

The First On-Site Evaluation of a New Filter Optimized for TARC and Developer

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ABSTRACT

In previous studies, we identified filter properties that have a strong effect on microbubble formation on the downstream side of the filter membrane. A new Highly Asymmetric Polyarylsulfone (HAPAS) filter was developed based on the findings.

In the current study, we evaluated newly-developed HAPAS filter in environmentally preferred non-PFOS TARC in a laboratory setting. Test results confirmed that microbubble counts downstream of the filter were lower than those of a conventional HDPE filter. Further testing in a manufacturing environment confirmed that HAPAS filtration of TARC at point of use was able to reduce defectivity caused by microbubbles on both unpatterned and patterned wafers, compared with a HDPE filter.

Keywords: TARC, highly asymmetric polyarylsulfone, filter, microbubble

1. INTRODUCTION

Microbubble-induced defects are one of the biggest problems in both Top Anti-Reflective Coating (TARC) and litho developer processes. TARCs and developers generally contain surfactants that stabilize microbubbles, which may be generated when the fluid experiences a sudden drop in pressure.

It is known that filtration products are able to reduce microbubbles that are present upstream of the filter membrane; however, pressure drop across the membrane can regenerate microbubbles. Our previous studies ^{[1], [2]} in conventional PFOS TARC and developer on filtration effects revealed the following factors as having significant effects on microbubble-induced defectivity:

1. High critical wetting surface tension (CWST), which causes good wettability
2. Reduced pore size, which facilitates microbubble trapping
3. Low pressure drop across the filter membrane, which minimizes gas coming out of solution and forming microbubbles downstream of the filter.

Based on this knowledge, Pall Corporation developed Highly Asymmetric Polyarylsulfone (HAPAS) membrane, which offers benefits based around the three properties identified above, as well as good chemical compatibility with TARC and developer. HAPAS-based filters have been shown to reduce microbubbles in developer.

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Recently, the Stockholm Convention on Persistent Organic Pollutants has moved to prohibit the use of both perfluorooctane sulfonate (PFOS) and perfluorooctanic acid (PFOA), which are currently the main components in most TARCs. Consequently, TARC formulations will need to be built around non-PFOS/PFOA materials. Thus, filter performance concerning microbubble reduction should be evaluated in non-PFOS/PFOA TARC.

In this paper, we report both in-line microbubble counting results downstream of the HAPAS filter and defectivity behavior following point-of-use filtration of a non-PFOS TARC.

2. EXPERIMENTAL

2.1 HAPAS filter

As shown in Table 1, the HAPAS filter used had a CWST of 74 mN/m, was rated for 30 nm particle retention, and shows 1.0 kPa of differential pressure at a filtration rate of 1 mL/s (filtration area = 760 cm²). This trade-off property between fine pore size and low differential pressure was achieved by utilizing the highly asymmetric structure, shown in Figure 1. Based on previous studies, these properties are strongly preferred to conventional high density polyethylene (HDPE) filters for microbubble reduction. Figure 2 shows the chemical bond-line structure of the HAPAS material.

Table 1. Comparison between filter samples in microbubble-related factors.

Factors	Unit	HDPE 50nm	HAPAS 30nm
CWST	mN/m	36	74
Pore size	nm	50	30
Flow Differential Presssure	kPa at 1ml/sec.	3.3	1

