ZERO DEFECTS
Entegris Newsletter

July 2015

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Entegris Reaches Milestones at its i2M Center for Advanced Materials Science

June 18, 2015 Entegris announced the first shipment of production quantities of UPE (ultra-high molecular weight polyethylene) membrane from its i2M Center for Advanced Materials Science in Bedford, Massachusetts. UPE membrane is a core material used in high-purity filtration solutions for semiconductor and life sciences applications.

"In the first half of 2015, we reached multiple milestones in our expansion plan to provide new membrane technologies to solve the yield challenges our customers face to manufacture semiconductor devices," said Entegris Vice President of the Liquid Microcontamination Control business unit, Clint Haris. *"Several key customers have completed their qualification process and are now receiving i2M-based products for use in current applications, as well as for their developmental programs. We're excited to take this step forward as we continue to commercialize other UPE-based technologies in 2015."*

The 80,000 sq. ft. facility opened in June 2014 as a $60 million investment intended to create one of the most advanced facilities of its kind. The investment included an expansion of membrane manufacturing capacity, implementation of advanced process controls and upgraded quality monitoring systems. In addition, the i2M Center is also used to develop and manufacture gas filtration and specialty coatings products.

▸ For more details on the i2M Center, just click on this link.

Entegris @ SEMICON® Europa

SEMICON® Europa will take place this year in Dresden on October 6-8.

Entegris will co-exhibit with the German Silicon Saxony cluster. You are welcome to join us at booth 2046.

In preview, two Entegris presentations are planned in the TechARENA 2 for MEMS and the Semiconductor Technology Conference:

▸ Contactless Horizontal Wafer Shipper Advancements

▸ FOUP Contamination Control Solutions for Advanced Technology Nodes

Refer to our Facebook event page for detailed information of our participation.

Looking forward to seeing you!

Visit Entegris
at Booth # 2046
6-8 October 2015

Entegris
creating a material advantage

Process Stability

InVue™ CR288 Concentration Monitor Application Note for BEOL Semiconductor Processing

By Entegris, Inc.

Semiconductor manufacturers and OEMs demand tighter process control solutions that increase wafer throughput, reduce chemical costs and prevent wafer scrap. Each requires a precise concentration monitor for back-end-of-line (BEOL) processing chemicals, such as oxide/metal etchants, post-CMP cleaners, photoresist strippers and surface preparation solutions. The right concentration monitor must exceed current technology, yet be cost effective to implement.

Entegris offers InVue CR288, a highly accurate, in-line, real-time concentration monitor that meets these stringent requirements for improved BEOL process efficiency by allowing users to:

- Precisely monitor and control the chemical dilution and blending
- Increase chemical bath lifetime, which reduces chemical usage and disposal costs
- Detect chemical excursions, such as mechanical component failures
- Collect real-time data for optimizing a process or tool, such as the actual homogenization within a chemical blend

The CR288's index of refraction (IoR) technology uniquely measures concentration based on the fluid's IoR. These real-time, in-situ concentration measurements maintain a high degree of accuracy, precision and resolution. The ability to calibrate the CR288 in the field eliminates the need to have proprietary chemistry sent to the factory, and without consumable parts, little or no maintenance is necessary. The CR288 offers a wide dynamic range that is insensitive to bubbles and color, and guarantees an immediate return of investment.

Figure 1. InVue CR288 liquid chemical concentration monitor shown with two flow cells.

Typical Installation

The illustration below shows a typical blending application. In general, the concentrated chemical is diluted using deionized water (DIW) before it is either placed directly on the wafer, or it is diverted to a holding tank where the chemistry is being recirculated in process.

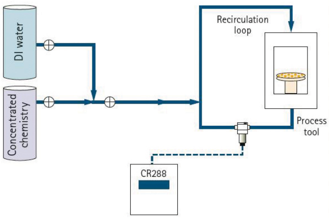


Figure 2. Typical blending application.

Case Studies

HF Dilutions

This graph compares the CR288's connectivity capability to measure concentration of HF dilutions from 1:100 to 1:1000. The conductivity signal saturates at approximately 5000 ppm. CR288 can measure the entire range (0 – 49 wt%), as well as the signal with more resolution, and has the potential for measuring dilutions lower than 1:1000.

