Application specific ratings of filters for negative tone developer

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ABSTRACT

Negative tone development is being employed widely because of its superior resolution. Pall is developing filtration products specially targeted for these high resolution applications. High particle retention and low extractables are key aspects of filtration products known to improve on-wafer defectivity. In the current study, we have found that filtration efficiency of the various filter types towards palladium-heptylamine nanoparticles correlates strongly to actual particle removal determined by on-wafer inspection metrology. Furthermore, using the afore mentioned nanoparticle testing metrology, high retention membranes with low extractables were selected. Particle challenge testing is much simpler than on-wafer defectivity inspection and enables faster and effective filtration membrane selection. Based on these results, the selected filtration membrane is expected to perform effective real particle removal in negative tone developer.

Keywords: Application specific filter ratings, negative tone developer, EUV lithography

1. INTRODUCTION

Negative tone development is being employed widely because of its superior resolution[1] and to accommodate progressively shrinking feature sizes including EUV lithography. Pall is developing a filtration product specifically targeted for this application. High particle retention and low extractables are key aspects of filtration products known to improve on-wafer defectivity.

The performance index of microelectronics-grade filter products is typically described in dimensions of particle removal rating, such as “2 nm”. These ratings describe a sieving mechanism for removal of hard particles from an aqueous colloidal system[2]. In real world applications, adsorptive mechanisms also play a critical role in contaminant filtration. To represent realistic filtration performance, complemental application specific ratings for DUV photoresists have been studied[3-6]. In this paper, the metrology for negative tone developer will be explored.

2. EXPERIMENTAL

2.1 On-wafer defectivity

Negative tone developer (n-butyl acetate, nBA) was passed through test filters of currently available filtration products listed in Table 1. An influent and the effluents were spin coated on 300 mmφ Si wafer then inspected by KLA-Tencor Surfscan SP5. The results of the SP5 were sorted by the size and separated at 50 nm because different behavior was found above and below this threshold.

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Table 1. List of test filters for on-wafer defectivity test. "✓" indicates better performance compared to other test filters.

Test filter	Adsorption*	Filter rating**	Extractables***
Filter A	✓		
Filter B		✓	
Filter C			✓

*: Polar groups on the surface
**: Gold nanoparticle retention
***: Organic extractables evidenced by GC-MS

2.2 Palladium nanoparticle challenge test

The filter was challenged with metal nanoparticles. Figure 1 illustrates the test stand employed.

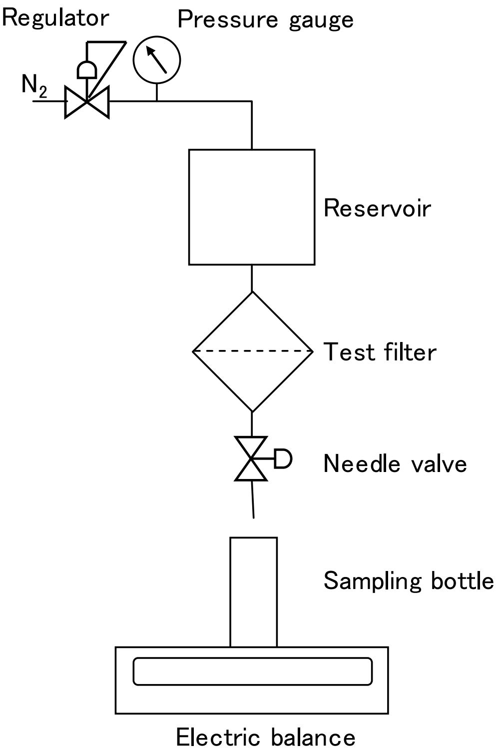

Figure 1. Schematic of filtration test stand employed for palladium nanoparticle challenge test.

The test filters were 47 mm diameter disks of both currently available filters (Filter A-C) shown in Table 1 and new filter product candidates (Candidate-1-3) shown in Table 2. Heptylamine-substituted palladium nanoparticles (Pd-HA), which were selected because of response to adsorptive filter surface and appropriate size for the test filter evaluation, were dispersed in nBA to be used as challenge particles. The diameter of the Pd core was 4 nm. The Pd-HA concentration in the influent was 0.5±0.025 ppb. Flow rate was 3 mL/min. The Pd concentration in the influents and the effluents were analyzed using inductively coupled plasma mass spectroscopy (ICP-MS).

