Reduced Defectivity Rates Using Oktolex™ Membrane Technology in Photochemical Filtration Applications

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In July 2017, Entegris launched Oktolex™ membrane technology to improve yield in ArF, KrF, and EUV lithography for Logic, DRAM, and 3D NAND Devices. Each Oktolex membrane is tailored to target the specific defect-causing contaminants of each unique photoresist or photochemical.

Specific "killer-defects", such as micro-line-bridges are one of the key challenges in photolithography's advanced applications, such as multi-pattern. They generate from several sources and are very difficult to eliminate. Point-of-use filtration (POU) plays a crucial role on the mitigation, or elimination, of such defects.

The goal of this study is to provide a comprehensive assessment of Oktolex technology compared to other traditional photochemical membranes. Defectivity transferred in a 45 nm line 55 nm space (45L/55S) pattern, created through 193 nm immersion (193i) lithography with a positive tone chemically amplified resist (PT-CAR), has been evaluated on organic underlayer (UL) coated wafers. Lithography performance, such as critical dimensions (CD), line width roughness (LWR), and focus energy matrix (FEM) are also assessed.

SIEVING VS. NONSIEVING PARTICLE REMOVAL

In sieving (size exclusion) removal, particles too large to pass though the pore structure of the membrane are captured either on the surface or in smaller passages inside of the structure. The smaller the pore size, the better the sieving efficiency will be.

Nonsieving removal is related to the adsorption of particles to the membrane surface and it is independent on the particle or pore size. A variety of intermolecular forces governs the interaction between the particle in solution and membrane surface such as electrostatic forces, Dipole forces, London forces, etc. As long as the particle can approach the membrane surface and experience a net attractive force, it will be captured.

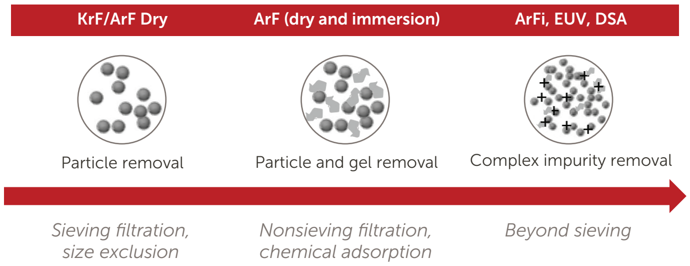

Figure 1. Illustration of different defect retention mechanisms.

The Oktolex membrane technology is an effective tool to improve membrane wetting properties, filtration efficiency, and selectivity. The tailored membrane technology enables precise contaminant targeting without negative impact on the chemical composition.

EXPERIMENTAL

Equipment: Lithography work was run in an ASML TWINSCAN™ NXT: 1970i with 1.35NA and a TEL LITHIUS Pro™ Zi track coat-develop system.

Material: The JSR PT-CAR AIM5484 coated on Brewer Science ARC®-29SR was used for patterned defect study.

Mask: A mask with solely L45P100 patterns and full field exposure was used for defectivity study.

Metrology: Pattern wafers were inspected on KLA 2925. Defects were reviewed and classified on KLA eDR-7110. CD-SEM measurements were carried out on a Hitachi CG-4000 system.

Point-of-use-filtration: Oktolex and native ultra molecular weight polyethylene (UPE) were compared.

Defect library: Defects were classified as in the defect library reported on Figure 2.

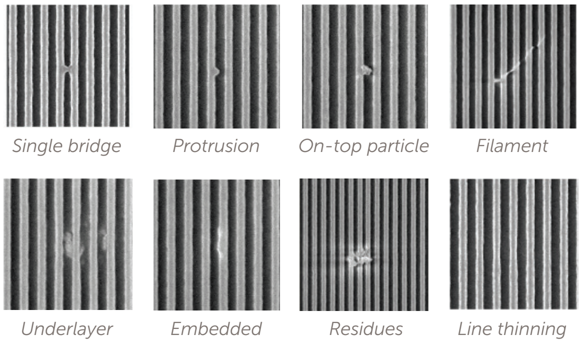

Figure 2. Defect library used in this work.

