CHEMICAL FILTRATION – DESIGNING FOR OVERALL EQUIPMENT EFFICIENCY

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Abstract

Overall Equipment Efficiency (OEE) is the measure of the portion of time that semiconductor device manufacturing equipment is actually making semiconductors. Maintaining a high number for OEE keeps the cost of semiconductors low, leading to lower cost electronic devices.

As line widths of semiconductor devices continue to shrink, there is a requirement to remove smaller particles from the process fluids. Tighter, or more retentive filters made of polytetrafluoroethylene (PTFE) membrane are used to purify the aggressive acids, bases and oxidizers used in the wet etch and clean process area. PTFE is hydrophobic, requiring IPA prewetting when the filters are used in aqueous-based chemicals. Chemical filters are disposable, requiring the process equipment to be shut down periodically to replace them at the end of their lifetime. The time needed to "wet", or prepare the filters with IPA, water flush, chemical flush and requalify the tool may take several hours; consequently valuable time is lost when wafers are not being processed. In addition, as the PTFE filters become tighter with a more dense membrane structure, there is more dewetting in outgassing chemicals containing hydrogen peroxide. This results in loss of flow in the systems and frequent changeout of filters.

To improve the OEE of the process equipment, the QuickChange® filter was introduced. The QuickChange process includes a modification to the PTFE membrane to make the surface less hydrophobic, which eliminates dewetting in outgassing solutions. Chemical flow rate and particle retention remain high in these outgassing baths, even under severe conditions such as draining the housing during chemical change-outs.

Extractables, particle retention and particle cleanliness of QuickChange filters are nearly identical to other competitive PTFE filters. Another advantage of QuickChange filters is that they are supplied in a prewet package, allowing the filters to be installed more quickly into any aqueous-based process chemical.

This paper will describe the attributes of the QuickChange filters, present the results of extensive field-testing and quantify the potential improvement in Overall Equipment Efficiency.

Introduction

The processes required to manufacture semiconductors use a number of aggressive chemicals (hydrofluoric acid, sulfuric acid, phosphoric acid, hydrogen peroxide, ozone and ammonia) to etch and clean the wafer surface. As the semiconductors become more complex, the spacing between the lines (conductive paths) is continuously reduced. As the line spacing is in the low nanometer scale, the tolerance for particles is extremely low as well. Membrane filters are used to remove particles in the chemicals as delivered to the process equipment and as applied to the wafer's surface.

Filters constructed entirely of PTFE materials have been the workhorse of the microelectronics chemical purification application. These filters have high flow rate, low ionic and organic extractables and can withstand the harsh chemical environments of acids and oxidizers at temperatures greater than 100°C. However, PTFE membranes have some limitations, primarily the result of their hydrophobic nature. Many of the fluids in the process are aqueous-based and do not spontaneously wet the PTFE membrane. As a result, the membrane must be prewet by the user. The prewetting involves IPA preconditioning of the filter, flushing the filter with water and then installing the filter in the process equipment. This prewetting procedure can take several hours and the wafer manufacturing plants are generally not equipped to do the process easily in a clean environment. In addition, PTFE membranes can dewet in outgassing applications that contain hydrogen peroxide type chemistries (SC1, SC2 or piranha type etch) at elevated temperatures. This problem is particularly evident as you move to smaller pore size membranes (<0.1 µm).

The dewetting reduces the lifetime of the filter, requiring that the process equipment be shut down to replace the filter. The long prewetting procedure keeps the equipment shut down longer during each filter replacement. Both frequent filter changeouts and long prewetting procedures reduce the OEE, driving up the cost of semiconductor devices, and in turn the cost of the consumer products using these electronic components.

The 2005 OEE for generic processing equipment was only estimated to be 30% (as shown in Figure 2). In the future, OEE was predicted to continually increase as semiconductor and wafer manufacturers face greater requirements to improve cost/performance ratios. While some of the increase in OEE may be due to differences in definition, it is clear that process equipment will be used more efficiently to keep the cost of devices low. It is not possible to state how much of the current downtime is the result of unplanned shutdowns due to filter replacement or planned downtime due to regularly scheduled maintenance. Filters with a longer usable lifetime can play a role in improving OEE in the areas of set up, quality control, test wafers and unscheduled downtime.