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Table 2. List of test filters of new filter product candidates for Pd-HA challenge filtration test. "✓" indicates better performance compared to other test filters.

Test filter	Adsorption*	Filter rating**	Extractables***
Candidate-1			✓
Candidate-2	✓		✓
Candidate-3	✓		✓

*: Polar groups on the surface
**: Gold nanoparticle retention
***: Organic extractables evidenced by GC-MS

3. RESULTS AND DISCUSSIONS

3.1 On-wafer defectivity at smaller than 50 nm

Figure 2 shows KLA-Tencor Surfscan SP5 defect counts sorted at ≤50 nm after spin coating of nBA with and without filtration using various filter types. As a result, defect counts for all the test filter effluents were reduced from the influent. The reduced counts probably suggest that the results indicate particle removal performance of the test filters. The filter A demonstrated significantly lower defect counts compared to the filter B as well as the filter C. This more correlates to adsorption performance in Table 1 than dimensional filter ratings and extractables, therefore adsorption performance of the filter is considered to give these results.

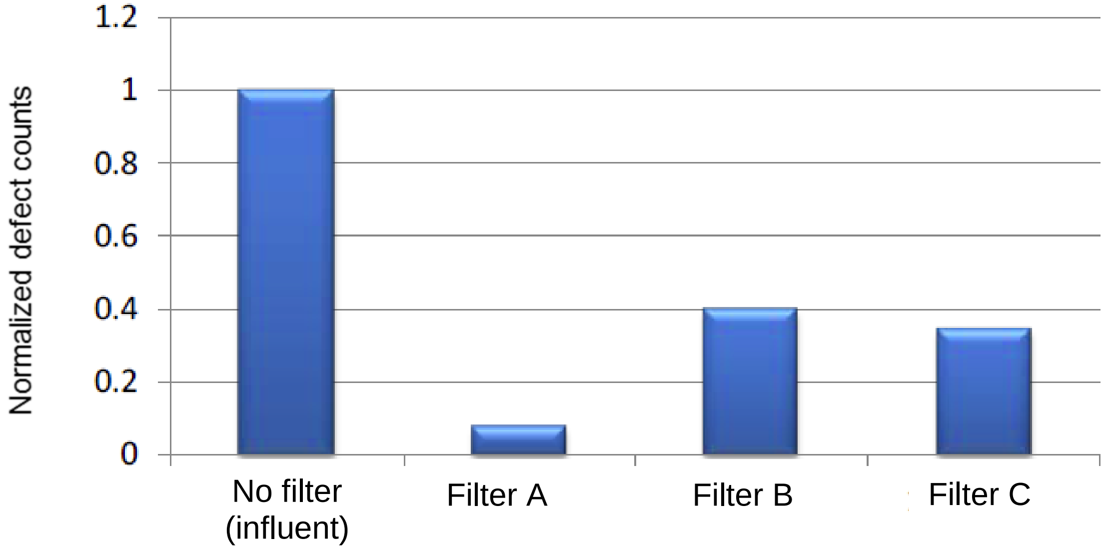

Figure 2. Normalized (no filter=1) defect counts (≤50 nm) on 300 mmφ wafer after spin coat of n-butyl acetate with and without filtration using various filter types. Inspection: KLA-Tencor Surfscan SP5.

3.2 Palladium heptylamine nanoparticle challenge test on currently available filtration products

Figure 3 shows challenge test results of palladium nanoparticles with heptylamine ligands suspended in nBA on the currently available filtration products. In this experiment, the filter A demonstrated significantly lower nanoparticle concentration in the effluent than either the filter B or the filter C. The results strongly correlate to the SP5 inspection results at ≤50 nm shown in Figure 2. The strong correlation suggests a possibility to utilize this Pd-HA challenge testing as a simulation test for SP5 on-wafer defectivity.

