Improving Material-Specific Dispense Processes for Low Defect Coatings

Brian Smith*[a], Raul Ramirez[b], Jennifer Braggin[b], Aiwen Wu[b], Karl Anderson,
John Berron[a], Nick Brakensiek[a] and Carlton Washburn[a]
[a]Brewer Science, Inc., 2401 Brewer Drive, Rolla, MO, USA 65401
[b]Entegris Inc., 129 Concord Rd., Billerica, MA 01821

ABSTRACT

Minimizing defects in spin-on lithography coatings requires a careful understanding of the interactions between the spin-on coating material and the filtration and dispense system used on the coating track. A wet-developable BARC (bottom anti-reflective coating) was examined for its interaction with polyamide and UPE media when utilizing the Entegris IntelliGen® Mini dispense system. In addition, a new method of priming the filter and pump is described which improves the wetting of the filter media, preventing bubbles and other defect-generating air pockets within the system. The goal is to establish plumb-on procedures that are material and hardware specific to avoid any defect problems in the coating process, as well as to gain a better understanding of the chemical and physical interactions that lead to coating defects. Liquid particle counts from a laboratory-based filtration stand are compared with on-wafer defects from a commercial coating track to establish a correlation, and allow better prediction of product performance. This in turn will provide valuable insight to the engineering process of product filtration and bottling at the source.

Keywords: liquid particle counts, defect type classification, wet-developable BARC, filtration, filter priming, pump priming, plumb-on procedure

1. INTRODUCTION

Minimizing defects in spin-on lithography coatings requires a careful understanding of the interactions between the spin-on coating material and the filtration and dispense system used on the coating track. This allows faster start-up when installing new materials on a track or replacing filters on existing materials. It has been shown in literature[1,2] that optimizing the start-up procedure can drastically affect the time required to prime a filter. Any time used to prime a filter is time that a track cannot be used, and minimizing that time is crucial. While reducing track downtime is important, properly removing trapped air from a filter membrane is also important. Any air trapped in the system that has not been efficiently flushed out of the system can result in on-wafer defectivity. Therefore, a careful balance must be struck between removing the air from the filter and reducing track downtime.

Two-stage dispense systems like the IntelliGen Mini, seen in Figure 1, separate filtration and dispense operations. In doing so, the user has the ability to control and optimize both operations to maximize throughput and minimize defectivity. In addition, due to the customization available on the system, the user can also utilize optimized priming routines to quickly and effectively prime a filter.

The goal is to establish plumb-on procedures that are material and hardware specific to avoid any defect problems in the coating process, as well as to gain a better understanding of the chemical and physical interactions that lead to coating defects. Liquid particle counts from a laboratory-based filtration stand are compared with on-wafer defects from a commercial coating track to establish a correlation, and allow better prediction of product performance. This in turn will provide valuable insight to the engineering process of product filtration and bottling at the source.

*bsmith@brewerscience.com

B. Smith, R. Ramirez, J. Braggin, A. Wu, K. Anderson, J. Berron, N. Brakensiek, C. Washburn, "Improving material dispense processes for low defect coatings," *Proceedings of SPIE*, vol. 7639, 2010, in press.

2. EXPERIMENTAL

In this study, two priming methods were compared. The first method is the standard IntelliGen Mini priming method[3]. This method utilizes the benefits of two-stage technology to separate the two portions of the pump to create a faster overall priming time with reduced chemical waste. Venting steps are first performed to fill the upstream portion of the filter with chemistry and release the trapped air through the filter vent. Then purge steps are used to fill the downstream portion of the filter, while also releasing the trapped air through the filter vent. The dispense system then continues with full purging cycles, including filtration and dispense cycles, keeping the filtered material within the system. This ability to cycle the material through the system reduces wasted chemistry and ensures the lowest possible defectivity.

Entegris recently developed a second method for two-stage technology dispense systems. This method utilizes a similar methodology to the standard priming method, but does not require the user to input the process. Laboratory results showed that this method reduced the time to prime the filter by 60% when compared to the standard method.