Two beneficial aspects of QuickChange filters have direct impact on OEE. First, the filter comes prewet in the bag. This reduces the time to bring a filter online. The process of prewetting the filter in the manufacturing process eliminates the need for the semiconductor or wafer manufacturer to do the IPA wetting and water flushing steps. The end result is faster filter qualification and reduced downtime. Figure 1 shows the TOC flush up of QuickChange and other PTFE filters. Because the standard filter has been wet with IPA, it takes more than 80 minutes, at 1 gpm of liquids flowing through it to approach the feed TOC. The QuickChange filter reaches the feed TOC of 5 ppb after only 10 minutes of flushing.

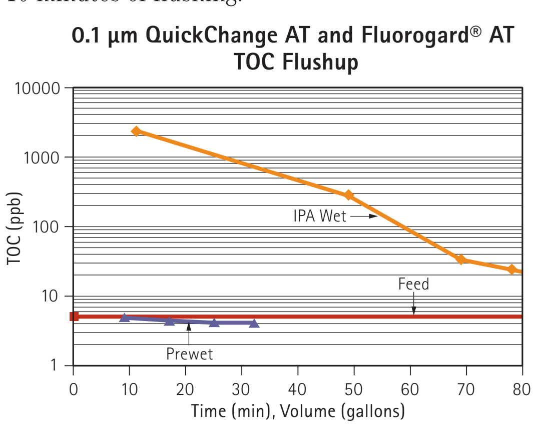

Figure 1. 0.1 µm QuickChange AT and Fluorogard AT TOC Flushup: 1 gpm flow; Fluorogard AT wet with 100% IPA.

Secondly, since QuickChange stays wet, filter lifetime can be extended. Regular maintenance schedules may then be extended to longer intervals. More importantly, unscheduled downtime due to filter dewetting, which results in low flow rates in the bath and higher particle counts, can be eliminated. Figure 2 shows the pressure drop of QuickChange and standard PTFE membrane filters used in an SC2 bath. Both filters have the same retention rating and have >2 LRV. The initial pressure drop of the standard filter is twice that of the QuickChange filter. When the chemical in the tank is drained and the housing is purged, the pressure drop of the standard filter increases significantly. The pressure drop of the QuickChange filter remains constant. After three tank drains, the standard filter pressure drop is three times that of the QuickChange filter.

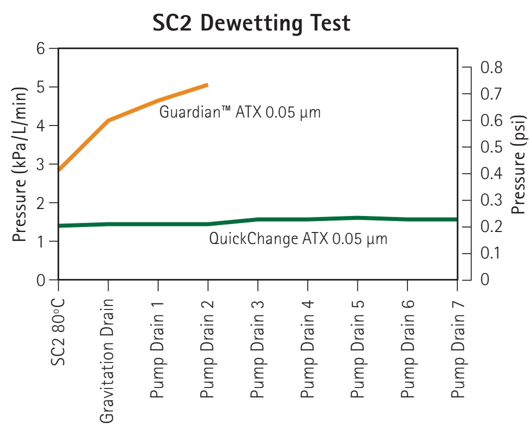

Figure 2. SC2 dewetting test: SC2 bath (0.2/1/5), 80°C; NSE pump.

An additional benefit of the nondewetting feature of QuickChange is the extended bellows and diaphragm pump life. When filters dewet, the pumps operate at higher discharge pressure. The air feed pressure must be increased to compensate for the higher-pressure drop of the filter. This results in more stress on the diaphragm or bellows pumps made of PTFE. Since pumps are one of the higher maintenance items in wet benches and distribution systems, reducing the stress on those parts could have a significant impact on operational uptime.

Because QuickChange filters do not dewet when the filter housing is drained, these filters allow for complete drainage when the chemical is changed. This reduces the carryover of dirty chemical during chemical changeout. Compromises in chemical quality are eliminated without risking gradual flow loss from dewetting.