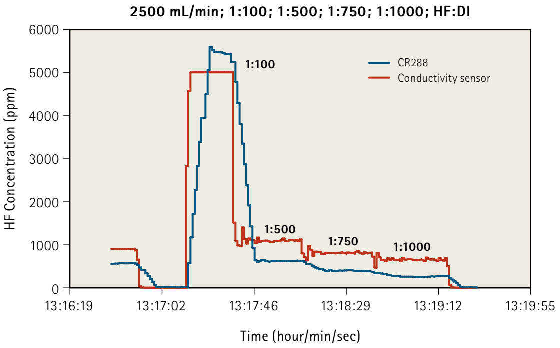


Figure 3. HF dilutions.

Photoresist Strip Dilutions

The CR288 offers continuous precision while conductivity cannot correctly measure photoresist strip in solution because photoresist strip is often a non-conductive chemical.

The plot in Figure 4 shows the CR288 IoR compared to a conductivity sensor output, both plotted as a function of time. The x-axis is the percentage of water added to the photoresist strip.

> **NOTE: The CR288 measures photoresist strip correctly throughout the process range.**

In contrast, the conductivity sensor is completely insensitive to the changes in concentration. It is only once the water concentration reaches a sufficient level that the conductivity sensor can measure anything at all.

The CR288 inherently outperforms conductivity in this critical metric.

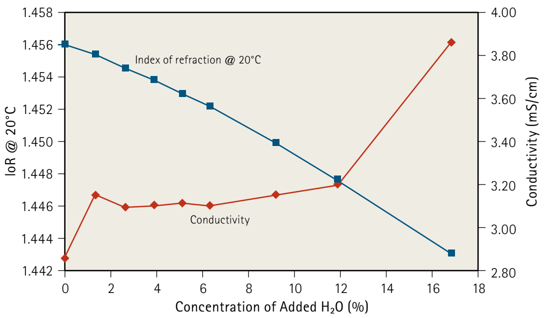


Figure 4. CR288 index of refraction vs. conductivity.

(continued)

Process Stability

IoR Precision of Measurement for Post-CMP Cleaner, ESC-784

In this study the CR288 kit was installed at the point-of-use (POU) on a post-CMP cleaning tool that dilutes the post-CMP cleaner at POU using two flowmeters. One sensor head was installed in each cleaning tank. The results show that the CR288 precisely monitored the POU dilution of the post-CMP cleaner in real time to at least the resolution of the flowmeters (0.1 wt%) with measurement resolution for even greater dilutions.

NOTE: Incoming chemical is highly concentrated and diluted to the target concentration of 2.78 wt%.

The CR288 monitors the POU blend to ensure that the target concentration of 2.78 wt% is met prior to wafer cleaning.

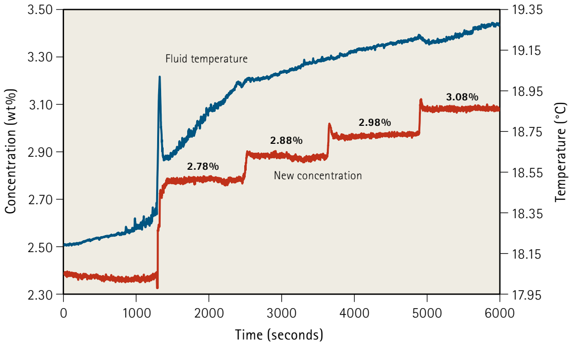
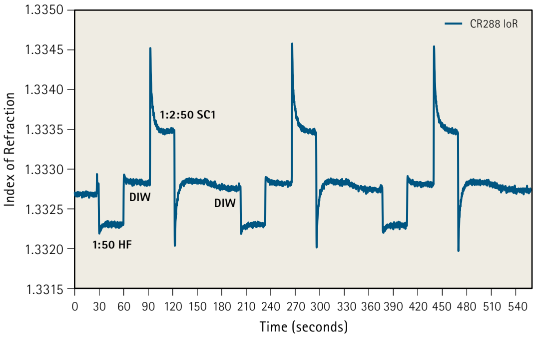


Figure 5. CR288 measurements of ESC-784 post-CMP cleaning chemistry.

CR288 Millisecond Measurement in HF/SC1 in Single Wafer Tool

While the OEM used the CR288 in an FEOL environment, the example applies equally to BEOL. The monitor shows three wafers being processed. A single flow cell was installed at the POU and measured premixed concentrations of distilled water, dilute HF and SC1. The data demonstrate that:

- Using a single sensor, the CR288 can monitor the chemical that was dispensed at the POU as it switches between RCA cleaning chemistries.
- The CR288's nearly instantaneous measurement allows users to measure the chemistry on each wafer. The NIR measurement takes two minutes to achieve the required resolution while production continues.
- Conductivity could only be tuned for one of the chemicals, not all three.



