Improving material-specific dispense processes for low-defect coatings

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ABSTRACT

The drive to smaller, less expensive, and faster devices requires radical changes in material development. The increased material requirements drive complex processes that in turn drive equipment requirements. For the photolithography area this demand for improved materials is seen in growing requests for device level–specific tuning of organic bottom anti-reflective coatings (BARCs) or photoresists for certain imaging requirements, such as numerical aperture, immersion conditions, and optical parameters. To test and utilize the myriad of BARC materials, there is a need to install them on a coater-track quickly and efficiently. Installation typically requires a new filter installation, dispense line cleaning, and usually a minimum of 8-10 L of material to clear out bubbles and other nuisance defects before coating test wafers. As the number of materials increases, the ability to quickly prime a new filter becomes increasingly important. In this study, the Entegris IntelliGen® Mini dispense system was utilized to test various pump priming processes to ultimately minimize the volume purged to reach a defect baseline. In addition, the impacts of the filter media and filter retention on priming efficiency were studied. Results show that priming processes that were not matched to the filter in use could actually cause the defects to increase during the process, thus requiring additional purging to reach baseline, and thereby negating any time or volume savings. Properly programmed priming recipes reduced the purging time and the purging volume by 50-70%.

Keywords: defects, BARC, filtration, filter priming, pump priming, plumb-on procedures, pressure drop

1. INTRODUCTION

The primary purpose of point-of-use filtration is as the last line of defense against defects being transferred from the chemical bottle to the wafer surface. As such, it is important to match the filter to the process chemical to maximize defect and throughput performance. It is also critical to properly prime the filter at installation, ensuring that all air is removed from the filter membrane. Air remaining in a filter can allow defects, including microbubbles, to pass through the membrane and onto the wafer, ultimately degrading yield.

Unfortunately, filter priming requires track downtime and a considerable amount of chemical waste. The chemical is used to displace air from the filter housing and membrane pore structure. By utilizing a two-stage technology dispense system, such as the Entegris IntelliGen® Mini seen in Figure 1, the chemistry can be either recycled back to the bottle after passing through the filter or sent directly to drain. Sending the material to drain is what significantly increases the cost of wasted material. By being able to recycle the material back to the bottle, the end-user is able to save a significant amount of chemical and ensure its cleanliness.

For chemical suppliers, the filter priming process is increasingly problematic. The rapid increase in lithography process techniques has increased the rate of chemical research and development. New materials are constantly being tested, and therefore a chemical supplier must often change filters to accommodate new chemistries that require lithographic and defect performance studies. The frequency of filter change at a chemical supplier is vastly increased over that of an

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end-user. Therefore, it is important to provide time- and cost-saving measures to chemical suppliers in the research and development phase. It is also hoped that these measures can be evaluated and passed along to the end-user when the chemical is finally ready for manufacturing and sale.

