An Update on the Improvement in Optimization of Point-of-Use Filtration of Metal Oxide Photoresists

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INTRODUCTION

Extreme ultraviolet lithography (EUV) is crucial for creating advanced integrated circuits with feature sizes below 10 nm. However, finding suitable photoresists for EUV exposure is challenging. Conventional chemically amplified resists have limitations in sensitivity, resolution, and line edge roughness (LER) when exposed to EUV radiation. Inpria Metal Oxide Resists (MORs) are a new class of inorganic photoresists that can overcome these challenges, offering high resolution and sensitivity for EUV lithography.

The emergence of metal oxides as new materials introduces additional challenges for the filtration process, which is necessary to remove impurities and defect sources from the resist solution. In this paper, we present comprehensive and comparative studies of the optimization of the efficiency and performance of various point-of-use (POU) filters in reducing defects in metal oxide resist materials. Entegris Impact® 8G format filters with different membrane properties and designs were tested to understand their impact on patterned wafer defects.

EXPERIMENT

The coating process of a MOR was accomplished in the module of a TEL Clean Track LITHIUS Pro™ Zi and Pro™ Z. The filter installation and testing procedure was identical for all testing filters. Before starting the defect study, a filter was primed to achieve baseline particle counts using methyl isobutyl carbinol (MIBC) solvent. The dispense recipe and coat recipe were kept constant as the filter was changed.

Developer Rinse Defects

This testing was adopted as a new indicator to increase wafer coating defect intensity and inspect the defectivity at a highly sensitive level. Si wafers were spin-coated with a metal oxide material of YATU 1011, followed by a developer washing to remove the coated photoresist and spin-drying. Afterward, the wafers were baked and inspected for defect counts using a KLA Surfscan® SP5 at 22 nm resolution.

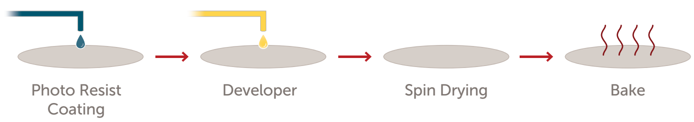


Figure 1. Process flow of thinner wash defect testing.

After Etched Inspections (AEI) of Bridge Defects

The photoresist material was spin-coated on wafer with the stack below (Figure 2) to prepare an inspection vehicle for defectivity studies. The dispense condition and coat recipe were kept constant. The exposure process was carried out using an ASML NXE3400 full field EUV scanner (0.33 NA) at 32 nm pitch size. The bridge defects on each wafer were then reviewed on KLA2935 and classified by defect review tool eDR7380.

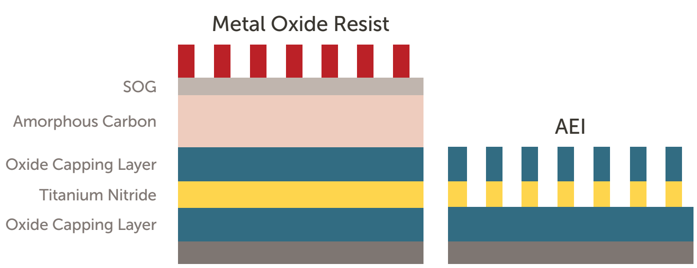


Figure 2. Inspection layer stack of AEI test vehicle.

Point-of-Use Filters

Impact 8G style POU UPE filters with varied retention ratings, membrane architecture, and filter design were tested in this study. Table 1 provides a comparison of the filter attributes.

ATTRIBUTE	3 nm UPE	CONCEPT #1	CONCEPT #2-1	CONCEPT #2-2	CONCEPT #2-3
Filtration area (cm^2)	1,200	3,000	3,000	3,000	3,000
Membrane characteristics	Conventional UPE membrane architecture	Enhanced UPE surface filtration	Complementary UPE surface filtration with depth filtration (Design #1)	Complementary UPE surface filtration with depth filtration (Design #2)	Complementary UPE surface filtration with depth filtration (Design #3)
Membrane thickness	Thick	Thin	Thick	Thick	Thick
Primary retention mechanisms	Sieving (size exclusion)	Sieving (size exclusion)	Sieving (size exclusion)	Sieving (size exclusion)	Sieving (size exclusion)

Table 1. Comparison of new UPE filter attributes.

RESULTS

The results of the developer rinse defect inspections and on-wafer pattern study are presented in Figure 3. The values of rinse defects and bridge defectivity were normalized by one of the 3 nm UPE filters as a reference in each run. The 4 advanced UPE filters with different membrane properties and morphology were tested. Both filters of Concept #2-1 and #2-2 showed worse defectivity than 3 nm UPE while the rest of the UPE filters, Concept #1 and #2-3, achieved nearly 10% and 20% improvement respectively.

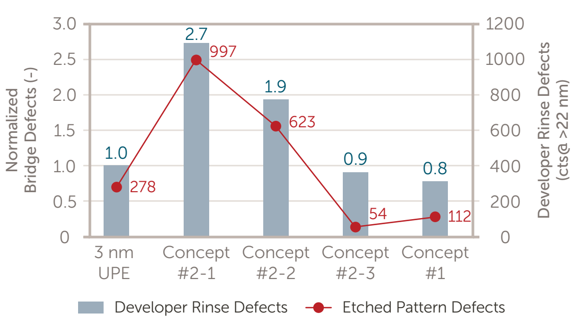


Figure 3. Comparison of developer rinse defects and etched pattern defects.