Description of the QuickChange Technology

QuickChange filters utilize all-PTFE membranes for their cleanliness and compatibility with harsh chemicals at higher temperatures. They also have excellent retention, high flow and can be formed into several filter formats. They have nearly complete chemical compatibility at up to 180°C. The primary disadvantage of PTFE is that it is hydrophobic. The surface does not have an affinity to water. A simple method to understand the difference between hydrophobic and hydrophilic membranes is that "phobic" membranes are afraid of water while "philic" membranes are not. Phobic membranes must first be preconditioned or "wetted" to perform in aqueous chemistries. Since many microelectronics chemicals are aqueous-based, the chemical does not want to stay in the open space, or pores, of the filter's membrane structure. A surface made of PTFE would rather be in contact with gas than liquid. In particular, chemicals that outgas like hydrogen peroxide, ammonium fluoride, BOE, SC1, SC2 and piranha can result in gas bubbles forming in the pores of the filter. These gas bubbles eventually fill the pores of the membrane, resulting in loss of flow rate performance, rendering the filter unusable.

The QuickChange surface modification results in an increase of the surface free energy of PTFE, from 18 dynes/cm to 35 dynes/cm. While this does not make the surface hydrophilic (spontaneously wettable), it makes it nondewetting. Once wet with water, the surface, which has been coated with PTFE resins, wants to retain the water in the pore structure. The water bubble point of the QuickChange filter is greater than 30 psig, 2 bar pressure. If air is placed on the upstream side of a water-wet QuickChange filter, it takes more than 30 psig to push air through the filter.

The QuickChange surface modification is as chemically inert as PTFE fluoropolymer resins. The membrane surface was exposed to a variety of chemicals at 25°C and elevated temperatures for extended periods of time (Table 1). The surface of the membrane was examined with Fourier Transform Infrared Spectroscopy (FTIR) for changes in the structure of the QuickChange membrane. There were none. While the time of exposure is shorter than the filter will be expected to last in the application, the analytical technique is very sensitive. A change in the molecular structure of the surface would have been detected within the time of exposure.

TABLE 1. SUMMARY OF MEMBRANE CHEMICAL EXPOSURE TESTING.

Chemical	Temperature (°C)	Duration (Days)	Effect on FTIR
96% H_2SO_4	150	4	None
96% H_2SO_4	25	90	None
Piranha	135	7	None
30% H_2O_2	50	4	None
30% H_2O_2	25	90	None
28% NH_4OH	25	90	None
37% HCl	25	90	None
2.4% TMAH	50	4	None
40% HNO_3	50	4	None

Performance Attributes of QuickChange Filters

The performance of chemical filters can be quantified by measuring a number of attributes including extractables, retention and flow rate.[4]

Extractables

A technique used to quantify the chemical compatibility of materials is extractables testing. QuickChange filters were soaked in one liter of 10% HCl for 16 hours. The chemical was then analyzed by ICP-MS and GFAA to detect the presence of ionics from the filter structure. Table 2 shows the performance of QuickChange PF80 filters compared to Wafergard® PF filters.

Both filters have low extractables. Slightly higher levels of sodium in QuickChange filters are eliminated in the second extraction, showing the ions are surface contamination and easily removed. In a typical 40-liter recirculation bath, total extractables would be less than 1 ppb.

A QuickChange AT filter was evaluated for ionic performance in a recirculated 5% HF bath. After recirculating the chemical for 96 hours, a sample was analyzed by ICP-MS. Ionic levels for QuickChange and a standard Fluorogard AT filter were the same (Table 3).

TABLE 2. TYPICAL EXTRACTABLES IN ONE LITER OF 10% HCL.

	10% HCl Extractables (µg/unit)									
	Na	**Mg**	**Al**	**Cr**	**Cu**	**Zn**	**Ni**	**Ti**	**Fe**	**Ca**
QuickChange PF80 (av. of 2)	13.9	1.1	2.1	2.6	1.0	1.7	0.7	<0.1	1.3	5.5
QuickChange PF80 second extract	5.3	0.4	<0.1	0.6	<0.1	1.7	0.2	<0.1	4.0	1.4
Wafergard PF80	1.6	<0.1	3.1	1.3	0.2	<0.1	0.3	<0.1	8.0	2.8

TABLE 3. ION CONCENTRATION IN 5% HF (PPB), 20 LITER BATH, MEASURED BY ICP-MS, CONCENTRATION IN PPB.