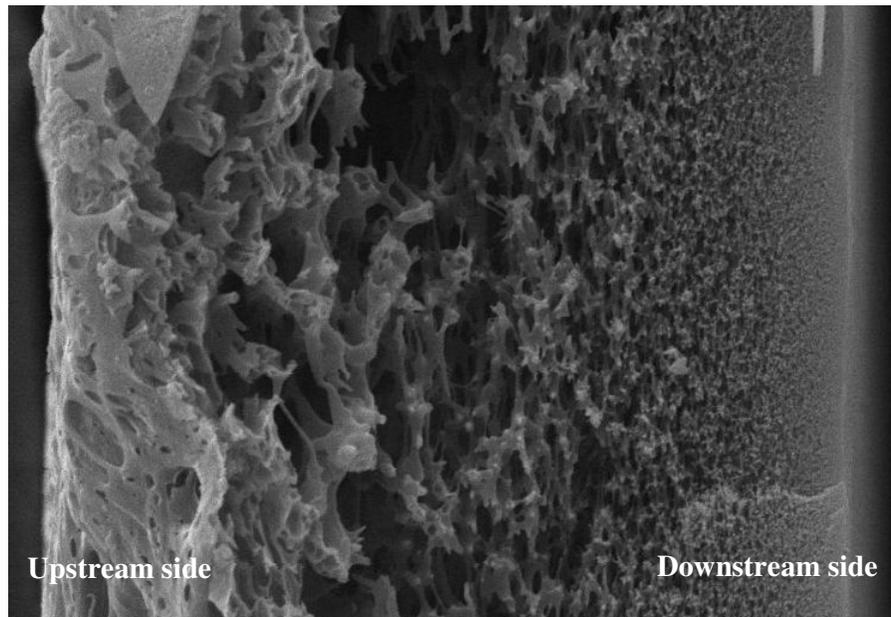


Figure 1. Cross-sectional SEM image of Highly Asymmetric Polyarylsulfone membrane.

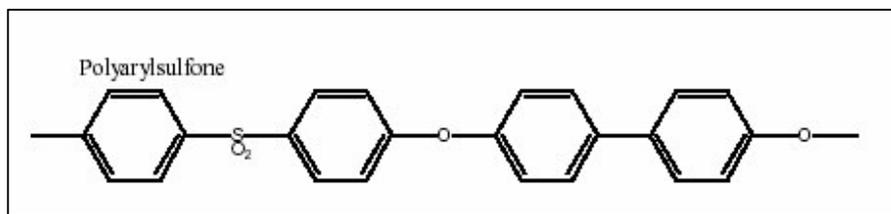


Figure 2. Bond-line structure of Polyarylsulfone.

2.2 Microbubble measurement using liquid particle counter

We compared the HAPAS filter with HDPE filters rated at 50 nm and 30 nm in laboratory filtration testing of the leading non-PFOS TARC. The 30 nm HDPE filter was found to produce visible bubbles in the effluent, as shown in Figure 3, while the 50 nm HDPE filter and 30 nm HAPAS filter were not. Thus, the 30 nm HDPE filter was excluded from subsequent testing. This result appears to be caused by greater pressure drop across the 30 nm HDPE filter. Microbubble reduction capabilities of the 30 nm HAPAS and 50 nm HDPE filters were compared using a RION KL-22 liquid particle counter. Figure 4 shows the experimental apparatus for this testing. Using the test apparatus, non-PFOS TARC was delivered to sample filters (via pressurized air) at a flow rate of 10 mL/min, and effluent particle counts ($>0.2 \mu\text{m}$) are measured simultaneously.



Figure 3. Visible bubbles found in the effluent of 30 nm HDPE filter.

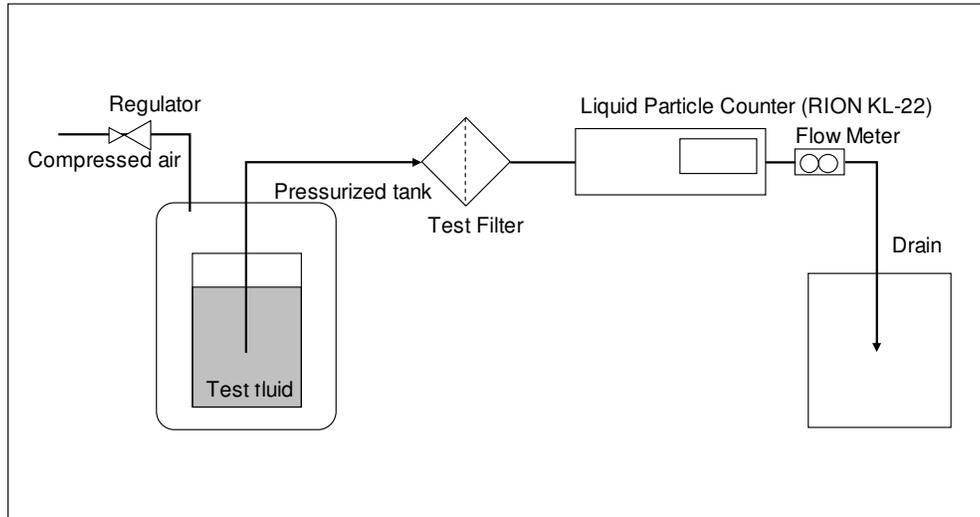


Figure 4. Experimental apparatus for microbubble measurement in laboratory testing.

2.3 On-site evaluation of HAPAS filter for point-of-use TARC filtration

In order to validate laboratory test results, the HAPAS filter was evaluated as a point-of-use filter for the same TARC in an actual photolithography process.

