# NTD CARs Purity Developments Toward Single-Print Capability in EUV Scanners

*Kozue Miura, Tetsu Kohyama – Nihon Entegris G. K.*


## ABSTRACT

Extreme ultraviolet (EUV) patterning technology has been pivotal in the production of advanced logic devices, evolving from 7 nm nodes since 2018 to the current 3 nm node.[1] As device scaling progresses, the associated complexity and cost of multi-patterning processes have driven the semiconductor industry to prioritize EUV technology development, particularly focusing on new resist materials to address stochastic issues.[2] The adoption of single-print capability with high numerical aperture (NA) EUV scanners presents a significant challenge for semiconductor fabs.[3] EUV chemically amplified resists (CARs) are particularly prone to scum defects caused by incomplete resist clearance during development, often attributed to polymer aggregation.[4]

This paper investigates optimized filtration membranes for enhancing defect detectability in EUV negative-tone development (NTD) CARs. A comparative study evaluates filters with different membrane surface functionalities and substrates, analyzing their impact on patterning performance through resist application, wafer exposure, and post-etch defect analysis. Our findings demonstrate the efficacy of optimized filter designs in reducing defect densities, providing actionable insights for refining EUV lithography processes to achieve higher yields and enhanced performance in semiconductor manufacturing.


## INTRODUCTION

EUV lithography has driven significant advancements in semiconductor manufacturing, enabling the transition from 7 nm nodes to the current 3 nm generation. This progress has been accompanied by increased complexity and cost due to the need for multi-patterning processes. To address these challenges, single-print capability using high NA EUV scanners has become a focal point for the industry. However, achieving this goal requires overcoming both stochastic defects and traditional defect types that impact pattern accuracy and yield.

CARs are prone to scum and bridging defects caused by polymer aggregation and incomplete resist clearance. Filtration strategies play a key role in mitigating these issues by improving polymer dispersity index (PDI) and removing defect-causing contaminants.

This study investigates two surface-modified ultra-high purity polyethylene (UPE) membranes, Functionalized UPE A and Functionalized UPE B, tailored for EUV Negative-Tone Development (NTD) CARs. By comparing their filtration performance under identical conditions, the research explores their impact on polymer retention, PDI improvement, and defectivity. Through detailed experimental analysis, we aim to provide actionable insights into optimizing EUV lithography processes by addressing both stochastic and traditional defect sources.

## EXPERIMENTAL

### Polymer Retention Test

We prepared two types of surface-modified UPE membranes, designated as Functionalized UPE A and Functionalized UPE B, which utilized different UPE substrates but shared the same functional group. Filtration performance was assessed using an EUV NTD CAR co-polymer from Fujifilm composed of unit A and unit B components (as shown in Figure 1). For the circulation test, 300 mL of a co-polymer solution was filtered multiple turnovers using a polymer retention test stand (Figure 2). Following circulation, the filtered solution was collected for metrological analysis. The solution was analyzed using UV-Vis spectroscopy (to determine the co-polymer adsorption rate), GPC (to evaluate molecular weight), and H-NMR (to identify unit composition).

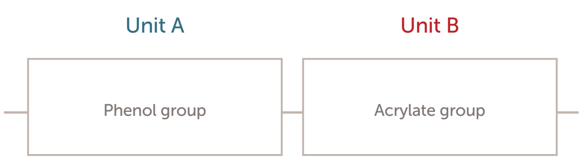


*Figure 1. Schematic molecular components of typical EUV CAR polymers.*

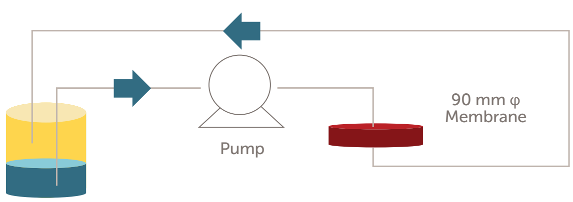


*Figure 2. Polymer retention test stand.*

### After Etched Inspections (AEI) of Bridge Defects

Functionalized UPE A and UPE B were evaluated separately to ensure an apples-to-apples comparison under identical experimental conditions. The photoresist material was spin-coated onto wafers using the stack shown in Figure 3 to create an inspection vehicle for defectivity studies. The exposure process was performed with an ASML NXE3400 full-field EUV scanner (0.33 NA) at a 44 nm pitch size. Bridge defects on each wafer were subsequently reviewed using the KLA2935 system and classified with the eDR7380 defect review tool.