Note: Fluid Temperature Compensation (Tcc) optimized for both HF and SC1. Recommend for tool manufacturer to allow Tool PLC to "swap" individual Tcc values for the two blends.

Figure 6. Three wafer cycles of HF, DI water and SC1 dispense: 30-second chemical dispense; 0.1 sec CR288 response time.

Entegris InVue Sensing and Control Products Deliver Greater Performance with Advanced Sensor Technology

By Lisa Pilati-Warner, Product Marketing Manager - Entegris, Inc.

With decreasing line widths and tighter process tolerances, semiconductor manufacturers require more precise control of their chemical mixing. To respond to these increasing demands, Entegris has partnered in the development of an **advanced capacitive ceramic sensor** for use in InVue Differential Pressure Technology based products NT, Integrated Flow Controllers and Flowmeters.

Figure 1. New G7 sensor

Features and Benefits

The new G7 sensor offers:

- Higher purity ceramic for improved repeatability and accuracy
- Temperature compensation for greater stability with changes in temperature
- Advanced microprocessor for greater speed of data processing
- More robust connection system for improved long-term reliability
- Embedded filter for humidity effects prevention

All benefits combined result in **tighter process control and in higher yields.**

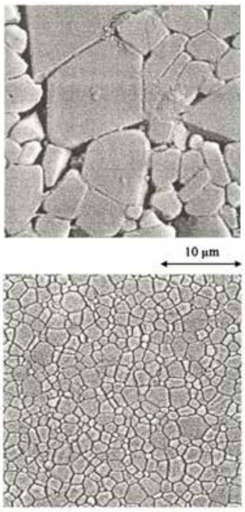


Figure 2. SEM photo of the grain structure of standard sensor ceramic (up) vs. high-purity ceramic (down) used in G7 sensor.

Improved Performance Data

Accuracy and Repeatability

Testing of InVue Integrated Flow Controllers with the current sensor vs. the new G7 sensor demonstrates the higher accuracy and repeatability achieved with the G7 sensor. As a result, Entegris has tightened its accuracy specification to ±1% of Full Scale flow for the full operating range and its repeatability specification to ±0.5%.

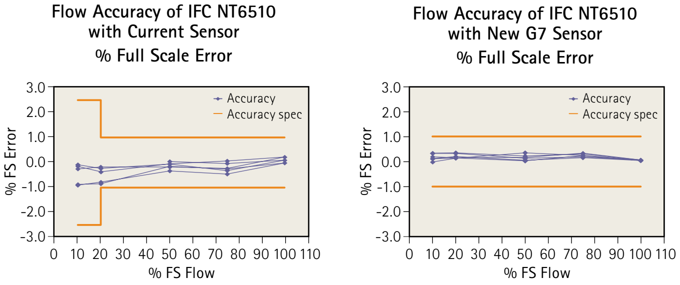


Figure 3. Sensor accuracy test. Current sensor vs. new G7 sensor

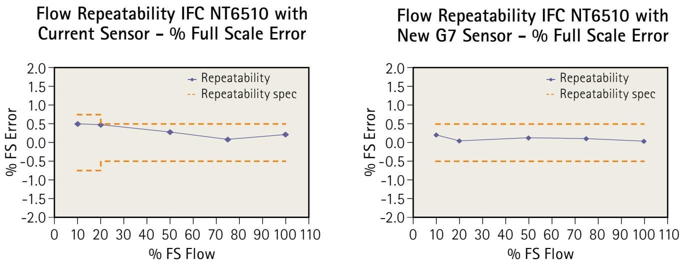


Figure 4. Sensor repeatability: current sensor vs. new G7 sensor.

Sensor Stability

Long term stability testing (110 days) of the new sensor shows a 4x improvement in sensor stability (average sensor drift) and a 10x improvement in unit-to-unit variation.