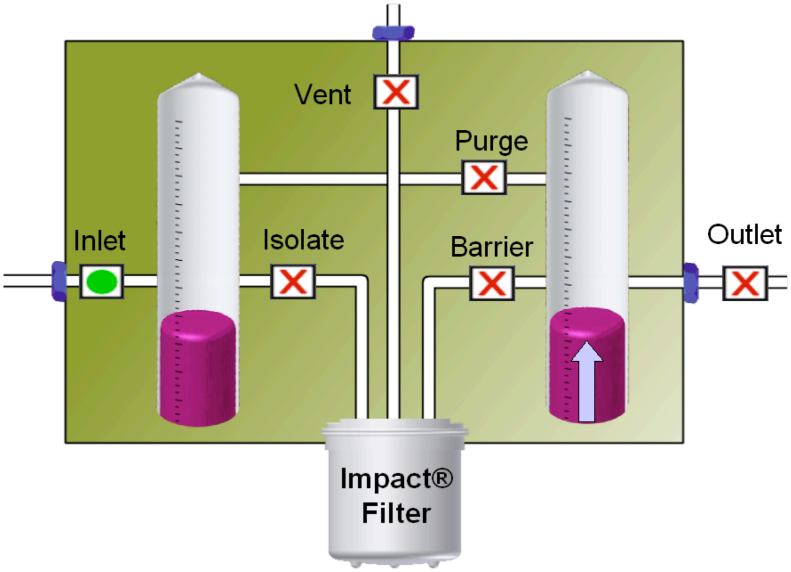


Figure 1: IntelliGen Mini dispense system.

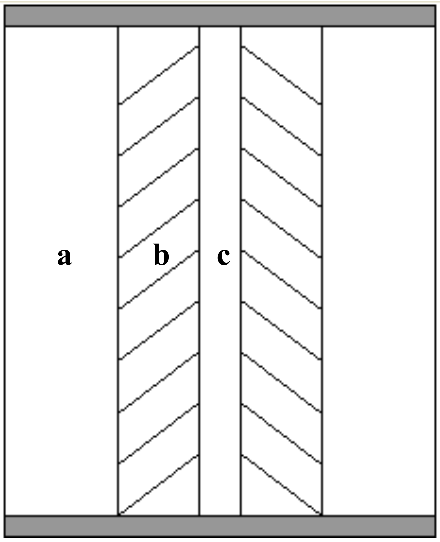


Figure 2: Longitudinal cross-section of a point-of-use filter.
(a) Upstream portion, (b) membrane, and (c) downstream portion of the filter.

Utilizing these priming methods a developer-soluble BARC (DBARC), ARC® DS-K101-304 film, with a final thickness of 40 nm based on a 1500 rpm casting speed, was installed on the IntelliGen Mini. Once either priming sequence was completed, 50 wafers were consecutively coated on a Tokyo Electron Mark8 track to see if a defect baseline was reached. Then, a sampling of those wafers was scanned by a darkfield inspection system to detect defects down to 80 nm. The Impact® 2 filters studied in this experiment included 10nm asymmetric polyamide, 5nm asymmetric UPE (ultra-high molecular weight polyethylene), and 10nm asymmetric UPE filters.

A baseline defect level was determined before initiating the test in order to compare the different priming methods and filter effects on the ARC® DS-K101 coating. A 20 nm symmetric UPE filter was used as the standard, baseline filter and the standard IntelliGen Mini priming sequence was used. Following the standard priming procedure, a series of dummy dispenses were performed over a period of several days to verify that the ARC® DS-K101 coating was at its baseline defect level.

