Exploration of UPE Membrane Technology in Point-Of-Use EUV CAR Photoresist Filtration

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ABSTRACT

The relentless advancement of Extreme Ultraviolet (EUV) lithography has ushered in the integration of high Numerical Aperture (NA) EUV technology, enabling the fabrication of cutting-edge semiconductor devices at 5 nm and beyond. With increased device scaling, the complexity of lithographic processes has grown, necessitating the development of innovative materials and optimized patterning techniques to mitigate the stochastic challenges inherent in EUV lithography. Alongside material innovation, defect reduction through advanced filtration at the point of use (POU) has emerged as a critical enabler for achieving the desired yield and performance in high-NA EUV processes. The findings presented in this study underscore the transformative potential of our filtration advancements for the semiconductor industry, focusing on the development and optimization of a novel Ultrahigh Molecular Weight Polyethylene (UPE) filter specifically designed to meet the stringent defectivity requirements of EUV Chemically Amplified Resists (CAR) toward the upcoming high-NA EUV lithography.

The poster concludes with strategic recommendations for implementing these advanced filtration solutions to bolster the semiconductor industry's push toward ever-smaller node manufacturing and highlights the indispensable role of filtration technology in advancing EUV lithography.

INTRODUCTION

The continuous drive for higher performance and energy efficiency in semiconductor devices has established EUV lithography as a cornerstone of modern chip manufacturing. The advent of high NA EUV systems has enabled unprecedented resolution, supporting the fabrication of advanced devices at sub-5 nm nodes. However, this technological progress is accompanied by increasing complexities in defect control and patterning precision, which directly impact manufacturing yields and device reliability.

Defects in EUV lithography often originate from both stochastic variations in patterning and contaminants introduced during material processing. Among these types of defects, bridges in EUV CARs have been proven particularly detrimental, necessitating innovative solutions to reduce their occurrence. POU filtration systems have emerged as a critical countermeasure, enabling to remove particulate contaminants with higher fidelity patterning in EUV processes.

This study investigates the performance of advanced UPE filters tailored for EUV CAR filtration. By optimizing membrane architecture and retention mechanisms, these filters aim to address the stringent defectivity requirements posed by high-NA EUV lithography. The experiments detailed here assess the filtration efficiency with EUV technological environments. Additionally, we present insights into the correlation between filtration parameters and defect mitigation, supported by a comprehensive analysis of patterned wafers.

EXPERIMENT

The coating process of an EUV CAR was accomplished in the module of a TEL Clean Track LITHIUS Pro™ Z series. The filter installation and testing procedure were identical for all testing filters. Before starting the defect study, a filter was primed to achieve baseline particle counts using PGME/PGMEA (7:3). The dispense recipe and coat recipe were kept constant as the filter was changed.

After Etched Inspections (AEI) of Bridge Defects

The photoresist material was spin-coated on wafer with the stack below (Figure 1) to prepare an inspection vehicle for defectivity studies. The exposure process was carried out using an ASML NXE3400B full field EUV scanner (0.33 NA), targeting as standard dense line/space patter with 32 nm pitch. The wafers were inspected on a brightfield BBP inspection tool (KLA2935), reviewed by SEM (eDR7380) and manually classified to separate the defects of interest (single bridge defects) from other defects.

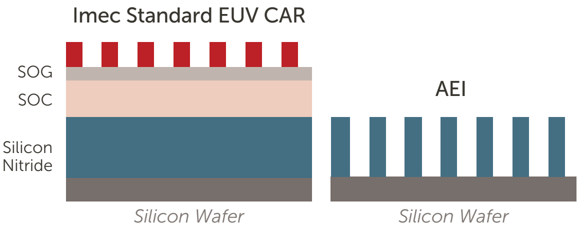

Figure 1. Inspection layer stack of AEI test vehicle.

Point-of-Use UPE Filters

Entegris 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.

RESULTS AND DISCUSSION

In previous studies, the size exclusion mechanism demonstrated superior performance compared to non-sieving interactions and complex membrane morphologies, such as those employed in the Azora® family, in reducing bridge defectivity in the EUV CAR photoresist (Figure 2). Building on the concept, the sieving-oriented UPE membrane, designated as the R02 filter, was developed to maximize filtration capabilities by enhancing membrane tortuosity. Notably, this design achieves these improvements without altering the membrane film thickness, thereby preserving flow rate benefits. This evolvement also enhances gel trap capability, effectively retaining unwanted contaminants (Figure 3). To achieve even finer filtration precision, an advanced UPE membrane, NEW UPE A, was developed with more specifically tailored pore sizes while maintaining the original membrane architecture.

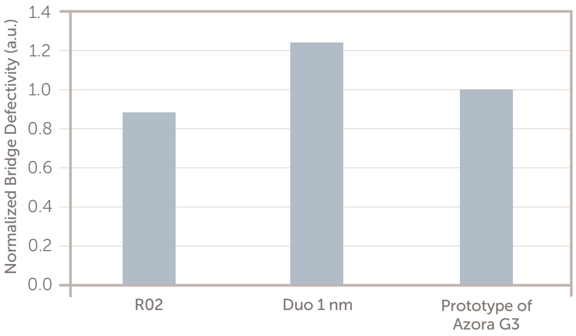

Figure 2. A comparative data of solvent rinse particles and bridge defectivity.