In order to validate the efficacy of the developer rinse defect metrology, the correlation analysis was conducted at the X-axis of the rinse defect values plotted against the Y-axis of the bridge defects (Figure 4). There was a strong correlation observed between these 2 factors, which demonstrated that the rinse defects were useful indicators to assess etched bridge defectivity performance with fewer resources and ease the hands-on burden of experiments.

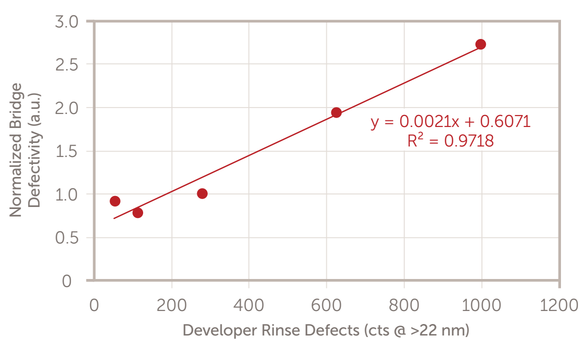


Figure 4. Correlation analysis between developer rinse defects and bridge defects.

A correlation analysis was conducted to understand how different filtration factors could contribute to defect reduction and to determine an optimization scheme for further improvement. The results of Advanced UPE #1 and #2 from previous experiments were included in the graphs to examine the coherency of all the data (Figures 4, 5, and 6).

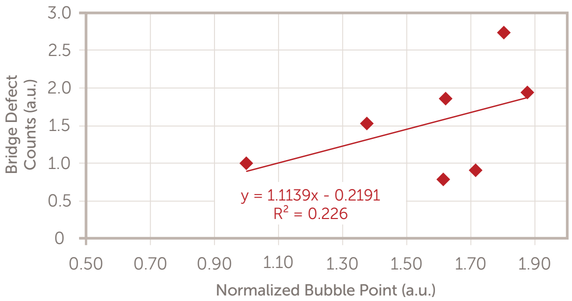


Figure 5. Correlation analysis between bridge defectivity and membrane pore size.

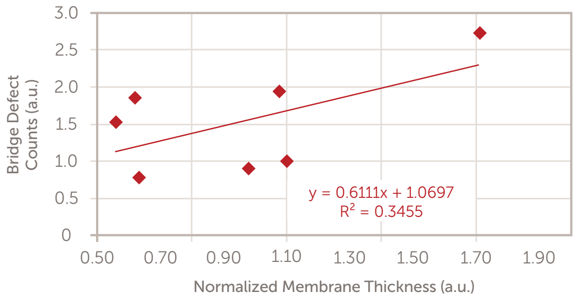


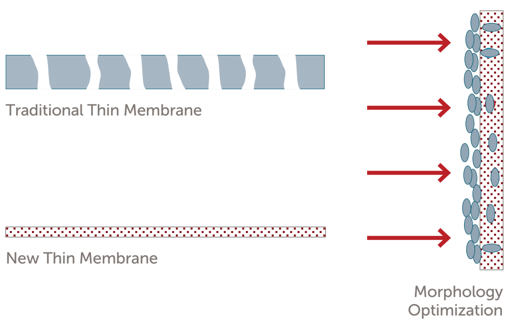
Figure 6. Correlation analysis between bridge defectivity and membrane thickness.

No conclusive insight was obtained, but it was noted that Concepts #1 and #2-3 showed a reduction in defectivity. Past studies suggested the importance of enhancing the UPE filter media's ability to retain soft particles like gel aggregates in MORs at high differential pressures. Subsequent investigations made significant progress towards these goals.

Concept of New UPE Membranes

Concept #1

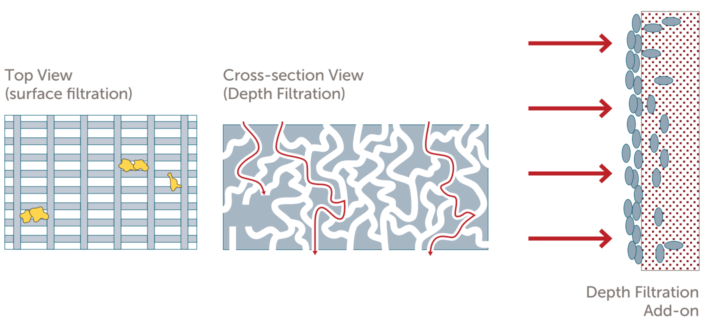
Maximize filtration capability through the enhancement of the membrane morphology tortuosity.



- Continue to shrink absolute pore sizes to improve removal via size exclusion
- Continue to improve pore size uniformity to enhance removal efficiency and consistency
- Enhance the tortuosity of membrane morphology to enhance gel trap capability

Concept #2

Complement filtration capability with depth filtration of membrane thickness.



- Incorporate depth filtration design to complement traditional thin membrane morphology
- Highly torturous morphology to enhance filtration residence time and utilize multiple filtration mechanisms (impaction, interception and size exclusion)

CONCLUSION

The pivotal findings of this study highlight the significant impact of filter choice on the defectivity and performance of Inpria MORs in EUV patterning. We identified challenges with MOR materials and presented compelling evidence for effective filtration solutions. Therefore, this study greatly contributes to EUV lithography and offers valuable insights for those using Inpria MORs in semiconductor device fabrication.

Acknowledgments

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