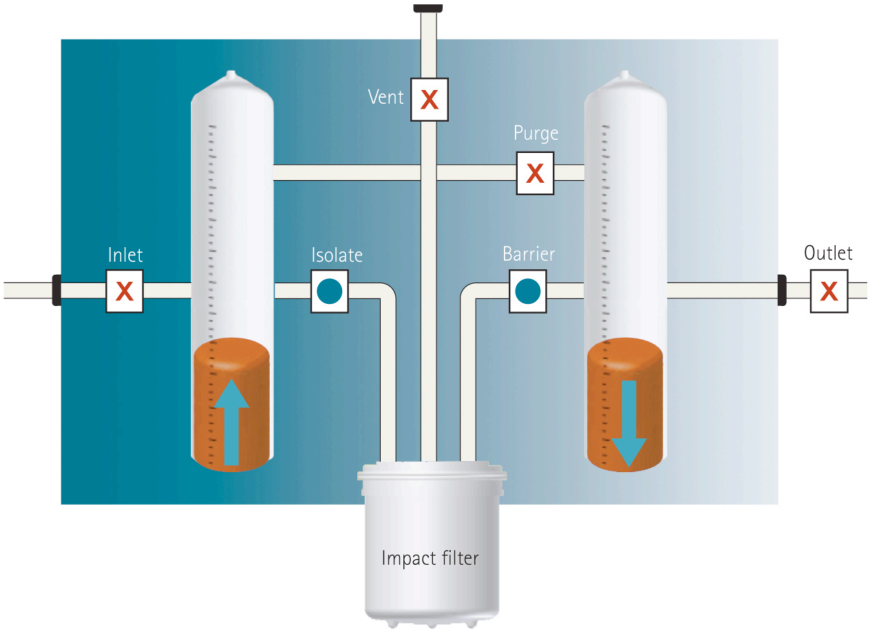

Figure 1. IntelliGen Mini dispense system.

2. EXPERIMENTAL

As the lithographic processes become more challenging, equipment and materials become increasingly expensive. It is important for the chemical manufacturers to ensure that the chemicals produced for the lithography industry are clean and will perform immediately using minimal end-user effort. A study was conducted to determine the proper filter priming sequence to reduce track downtime and reach baseline defectivity by using the minimum amount of BARC. Several filter priming sequences were tested.[1,2,3] Once the filter priming sequence was complete, purging up to 3 L of the BARC through the pump, dispense lines, and dispense tip began. On-wafer defect measurements were tested at various points during the purging cycle. This process would determine the effectiveness of the filter priming process with the BARC as well as the compatibility of the BARC and filter media.

The filter priming method utilized in this study is based on a recirculation methodology whereby the chemical is circulated through the filter and the two dispense chambers. The method utilized by the IntelliGen Mini does not require the user to input the entire sequence, but to simply load a pre-programmed sequence that is automatically run by the dispense system. Initial laboratory results showed that this method reduced the time to prime the filter by 60% when compared to the standard method.

Utilizing the new priming sequence, ARC® 162-308 coating, with a final thickness of 80 nm based on a 1500-rpm casting speed, was installed on the IntelliGen Mini. Once the filter priming method was completed, five wafers were consecutively coated on a TEL® Mark 8 after purging varying amounts of ARC® 162 coating through the dispense tip. Those wafers were then inspected by a dark-field inspection system with an 80-nm defect detection capability. The

Impact® 2 filters studied in this experiment included 20-nm asymmetric nylon, 10-nm asymmetric DUO, and three different UPE filters that were designed to create different levels of pressure drop across the membrane during filtration. Pressure drop across a membrane can be influenced by final pore size, membrane design, and membrane thickness.

3. RESULTS AND DISCUSSION

3.1 Baseline defectivity

A filter's effectiveness can be examined many ways. The first determination is to create a situation where the filter is fully wetted or passivated. A fully wetted filter should not pass defects or microbubbles through the membrane. The hold-up volume in the test setup from source bottle to dispense nozzle is approximately 250 mL. In this study it was assumed that the baseline defect level was reached when at least 10 times the hold-up volume, 2.5 L, had been purged through the system, thus creating a metric for comparison.

Displayed in Figure 2 is the baseline information where the volume purged through the filter is greater than or equal to 2.5 L after filter priming. Using a 95% confidence limit while comparing the average defect levels for each filter, it can be seen that the UPE filter with a high pressure drop has a higher defect count when compared to the other filter types. These results indicate that improper filter priming and improper purging parameters can influence the amount of material needed to reach the baseline defect level.[1] The priming and purging recipes were set up using a 20-nm UPE filter, which would have a lower pressure drop. It is highly possible that the pressure drop across the filter is high enough to cause microbubbles to form when using priming and purging routines optimized for a different filter.

