Optimized filtration for reduced defectivity and improved dispense recipe in 193 nm BARC lithography

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ABSTRACT

The implementation of 193 nm lithography into production has been complicated by high defectivity issues. Many companies have been struggling with high defect densities, forcing process and lithography engineers to focus their efforts on chemical filtration instead of process development. After-etch defects have complicated the effort to reduce this problem. In particular it has been determined that chemical filtration at the 90 nm node and below is a crucial item which current industry standard pump recipes and material choices are not able to address. LSI Logic and Pall Corporation have been working together exploring alternative materials and resist pump process parameters to address these issues. These changes will free up process development time by reducing these high defect density issues. This paper provides a fundamental understanding of how 20nm filtration combined with optimized resist pump set-up and dispense can significantly reduce defects in 193nm lithography.

The purpose of this study is to examine the effectiveness of 20 nanometer rated filters to reduce various defects observed in bottom anti reflective coating materials. Multiple filter types were installed on a Tokyo Electron Limited Clean Track ACT8 tool utilizing two-stage resist pumps. Lithographic performance of the filtered resist and defect analysis of patterned and non-patterned wafers were performed. Optimized pump start-up and dispense recipes also were evaluated to determine their effect on defect improvements. The track system used in this experiment was a standard production tool and was not modified from its original specifications.

Keywords: BARC, 193nm lithography, filtration, post-etch defects, photoresist pump, micro-bridge defects, nylon 6,6,

1. INTRODUCTION

Defect reduction has been an enabling part for advancing semiconductor technology. Applying finer filtration to the various processes including etch, chemical mechanical polishing and cleaning steps during process development and the associated defect inspection and classification has been commonplace. In contrast, the use of finer filtration in the lithography area has not been widely explored. Many lithographers and resist suppliers expressed concerns about adopting finer filtration due to concerns about polymer shear or surfactant stripping which could adversely affect resist performance.

With the transition to 193nm resist, the initial implementation focused on the traditional metrics such as exposure latitude, depth of focus, critical dimension, post exposure bake temperature sensitivity, resist profile and process windows. However, early on in the implementation of these resists the need for reducing defect density was clearly needed [3].

Original efforts started in 1999 demonstrated that finer filtration would not adversely affect these metrics[1]. However these investigations did not address if finer filtration in lithography could provide lower defect densities as it has in other semiconductor processing areas. In addition, it has been seen that defect densities of non-patterned test wafers does not clearly represent defect densities observed in patterned, after develop or after etch inspections. Micro bridge defects associated with patterned 193nm resists[3] and defects associated with the corresponding BARC have been reported[1]. These problems have been identified as widespread and further investigation was needed.

1.1 Filter construction

The filters evaluated are constructed with a pleated membrane, with appropriately designed support and drainage layers. The support material, utilized upstream and downstream of the membrane, provides support and venting for the filter membrane, and improves flow characteristics. Hardware materials, including cage, core, and end caps, provide a rigid structure to facilitate handling. The testing includes filters with membranes constructed of various hydrophobic ultra-high molecular weight polyethylene (PE) and hydrophilic nylon 6,6 materials.

The testing involves installing a 0.02 µm rated nylon 6,6 filter and monitoring the various defect densities as compared to existing PE media. Various defect types are identified and the effects of the 20nm filtration as compared to standard industry filtration choices are explored.

In addition, our experimentation required the adoption of small capsule filters incorporated in a standard dual stage pump system. Adoption of 20 nm nylon 6,6 filter capsule into the existing dual stage pump was accomplished by using a manifold, which allowed the use of alternative capsules within the dual stage pump system.

1.2 193nm chemistries

The adoption of second-generation acrylate based 193nm photoresists has caught the industry by surprise with widespread incidences of micro-bridge defects. These defects have been reported in several recent papers[1] and have been observed in different formulations from different manufacturers. These resists, which utilize chemical amplification to greatly enhance photosensitivity, are based on a deblocking reaction catalyzed by photogenerated acid in exposed areas. This results in a solubility difference between the exposed and unexposed regions of the photoresist.

