The Effect of Polarized 193nm Irradiation on Photomask Haze Formation

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ABSTRACT

Various sources contribute to mask haze formation including: chemical residuals from mask cleaning, out-gassing from pellicle glue/materials, and contaminants from the scanner ambient. This joint work examines cleaning techniques for haze minimization and whether or not there is haze formation after continuous laser irradiation. Masks with various designs and different cleaning techniques were tested in an ideal environment, isolated from out-gassing or other possible contaminants from the fab environment. Masks with and without patterns were subjected to 40kJ, accumulated dose, of laser radiation to simulate a wafer fab environment. Ion Chromatography (IC) and other surface analytical techniques were used to check the surface condition of masks before and after laser exposure. No haze was found on masks through transmission and IC measurements, when the test chamber was N_2 purged. This may suggest that new cleaning techniques have helped reduce chemical residuals on masks. It is less likely for haze to grow when masks are clean to an ionic level and when laser exposure occurs in an uncontaminated, purged environment.

Keyword: 193nm laser, haze, mask clean

1. INTRODUCTION

After a mask is subjected to continuous 193nm laser exposure, crystal formation, known as haze, occurs.. Masks became less useful due to transmission loss or defect generation, which is directly related to the formation of haze. To maintain a consistent yield level, the masks have to be re-cleaned or a duplicate mask must be purchased to maintain line volume.

Possible sources of haze formation can be categorized into four origin points:

1. Residuals from cleaning chemistry (i.e. sulfuric acid and ammonia hydroxide)
2. Pellicle/adhesive out-gassing
3. Shipping/storage box
4. Fab environment

This body of work was designed to be a partitioning test, which focused on various cleaning strategies by isolating the mask surface from the effects of items 2, 3 and 4; above. The test masks did not have pellicles, which eliminates the possibility of out-gassing from pellicles and adhesives. The exposure test was conducted in a sealed chamber with N_2 purge (O_2 concentration 5~6 ppm). All masks were stored in the same brand boxes for 1~2 weeks during shipping and storage.

2. EXPERIMENT

2.1 Experiment conditions

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All mask blanks were standard 193nm MoSi substrates. The pattern was written with a NuFlare EBM3500B 50KeV tool. Samples 1, 2, and 3 were cleaned with a PKL PMCD cleaner. Sample 4 was cleaned on a Steag ASC5500. All samples were inspected on a KLA-Tencor SLF77 or SLF87 to ensure there were no significant defects prior to laser exposure.

The laser used for this test was a Cymer Nanolith 7000 and was modified to run at higher pulse energies, 4000 Hz, 100% duty cycle [1]. Broadband radiation is produced from both ends of the laser cavity , which was built using 30% reflectors (see Figure 1). The bandwidth is estimated at 0.5 nm FWHM. Radiation from each end of the cavity travels through a two-prism anamorphic 4x beam expander. The beam on the left is referred to as the non-stretched beam, a 21 nsec pulse. The beam from the right goes through an optical pulse stretcher and is referred to as the stretched beam. The optical pulse stretcher consists of 2 beam splitters and 10 concave mirrors creating a confocal resonator. It distributes the original pulse energy into a train of secondary pulses to produce an effective pulse length of 91nsec.

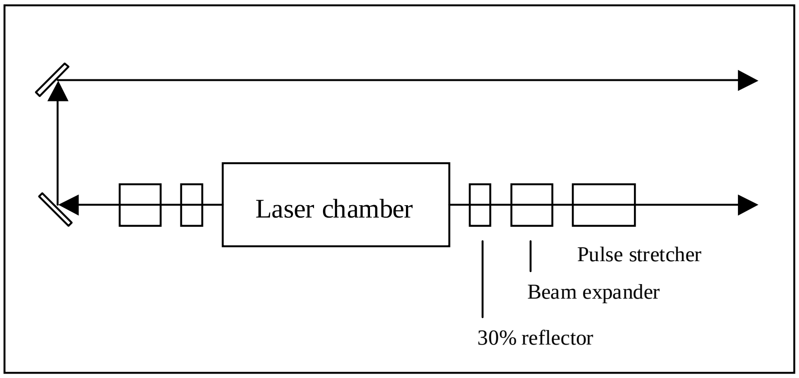

Figure 1: Laser Configuration

The test chamber was sealed and was N_2 purged in the optical path during laser exposure. Laser incident fluency was controlled at a similar level at a reticle stage on the latest 193nm scanners. A total of four beams with a beam spot size of 4mm in diameter were shone on the samples (see figure 2). The upper two beams are not stretched. The bottom two beams are stretched. Incident fluency at the beams on the right is only half of that for the beams on the left. An optical power meter is positioned right behind the mask to collect all transmitted light.

Both bright light inspection and IC were carried out on the masks after exposure.

