Start-up performance and pattern defectivity improvement using 2 nm rated Nylon filter developed with lithography filtration expertise

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ABSTRACT

A new 2 nm rated Nylon filter was developed to have features required for lithography filtration process such as finer pore size, extended contact time for adsorption enhancement and updated cleanliness for faster start-up. The contact time is extended by 1.6 times of the 10 nm rated product in the same sized capsule filter. Finer pore size is achieved and demonstrated by the removal performance of gold nanoparticles. For start-up performance, particles and metal cleanliness were improved.

To validate the features applied for the new 2 nm Nylon filter, on-wafer tests are conducted in comparison to conventional product such as 5 nm Nylon filter. Filter start up performance is tested with KLA Tencor Surfscan SP5^{XP} inspection on solvent spin coated Si wafer. For bridge defects, 40 nm half pitch after development pattern defectivity with ArF immersion lithography is tested. The new 2 nm rated Nylon 6,6 filter performed best for all the tests. Cleanliness probably played a role in start-up performance. Sieving, which is related to filter pore size was effective in resist coating defectivity. And both the finer pore size and hydrophilic adsorption are effective in after development inspection at 40 nm half pitch L/S pattern, which is nearly the theoretical limit of the ArF immersion lithography.

Keywords: Nylon 6,6, Filtration, Bridge defects, Defectivity, 2 nm

1. INTRODUCTION

Improving defectivity is a continuous requirement for lithography as the feature size continuously shrinks and inspection tools are being improved for smaller defects. Point-of-use (POU) filtration for the lithography fluids has been playing a certain role for minimizing defectivity.

We have studied bridge defects in POU photoresist filtration and there are findings that is effective for reducing them. For example, adsorption of the gel-like microbridge precursors on the Nylon filtration media was observed in many studies [1-3]. And extended contact time between the gels in the resist and the filtration media was found to enhance the adsorption [1]. Thicker media and enlarged filtration area enables this. And finer pore size is also effective to reduce microbridges by enhancement of the sieving performance [2].

On the other hand, filter start-up performance is also critical for point-of-use filtration because it affects resist consumption and track tool down time [4,5].

A new 2 nm rated Nylon 6,6 filter was developed to have above features. The contact time is extended by 1.6 times of the 10 nm rated product in the same sized capsule filter. Finer pore size is achieved and demonstrated by the removal performance of gold nanoparticles. For start-up performance, particles and metal cleanliness were improved.

To validate the features applied for the new 2 nm Nylon 6,6 filter, on-wafer tests are conducted in comparison to conventional product such as 5 nm rated Nylon 6,6 filter and 2 nm rated high density polyethylene (HDPE) filter. Filter start up performance was tested in Tokyo Ohka Kogyo (TOK) OK73 thinner with KLA Tencor Surfscan SP5^{XP} inspection at >17 nm resolution. Bridge defects reduction was tested at 40 nm half pitch line and space (L/S) pattern, which is nearly the theoretical limit of the ArF immersion lithography.

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2. EXPERIMENTAL

2.1 Intrinsic performance of filtration products

2.1.1 Particle removal efficiency

Gold nanoparticles at 2 nm in diameter (BBI EMGC2) were dispersed in deionized (DI) water with appropriate protective ligand, which minimizes the adsorption between the particles and the filter media to evaluate sieving performance. The nanoparticle suspension was then challenged to 47 mm ϕ disks of 5 nm and 2 nm rated Nylon 6,6 filter media. The Au concentrations in the influent and the effluent were measured using inductively coupled plasma mass spectrometry (ICP-MS, Agilent 7700s) for gold nanoparticle removal efficiency by the test filters.

2.1.2 Metal extractables

DI water was filled in Pall PhotoKleen™ EZD-3XL test filter capsules (Figure 1) and kept for 24 hours. Metal concentrations in the DI water after 24 hours soaking were measured using ICP-MS (Agilent 8900) for metal extractables in the filtration product.

Figure 1. Pall PhotoKleen EZD-3XL filter capsule for lithography point of use filtration.