Metal	Fluorogard AT 48 hours	Fluorogard AT 96 hours	QuickChange AT 48 hours	QuickChange AT 96 hours
Na	0.3	0.32	0.2	0.25
Mg	0.02	0.12	0.16	0.21
Al	0.72	0.8	0.8	1.05
K	0.1	0.22	0.12	0.25
Ca	0.4	0.47	0.37	0.52
Fe	2.2	2.27	2.85	3.19
Cu	0.02	0.015	0.02	0.018
Zn	0.45	0.47	0.4	0.54
Cr	–	0.017	–	0.17
Mn	–	0.006	–	0.015
Co	–	0.02	–	0.035
Ni	–	0.017	–	0.1
Total	**4.21**	**4.75**	**4.92**	**6.35**

QuickChange PF and standard Wafergard PF filters were soaked in 30% hydrogen peroxide for 28 days. At 1, 3 and 7 days, the peroxide was replaced with fresh chemical and measured for ionic content. Neither filter showed significant levels of ions (Figures 3 and 4).

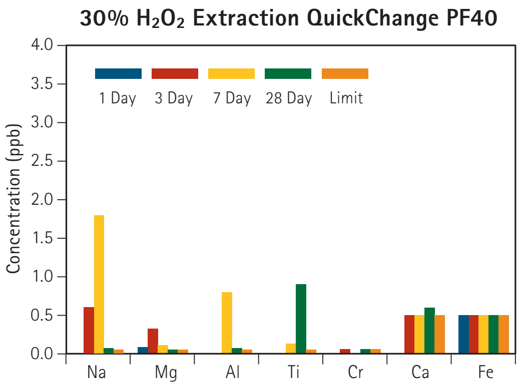

Figure 3. 30% H_2O_2 extraction QuickChange PF40: 600 mL of H_2O_2; replace H_2O_2 after each measurement.

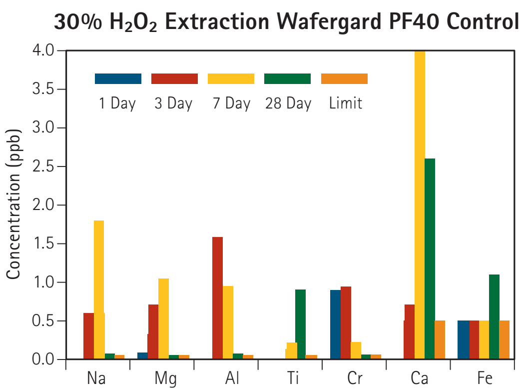

Figure 4. 30% H_2O_2 extraction Wafergard PF40 Control: 600 mL of H_2O_2; replace H_2O_2 after each measurement.

Particle retention performance is quantified in the laboratory using the proposed Sematech® particle retention test method.[5] The filter is challenged with polystyrene latex beads ranging in size from 0.05 µm to 0.5 µm. The particle concentrations are measured with optical particle counters (OPC). The initial particle retention and retention performance after loading can be measured.

Figure 5 shows the initial retention of QuickChange PF filters as a function of particle size. Retention is reported in "log reduction value" (LRV). LRV is the log of the number of particles in the feed divided by the number of particles in the filtrate. An LRV of 2 is equivalent to 99% retention.

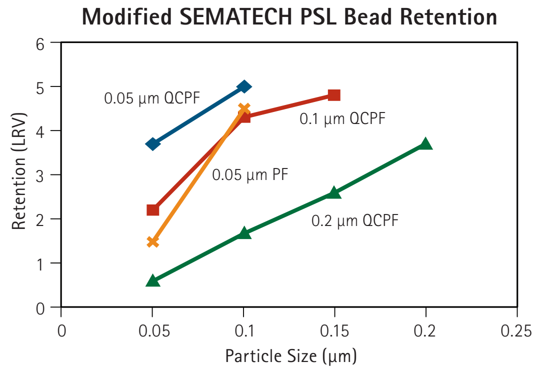

Figure 5. Modified SEMATECH PSL bead retention.