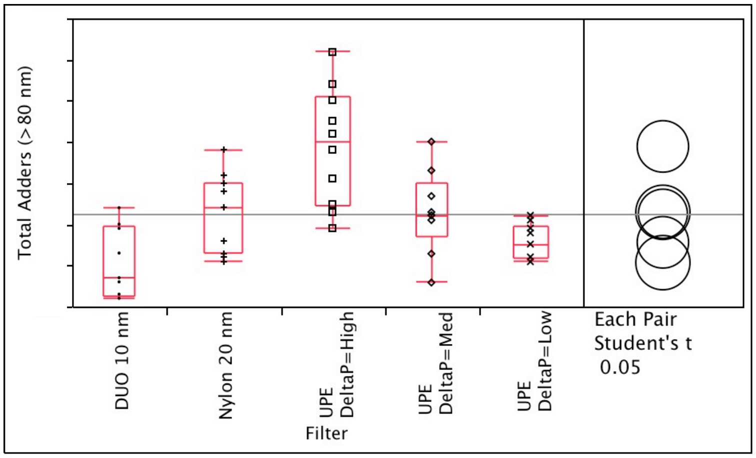

Figure 2. Baseline defect results for all media types.

To determine if pressure drop is the cause for the increase in microbubbles, a comparison of the defect counts with respect to pressure drop would show an increasing trend as pressure drop increases. In addition, a comparison of the defect size distribution between different pressure drops, as shown in Figures 3 and 4, would show the same effect. Because all three UPE filter types are considered asymmetric, filter media construction is not a factor. Figure 3 shows the expected trend after modeling a linear-fit line to the UPE filter media versus pressure drop of the filter.

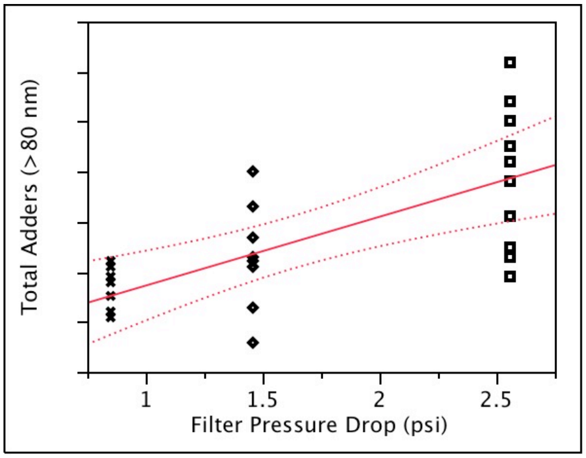

Figure 3. Baseline defect results through pressure drop for UPE filter.

Microbubbles typically are ~ 80-160 nm in size. By comparing these size ranges with respect to filter pore size in Figure 4, the defect distribution also shows an increase with increasing pressure drop. About 30-50% more defects are created with the high pressure drop filter compared to the low pressure drop filter. The vast majority of the defect adders come from microbubble creation and can be seen as the linear response in Figure 3 of an increase in defect counts per wafer of about 30-50% with increasing pressure drop. Reducing the filtration rate of the material would help minimize pressure drop across the filter. The conditions initially tested utilized a filtration rate of 1 mL/s, and if the rate was reduced to 0.5 mL/s or less, the pressure drop across the filter would be reduced and would likely minimize microbubble formation.

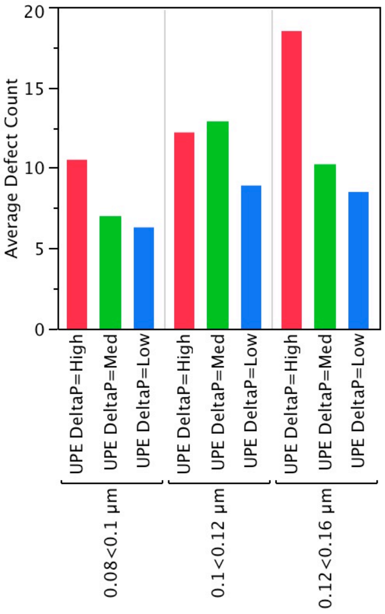

Figure 4. 80- to 160-nm defect bin sizes comparing UPE filter through pore size.

The other filter media, DUO and nylon, can be compared to the low pressure drop UPE filter. Figure 5 shows a comparison of these filters. The Entegris Duo filter utilizes two membrane types: an upstream nylon medium and a downstream UPE medium. The results from Figure 5 show that the DUO and UPE filters have similar distributions and are identical in performance with 95% confidence limits. The 20-nm nylon filter performs slightly worse than the 10-nm filters, which can be seen as the pore size difference. At this point the conclusion is that, at the same pore size, the DUO filter and UPE filter perform identically for on-wafer coat defects.

