (due to oxidation of sidewalls) are transferred on wafer prints (up to + 2.5 nm), does it affect the process window of critical features?

Actually the most critical features in the design are identified by OPC scripts: those OPC hotspots have the smallest process window. In this specific design, two hotspots were identified. The process window is evaluated through Focus Exposure Matrix wafers (FEM), where focus and exposure dose vary and explore all combinations. These FEM give the Depth Of Focus (DOF) and Energy Latitude (EL) which are required as large as possible. In this specific test case, the process window is tiny and shifted to
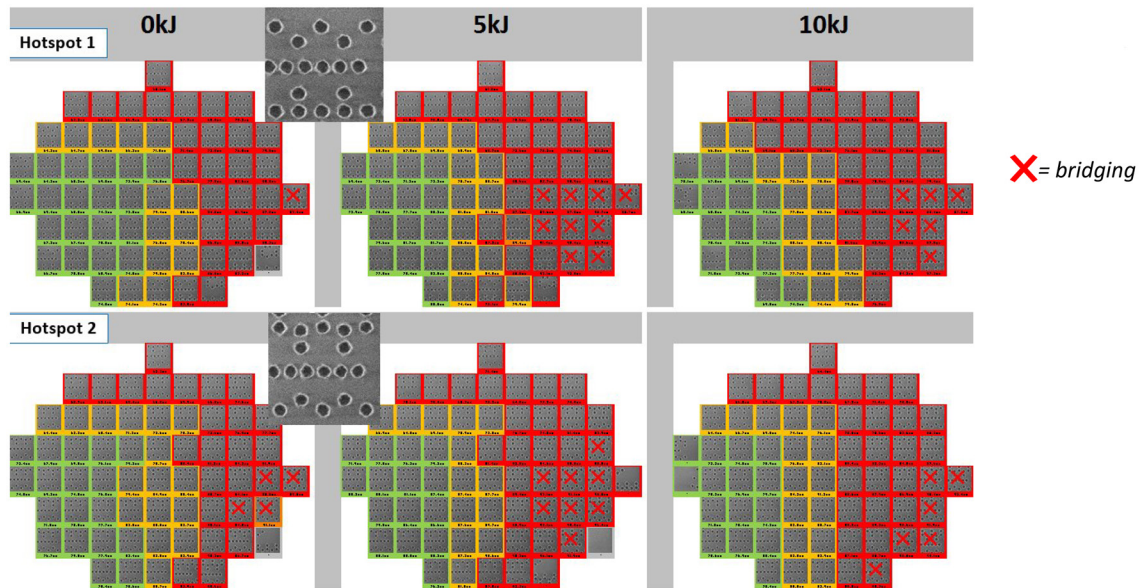
Figure 4.3.4: Process window of OPC hotspots on reference die (not aged).
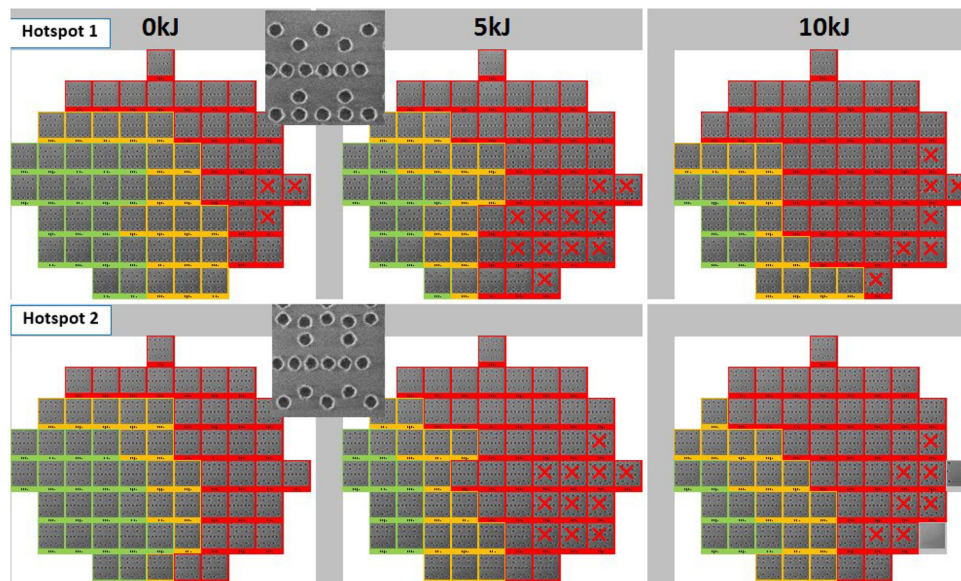