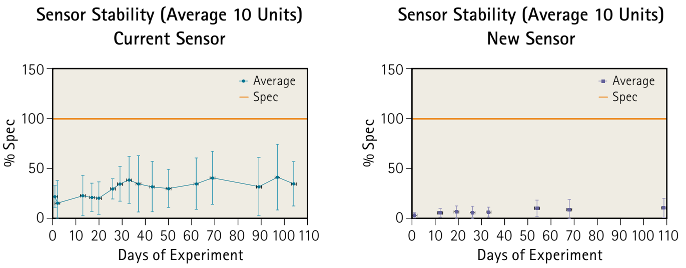


Figure 5. Sensor stability test of 10 units after 110 days. Current sensor vs. new G7 sensor.

A Solution for All Chemistries

In addition to providing increased performance in accuracy, repeatability and stability, **the higher ceramic sensor, when used in combination with the CTFE isolator has proven to be a reliable solution for hydrofluoric acid applications.** This improved compatibility allows Entegris to offer one solution for all chemistries – eliminating the need for a separate product offering for use in HF.

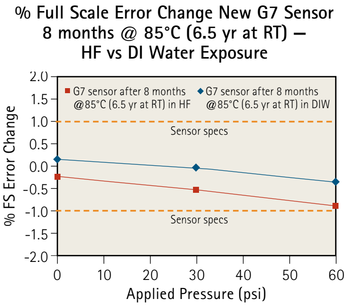


Figure 6. Chemical exposure of G7 sensor to HF and DI water.

Product Release Schedule

Entegris is releasing the NT6510 and NT6520 Integrated Flow Controllers with the new sensor to the market in July, 2015. Later in the year, the Integrated Flow Controllers, NT6500 and NT6501 along with flowmeters, NT4400 and NT4401 with the new sensor, will become available.

A Comprehensive Approach for Micro and Multiple Bridge Mitigation in Immersion Photolithography

By L. D'Urzo – Entegris GmbH; W. Schollaert, X. Buch – JSR Micro N.V.; H. Stokes, Y. Thouroude – Dainippon Screen Deutschland

Efforts to extend 193 nm lithography have introduced multiple patterning solutions to print a single level layer. Due to this increased complexity, defectivity on each layer is becoming very critical. Micro and multiple line bridges are one of the primary challenges in photolithography contributing to this complexity. These defects originate from several root causes and are difficult to eliminate. Point-of-use filtration plays a significant role on the mitigation of such defects. The impact of filtration rate and pressure was previously documented.[1, 2] **In this research, we demonstrate that the combination of membrane and pore size selection, photoresist optimization and hardware optimization can impact micro and multiple bridge mitigation in a 45 nm line/space pattern created through immersion lithography.**

Experimental

This study ran on an immersion cell comprising an ASML® NXT:1950i with 1.35NA and a SOKUDO® DUO coat-track system, equipped with an Entegris two-stage pump. Evaluated filters and coat-track hardware settings for testing are summarized in Table 1.

Resist	Filter	Filtration Rate	Filtration Pressure	Installation
Resist A	10 nm UPE	Low	Low	BKM
		Low	Low	
	3 nm DUO UC	High	High	
	3 nm UPE UC	Low	High	
		High	Low	
	3 nm UPE UC	Low	Low	DRY
	3 nm UPE standard	Low	Low	
Resist B	10 nm UPE	Low	Low	BKM
		Low	Low	
	3 nm DUO UC	High	High	
	3 nm UPE UC	Low	High	
		High	Low	
	3 nm UPE UC	Low	Low	DRY
	3 nm UPE standard	Low	Low	

Table 1. DOE implemented during this evaluation.

Coat	EXP	DEV	Target
Spin on carbon 135 nm Minimum 80% C-content	NA1.35 Annular ill. 0.9/0.7	2.38% TMAH	45 nm L/S
Spin on glass 33 nm Minimum 41% Si-content	Best dose		
Resist 105 nm	Best focus		

Table 2. Litho process conditions for all defect tests .

Defects were measured on the KLA-Tencor® 2835 and reviewed with the KLA-Tencor eDR-7100. Classification for the 500 randomly selected and reviewed defects was based on commonly understood lithography defect types associated with 45 nm dense lines. Line width roughness (LWR) was measured with a Hitachi® S-938 series CD-SEM.

Line Preparation

Chemical supply line preparation was performed according to the SCREEN coat-track team's BKM. A brief summary of the line cleaning is provided in Figure 1. Every filter has been installed by following this procedure, except for the dry experiment, where filters were immediately soaked with photoresist.

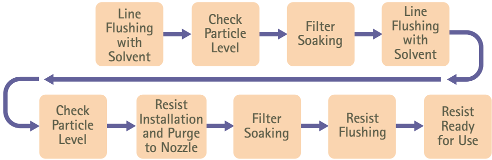


Figure 1. Line clean and filter BKM installation procedure.

