

# Point-of-Use Filtration Strategy for Negative Tone Developer in Extended Immersion and Extreme Ultraviolet (EUV) Lithography

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## INTRODUCTION

Negative tone development (NTD) has dramatically gained popularity in 193 nm dry and immersion lithography, due to superior imaging performance.

Several comparative research works between positive tone development and negative tone development have been carried out for both memory and logic devices and have been showing the superiority of NTD in terms of imaging quality.<sup>1,2,3</sup>

The introduction of NTD, appealing for extending 193 nm lithography capability, is becoming a strong requirement for extreme ultraviolet (EUV) lithography.

Popular negative tone developers are organic solvents such as n-butyl acetate (n-BA), aliphatic ketones, or high-density alcohols such as methyl isobutyl carbinol (MIBC).

Their leaching behavior on common polymeric membranes calls for improvements on traditional point-of-use (POU) filtration strategy.

In this work, we presented a comparative study between ultra-high molecular weight polyethylene (UPE) and polytetrafluoroethylene (PTFE) POU filtration. Preliminary results correlate with the occurrence or the mitigation of micro-bridges in a 45 nm dense line pattern created through immersion lithography as a function of POU membrane.

This study is part of a more comprehensive investigation about NTD and its interaction with synthetic polymeric membranes.

## EXPERIMENTAL

### Equipment:

- Organic extractables were measured with a GC-MS from Agilent®
- Metal extractables were analyzed by an ICP-MS from Agilent
- Lithography processing was performed using an ASML® NXT 1950i with 1.35NA and a SOKUDO® DUO track coat-develop system, equipped with an Entegris dual stage pump

**Material:** A negative tone photoresist was coated on a bottom-anti-reflective coat (BARC), and developed with an n-BA based material

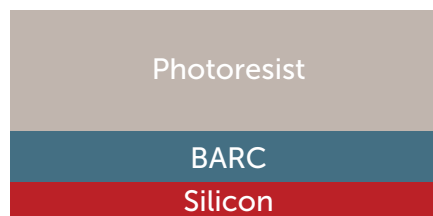


Figure 1. Material stack

**Point-of-Use-Filtration:** A 5 nm ultra molecular weight polyethylene (UPE) and a 10 nm polytetrafluoroethylene (PTFE) were compared

**Metrology:** Defects on a 45 nm line/100 nm pitch (L45P100) pattern were measured on the KLA-Tencor® 2835 and reviewed on KLA-Tencor eDR-7100

## RESULTS

### Organic and Metal Extractable

A 5 nm UPE and 10 nm PTFE membrane were soaked in n-BA for one and seven days to compare organic and metal extractable levels. The organic extractable of 10 nm PTFE detected by GC-MS is significantly lower than what was measured for 5 nm UPE. There is no significant difference in organic extractables as a function of the soaking time. The metal extractables in n-BA are extremely low for both membranes, almost at the detection limit (0.01 ppb).

#### Organic Extractables in n-BA

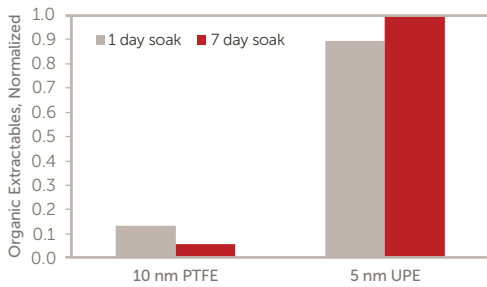


Figure 2. Organic extractable comparison between UPE and PTFE

### Comparative Pattern Defectivity

The following defect modes were investigated (Figure 3):

- Embedded particle
- Micro-bridge
- Protrusion
- Line slimming
- Fall on particle
- Residue

A mask with solely L45P100 patterns and full field exposure was used for the defectivity study. Patterned wafers were measured on the KLA-Tencor 2835 and defects were reviewed with the KLA-Tencor eDR-7100 and classified. Data were collected over a time frame of several months; a normalized value of each defect mode was reported, with the highest defect count taken as reference (i.e., count of micro-bridges on old UPE).