Figure 4.3.5: Process window of OPC hotspots on aged die.

lower exposure doses (by -1.8mJ) and positive focus (+ 40nm), even before aging and in reference die, as shown below in Fig 4.3.5. Fortunately, this critical contact hole is redundant, so that the device is till functional.

After aging of 5kJ/cm² or 10kJ/cm², the process window shrinks and shift even more to smaller exposure doses, whereas reference die keeps the same process window (Figures 4.3.4 and 4.3.5).

As the process window is so reduced for those most critical hotspots even at initial state, another hotspot has been identified, with less aggressive design rules.

Here again, as show below in Fig 4.3.6, the process window is

shrunk and shifted to lower exposure doses (by -0.6mJ) and positive focus (by +40 nm) after aging. However, the change is much less and so seems to depend on feature's initial printability margin.

Comparison with Real Production Reticles

According to the few measurements done on real production masks for comparison with the test mask, it appears that accelerated aging is much faster: +8nm after 5kJ/cm² on test mask is equivalent to 35,000 real wafers 300mm (see on Fig 4.3.7). Obviously, laser pulse energy and frequency are different between test bench and an industrial immersion scanner. As the small beam size on test bench doesn't allow to get the full signature of CD shift,
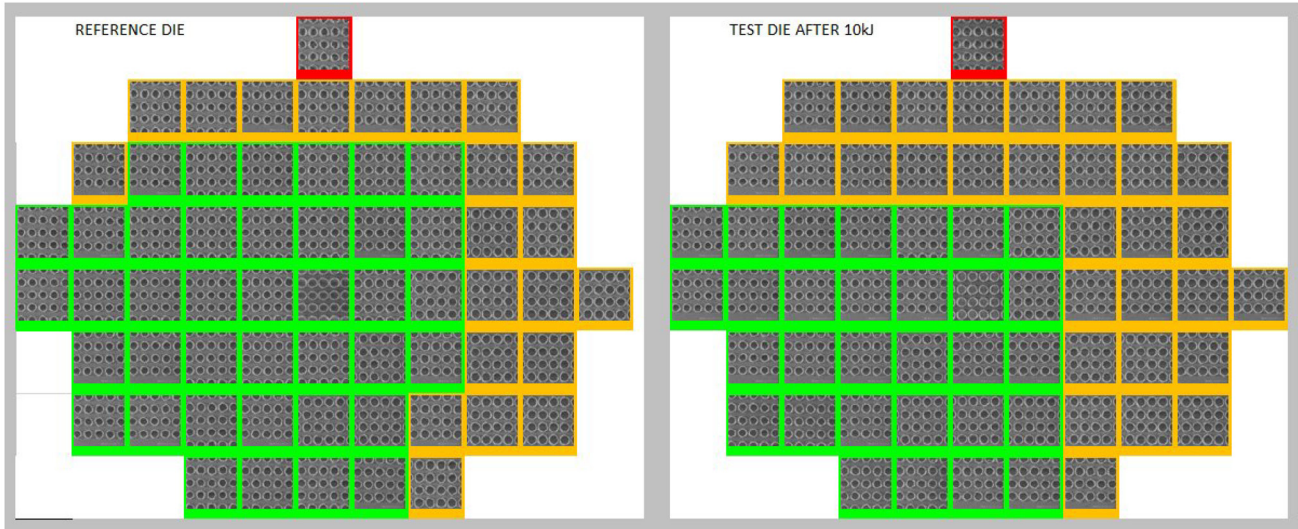
Figure 4.3.6: Comparison of process windows between reference die (left) and test die after 10kJ/cm² (right).
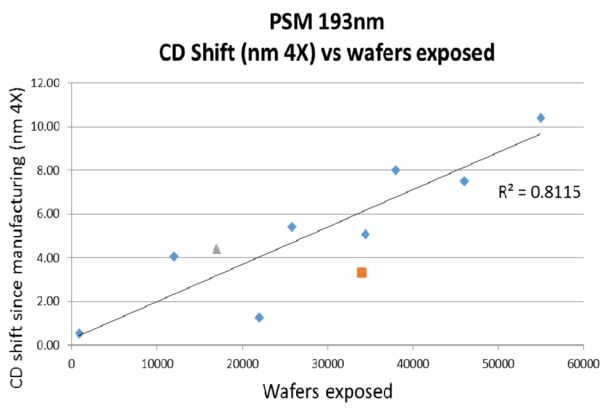