Liquid particle counts were collected separately from the wafer testing using a recirculation-type system. A 1L sample of the DBARC was used for each filter test. First, the recirculation system was cleaned with PGMEA until the counts dropped below 1 count/mL for the 0.15-µm bin size. Then, the system was drained, subsequently filled with DBARC, and the filter being tested was installed in the system. After filter installation, the dispense sequence was started with a target flow of 120mL/min. Once the target flow was reached the particle counter was started and sampled until counts reached a steady state.

3. RESULTS AND DISCUSSION

3.1 Liquid Particle Counts (LPC)

Liquid particle counters have not kept up with the size of defects that are detected by leading-edge manufacturers, making it difficult to ensure clean wafers for today's demanding manufacturing requirements. However, LPC's (liquid particle counts) are still a useful, low-cost, and fast diagnostic tool to help understand filter wetting characteristics and filter compatibility trends. One would expect that if the on-wafer coat defects show the same trend as LPC's, this should allow filter and chemical suppliers to begin preliminary investigations on new filter media or smaller pore size with a faster response method, such as LPC's. If these results indicate lower LPC's, that would then infer lower coat defects on a wafer, ultimately saving valuable time and money to verify these results.

To better understand the correlation between LPC's and on-wafer defectivity results, 20 nm to 5 nm pore size UPE filters were tested to see if a trend could be found with decreasing pore size using liquid particle counts. The results of this experiment are shown in Figure 3. In general, the 5 nm UPE filter LPC counts dropped and came to baseline faster than the larger pore size filters. The faster time is due to the asymmetric design of the filter membrane that creates a smaller pressure differential and allows the trapped air to flow out of the filter faster. The 10 nm UPE filter eventually comes to a baseline slightly below the 20 nm UPE filter with 0.7 and 0.4 particles/mL, respectively, thereby showing a trend in decreasing particles with decreasing pore size filter.

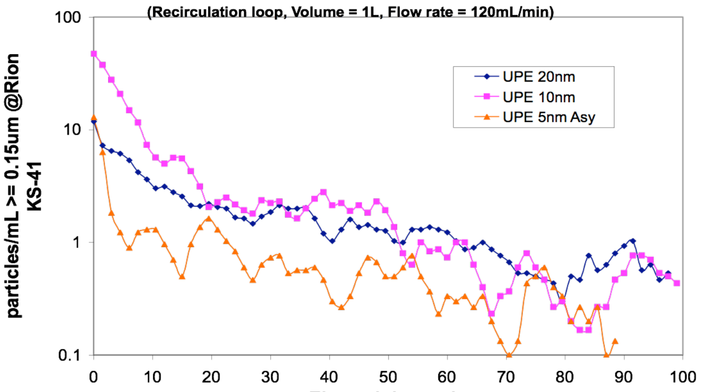


Figure 3: LPC results of ARC® DS-K101 with decreasing pore size.

Table 1 summarizes approximate time to steady-state LPC and the steady state LPC value.

Testing filter	Time for particle counts to reach the steady state (min)	Particle counts @ the steady state (counts/mL>0.15um)
20nm UPE	~60	0.7
10nm UPE	~60	0.5
5nm Asy. UPE	~30	0.4

3.2 On-wafer defects

After each filter change and priming sequence was completed, 50 wafers were consecutively coated to check for any trends associated with incomplete priming. Out of those 50 wafers, 11 were selected for further defect analysis. More specifically, coated wafer runs 1,2,3,5, 10, 17, 25, 26, 34, 42, and 50 were inspected. If the priming sequence was not completed properly, air or other contaminants would still be in the pump or lines leading to the dispense tip, which could cause defects during the DBARC coating. This transient effect would be seen as a gradual reduction in defects as more wafers or dummy dispenses occurred. A good priming sequence should not allow this type of transient behavior to occur. Both priming sequences tested are capable of completely wetting the filter enough to eliminate any transient coating defect trends after a filter change. Table 1 lists the regression results of the different filter and priming sequences. As can be seen, the linear regression fits are very low and the null hypothesis rejection is higher than alpha so there is no trend with number of wafers ran. With no visible trend all wafers in each filter priming sequence was used to generate any further conclusions.