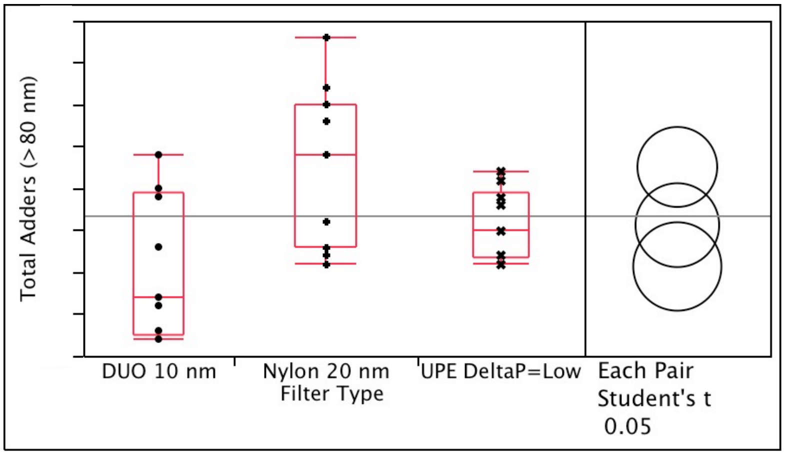

Figure 5. Baseline defect results for large pore and low pressure drop filters.

3.2 Filter media effectiveness

Completing the filter priming sequence properly and purging enough material to reach the defect baseline is only part of the solution for a low-defect BARC coating. Different filter media may be more efficient at removing impurities in the BARC and have faster and less costly start-up for end-users. When the end user matches the filter to the BARC, the benefit will be a decrease in BARC consumption at filter start-up, thus increasing the amount of available BARC for normal production.

To compare the effectiveness of priming, on-wafer defect monitors were checked periodically after priming was completed and 80 mL had been purged through the dispense line. Once that step was completed, purging began through the pump and dispense line using a 1 mL/s rate for filtration and dispense. Effective filter priming should completely wet the filter after one sequence, which results in initial defect results being close to baseline level upon completion. If the filter medium or the priming method is not correct, the defect baseline will not be reached without additional purging of material. Comparing how fast these filters start up may yield additional information on long-term compatibility with the filter medium. Figure 6 shows the results of the purging routines for the three different UPE filters with varied pressure drop. All three filters start up nearly identically, with a defect baseline being reached within the first 500-1000 mL purged through the pump. The rapid drop indicates that the defects caused by wetting of the filter are most likely microbubbles and are quickly vented or purged out of the system, and thus the filter priming sequence is adequate for any UPE filter. As previously stated, the differences in the baseline defectivity are most likely due to an increase in pressure drop across the filters. Thus the purging routine needs to be changed based on the filter pressure drop to achieve the best effectiveness.

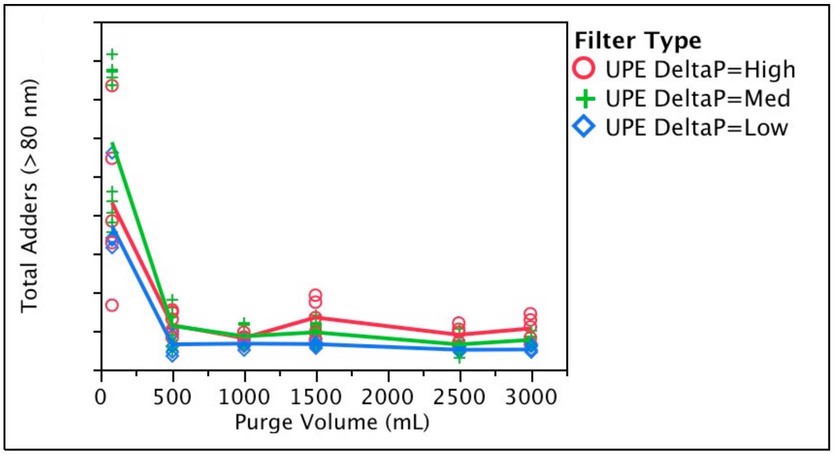

Figure 6. Defects through purging volume with UPE filters.