The various functional groups joined on to the acrylic polymer backbone, which provide etch resistance, acid decomposition, adhesion promotion and hydrophilicity, seem to contribute to this defectivity. The naturally hydrophilic nylon 6, 6 membrane filtration materials chosen for this installation have shown an affinity for reducing in these defects[1]. It is hypothesized that the nylon 6,6 membrane removes low solubility oligomers of non-functioning polymer components. The nylon 6,6 membrane's naturally hydrophilic characteristic also eliminates phobic sites, which can be commonplace with PE and surface modified membranes. The nylon 6,6 membrane performance indicates an absorptive affinity for these undesired defects in addition to its superior sieving characteristics.

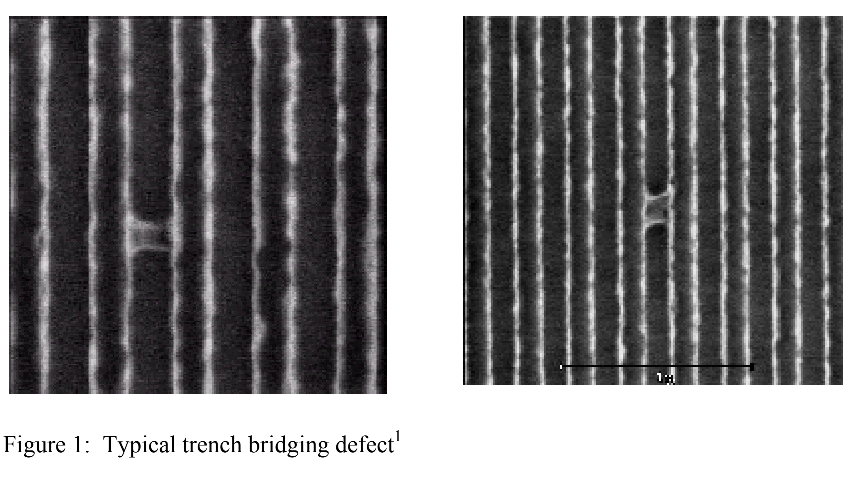

Figure 1: Typical trench bridging defect[1]

1.3 BARC Chemistries
Bottom Anti-Reflective Coatings (BARC) are organic polymer films or Inorganic films (IARC) with absorptivities and refractive indexes that match the photoresist film at the wavelength employed. Organic films are spun onto the wafer to suppress reflections from the substrate.

2. DISCUSSION

Our testing involved developing a short loop to determine the mechanism of the blocked poly defect. This defect is approximately 0.10 to 0.25 µm in size and cannot be detected through our standard inline defect monitor at poly mask and at poly etch. The defect is highlighted only after spacer nitride etch. Because the defect appears after nitride etch, we theorize that it is initially a much smaller defect acting as a micro mask which becomes larger after the etch process.

We have found that replacing our standard BARC 0.1 µm UPE filter with 0.02 µm nylon 6,6 filter has reduced this defect tremendously. We also evaluated a polyethylene 0.02 µm filter. Although the PE filter reduced the number of defects, the 0.02 µm nylon 6,6 filter was 57% better at reducing this defect. The following charts illustrate the current defect and the reduction benefits observed with the 0.02 µm nylon 6,6 filter.

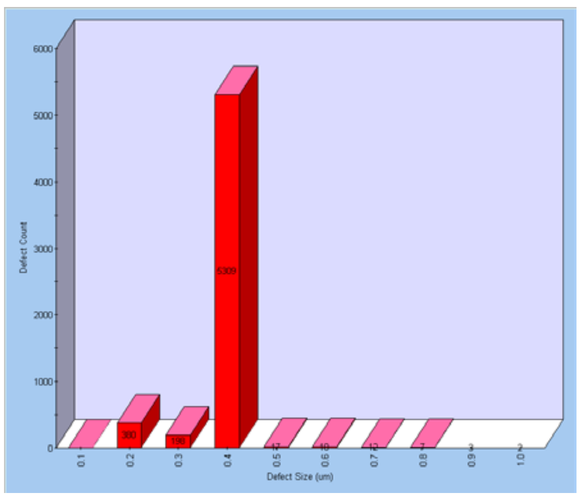

Fig.2: Initial defect size distribution

Initial testing gave an indication that moving to a smaller pore size BARC filter helps to reduce the blocked poly defects.