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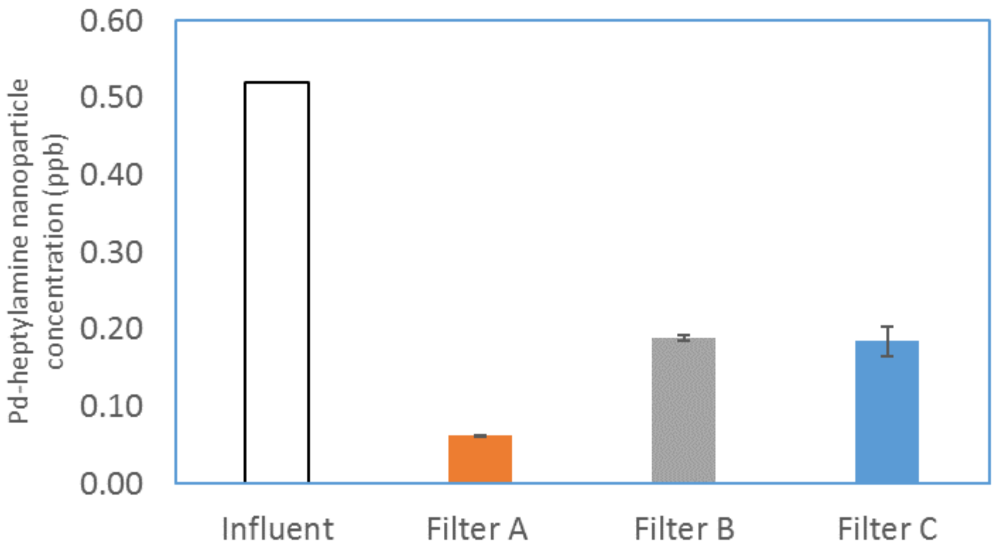

Figure 3 Palladium-heptylamine nanoparticle challenge results on currently available filters in nBA. Flow rate is 3 mL/min. for 47 mmφ disk filter. n=2. Error bar is max and min.

3.3 On-wafer defectivity at larger than 50 nm

Figure 4 shows SP5 defect counts at >50 nm on 300 mmφ wafer after spin coating of nBA with and without filtration using various filter types. In contrast to Figure 2, Filter C performed the lowest defect count in this size range. The defect counts in Filter A and Filter B were greater than the No filter, may indicate particle shedding or extractables from these filters and may not suggest particle removal efficiency. The results correlates to the level of extractables performance summarized in Table 1. Further, based on a fact that some extractables of filter products are known to cause on-wafer defects by crystallization in spin coating[7], extractables are considered to give these differences.