Previously it was stated that the baseline defect trend for the DUO and UPE filters was identical, but comparing the on-wafer defects through purging volume (Figure 7) implies that the DUO and nylon filters have more trouble reducing defects as quickly as the UPE filter. Two phenomena may explain these data. The first is microbubble formation, as previously discussed. The second is passivation of the filter media. SEM review of the defects is needed to completely identify the cause of the defects. Through internal Brewer Science® testing, it has been determined that the nylon filter membranes have an affinity for a certain constituent in the BARC chemistry.[4,5] This constituent is required in the BARC for proper curing and photoresist compatibility. Over time this affinity is passivated and would show up as a reduction in defects down to the same typical baseline as other filters. While these particular membranes may show improvements in long-term defectivity, it must be understood that the startup with these filters requires significant amounts of additional BARC material to initially passivate the filter membrane and ensure good results.[6]

Because the DUO filter is made up of both UPE and nylon filter media, it seems reasonable that the DUO filter would passivate more quickly than the nylon filter, as seen in Figure 7. DUO filter media may provide a compromise in both filter startup as well as the possible benefits that media type has in post-litho or post-etch areas.

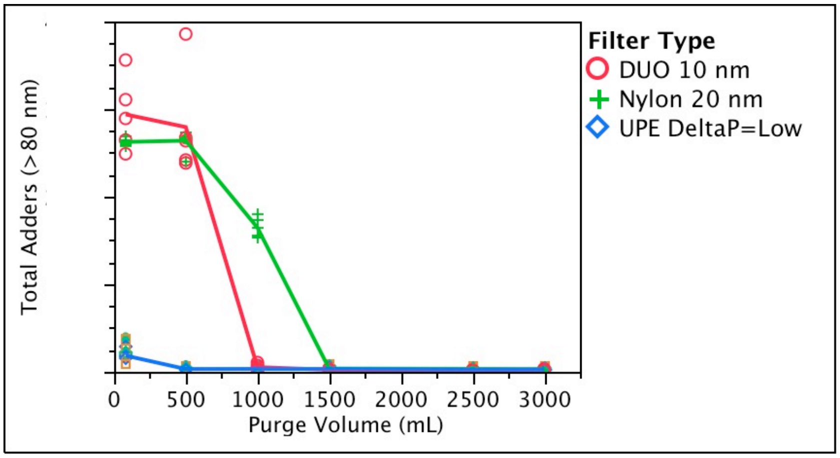

Figure 7. Defects through purging volume with filters having a pore size greater than 10 nm.

4. CONCLUSION

As device manufacturers continue to strive for higher-yielding wafers and increased productivity, it becomes clear that defects during wafer coating pose a significant challenge. During product development in chemical manufacturing, a clear understanding of filter interactions that can occur will enhance future product evaluations. As shown in this paper, proper filter priming with the proper purging process will yield quicker startup after filter changes. In addition, end-users can improve their processes by understanding the differences between filter membranes and their interactions with specific chemicals.

At device manufacturing sites, optimized priming recipes will allow coater tracks to return to production faster after a filter change and will reduce the time and material needed to bring the material into specifications for defects, such as the new automated approach that can save as much as 60% of the time required by the current method employed.

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REFERENCES

[1] Batchelder, T., “Optimized filter priming method to minimize maintenance downtime,” Entegris, Inc., Applications Note 3811-2706 (2006).
[2] Wu, A., and Chow, W., “A technique for rapid elimination of microbubbles for photochemical filter startup,” *Proc. SPIE*, 7140, 71402Y (2008).
[3] Batchelder, T., and Braggin, J., “Priming method for IntelliGen Mini,” Entegris, Inc., Applications Note 3811-5352 (2007).
[4] Brewer Science, Internal communication (2010).
[5] Brewer Science, Internal communication (2009).
[6] Do, Phong, et al. “Optimized filtration for reduced defectivity and improved dispense recipe in 193 nm BARC lithography,” *Proc. SPIE*, 5376, 1215-1222 (2004).