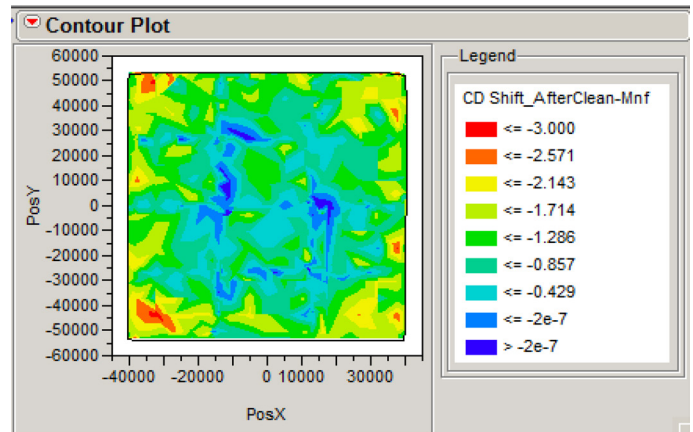Figure 4.3.7: Evolution of CD shift on 193nm PSM with wafer exposures 300mm.

Figure 4.3.8: Signature of CD shift on a PSM hole layer, 40nm logic technology node, after 22,000 wafers 300mm exposed.

a production PSM hole layer, 40nm logic technology node, has been measured after 22,000 wafers 300mm exposed. As shown in Fig 4.3.8, the CD shift impacts the edges more than the centre for PSM, unlike binary masks.

4.4. Reticle characterization – TEM Cut

One key point is to ensure that the accelerated test bench has reproduced the same degradation as reported on production masks. That's why both test and production masks have been cut and observed with TEM-EDX technique (following figures from 4.4.1 to 4.4.8). TEM-EDX highlights that the grown material on sidewalls is made of $Mo_xSi_yO_z$ on both production and test masks. This confirms that the test bench was successful to reproduce the real aging seen in production. It explains why the grown material is not removed by a standard cleaning, because the cleaning must respect the MoSi blank itself. Moreover, the chemical nature may explain the small impact on printability. Indeed, a study[9] concludes $Mo_xSi_yO_z$ optical properties can be tuned by changing the relative

concentration in the film. Mo chemical state and local coordination arrangement can also play a role. Actually, Mo_xSi_yO is used since middle age in the gothic churches for the stained glass windows.