2.3.1 Filter comparison of defectivity on TARC-coated bare wafer

Varying the point of use filters in a coater/developer, non-PFOS TARC was spin-coated directly onto a bare wafer, then baked for 60 seconds at 90°C. Particle counts on the wafer were measured using a wafer inspection system.

2.3.2 Filter comparison of killer defects on patterned wafer

With the same spin-coating process used on the bare wafer, non-PFOS TARC was processed on a resist layer for a defect evaluation on the patterned wafer. After applying a TARC coating, the wafer was patterned via ArF laser exposure, and then developed according to standard process recipes. For the patterned wafers, defects on the wafer were located using a defect inspection tool, and then reviewed using SEM to identify killer defects associated with TARC application.

3. RESULTS

3.1 Microbubble measurement using liquid particle counter

As shown in Figure 5, the HAPAS filter achieved almost an order of magnitude fewer microbubbles.

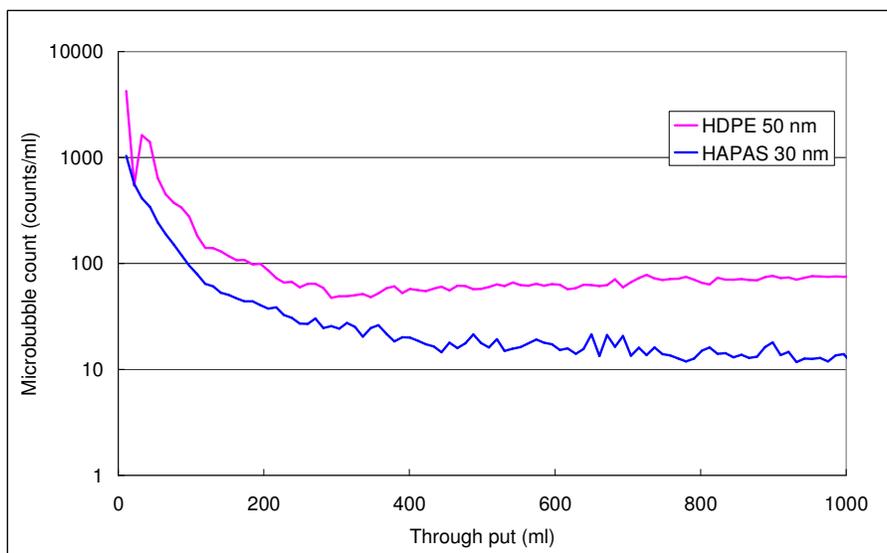


Figure 5. Microbubble count (>0.2 μm) in filter effluent of non-PFOS TARC.

3.2 On-site evaluation of HAPAS filter for point-of-use TARC filtration

3.2.1 Filter comparison of defectivity on TARC-coated bare wafer

As shown in Figure 6, compared with the 50 nm HDPE filter, the HAPAS filter showed greatly improved defect reduction on a TARC-coated (unpatterned) bare wafer.

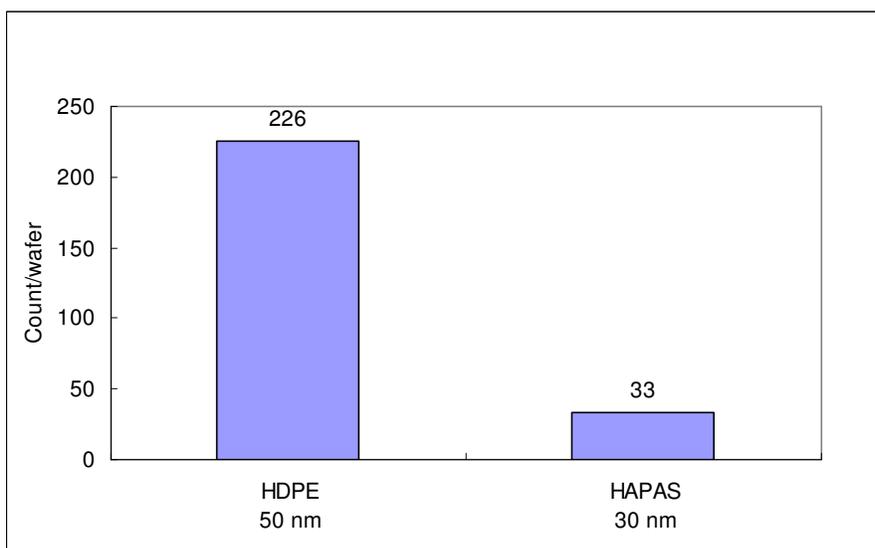


Figure 6. Filter comparison of defectivity on TARC-coated bare wafer: Test fluid is non-PFOS TARC.