ATTRIBUTE	**NEW UPE A**	**R02**	**DO1A**	**DO1**
Filtration area (cm²)	4,200	3,000	3,000	3,000
Membrane characteristics	Specifically tailored UPE surface filtration	Enhanced UPE surface filtration architecture	UPE surface filtration architecture (Design #1)	UPE surface filtration architecture (Design #2)
Primary retention mechanisms	Sieving (size exclusion)	Sieving (size exclusion)	Sieving (size exclusion)	Sieving (size exclusion)

Table 1. Comparison of filter attributes.

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

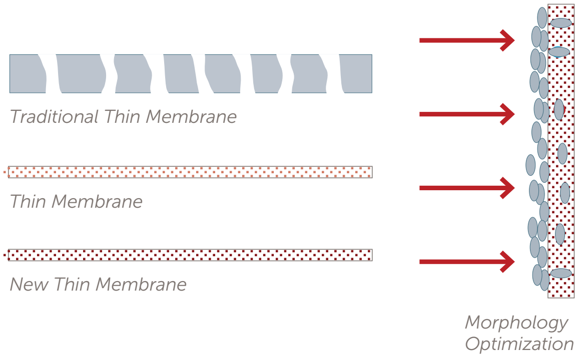

Figure 3. Schematic of R02 and NEW UPE A membrane structures.

The on-wafer experiments confirmed that our UPE technology has undergone significant advancements over time, as evidenced by the superior performance of more advanced filters. Additionally, comparative analyses revealed that the NEW UPE A filter offers notable advantages over earlier models in bridge defectivity (Figure 4). The results underscore the dominance of the sieving mechanism in mitigating bridge defects by effectively removing contamination sources. A correlation analysis well-supports the conclusion that pore size is a critical factor in reducing bridge defects (Figure 5). Despite these promising findings, further investigations are required to fully elucidate the defect removal mechanisms. One hypothesis suggests that bulky and rigid molecules, such as protection and phenol groups in typical EUV CAR polymers (Figure 6), can make aggregation until chemical consumption. These aggregates are effectively retained by the membrane's specific pore sizes due to their rigidity and size, while normal resist molecules pass through unimpeded.

Future studies are planned to delve deeper into these findings, with a focus on understanding the interplay between molecular properties and filtration mechanisms. Insights from subsequent bridge defect studies will guide the development of next-generation filters, paving the way for more comprehensive filtration solutions tailored to the evolving demands of EUV lithography.

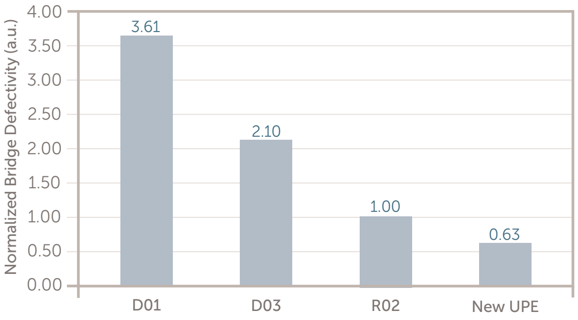

Figure 4. A comparative data of etched bridge defectivity among advanced UPE filters.

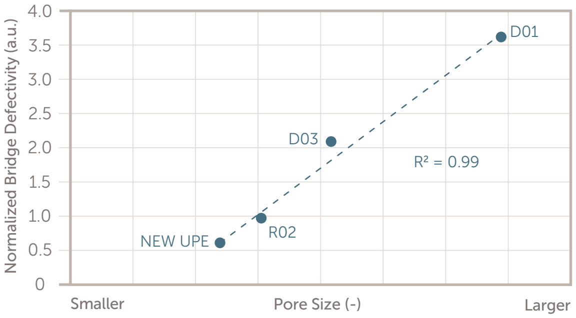

Figure 5. Correlation between bridge defectivity and pore sizes of most advanced UPE filters.

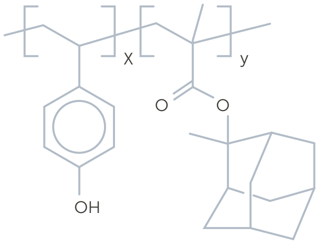

Figure 6. Schematic molecular structures of typical EUV CAR polymers.

CONCLUSION

This study highlights the pivotal role of advanced filtration strategies in addressing the unique challenges posed by EUV CAR resists, where precise pore size control is essential for mitigating bridge defectivity and ensuring pattern fidelity. Given the sub-nanometer precision required in EUV lithography, the adverse effects of unfiltered contaminants are significantly amplified, necessitating a profound understanding of tailored filtration technologies.

By exploring the detailed interplay between filtration mechanisms and EUV CAR resist performance, this poster offers valuable insights into the development of state-of-the-art filtration solutions. These findings underscore the potential of advanced membrane designs to enhance the robustness and reliability of EUV lithography processes, opening the pavement for next-generation semiconductor manufacturing. Future work will continue to refine these methodologies, further bridging the gap between filtration technology and the stringent demands of EUV CAR photoresist materials.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the teams at imec, and the equipment supplier, in particular, Hisashi Genjima from Tokyo Electron Kyushu Ltd. for their great support in collaborative efforts.

This paper was first presented at the 2025 SPIE Advanced Lithography and Patterning conference.

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