The larger the particle size, the better the retention for each filter rating. Five LRV is the limit of sensitivity for the test. Each filter has approximately 3 LRV at the rated pore size. The retention of 0.05 µm QuickChange filters have slightly better 0.05 µm particle retention than the control filter.

Particle Cleanliness

In addition to retaining particles, the filter device must not contribute particles to the clean fluid. Since fluids are so clean, there is potential that the filter structure may shed particles into the fluid under flow or pulsed flow conditions. The filter must be constructed in a clean environment and then flushed following manufacturing to ensure that the filters are particle free.

Particle cleanliness is examined in the laboratory by flushing clean water at 12 L/min through the filter for two hours. The particle level downstream of the filter is monitored by a PMS HSLIS optical particle counter capable of detecting particles >0.1 µm.[6] The flow is then pulsed at 15-minute intervals.

Figure 6 shows the cleanliness performance of a 0.05 µm QuickChange ATX filter. After the insertion of the filter into the test system, particle counts return to the background of the system after 30 minutes. This increase of "particles" is due to clearing air from the system. There is no effect of pulsing on particle levels. This particle performance is typical of clean filters.

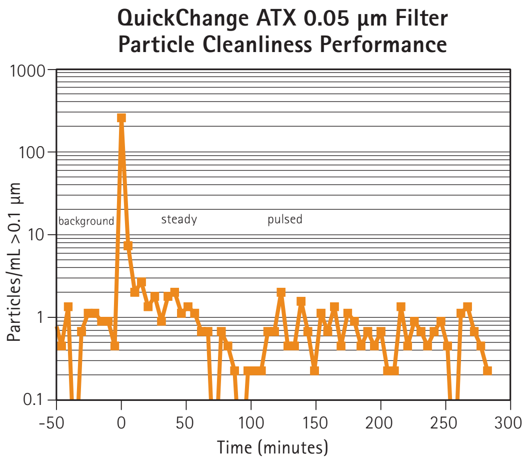

Figure 6. Particle cleanliness performance of QuickChange ATX 0.05 µm filter: DI water 3 gpm; steady flow for 120 minutes; pulsed for 120 minutes.

Flow performance

The flow performance of QuickChange filters in actual installations is superior to standard PTFE filters. The water flow rate of standard PTFE filters can be degraded after flushing the IPA from the filter with water and transferring the filter to the process housing. The action of fully draining a standard filter while "water wet" can result in 40% increase in pressure drop. This effect is most obvious with 0.1 µm and 0.05 µm filters. There is little loss in flow when installing a QuickChange filter into the process housing. Table 5 shows the change in pressure drop for standard and QuickChange filters.

Table 6 presents a tabulation of the pressure drop (filter resistance) of several styles of QuickChange filters. The testing was done with water at 1 centipoise. The pressure drop of the filter can be estimated by multiplying the resistance by the flow rate and the fluid viscosity.[7]

TABLE 5. EFFECT OF HOUSING DRAIN (4 TIMES) ON PRESSURE DROP OF WATER-WET FILTERS.

Filter	Pore Size (µm)	Initial Resistance (kg/cm²/L/min-cP)	Resistance after Draining (kg/cm²/L/min-cP)	% Increase
QuickChange PF	0.1	0.016	0.020	25
QuickChange PF	0.05	0.031	0.038	22
QuickChange ATX	0.1	0.012	0.016	33
QuickChange ATX	0.05	0.018	0.019	5
QuickChange AT	0.1	0.010	0.012	20
Guardian™ ATX	0.1	0.008	0.036	300
Guardian AT	0.1	0.015	0.025	67
Guardian AT	0.05	0.025	0.045	80

TABLE 6. RESISTANCE TO FLOW OF QUICKCHANGE FILTERS.

Filter	Pore Size (µm)	Resistance (kg/cm²/L/min-cP)	Resistance (psid/gpm-cP)
QuickChange PF	0.2	0.008	0.44
QuickChange PF	0.1	0.018	1.00
QuickChange PF	0.05	0.035	1.94
QuickChange AT	0.2	0.006	0.33
QuickChange AT	0.1	0.011	0.61
QuickChange AT	0.05	0.025	1.39
QuickChange ATX	0.2	0.005	0.28
QuickChange ATX	0.1	0.009	0.50
QuickChange ATX	0.05	0.018	1.00

Performance of QuickChange Filters in Chemicals

QuickChange filters have been extensively beta tested in recirculated chemical baths and in distribution systems. The following results are typical of the performance that was previously observed (at the time of the original testing in 2005).