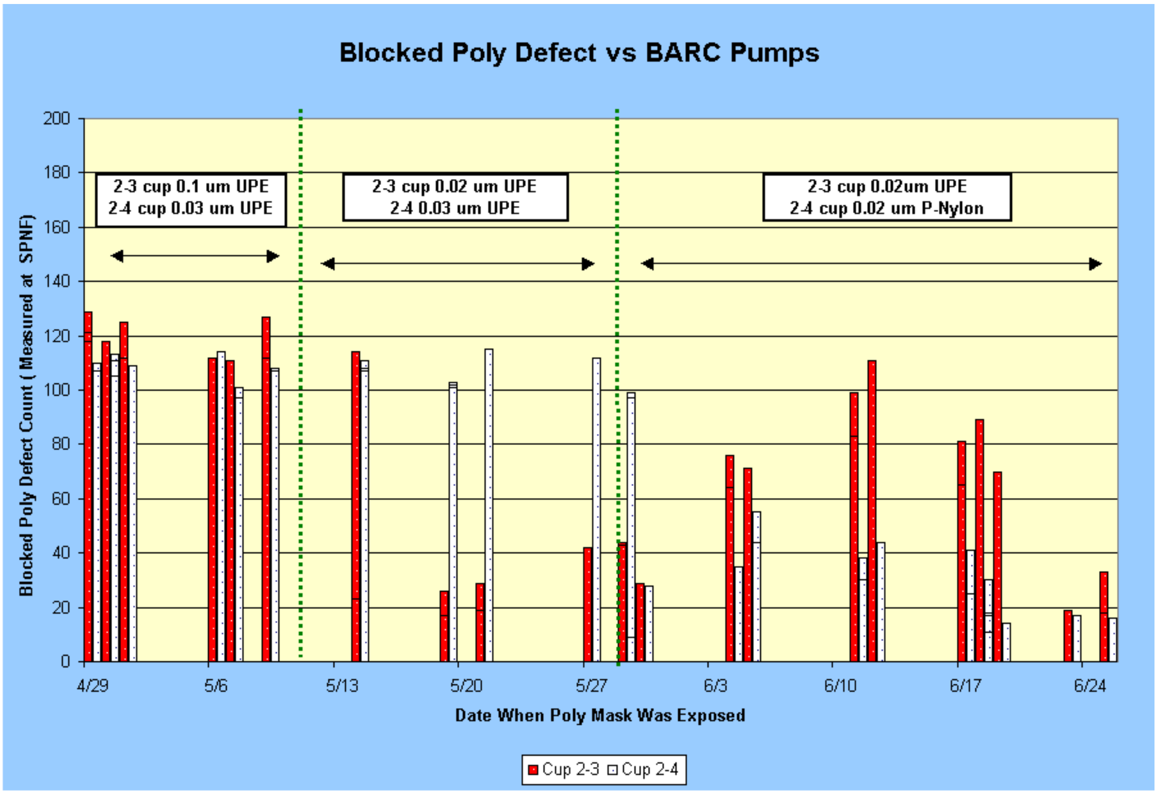

Fig.3

2.1 After trench etch BARC defect

We believe one source of defects found after trench etch is coming from impurities in the BARC material. We call these defects cones. An example of a cone defect is shown in figure below.

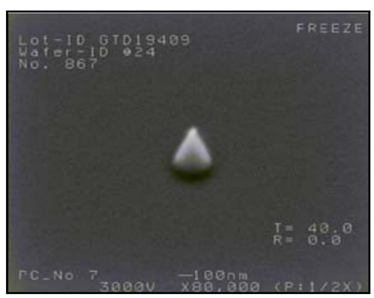

Figure 4: Typical cone defect.

As shown below, significant defect reduction was observed when we switched to the 0.02 µm nylon 6,6 filter as total defect counts were reduced by 35%. New developable BARCs are currently being investigated to further reduce these defects.

TRK1 utilizes 0.1 µm PE filters on the DUV44 while track TRK2 adopted the 0.02 µm nylon 6,6 filter.