5. Summary and Conclusions

This study has highlighted that the aging growth is confirmed on PSM, even if much slower than it is on binary masks. There is a consistent CD shift due to oxidized sidewalls, observed on production masks and reproduced on an accelerated test bench. In both production and experimental cases, the grown material is made of $Mo_xSi_yO_z$, which can be more or less transparent to 193nm light in certain conditions. This explains the slight impact on wafers: only the most critical features are affected by a shrunk process window, while on common patterns the overall CD shift on wafer can be easily managed in production. To conclude, aging on PSM cannot be totally neglected, and the slight CD impact should be carefully monitored when exposures exceed 50,000 wafers
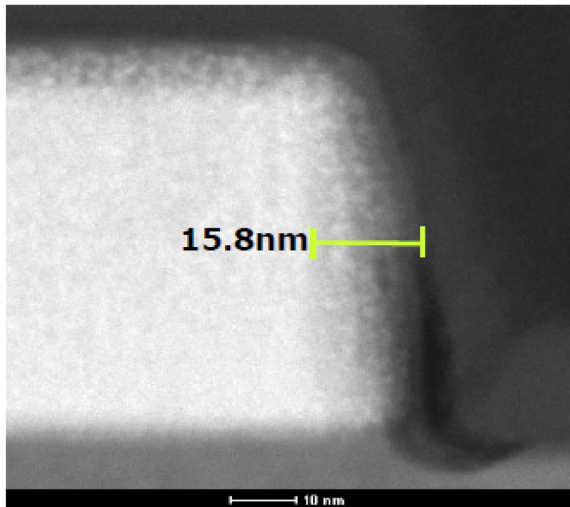
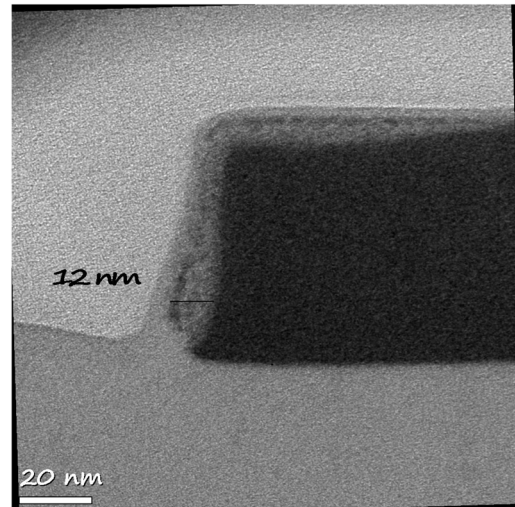Figure 4.4.1: Production mask after 40k wafers 300mm – exposed area.

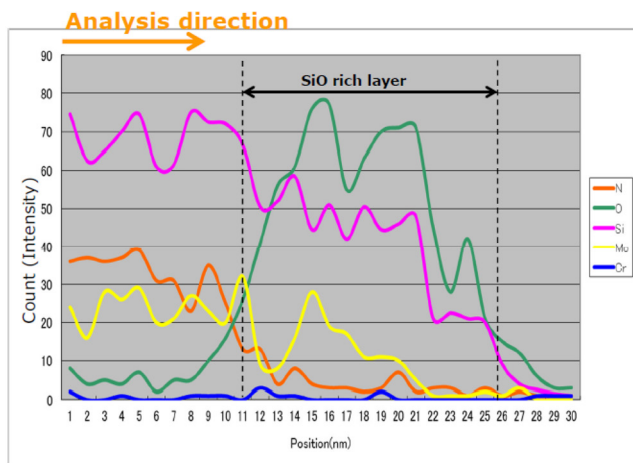Figure 4.4.2: Test mask after 10kJ/cm^2 – exposed area.

Figure 4.4.3: Production mask after 40k wafers 300mm – exposed area.
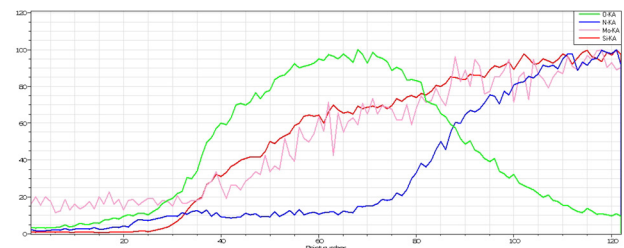

Figure 4.4.4: Test mask after 10kJ/cm^2 – exposed area.