2.2 Test mask design

Table 1 summarizes the two mask designs used. Samples 1, 3, and 4 are a “window” design, which contains a Cr border, a MoSi inter box, and a clear quartz box inside the MoSi box (figure 2 (left)). Sample 2 is a “grating” design, which has a 70x70 mm box with 1 um lines and spaces (duty cycle 1:1) inside a MoSi border (figure 2 right). There is no Cr on sample 2. The goal of the grating design is to emulate a real production mask with an actual device pattern.

Table 1 summarizes the conditions of each sample and accumulated dose.

Sample	Type	Clean	Time in Box (Day)	Incident Fluency (uJ/cm2)	Accumulated Dose (kJ)
1	**Window**	**Baseline**	**7**	**25~62**	**21~41**
2	**Grating**	**Baseline**	**15**	**25~60**	**19~39**
3	**Window**	**Thermal treatment**	**16**	**24~62**	**19~40**
4	**Window**	**UV/O3**	**12**	**21~74**	**17~38**

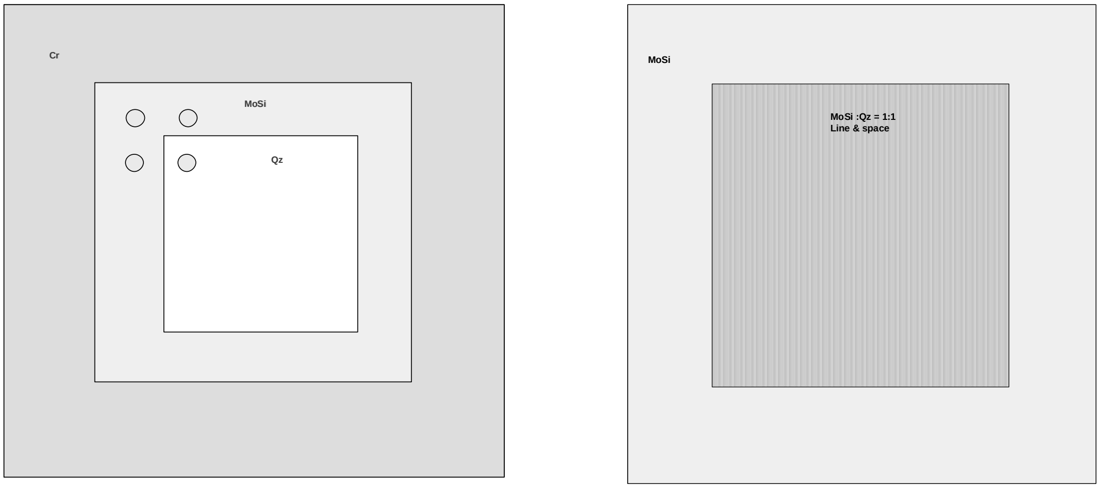

Figure 2: Test mask design: window mask (left) and grating mask (right)

Initially, three of the beams were positioned on the MoSi area and the 4th beam was placed on the clear Qz (position 1 shown in Figure 3 left). It was found that the energy level of transmitted light was very low for beams in the MoSi area. For samples 2, 3 and 4, the beam positions were moved near the MoSi and clear Qz border to increase transmission intensity (Figure 3 right), and therefore minimize error that may be induced from the power meter.

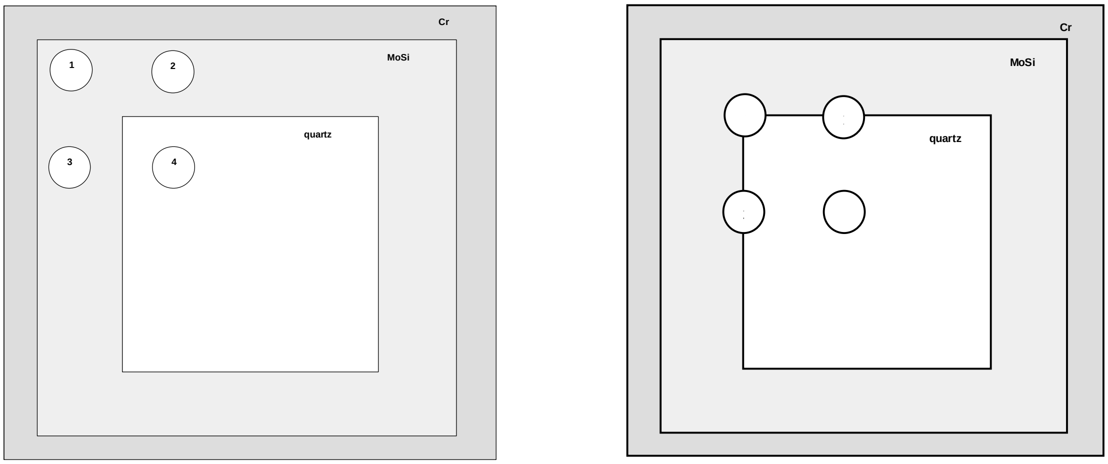

Figure 3. Left figure is measurement position 1. Right figure is measurement position 2

3. RESULTS AND DISCUSSION

3.1 Transmission measurement

Figure 4 presents transmission as a function of accumulated dose for sample 1 with measurement position 1. After 25~40 kJ laser irradiation, no significant intensity drop was observed. The fluctuation is due to laser gas re-fill, which tends to increase the incident light intensity right after re-fill and then stabilizes. It is important to point out that there is almost no intensity drop from the beginning of the exposure to the end of the exposure.