RESULTS

Defectivity

A typical defect pareto is shown in Figure 3. Each bar represents the normalized average of three wafers. For an easier comparison, data are normalized on aged resist results. The main defectivity mode related to resist filtration are microbridges and residues. Few filaments were also observed. On-top particles are mainly modulated by developer and rinse filtration, as reported elsewhere.[1] Defects from UL are not modulated by resist filtration and are not objects of this study. As we focus this research on resist filtration, both on-top and UL defects are removed from Figure 3 for clarity.

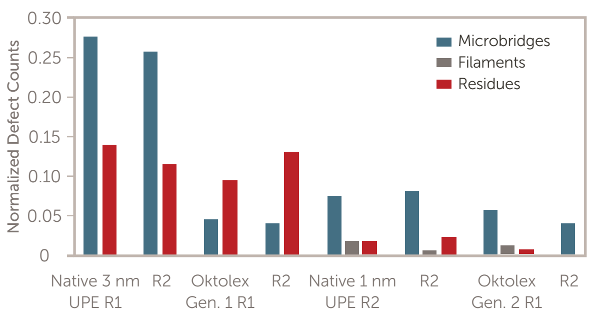

Figure 3. Normalized defect pareto.

While residues are clearly triggered by membrane pore size, microbridges are not. The normalized count of single bridge is reported in Figure 4. In the case of native membranes, the amount of microbridges is triggered by pore size shrinking. However, the Oktolex Gen. 2 filter performs similarly to native and Oktolex Gen. 1.

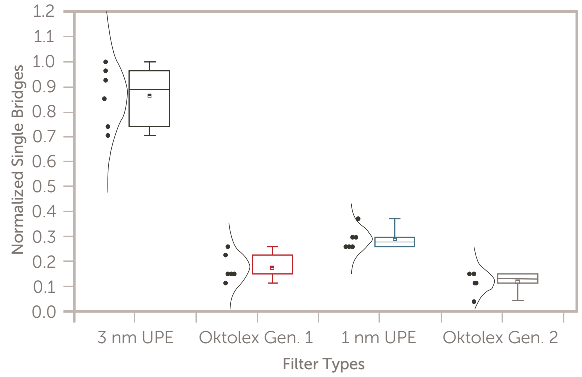

Figure 4. Normalized single bridge count/wafer, arranged by experimental group.

CD, LWR, and FEM measurement

This study was complemented with CD, LWR, and FEM measurements. CD and LWR results are shown in Figure 5 (a, b). Each point represent the average of 72 measurement locations/wafer. Apart a relatively broader distribution observed on 3 nm UPE, no significant shift between experimental groups has been measured.

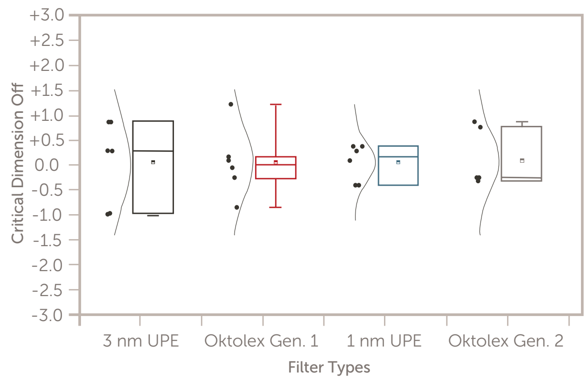

Figure 5a. CD offset calculated on 72 measurement locations/wafer. 3 nm UPE is taken as reference.