2.2 On-wafer defectivity

Solvent pre-wetting was applied before supplying photoresist to the POU test filters because the procedure is found to be effective to reduce resist consumption starting-up the filter [6]. Overall test flow is as follows: Test filter installation in a coater developer; Pre-wetting by supplying a solvent and spin coating the solvent on Si wafer for start-up evaluation; Replacing the solvent with photoresist and spin coating the photoresist on Si wafer for coating and pattern defectivity.

2.2.1 POU filter start-up performance using OK73 thinner

The purpose of this test is to evaluate the filter start-up performance. Known factors of start-up performance are particle cleanliness, organic extractables and media wettability with the solvent.

Test filter (Pall PhotoKleen EZD-3XL) assembled with 5 nm rated Nylon 6,6, 2 nm rated HDPE and 2 nm rated Nylon 6,6 media was installed in Tokyo Electron CLEANTRACK LITHIUS Pro-Z coater developer. Using the coater developer, TOK OK73 thinner was filtered with the above POU test filters to be spin coated on 300 mm ϕ Si wafer. Then the Si wafer was submitted to KLA-Tencor SP5^{XP} inspection tool at >17 nm resolution. The spin coating was done in each 270 mL of the thinner throughputs, and the total throughput for one test filter was 2 gallons. The initial 900 mL was discarded to avoid possible contamination that may accompany the transition from stagnation to flow.

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2.2.2 Coating and after development inspection using ArF immersion photoresist

Commercial photoresist is commonly refined with strict filtration before shipping and no defect precursor such as gels are expected. But the real-world photoresist experiences some undesirable conditions such as shipment and storage that potentially generate gels. To reproduce the worst case situation, some refining steps are reduced from the conventional production process for the test, therefore the results may indicate elevated defect counts than commercial products.

After the start-up performance test using 2 gallons of OK73 thinner, the thinner in the coater developer was replaced with positive tone ArF immersion photoresist (TOK) prepared with above procedure. The spin coating on the Si wafer was done in the same manner as the OK73 thinner test. The Si wafer was then exposed using ASML 1900Gi ArF immersion exposure tool at 40 nm half pitch L/S pattern and developed using CLEANTRACK LITHIUS Pro-Z coater developer. Both coating defectivity and pattern defectivity were evaluated. Coating defectivity test demonstrates performance of removing particles, which are appear on the spin coated resist layer. The coating inspection was conducted using KLA-Tencor SP5^{XP} inspection tool at >50 nm resolution. Pattern defectivity test demonstrates killer bridge defects, which is buried inside the resist layer and appear only after development. The after development inspection was conducted using Applied Materials SEMVision G5 defect review SEM.

3. RESULTS AND DISCUSSIONS

3.1 Intrinsic performance of filtration products

3.1.1 Particle removal efficiency

Figure 2 shows the particle removal efficiency of the new 2 nm rated Nylon 6,6 media in comparison to conventional 5 nm rated Nylon 6,6 media in DI water. The particle removal efficiency of the 2 nm rated Nylon 6,6 media is significantly higher than 5 nm rated filter, indicating higher sieving performance of the 2 nm Nylon 6,6 media because the test was designed to evaluate sieving performance.

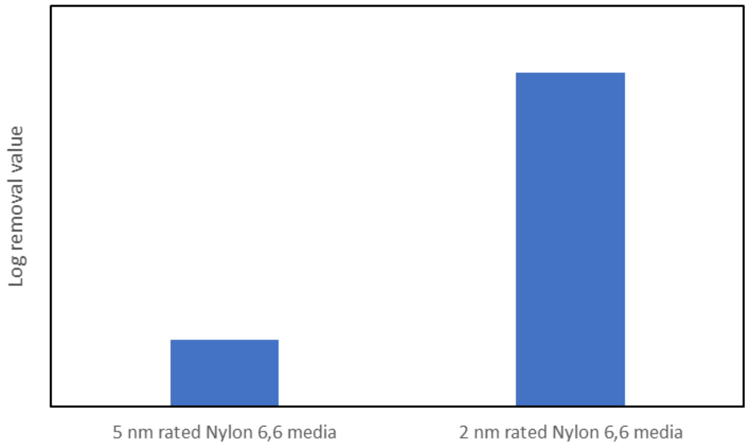

Figure 2. 2 nm gold nanoparticle retention of 2 nm and 5 nm rated Nylon 6,6 filters. Gold nanoparticle challenge test in DI water. Log removal value=$\log_{10}$(particles in upstream side of the filter divided by particles in downstream side of the filter).