3.2.2 Filter comparison of killer defects on patterned wafer

Figure 7 shows SEM images of a killer defect on the patterned wafer. This kind of defect appears to be due to microbubbles from its circular shape. The right image in Figure 7 shows the critical disconnection of the pattern along the defect edge. Comparative killer defect counts are given in Figure 8: The HAPAS filter showed greater reduction of killer defects on patterned wafers.

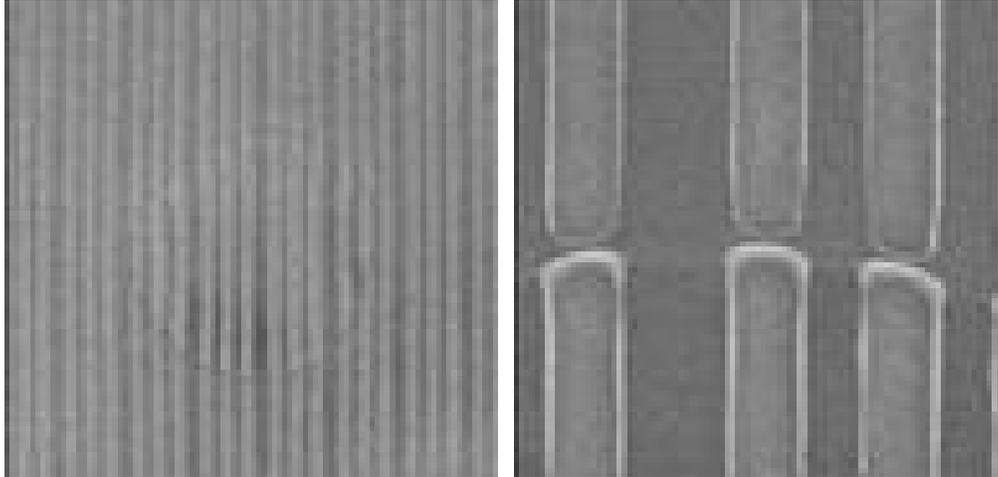


Figure 7. SEM images of a killer defect: Left, whole view; Right, enlarged view at the edge of the defect.

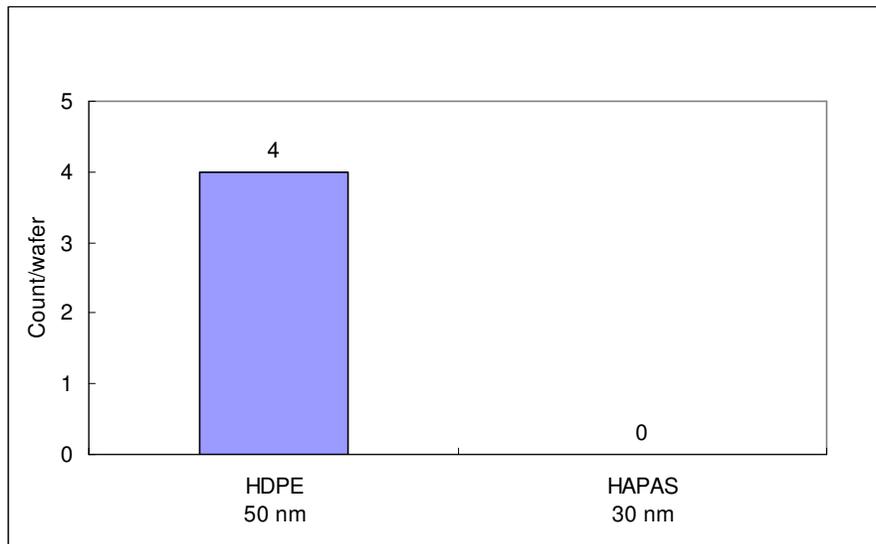


Figure 8. Filter comparison in killer defects on patterned wafer: Test fluid is non-PFOS TARC.

4. CONCLUSIONS

In conclusion, it was confirmed that the HAPAS filter, which was developed for minimization of microbubble formation based on previous research findings demonstrated reduced microbubbles as well as improved defect reduction performance in an environmentally preferred non-PFOS TARC, compared to a conventional HDPE filter. Factors contributing to the superior performance of HAPAS were high critical wetting surface tension (CWST), which causes good wettability, reduced pore size, which facilitates microbubble trapping, and low pressure drop across the filter membrane, which minimizes gas coming out of solution and forming microbubbles downstream of the filter.

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