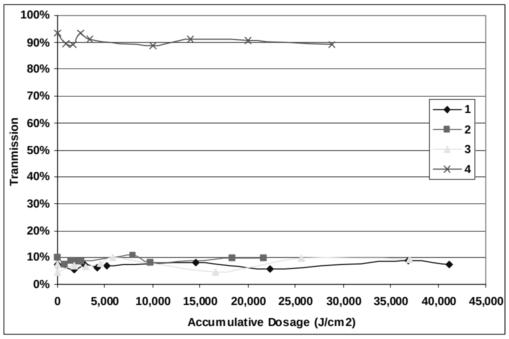

Figure 4: Transmission vs. dose for sample 1 with measurement position 1.

In order for the three curves (beam spots 1, 2, and 3, Figure 4) to be separated, beams were moved closer to the border between the MoSi/Qz boundary so that each position would lead to different levels of transmitted light due to different MoSi coverage (Figure 3 right). Again, there is no significant intensity drop as illustrated in figures 5 and 6. The fluctuation in figure 6 is due to a temporary laser shut down for maintenance and gas re-fill.

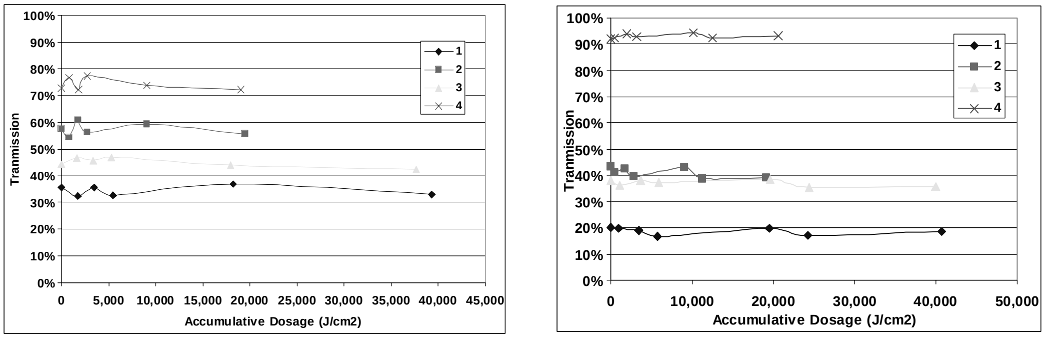

Figure 5. Left figure Sample 2 (grating), right figure sample 3 (window). Both were exposed with position 2.

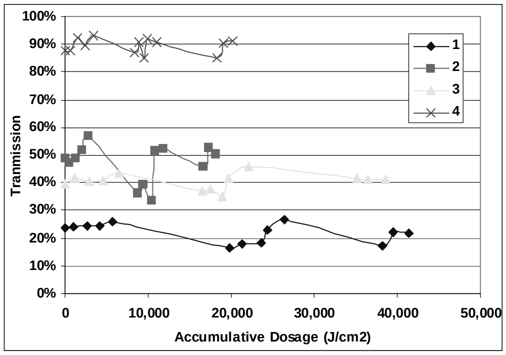

Figure 6. Sample 4 (grating) with measurement position 2

3.2 Post exposure measurement

No visible haze was found after laser exposure through bright light inspection. This is further confirmed through the Ion Chromatography test. Sulfate and ammonia ion concentration did not increase after laser exposure.

4. CONCLUSION

With advanced cleaning techniques, no haze, due to ionic contamination on the mask's surface, was found with up to 40 kJ laser irradiation. This suggests that masks, which are clean after advanced cleaning are less susceptible to haze formation. N_2 purge during exposure and no source of out-gassing from pellicles/glue may further curtail haze formation. Because the size of the laser beam spot is relatively small compared to the actual illumination slit on a 193nm scanner (about 24% of the 8x26mm slit); it would be desirable to study haze formation on a a test bench with illumination characteristics similar to a 193nm scanner illumination system.

5. ACKNOWLEDGEMENT

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6. REFERENCE

1. J. Martin Algots et al, "Compaction and Rarefaction of Fused Silica with 193-nm Excimer Laser Exposure", Proceeding of SPIE Microlithography Conference 2003, 5040-173.