A 0.1 µm QuickChange filter was used in an SC1 cleaning bath at a disk manufacturer. The customer had experienced a problem with a prewet PTFE filter from another supplier, where the flow in the bath was reduced and the filter lifetime was shortened. When a QuickChange AT 0.1 µm filter was installed, the flow was 4.5 gpm. After six weeks, the filter was removed and analyzed. The pressure drop of the filter had increased to about twice its original value due to pluggage, but the particle retention performance and flow in the bath were still good. Table 7 summarizes the results of this evaluation.

TABLE 7. PERFORMANCE OF QUICKCHANGE AND COMPETITIVE PREWET PTFE FILTERS IN SC1 BATH 30°C, 0.1 µm RATED FILTERS.

	QuickChange	Prewet PTFE
Flow in the bath	17.0 L/min (4.5 gpm)	11.3 L/min (3.0 gpm)
Lifetime of filter	>6 weeks	2 weeks

QuickChange AT 0.1 µm were installed in a 30% hydrogen peroxide delivery system. The delivery system has two sets of two filters in parallel. One set filters the drum while the other set filters the chemical before it enters the fab's bulk chemical distribution system. The customer had previously experienced some dewetting of the standard PTFE filters in the distribution system. After QuickChange filters were installed, there was no loss in flow rate performance. In addition, the particle levels found in the hydrogen peroxide running in the distribution system were reduced. Figure 7 shows the particle levels versus particle size in the hydrogen peroxide. The QuickChange particle levels are significantly lower overall particle sizes. It is believed that the better wetting performance of the QuickChange surface leads to improved results.

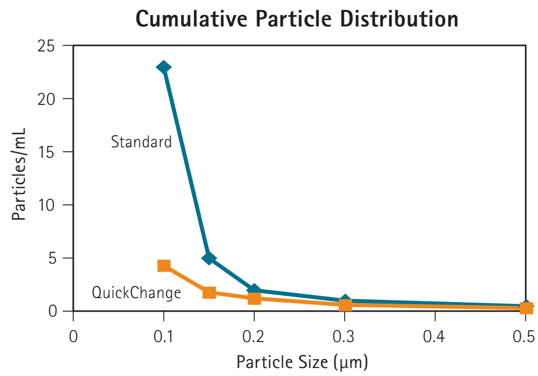

Figure 7. Cumulative particle distribution: 30% hydrogen peroxide; 0.1 µm rated filters .

When filters are installed in filtration systems, it takes some time to reach the lowest particle counts achievable. Figure 8 shows the particle flush up of QuickChange ATX 0.1 µm and standard PTFE 0.1 µm filters in 96% sulfuric acid flowing at 22°C. The QuickChange filters reach lower particle counts much sooner. In fact, the initial particle counts from the QuickChange filters were equal to the standard filter after 800 minutes of recirculation (Figure 8).

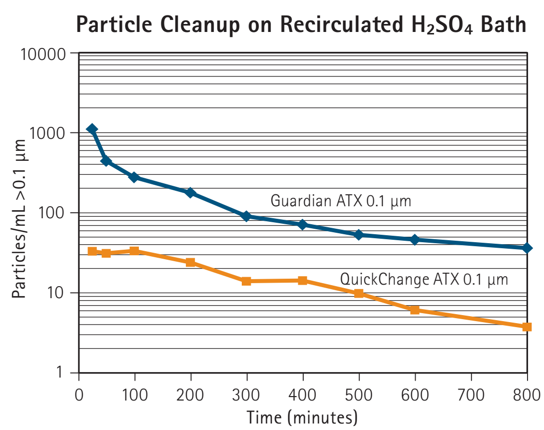

Figure 8. Particle cleanup on recirculated H_2SO_4 bath: 3.5 L/min flow; 96% H_2SO_4, 22°C.