Media Type	Priming Sequence	Pore Size	Regression R^2 fit	Prob>F (α<0.05)
Polyamide	POR	10 nm	0.007	0.8016
Polyamide	One-Button	10 nm	0.336	0.0614
UPE	One-Button	10 nm	0.104	0.3322
UPE	POR	5 nm	0.129	0.278
UPE	POR	10 nm	0.239	0.1274

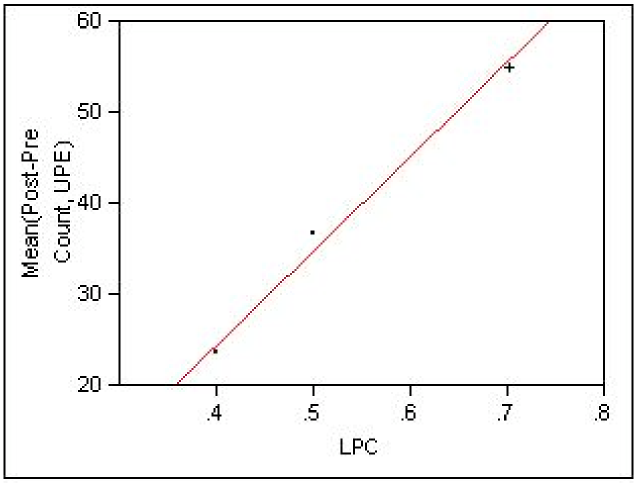
Table 2: Linear regression fit data for sampled wafers.

Completing the filter priming sequence properly 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. As the pressure drop across the filter may change with different BARC materials, that pressure drop may push impurities through the filter or even cause the filter to rupture if the pressure differential is extreme. From the data gathered form this round of testing several trends can be established by looking at pore size, media type, and its impact on the defect levels of ARC® DS-K101.

Reducing the filter pore size is a standard and effective way that the industry has been able to keep reducing defects, with this test it was an easy factor to look at since the original defect baseline for ARC® DS-K101 was created with a 20 nm symmetric UPE filter, and the experiment targeted filters with 10 and 5 nm filter pore sizes, a factor of 4 size in difference from smallest to largest pore size. Compiling all the UPE filter data in JMP® along with the original 20 nm baseline data, and fitting a linear regression line with 95% confidence limits to that data. It can be seen, in Figure 5, that we can achieve about a 50% reduction in coated wafer defects when comparing the 5 nm to the 20 nm filter pore size. In conclusion, reducing pore size while keeping the media the same is still a viable means of reducing defects on a coated wafer.

For each of the UPE filters at the pore size of 5, 10, and 20 nm, the average on-wafer defect count was compared to the liquid particle counts for the same pore size filter. The results are shown in Figure 4. A R^2 value for the least square fit line is 0.99 is found, indicating a very high degree of correlation. From this data it is very easily determined that the liquid particle counts trended the same as on-wafer defects, when the same material was tested. For ARC® DS-K101 it may be possible now to predict the on-wafer defects by liquid particle counts by the expression that is found here assuming that it is a UPE filter. This implies for manufacturing purposes that such a curve generated with a specific material and filter type would permit prediction of on-wafer defects with some level of confidence based on LPC counts.

Figure 4: On-wafer Defect vs LPC results for UPE filter type.



One disadvantage of reducing pore size is the increase of pressure drop across the filter. To combat this the 10 nm and 5 nm pore size are designed to have a gradual decrease in pore size across the filter. This allows the pump to only have to push through a small cross section of filter with the tightest pore while still keeping the ultimate pore size retention. With respect to the impact of ARC® DS-K101 the construction change from a symmetric to asymmetric is confounded with the pore size test, since defectivity is reduced the pore size and construction change both may have some impact on the reduction of defects.