3.1.2 Metal extractables

Figure 3 shows the metal extractables of PhotoKleen EZD-3XL capsule filter assembled with 2 nm Nylon 6,6 media in comparison to conventional 5 nm rated Nylon 6,6 media in the same capsule format. Metal extractables was significantly reduced with 2 nm rated Nylon 6,6 filter.

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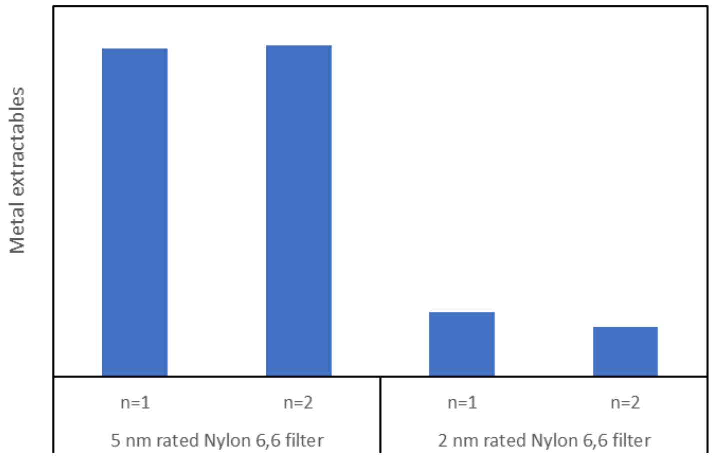

Figure 3. Total metal extractables (Li, Na, Mg, Al, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Ag, Cd, Sn, Ba, W and Pb) in DI water for PhotoKleen EZD-3XL filter with Nylon 6,6 media. Soaking duration is 24 hours.

3.2 On-wafer defectivity

3.2.1 POU filter start-up performance using OK73 thinner

Figure 4 shows >17 nm defect counts on Si wafer after coating OK73 thinner vs. POU filtration throughput. Both 2 nm and 5 nm rated Nylon 6,6 filter performed significantly lower counts from the initial data point than 2 nm rated HDPE filter. Some cleanliness property of the test filters probably played a role because the defect counts decreased with throughput and the first data (900 mL) of 2 nm rated HDPE was larger than the data without filter. However, metal extractables shown in Figure 3 does not seem to contribute this result because the both Nylon 6,6 products behave similar while metal extractables from 2 nm rated Nylon 6,6 was much lower. Media wettability with the solvent (i.e. microbubbles) is another possible reason but it is unlikely that microbubbles at 17 nm diameter exist resisting extremely high Laplace pressure [7].