QuickChange PF 0.1 µm Chem-Line™ II disposable filters were installed in a SMS GAMA-1 wet bench processing a sulfuric/ozone mixture. During the qualification of the bath, water at 60°C was circulated in the bath and wafers were added. The particle levels in the bath as a function of time were measured. The rate of cleanup of the bath would be related to the flow in the bath and the particle retention of the filters. The QuickChange filters cleaned up the bath much faster than competitive disposable filters constructed entirely of PTFE (Figure 9).

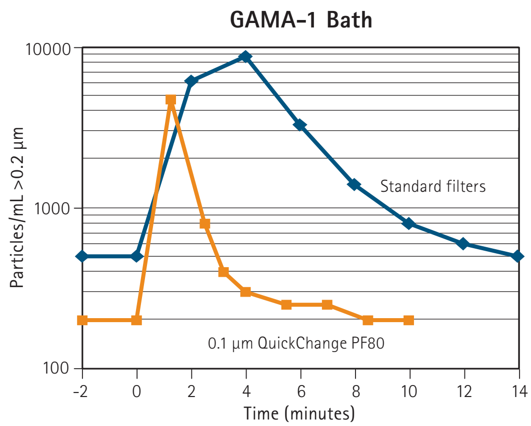

Figure 9. GAMA-1 bath: 60°C DI water; time 0; insert 50.

A wafer manufacturer uses SC1/SC2 baths to clean the wafer surface. They are using 0.1 µm filters in the SC1 bath, while 0.05 µm rated filters are used in the SC2 bath. Initially, Fluorogard ATX filters were installed in the systems. When those filters were replaced with QuickChange ATX filters, particle counts on the wafers decreased by 50% in System #1. System #2 reached an average particle count on the 8-inch wafer of 2.3 particles >0.16 µm. The particle data is shown in Table 8.

TABLE 8. PARTICLE LEVELS ON WAFERS AFTER SC1/SC2 CLEAN, 200 MM WAFERS, PARTICLES >0.16 µm.

Filter	System	Average >0.16 µm	Standard Deviation
Fluorogard ATX	#1	15.3	10.7
QuickChange ATX	#1	7.7	3.9
QuickChange ATX	#2	2.3	2.2

A semiconductor device manufacturer uses 0.05 µm Fluorogard ATX filters in both the SC1 and SC2 baths. They monitor the particles on the wafers after both baths and the flow of the SC2 bath as measured by pump strokes per minute. When they changed to QuickChange ATX filters in two systems, the particle counts on the wafers decreased, the pump stokes increased, and the pump stroke rate became constant. Figure 10 shows the performance of one of the systems.

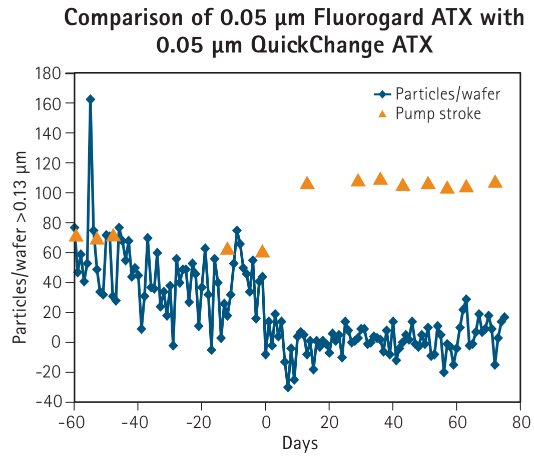

Figure 10. Comparison of 0.05 µm Fluorogard ATX with 0.05 µm QuickChange ATX: SC1/SC2 bath; particles on wafers >0.13 µm.

Handling Issues

QuickChange requires no special storage or handling. The filter is packaged in ultrapure water and can be drained and installed in the filter housing without further water flushing. As a precaution, the user may wish to circulate DI water to ensure that the housing has been sealed correctly. As with a traditional filter, it is recommended that the housing be vented during the startup with chemicals. This allows the air in the housing to be purged and for the full area of the filter to be utilized. For recirculated baths with outgassing chemicals, the housing should be continuously vented back to the weir of the tank to ensure that the housing does not fill with air.