300mm. Thus iCDU on X5.2 inspection system has been demonstrated as an efficient way to monitor inline this degradation directly on PSM.

6. Acknowledgements

7. References

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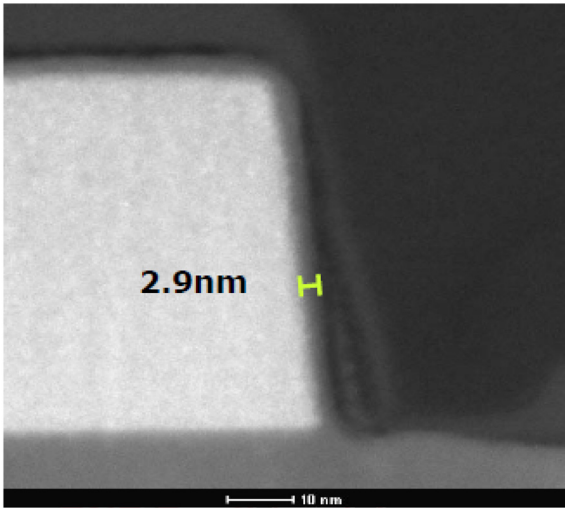
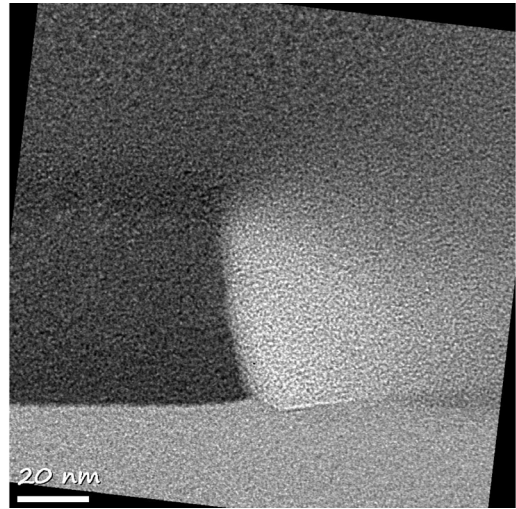Figure 4.4.5: Production mask after 40k wafers 300mm – not exposed area.

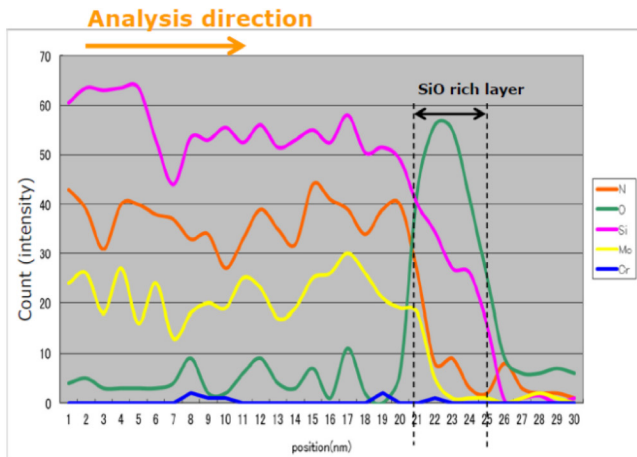Figure 4.4.6: Test mask after 10kJ/cm^2 – Reference die, not exposed.

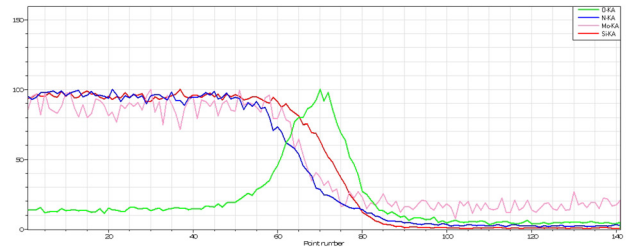Figure 4.4.7: Production mask after 40k wafers 300mm – not exposed area.