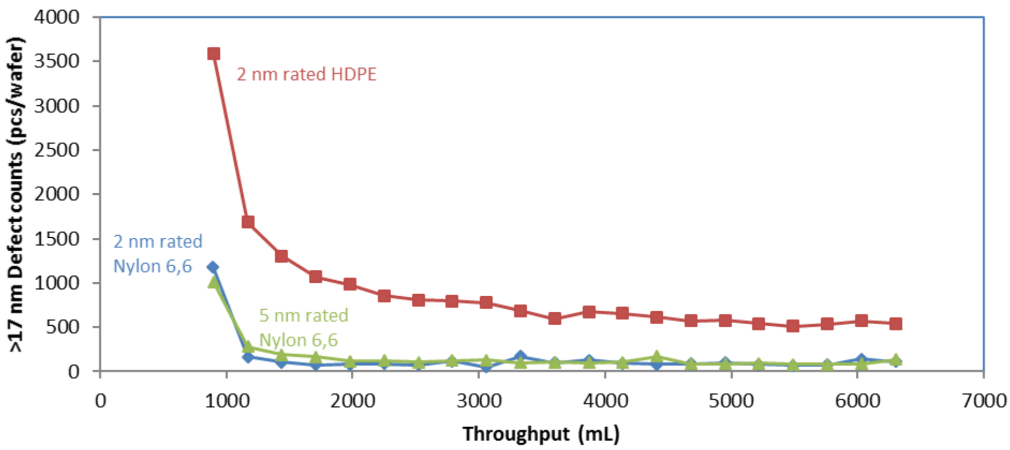

Figure 4. Defect counts > 17 nm threshold on bare Si wafer vs. throughput of POU filtration right after filter installation in CLEANTRACK LITHIUS Pro-Z. Test fluid was TOK OK73 thinner. Test filter format is Pall PhotoKleen EZD-3XL. Defect inspection was conducted using KLA-Tencor Surfscan SP5^{XP}.

3.2.2 Coating defectivity

Figure 5 shows >50 nm defect counts on Si wafer after coating positive tone ArF immersion resist vs. POU filtration throughput. No decreasing trends were observed in the defect counts throughout the test for all filter types, indicating

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filter start-up has been successfully completed during OK73 test. Both 2 nm rated Nylon 6,6 and 2 nm rated HDPE were slightly lower than 5 nm rated Nylon 6,6 probably indicate that sieving performance was effective in this test.

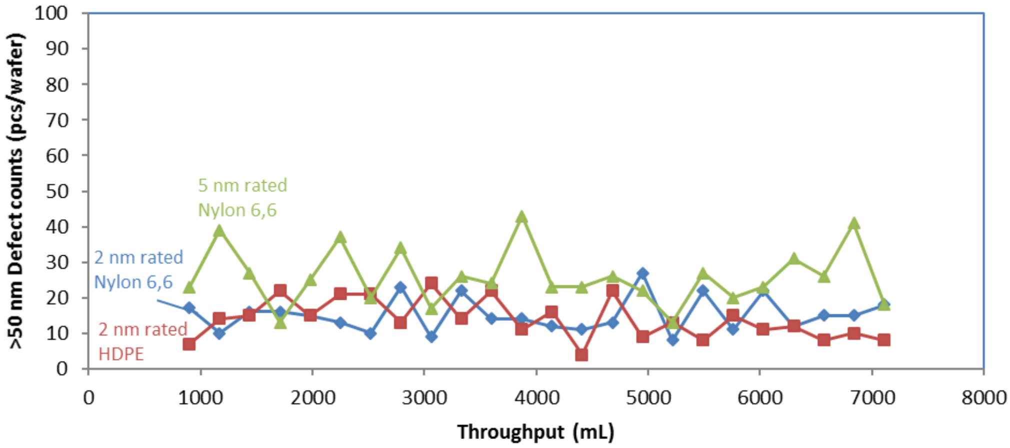

Figure 5. Defect counts > 50 nm threshold on Si wafer vs. throughput of POU filtration after replacing the pre-wet solvent with photoresist. Test fluid was TOK positive tone ArF immersion resist. Test filter format is Pall PhotoKleen EZD-3XL. Defect inspection was conducted using KLA-Tencor Surfscan SP5^{XP}.

3.2.3 Bridge defects

Figure 6 shows SEM images of the bridge defects. These were picked up to focus on filtration related defects and compiled in Figure 7. Figure 7 shows the bridge defect counts vs. POU filter throughput. As a result, 2 nm rated Nylon 6,6 performed lower and more stable defect counts than 2 nm rated HDPE and 5 nm rated Nylon 6,6. Lower counts than the same size rated HDPE suggests hydrophilic adsorption effect of Nylon 6,6 and lower counts than 5 nm rated Nylon 6,6 suggests sieving effects. Based on the results, both very fine pore size and hydrophilic adsorption are required to achieve the low bridge defect counts.