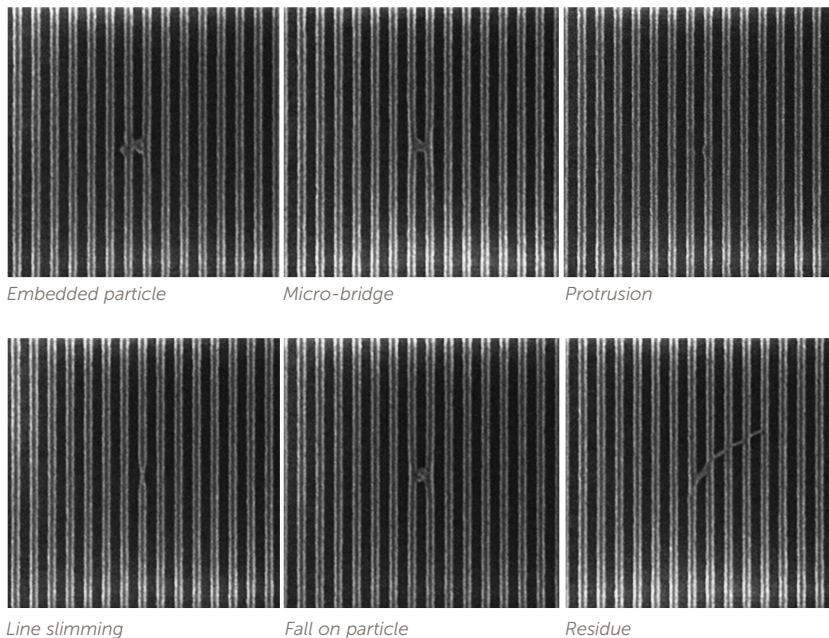


Figure 3. Scanning Electron Microscopy (SEM) images of investigated defect modes

### Comparative Pattern Defectivity, Fresh and Old UPE

In Figure 4 we show the comparative defect data collected on a L45P100 patterned wafer developed with n-BA, when UPE filters are installed. We compared the performance at the beginning and at the end of the filter lifetime. Some defect modes are clearly affected by the age of filter, in particular the number of micro-bridges, embedded particles dramatically increases along with the utilization.

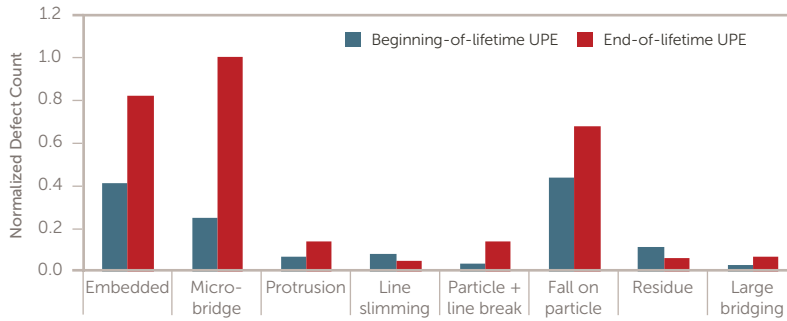


Figure 4. Comparative pattern defectivity, fresh vs. old UPE

### Comparative Pattern Defectivity, Fresh PTFE vs. Fresh UPE

In Figure 5 we show the comparative defect data between UPE and PTFE at the beginning of their lifetime. Data are collected on L45P100 patterned wafers developed with n-BA. Embedded particles, micro-bridges, and protrusions are greatly mitigated when PTFE is used.

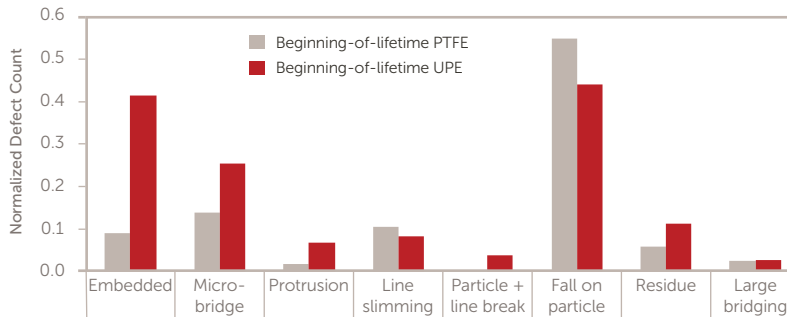


Figure 5. Comparative pattern defectivity, fresh PTFE vs. fresh UPE

## CONCLUSIONS AND OUTLOOK

Data presented in this study are part of a more comprehensive study aimed at gaining a thorough knowledge of point-of-use filtration for negative tone developer materials, such as n-butyl acetate (n-BA), aliphatic ketones, or high-density alcohols such as methyl isobutyl carbinol (MIBC).

In the case of n-BA based developer, an increase of micro-bridges, protrusions, and embedded particles can be observed with the utilization of UPE along filter lifetime, potentially due to membrane degradation and oligomer leaching. This phenomena calls for an improved POU filtration strategy.

Initial comparative data on patterned wafers shows that PTFE brings about a relevant defectivity reduction when compared to UPE at the beginning of the filter lifetime. The study of PTFE behavior at the end of the filter lifetime is currently under investigation.

While UPE based filtration may be sufficient for 28 nm and 20 nm technology nodes, based on the encouraging results for sub 20 nm technology nodes a new generation of PTFE products should be considered and are currently under development.

## REFERENCES

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