Figure 4.4.8: Test mask after 10kJ/cm^2 – Reference die, not exposed.

Industry Briefs

■ TechInsights Analysts Share Their View on Where Technology is Going

In 2016, wearables were extremely interesting mainly because there was so much uncertainty around whether or not the market will be viable. The year saw some truly low-cost smart and fitness devices, and some market surprises like Fitbit buying Pebble. The Apple Watch 2 was an improvement over the Watch 1. While wearables will remain intriguing, even more interesting to watch is the wearables market. Hearables can be as simple as ear buds and basic hearing aids or as complex as devices that correct and amplify sound, sync with wireless devices for virtually any application, and even measure biometric outputs. That's just the beginning. New sensors being packed into small devices are bringing us devices with nearly 30 sensors per device.

Another extremely interesting technology to watch is the rise of intelligent personal or family assistants. This market started with the introduction of the popular Alexa and Echo. Sony may release their assistant this year with more sure to follow. As far as timing, we will have to wait and see.. In addition, more changes are coming for artificial intelligence or assistants on mobile devices with Samsung announcing Bixby ahead of its G8 launch. Of course there are a slew of IoT technologies to watch like the acceptance of Zigbee, Z-Wave, LoRa, and Bluetooth 5.0, all of which seem to be vying aggressively for consumer IoT/connected home market. Rumors are gaining strength around how the Samsung S8 will have Bluetooth 5, which could mean a new Wi-Fi modem.

http://electroiq.com/blog/2017/06/the-automotive-electronics-market-a-view-from-a-material-supplier/

■ The Automotive Electronics Market: A View From a Material Supplier

Solid State Technology

Large efforts are being deployed in the car industry to transform the driving experience. Electrical vehicles are in vogue and governments are encouraging this market with tax incentives. Cars are becoming smarter, capable of self-diagnostics, and in the near future will be able to connect with each other. Most importantly, the implementation of safety features has greatly reduced the number of accidents and fatalities on the roads in the last few decades. Thanks to extensive computing power, vehicles are now nearing autonomous driving capability. This is only possible with a dramatic increase in the amount of electronic devices in new vehicles.

Automotive electronics is, however, very different from the consumer electronics market. The foremost focus is on product quality, and the highest standards are used to ensure the reliability of electronics components in vehicles. This has also an impact on the quality and supply chain of materials such as gases and chemicals used in the manufacturing of these electronics devices.

While it is clearly challenging to describe what the driving experience will be in 10 to 15 years, some clear trends can be identified:

• Safety: The implementation of integrated vision systems, in connection with dozens of sensors and radars, will allow thorough diagnoses of surrounding areas of the vehicles. Cars will progressively be able to offer, and even take decisions, to prevent accidents.

• Fuel efficiency: The share of vehicles equipped with (hybrid) electrical engines is expected to steadily grow. For such engines, the electronics content is estimated to double in value compared to that of standard combustion engines.

• Comfort and infotainment: Vehicle drivers are constantly demanding a more enhanced driving experience. The digitalization of dashboards, the sound and video capabilities, and the customization should heighten the pleasure of time spent in the vehicle.

In order to comply with the current quality standards of the automotive industry, manufacturers will need to adhere to more stringent standards.

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Calendar

2017

✳ **SPIE Photomask Technology and SPIE International Conference on Extreme Ultraviolet Lithography 2017**
11-14 September 2017
Monterey, California, USA
www.spie.org/puv

2018

✳ **SPIE Advanced Lithography**
25 February-1 March 2018
San Jose Marriott and
San Jose Convention Center
San Jose, California, USA
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✳ **Photomask Japan 2018**
18-20 April 2018
Pacific Yokohama
Yokohama, Japan

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