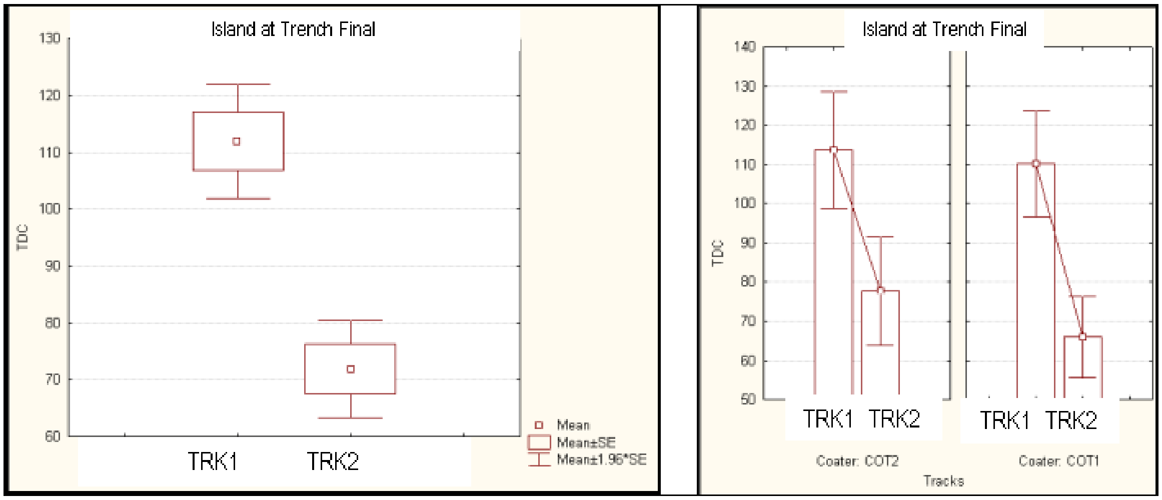

Fig.5: Cone defects at Island

2.2 Poly blocked etch defects

One type of defect seen after poly etch is poly blocked etch defects. One possible source of the defect is impurities within the BARC materials. An example of the poly blocked etch defect is shown below.

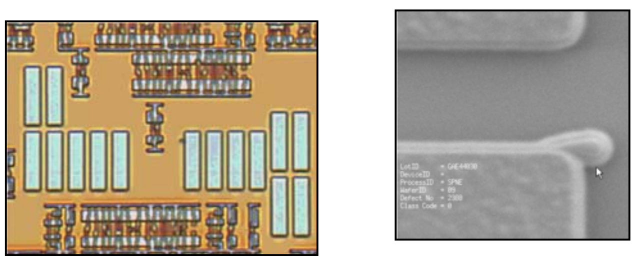

Fig.6: Typical poly blocked etch defects (optical and SEM image**)**

As shown in the following chart, TRK1 utilized our standard 0.1 µm PE Filter while track TRK2 adopted the 0.02 µm nylon 6,6 filter. The nylon 6,6 filter reduced defect counts by 23% over our standard filter.

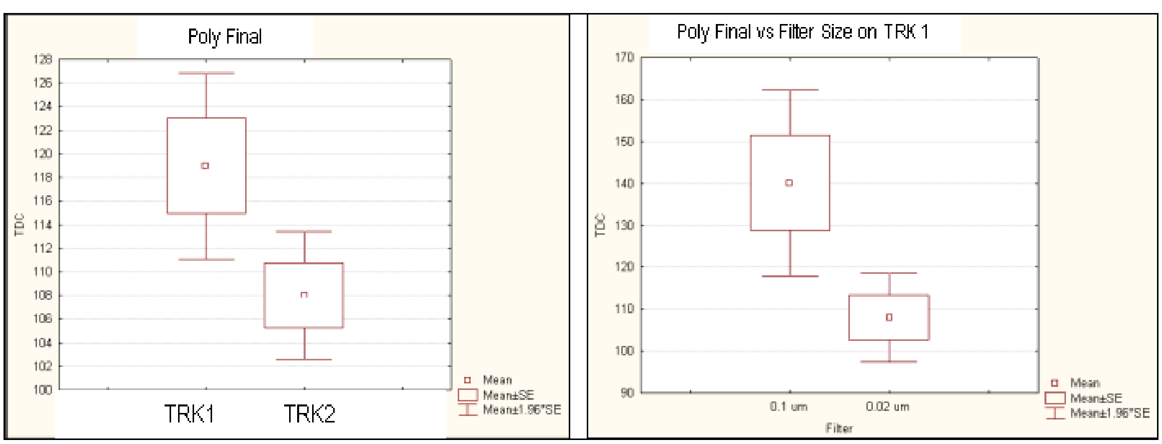

Fig.7: Poly blocked etch at FI

2.3 Metal mask inspection on all tracks

A 0.02 µm nylon 6,6 resist filter was installed on TRK3, CUP 2-1 for PEK 130 resist on 4/10/03. Test data shows a significant difference between TRK3, which utilizes the 0.02 µm nylon 6,6 filters, versus other tools that utilize the 0.1 µm PE filter for PEK 130 resist.