Resist

Novel photoresists have been developed by JSR® that show improved defectivity and line width roughness under immersion exposure conditions when no topcoat is applied.

The new resist design to improve defectivity is built around increased hydrophilicity of the resist surface when in contact with standard TMAH developer (Figure 2).[3]

Line width roughness improvement is achieved by improved resist contrast (Figure 3) through the introduction of a new lactone unit in the polymer backbone.[4]

Novel lactone units in the polymer backbone improve litho-performance but could also influence the resist filter interaction once installed on the track. This study is showing the effect of a conventional type lactone (resist A) and a new lactone type (resist B) on defectivity using new designs in POU-filters.

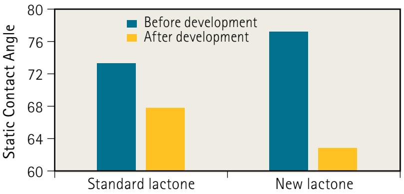


Figure 2. Reduced static contact angle (increased hydrophilicity) after development by new lactone design.

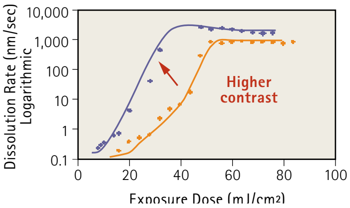


Figure 3. Improved contrast by polymer design.

(continued)

Filters

The filters in Table 3 were tested.

Pore Size (nm)	Membrane	Design	Option
10	UPE	Impact® 2V2	Standard
3	UPE	8G	Standard and Ultra Clean (UC)
3	UPE and Polyamide (DUO)	8G	Ultra Clean (UC)

Table 3. Details of filters used during the experiment.

Ultra Clean Technology (UC)

The ultra clean option has been implemented on all advanced lithography filter families. UC defines a comprehensive approach to filter cleanliness, from raw materials to metrology and final QC. To achieve this, all steps of the product's supply chain or manufacturing are controlled and optimized as explained in Figure 4.

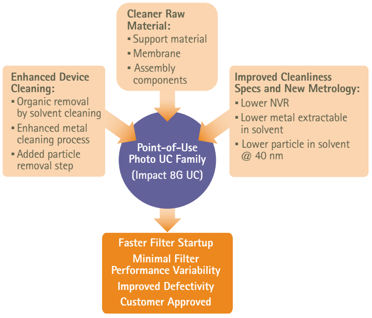


Figure 4. Ultra Clean filtration: production cycle and output.

UC filters allowed us to achieve improved defectivity due to lower particles, metals and organic extractables, associated with a consistently faster start up time. A comparison between standard and ultra clean is provided in Table 4.

	Impact 2V2	8G Standard	8G Ultra Clean	8G Ultra Clean Plus
Targeted technology node	>28 nm	>28 nm	20 – 14 nm	10 nm
Metal (a.u)	1	0.5	0.05	0.01
Organic (a.u.)	1	1	0.13	0.06

Table 4. Metal and organic extractable from standard and ultra clean membranes, expressed in arbitrary units, for different filter generation.

Dual Membrane Technology (DUO)

The dual membrane filter technology enables different retentive mechanisms by the use of two different membranes, in this study ultra-high molecular weight polyethylene (UPE) and polyamide is used.

The retention mechanism of a UPE membrane is based primarily on size exclusion; due to the presence of polar groups in the backbone, polyamide exhibits primarily nonsieving behavior.

Consequently, a dual membrane provides sieving and nonsieving retention that has been proven to be beneficial especially for impurities that are typically not removed by a pure sieving effect, such as soft particle (gels) retention.

On the other hand, the DUO choice has to be carefully evaluated for each resist type to avoid the unwanted retention of polar photoresist components or additives.

Results and Discussion

Defect Library

Defects were classified according to Table 5. Our study mainly focused on line roughness (class 1), single (class 2) and multi bridge (class 3) mitigation.

A scanning electron microscopy (SEM) image of each defect mode is shown in Figure 5.

Code Class	Mode
1	Roughness
2	Single bridge
3	Multi bridge
5	Particles
7	Other
8	Bubbles
10	Substrate
11	Line collapse
12	Residues

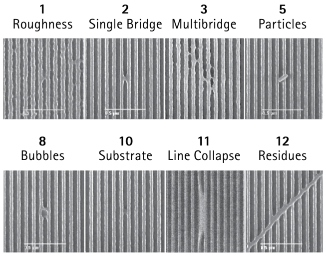


Figure 5. SEM images of each defect mode.