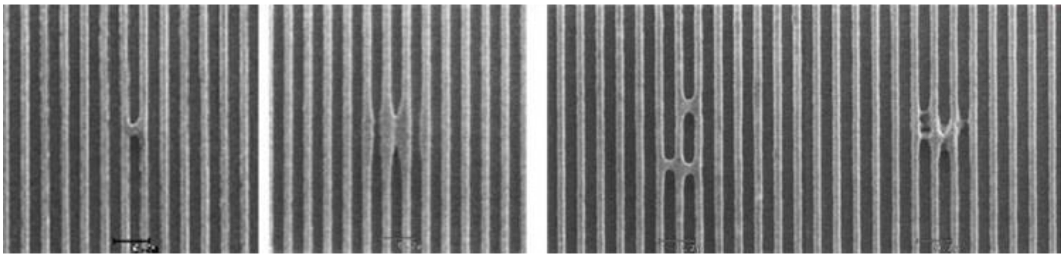

Figure 6. Bridge defect SEM images in after development inspection. 40 nm half pitch L/S fabricated with positive tone ArF immersion process.

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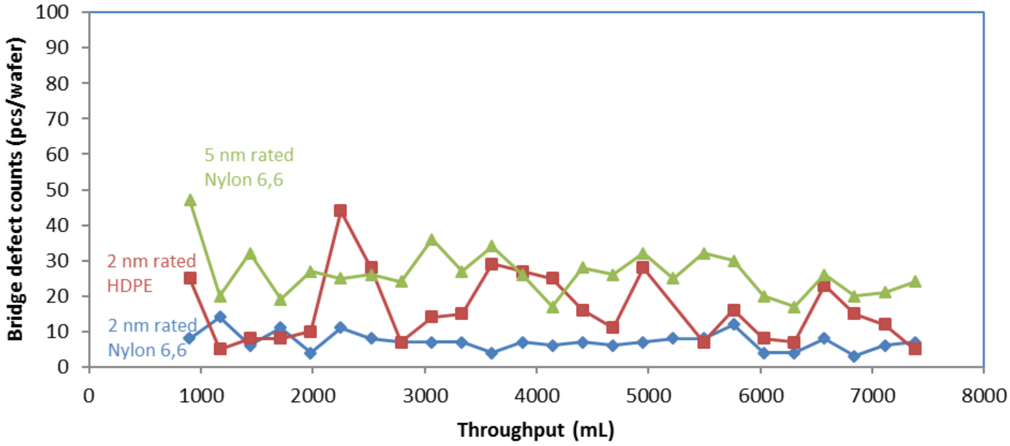

Figure 7. Bridge defect counts at 40 nm L/S pattern vs. throughput of POU filtration after replacing the pre-wet solvent to photoresist. Test fluid was TOK positive tone ArF immersion resist. Test filter format is Pall PhotoKleen EZD-3XL. Defect review was conducted using Applied Materials SEMVision G5.

4. CONCLUSION

Newly developed 2 nm rated Nylon 6,6 media performed better gold nanoparticle retention than conventional 5 nm rated Nylon 6,6 media. Metal extractables were reduced significantly but did not seem to contribute the start-up performance.

For on-wafer defectivity, 2 nm and 5 nm rated Nylon 6,6 filter performed better than 2 nm rated HDPE in start-up performance during OK73 thinner pre-wetting. 2 nm rated Nylon 6,6 and HDPE were better than 5 nm rated Nylon 6,6 filter in resist coating defectivity and the minimum and stable bridge defect counts were demonstrated with 2 nm rated Nylon 6,6 filter.

In summary, the new 2 nm rated Nylon 6,6 filter developed to have the features required for lithography application performed best for all the tests. Cleanliness probably played a role in start-up performance. Sieving was effective in resist coating defectivity. And both the finer pore size and hydrophilic adsorption are effective in after development inspection at 40 nm half pitch L/S pattern, which is nearly the theoretical limit of the ArF immersion lithography.

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