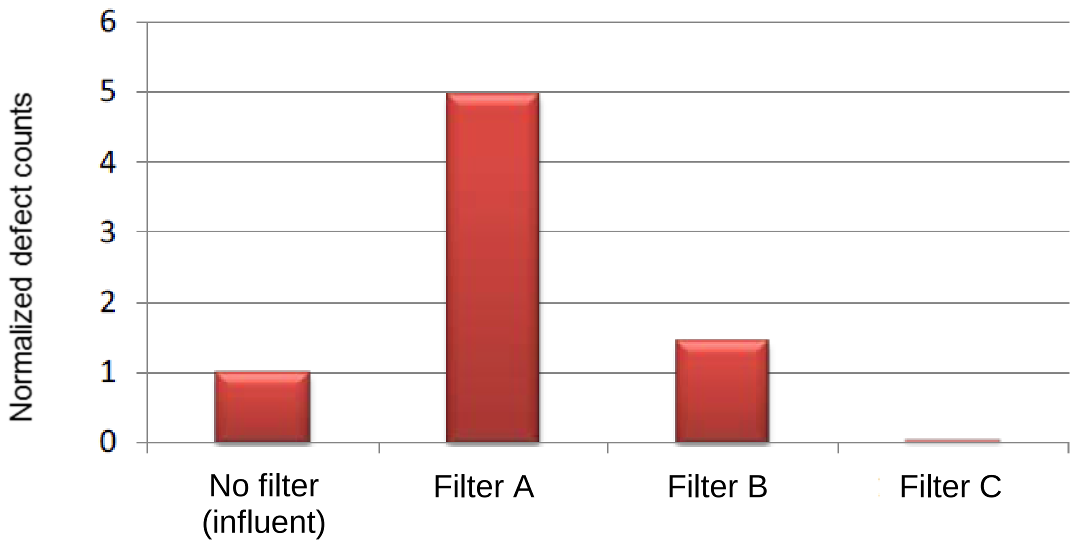

Figure 4. Normalized (no filter=1) defect counts (>50 nm) on 300 mmφ wafer after spin coat of n-butyl acetate with and without filtration using various filter types. Inspection: KLA-Tencor Surfscan SP5.

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3.4 Palladium heptylamine nanoparticle challenge test on new filter product candidates

Based on the SP5 results shown in Figure 2 and 4, adsorption as well as lower extractables are found to be critical for minimizing overall SP5 defects in nBA filtration. The test filters of new filter product candidates shown in Table 2 were selected with respect to low extractables and various adsorption performance. Pd-HA challenge results on the new filter product candidates are shown in Figure 5. As a result, candidate-2 and 3 performed similar retention as the filter A, indicating that these candidates are expected to perform effective particle retention performance in on-wafer defectivity.

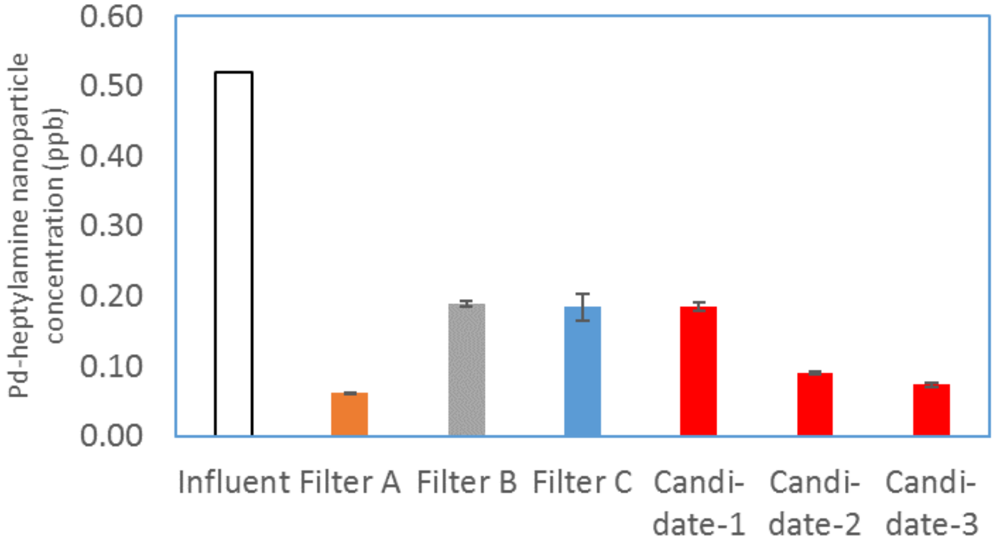

Figure 5 Palladium-heptylamine nanoparticle challenge results on new filter product candidates (Candidate-1 to 3) in nBA. Flow rate is 3 mL/min. for 47 mmφ disk filter. n=2. Error bar is max and min.

4. CONCLUSION

Particle challenge testing is much simpler than on-wafer defectivity inspection and enables faster and effective filtration membrane selection. Current study indicated that Pd-HA challenge test correlates strongly to on-wafer SP5 defectivity at ≤50 nm. Based on this, Pd-HA challenge test is expected to support effective new filter selection.

Since some of the new product candidates showed effective retention in Pd-HA nanoparticle challenge test, they are expected to reduce on-wafer SP5 defectivity at ≤50 nm. In addition, minimized extractables of the new product candidates are expected to reduce defectivity at >50nm. These results suggest that the new product candidates effectively improve real particle removal in SP5 evaluation in negative tone developer.

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