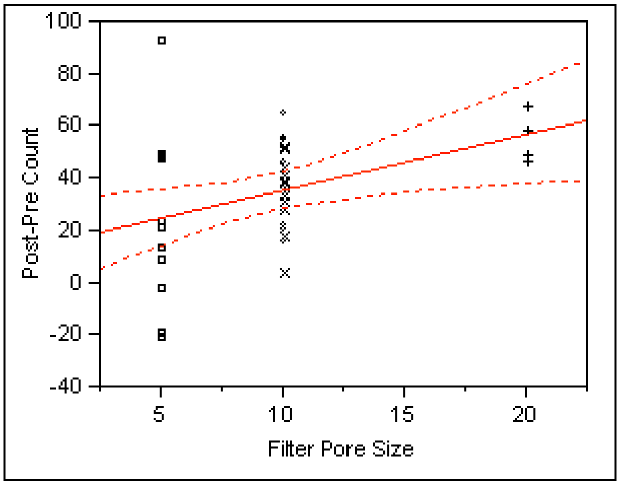


Figure 5: ARC® DS-K101 defects vs. UPE filter pore size.

Finally, the impact of media type on ARC® DS-K101 can also be ascertained with this data. Shown in Figure 6, is the analysis of the 10 nm pore size for Polyamide and UPE. Here there is a significant difference between the media type with Polyamide having higher defects. This is most likely due to an interaction between the media and ARC® DS-K101, which actually changes the molecular weight distribution of ARC® DS-K101.[4] Careful consideration of media type should be reviewed to yield the lowest coat defectivity.

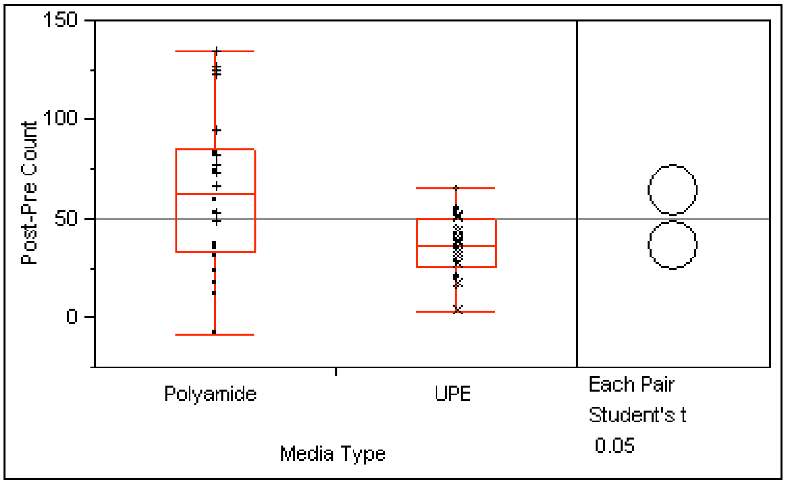


Figure 6: ARC® DS-K101 defects vs. media type with a 10 nm pore size.

4. CONCLUSION

As device manufacturers continue to strive for higher yielding wafers faster during a product evaluation, ramp, or after preventive maintenance, it becomes clear that defects during wafer coating is a significant challenge during those three situations. Clear understanding in chemical manufacturing of filter interactions that can be seen during product development will enhance future product evaluations, such as ARC® DS-K101 yields better defect results with a UPE filter over polyamide. LPC results that trend with on-wafer defects will allow chemical and filter manufacturers to quickly see if new filtration processes can yield cleaner products without resorting to more expensive and time-consuming on-wafer defectevaluations of every process change. It has been shown that by decreasing UPE pore size, lower levels of on-wafer defects and LPC's could be detected with ARC® DS-K101.

At device manufacturing sites, optimized priming recipes will allow coater tracks to return to production faster after a filter change and not have to expend extra time and material to bring the material into specifications for defects, such as the new automated approach than can save as much as 60% on time compared to the current method employed.

ACKNOWLEDGEMENTS

The authors would like to thank Entegris colleagues Traci Batchelder and Paul Magoon for useful discussions.

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