Resist A versus Resist B

Figure 6 shows the aggregate defect performance, reported in arbitrary units, obtained using resist A and B with different membranes. This difference clearly shows that resist is the main contributor for defectivity in our study.

LWR is shown in Table 6; within the same resist type, UPE UC gives lower LWR.

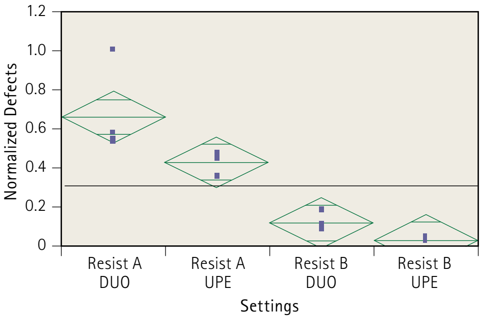


Figure 6. The aggregate defect performance, reported in arbitrary units, obtained using resist A and B with different membranes.

Code Class	3 nm UPE UC	3 nm DUO UC
Resist A	5.8	6.0
Resist B	3.8	4.0

Table 6. LWR data for resist A and B with different membrane.

UPE Membrane Data Set

Figure 7 illustrates the defects obtained with resist A and B using a 3 nm UPE UC at different filtration pressure and rate. The results clearly show the beneficial effect of using resist B and reducing pore size. Single and multiple bridges were all effectively mitigated by using resist B in a wide process window; the best performance is achieved at high-pressure and high-filtration rate.

(continued)

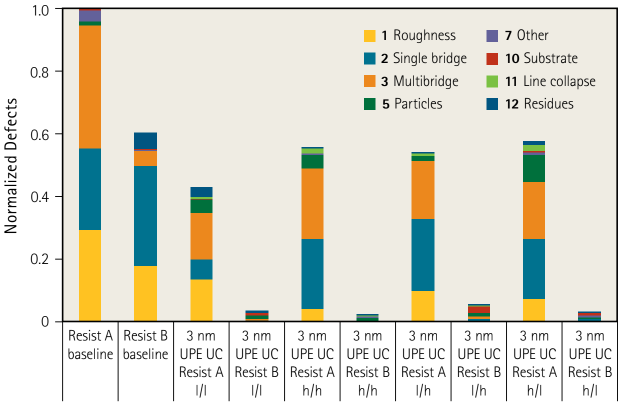


Figure 7. Defects observed with resist A and B on 3 nm UPE UC at different filtration pressure and filtration rate compared with 10 nm UPE baseline.

DUO Membrane Data Set

Figure 8 illustrates significant reduction in roughness, single bridges, and multibridge on resist B. The best condition was achieved at low-pressure and low-filtration rate. Also, with the DUO case resist B shows overall better defectivity results vs. resist A. Finally, resist A appears to be slightly more sensitive to line collapse under our testing conditions.

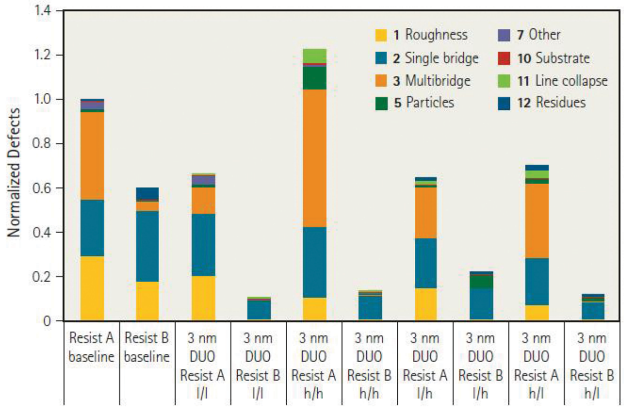


Figure 8. Defects observed with resist A and B on 3 nm DUO UC at different filtration pressure and filtration rate compared with baseline (10 nm UPE).

Ultra Clean Membrane Testing

The performance of 3 nm UPE UC filters was compared with 3 nm standard UPE, both installed dry (Figure 9). Filtration rate and pressure for this experiment are reported on Table 1.

With resist A, the occurrence of multibridges is extremely severe in the case of standard UPE installed dry; with ultra clean membrane technology these defects are consistently mitigated.