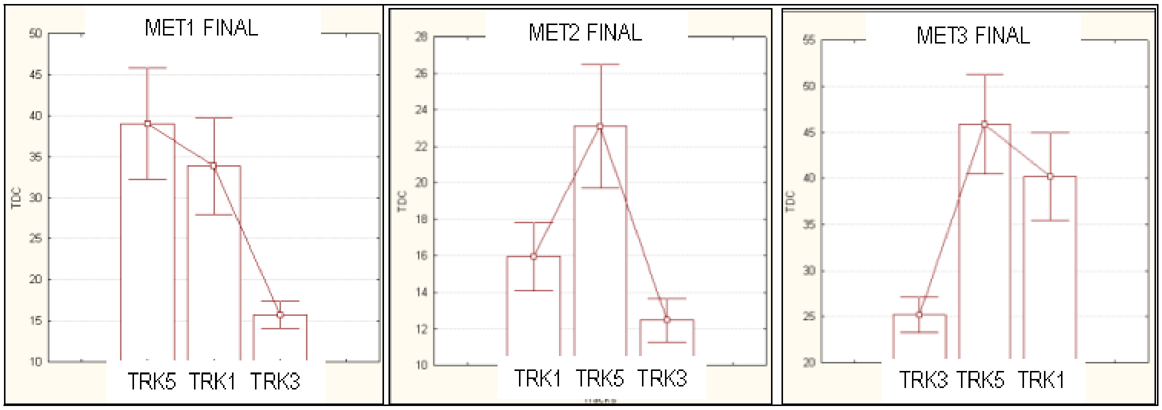

Fig.8: Metal defect comparison

3. Results

3.1 Island / Poly

- 0.03 µm PE resist filter seemed to have little impact at Island
- 0.02 µm nylon 6,6 BARC filters reduced defects by 35% for Island and 23% for Poly.
- New materials are being evaluated by photo to reduce cone defects even further.

3.2 Metal / Vias

- 0.02 µm nylon 6,6 resist filters have a significant impact on defect reduction at Metals by 17 % at FI.
- Lowering pump filtration rates to 0.1 ml/sec also shows a significant impact in reducing defects at Via (50%) and Metals (50%).

A strong correlation exists between the implementation of 0.02 µm nylon 6,6 BARC filters and a reduction in defect densities. Although the 0.03 µm PE filter has reduced the defects, it is not good enough. Moving to a 0.02 µm nylon 6,6 filter further reduced this defect. The 0.02 µm nylon 6,6 filter is found to be 57% better than the PE filter at reducing defects.

3.3 Pump discussion

During the evaluation, a direct correlation was observed between adopting finer, hydrophilic filtration and reduced defect densities utilizing a two-stage pump system. One of the biggest advantages of the two-stage pump system is the ability to separate filtration rate from the dispense rate. This has allowed the equipment engineer to reduce filtration rates to minimize gel extrusion and filter pressure drop while maintaining dispense repeatability.

However, the perceived increase in pressure drop across smaller pore size filters appeared to cause problems during the two-stage pump initialization subroutine. When dispensing in maintenance mode very low defect levels were observed. Once the system was switched to production mode and initialized, bubble formation was observed at the pump output line as well as the dispense nozzle tip. Subsequent dispenses showed a high level of micro-bubble formation at patterned wafer inspect.

