Ultra-Clean Nylon Filtration for EUV Underlayer Defect Mitigation at the N2 Node

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ABSTRACT

Extreme Ultraviolet (EUV) lithography requires stringent defect control as device scaling and GAA architectures advance toward the N2 node. EUV resists inherently face trade-offs among resolution, LWR, and sensitivity, and the use of thinner films increases susceptibility to profile distortion and edge defects. Supplemental EUV underlayer (UL) films help mitigate these effects, but UL processing also demands robust filtration to prevent particle-induced defects. In this study, we evaluate EUV resist process trade-offs and introduce a structurally optimized Nylon membrane designed to enhance UL filtration performance. By tuning membrane microstructure, we achieved higher particle capture efficiency while maintaining industry-leading cleanliness. Experimental results under UL-relevant conditions show significant defect reduction, demonstrating that advanced membrane design is essential for sustaining yield in next-generation EUV patterning.

INTRODUCTION

EUV lithography continues to push device scaling, exposing limitations in resist performance and process integration. A key challenge arises from the inherent trade-off among resolution, line-width roughness (LWR), and sensitivity, which becomes more severe as feature sizes shrink. The need for thinner resist films to avoid pattern collapse reduces pattern transfer margin and increases susceptibility to edge placement errors. In addition, substrate interactions and thin-film confinement effects can distort resist profiles, leading to bending, footing, or undercutting during development. These phenomena are further intensified by the high absorption and photon energy of EUV radiation, as well as the intrinsic constraints of chemically amplified resists (CARs).

While EUV processes do not require anti-reflective coatings, the integration of optimized underlayer (UL) materials has become essential for improving pattern verticality, suppressing resist deformation, and maintaining sensitivity. However, UL processing introduces its own complexity: even sub-micron particles introduced upstream can generate printing defects, making filtration performance a critical and often overlooked component of process stability. This creates a growing need for filtration media that combine exceptional cleanliness with microstructural efficiency tailored for EUV UL applications.

OUR APPROACH

To address the challenges of membrane cleanliness and structural efficiency, we propose two complementary strategies:

Strategy 1: Base Nylon Cleanliness Improvement

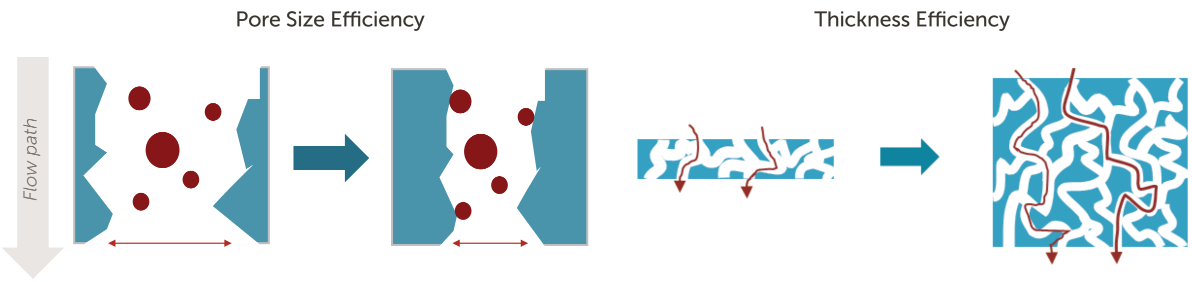
A low-metal, low-organic nylon base membrane is developed to minimize extractables and improve overall cleanliness.

Strategy 2: Membrane Structural Optimization

This strategy enhances membrane performance through two key design principles:

Pore Size Efficiency: Increasing the probability of particle-membrane surface interactions by reducing pore size, thereby narrowing the distance between particles and the membrane surface (a).

Thickness Efficiency: Improving particle retention and chemical interaction by optimizing membrane thickness to increase residence time within the membrane (b).



Structural optimization through (a) pore size and (b) thickness efficiency

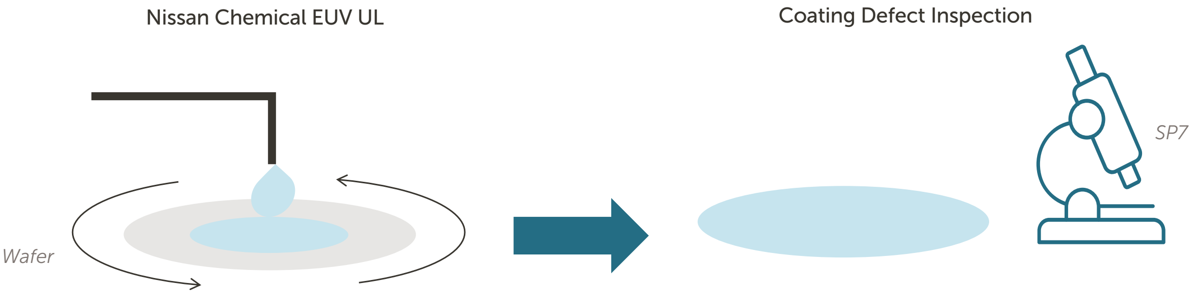
EXPERIMENTAL

Cleanliness Test: PGME/PGMEA extraction

A 10-inch cartridge filter was soaked in PGME/PGMEA solvent for 24 hours. The extracted solution was analyzed by ICP-MS (Inductively Coupled Plasma Mass Spectrometry) for metal extractables and NVR (Non-Volatile Residue) analysis for organic extractables.