Resist B clearly succeeds in the elimination of such multiple bridges. When a standard membrane is used dry, bubbles are observed.

UPE UC used without any solvent priming shows a dramatic reduction of defectivity, particularly micro bridges (class 1 and 8).

This proves that the use of ultra clean technology effectively decreases installation time and simplifies the installation procedure. Optimized UC are under development to reach the performance currently achievable with extended solvent priming.

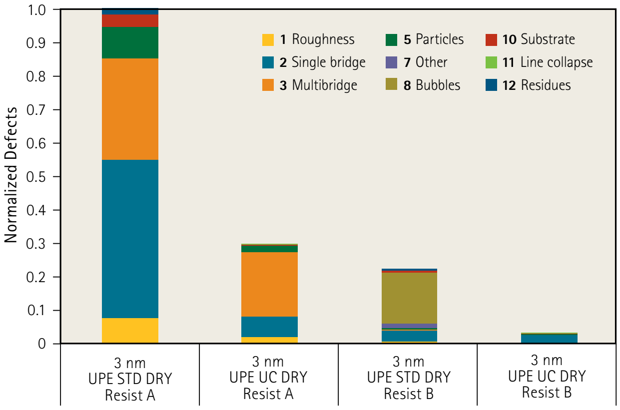


Figure 9. Comparison of 3 nm standard UPE and 3 nm UPE UC filters installed "dry." Data are in arbitrary units with 3 nm UPE STD DRY resist A used as reference.

Conclusions

The main goal of this study is the elimination of killer defects such as bridges and microbridges and the improvement of line roughness. Experimental evidence achieved in this evaluation demonstrates that an effective defectivity reduction is possible by a comprehensive optimization of resist formulation, membrane technology, and photolitho track hardware settings.

Finer pore size filters show and resist has a major impact on overall defect improvement.

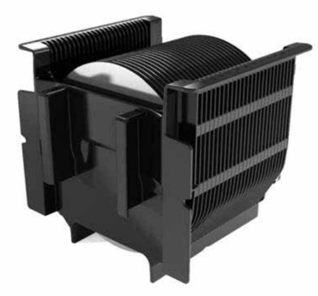
Ultra clean membranes can consistently decrease installation time and cost. Continuous improvement in resist design is necessary to be able to address the increasing requirements of defect reduction from IC manufacturers. It is clear that a detailed investigation is necessary to recommend the best filter and filter setting for a specific resist.

References:

1. J. Braggin et al., "Point-of-use filtration methods to reduce defectivity," SPIE Vol. 7639 (2010).
2. J. Braggin et al., "Analysis of the point-of-use filtration on microbridging defectivity," SPIE Advanced Lithography, February 2009.
3. C. Tang et al., "Non-Topcoat Resist and Defect Reduction," LithoVision 2013.
4. S. Sharma et al., "ArF Photoresist LWR Improvement," LithoVision 2014.

Product Highlight

STAT-PRO® 9000 CNT-Enhanced PEEK Carbon Transport Carrier: Improved Carrier Performance for a Higher Yield



Trends in wafer processing technology have mandated advancements in wafer carrier technology to support today's advanced semiconductor processing facilities.

Entegris, with more than 45 years of experience in material science, has developed STAT-PRO® 9000 Carbon Nanotubes (CNT)-enhanced PEEK Carbon Compound transport carriers with exceptional value in response to semiconductor industry's demand for improved carrier performance at a lower price compared to Stat-Pro 3000 carbon fiber PEEK carriers.

STAT-PRO 9000 offers:

- Superior performance relative to all materials available in the semiconductor market
- Mixed run capabilities
- New carriers run side by side with customers existing carrier population

Material Characteristic, Feature and Benefit

High-mechanical performance	• Superior dimensional stability • Precise, reliable process tool/AMHS interface • Precise and predictable wafer location	• Less tool downtime • Higher yield • Greater throughput
Improved wear performance	• Reduced particle generation	• Higher yield
Improved surface resistivity	• Optimal and consistent SR range	
Extremely low molecular contamination	• Ultra clean material	
Low water absorption	• Reduced pump down time	• Greater fab efficiency • Greater throughput
High thermal capability	• High continuous use temperature (120°C) • High wafer insertion temperature (340°C)	

▸ Integrate Entegris STAT-PRO carriers into your fab operations will significantly contribute to **optimize your fab and yield.**

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