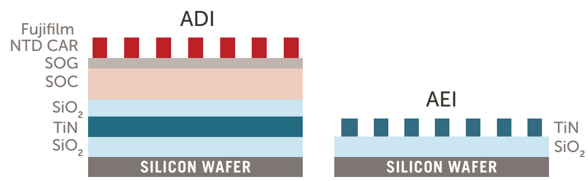


*Figure 3. Inspection layer stack of AEI test vehicle.*

## RESULTS AND DISCUSSION

### Filtration Performance of Polymer Retention Test

As designed, high molecular weight polymer adsorption was higher in Functionalized UPE B than Functionalized UPE A. Functionalized UPE B improved the PDI of NTD resist polymer. On the other hand, Unit A (Phenol group) rich polymer was more adsorbed by Functionalized UPE A. (Table 1)

| | | MOLECULAR WEIGHT GPC | | FILTRATION SOLUTION UNIT RATIO (UNIT A/UNIT B) NMR UNIT A |
|---|---|---|---|---|
| SAMPLE NAME | ADSORPTION UV-VIS | ΔMW | ΔPDI | |
| Feed | – | – | – | 1 |
| Functionalized UPE A after filtration | 37% | -1500 | -0.04 | 0.78 |
| Functionalized UPE B after filtration | 39% | -1600 | 0.10 | 0.91 |

*Table 1. Comparison of polymer retention performance between Functionalized UPE A and B.*

### After Etched Inspections (AEI) of Bridge Defects

The total number of defects was higher with Functionalized UPE B (Figure 4 and 5). As shown in Table 1, although the PDI of the polymer was improved, the defect count increased with the use of Functionalized UPE B. Since stochastic defects account for the majority of defectivity, Functionalized UPE B would theoretically offer more significant benefits than Functionalized UPE A. However, if this is not the case here, the results suggest that traditional defect types still dominate the defectivity budget. Stochastic challenges are inherently probabilistic. Improving the PDI enhances polymer homogeneity, promoting more uniform interactions between incident photons and polymers, thereby suppressing stochastic phenomena. Thus, the results show that single bridges and multiple bridges primarily originate from traditional defect types, suggesting that phenol-rich copolymers are significant sources of these defects. While further studies on bridge defects will provide deeper insights into the underlying mechanisms, this study concludes that targeting the phenol component in the NTD polymer is an effective strategy for controlling bridge defectivity.

P44 L/S-Defect EUV NTD Resist After Filtration

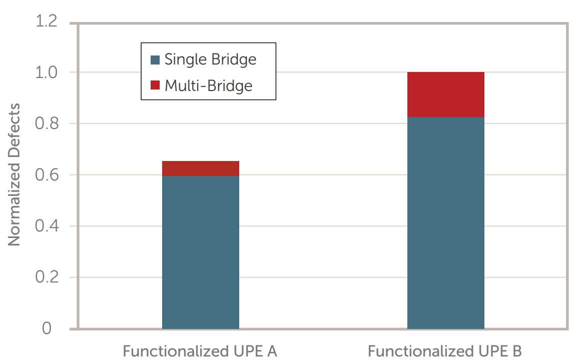


*Figure 4. A comparative data of bridge defectivity.*

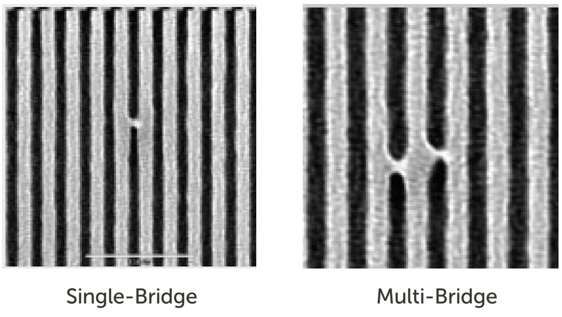


*Figure 5. Classification of the defect mode.*

## CONCLUSION

This study highlights the critical role of filtration strategies in the performance of EUV CARs. Effective filtration is essential for reducing defects that compromise pattern accuracy, especially in EUV lithography, where sub-nanometer precision is imperative. Unfiltered contaminants can significantly impact resist properties, underscoring the need for filtration techniques tailored to the unique demands of EUV lithography.

The results demonstrated Functionalized UPE B effectively removed high-molecular-weight components from the NTD resist polymer, achieving the targeted improvement in polymer PDI. However, despite this improvement, the NTD resist filtered through Functionalized UPE B exhibited a higher defect density compared to Functionalized UPE A.

This study concludes that, in addition to removing high-molecular-weight polymers to address stochastic defects, it is equally crucial to target phenol-rich polymers, which contribute to traditional defect types in EUV resist materials. Addressing both types of defect sources is key to optimizing filtration strategies and enhancing the overall performance of EUV lithography processes.

## ACKNOWLEDGEMENTS

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