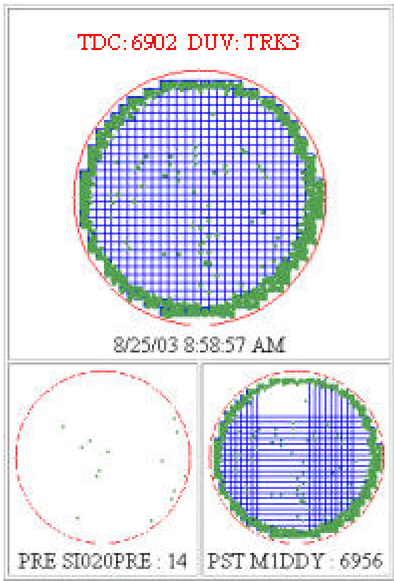

Fig.9: Micro-bubble defects

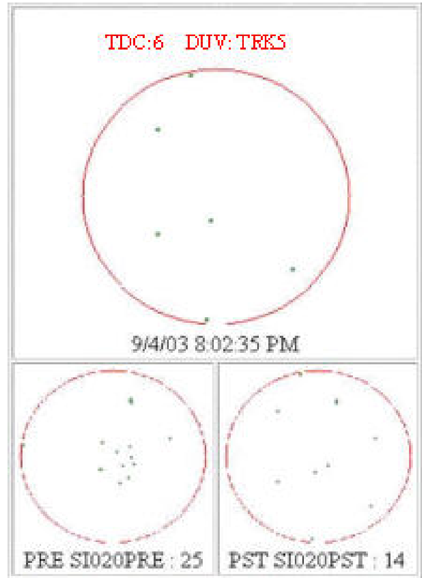

Fig.10: Typical defect counts

We hypothesized that during the transition from initialization mode to dispense mode a negative pressure is developed between the feed pump and dispense pump stages. This was verified by monitoring dispense stage internal pressure during initialization and dispense modes with the lowest possible filtration rate selected. Raw data indicated a high negative pressure drop during pump initialization

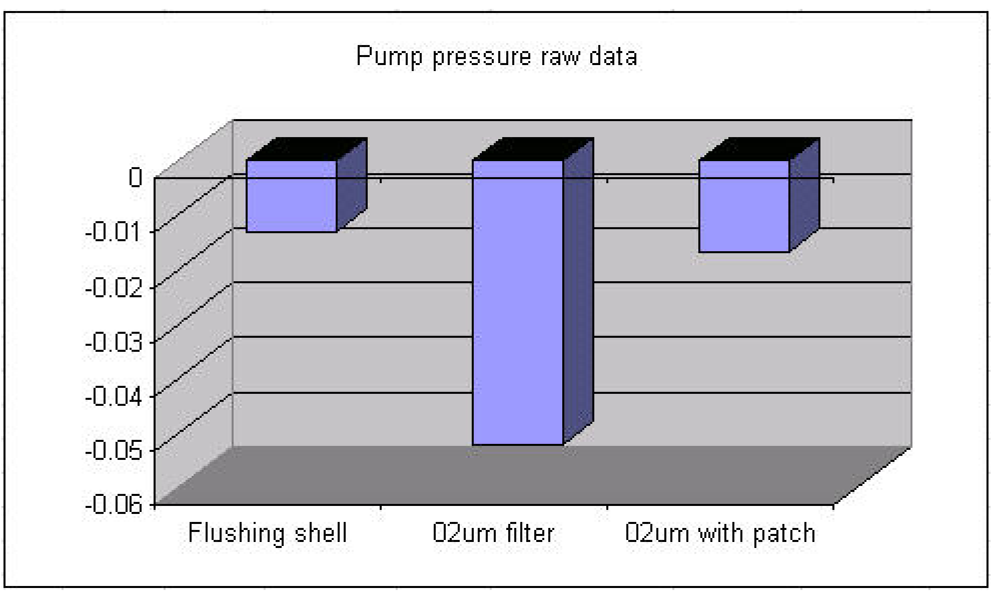

Fig.11

Negative pressure was also observed from the dispense stage to the dispense valve as evidenced by the formation of aspirated bubbles at the nozzle tip during the start of the first dispense after initialization. This could be addressed by increasing dispense valve open delay time, but would compromise normal dispense condition set-up.

A pump system software patch was then implemented to reduce negative pressure to acceptable levels through modifications to valve and pump timing cycles during the initialization subroutine. Subsequent testing has revealed no further issues.

4. CONCLUSIONS

Finer filtration combined with the hydrophilic nylon 6,6 media has demonstrated some of the lowest defect densities. To enable further reduction in critical dimensions with minimized defects, finer filtration is needed.

The implementation of 20nm filtration in the BARC process clearly shows after-etch defect reductions. Problems that in the past were attributed to the etch process are now being related to the BARC chemistries and can be significantly reduced.

Finer filtration of 193nm chemistries is possible accompanied by superior defect reductions. However, current pump capabilities combined with efforts to reduce filter size and hold up volume may be counter intuitive to defect reduction strategies. A balance needs to be established for using existing two stage pump systems while trying to adopt finer filtration.

5. REFERENCES

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