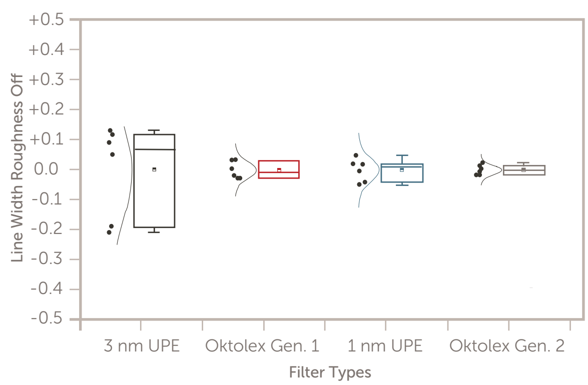

Figure 5b. LWR offset calculated on 72 measurement locations/wafer. 3 nm UPE is taken as reference.

FEM wafer maps are shown Figure 6, measured on 3 nm native UPE and Oktolex membrane. No changes have been observed between the two groups.

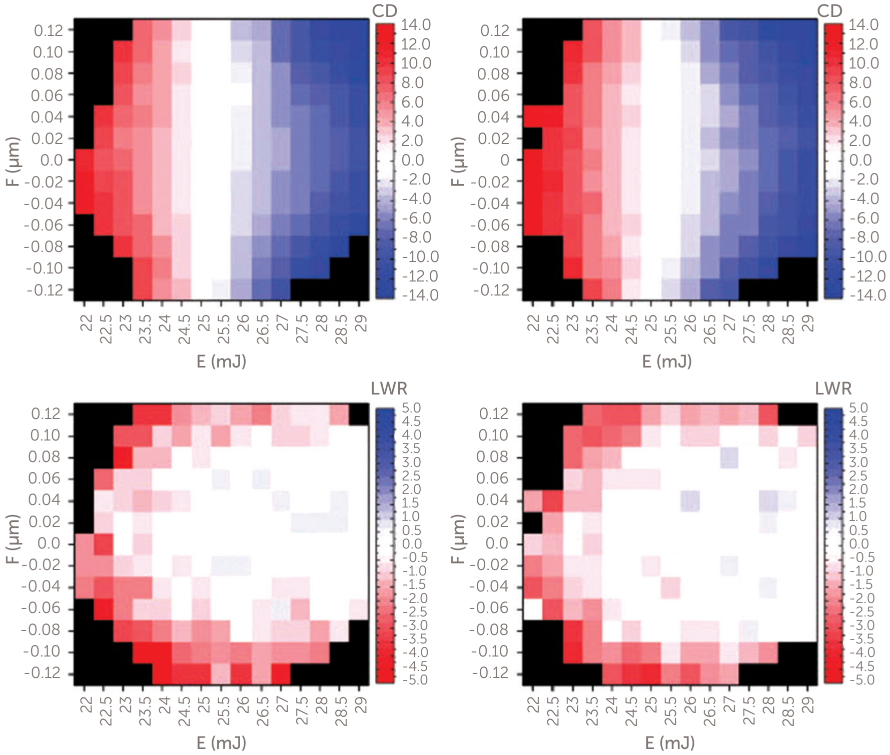

Figure 6. FEM wafers. The offset value for CD and LWR in the case of native (left) and Oktolex (right) are reported.

CONCLUSIONS

Oktolex membrane technology represents a powerful tool which enhances defect retention. In this work, we demonstrated the superior performance of Oktolex, the best membrane technology in immersion lithography. Even though Gen. 2 shows the best performance, an improved retention was achieved with Gen. 1. This allows a strong filter performance enhancement without necessarily shrinking membrane's pore size. It has been also proven that Oktolex membrane technology does not alter CDs, LWR, and provides similar FEM, suggesting that no unwanted retention of resist components takes place.

REFERENCE

[1] Kamei, Y.; Shiozawa, T.; Kawakami, S.; Foubert, P.; De Simone, D.; D'Urzo, L.; Bayana, H.; Nafus, K., *"Track process optimization for UV HVM,"* EUVL Symposium, Hiroshima, Japan (2016).

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