Defect Inspection with EUV UL

Nissan Chemical EUV underlayer (UL) was spin-coated on wafers to achieve a thin film, and coating defects were measured using the Surfscan SP7 tool, counting particles ≥24 nm as defects.

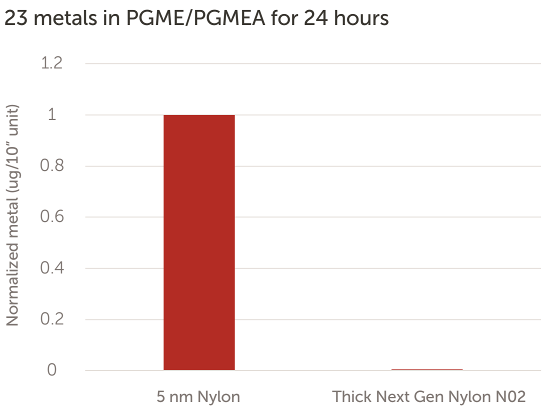


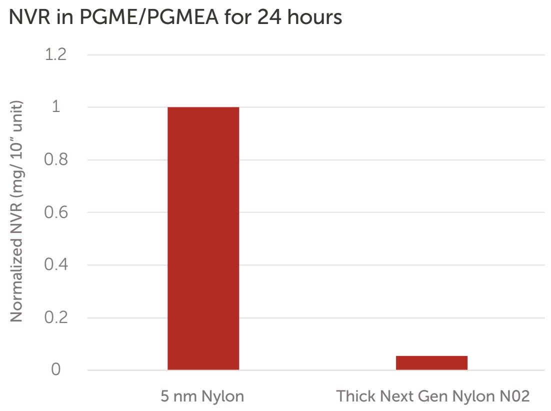
EUV Underlayer coating on wafer and Surfscan SP7 defect inspection

RESULTS AND DISCUSSION

Cleanliness Test: PGME/PGMEA extraction

The 24-hour cleanliness test demonstrated a significant reduction in both metal contaminants and non-volatile residues (NVR) when using the next-generation thick nylon (N02). Compared with conventional 5 nm nylon, metal extractables were reduced by more than 90%, and NVR levels were substantially lowered, indicating superior material purity and suitability for advanced lithography processes.

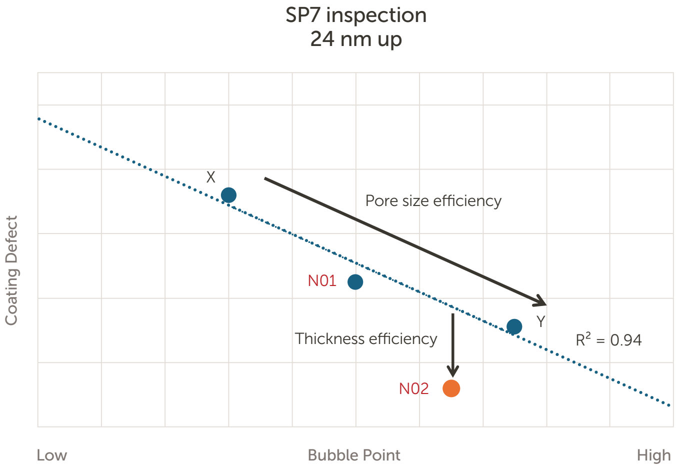




Defect Inspection with EUV UL

Defect inspection was conducted to evaluate the impact of membrane properties on coating quality using EUV underlayer materials provided by Nissan Chemical. The results showed that reducing membrane pore size significantly decreased defect counts, confirming that finer filtration more effectively removes particles responsible for coating defects. In addition, increasing membrane thickness provided further defect reduction beyond pore size effect, indicating that filtration depth contributes to particle retention and enhances coating performance. Correlation analysis revealed a strong negative relationship ($R^2 = 0.94$) between normalized membrane bubble point (BP) and defect counts, where higher BP – associated with smaller pores and greater membrane thickness – corresponded to fewer defects. Notably, the sample with increased membrane thickness exhibited the lowest defect count despite having a BP lower than the maximum value. This finding demonstrates that membrane thickness provides an additive benefit beyond pore size optimization.

Sample name	Thickness
X	Thin
N01	Thin
Y	Thin
Thick Next Gen Nylon N02	Thick



Correlation between normalized BP and coating defect counts measured by Surfscan SP7 (particles ≥24 nm considered as defects).

CONCLUSION

This study demonstrated that optimizing membrane properties can significantly improve coating quality for EUV underlayer applications. Reducing pore size effectively minimized particle-induced defects, while increasing membrane thickness provided an additional performance gain beyond what can be achieved through pore-size optimization alone. A strong negative correlation between membrane bubble point and defect counts confirmed the critical roles of fine filtration and depth retention. These findings suggest that a combined approach – optimizing both pore size and membrane thickness – offers a robust solution for defect control in advanced lithography processes. Future work should focus on balancing filtration performance with process compatibility to enable practical implementation into high-volume manufacturing.

ACKNOWLEDGEMENT

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