It is recommended that QuickChange filters not be frozen during shipment or storage. However, it has been shown that there are no deleterious effects of freezing on the filter performance. The flow and retention remain unchanged. Table 9 shows that traditional PTFE filters can lose most of their flow after two freeze/thaw cycles, while QuickChange filters retain 100% of their flow.

TABLE 9. PRESSURE DROP (BAR/L/MIN) OF STANDARD AND QUICKCHANGE FILTERS AFTER TWO FREEZE/THAW CYCLES.

Filter	Initial	Freeze/Thaw
Standard PF	0.0144	0.0270
QuickChange PF	0.0144	0.0144
Standard pleated	0.0119	0.0935
QuickChange AT	0.0119	0.0124

Shelf Life

QuickChange filters are warranted to perform in the process application after unlimited shelf life storage as long as the package has remained integral. This warranty is supported by a controlled manufacturing process, validated autoclave cycles, ongoing performance testing of QuickChange filters and testing of prewet filters after 10 years of storage.

The manufacturing process for QuickChange prewet filters is designed to eliminate particulate contamination from microorganisms. The ultrapure DI water used to process the products is filtered with 0.1 µm rated filters. The prewet filters are then sealed in bacteria impervious PTFE FEP bags and sealed. An independent testing laboratory using bacillus subtilis has validated the performance of these bags.[8] The bags are then autoclaved at 121°C to ensure that biological organisms in the water and on the filter have been killed. The autoclave cycle is validated with temperature probes to ensure that the filter packages have been exposed to 121°C.

During ongoing shelf life testing, samples of QuickChange filters are evaluated for particle cleanliness, flow and biological purity of the water in the bag. After six months of storage, the QuickChange filters perform as well as the day they were placed in the bag and autoclaved.

Real-time shelf-life testing has been done on earlier versions of prewet filters. In 1986, the process for prewetting, packaging and sterilizing PTFE membrane filters was introduced by Millipore®. At that time, the work focused on Fluorogard Plus filters. These filters contain PTFE membranes and polypropylene supports, core, sleeve and end cap. The filters were IPA-wet; water-flushed, and sealed in a trilaminate (polyester, aluminum and polypropylene) bag with several hundred milliliters of water. The package was then sterilized in an autoclave cycle. While this process is not identical to the current QuickChange process, the key elements are the same and allow for the use of shelf life testing predicting the performance of QuickChange products.

Figure 11 shows the results of a particle cleanliness test run on three Fluorogard Plus filters after 10 years' shelf life exposure. The particle performance is excellent. The particle levels returned to background within 30 minutes of installation. There was no particle shedding in steady or pulsed flow.

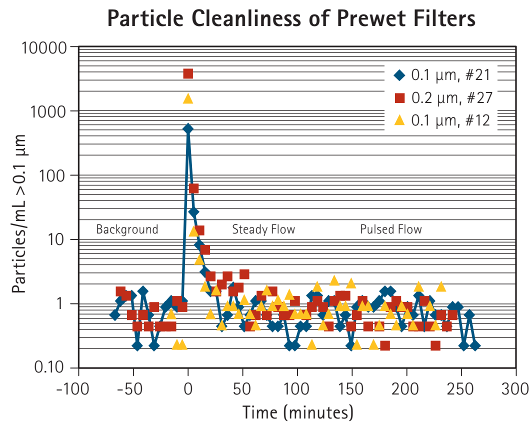

Figure 11. Particle cleanliness of prewet filters after 10 years' shelf life; Fluorogard TP (CWFG01TPE, CWFV01TPE); prewet, autoclaved and sealed in a bag for 10 years.

The flow rate of the filters was similar to other units packaged in 1986. Table 10 reports the pressure drop of each filter measured with water at 1 gpm.

TABLE 10. PRESSURE DROP OF FLUOROGARD PLUS PREWET FILTERS AFTER 10 YEARS' SHELF LIFE

Filter	Psid/gpm (Water at 1 cP)
0.2 µm #27	0.45
0.2 µm #46	0.39
0.1 µm #21	0.78
0.1 µm #12	0.97

The filters were then retention tested using the proposed SEMATECH test method. The retention of the filters was quite good, 4.5 LRV at rated pore size. Figure 12 shows the results of the retention test.

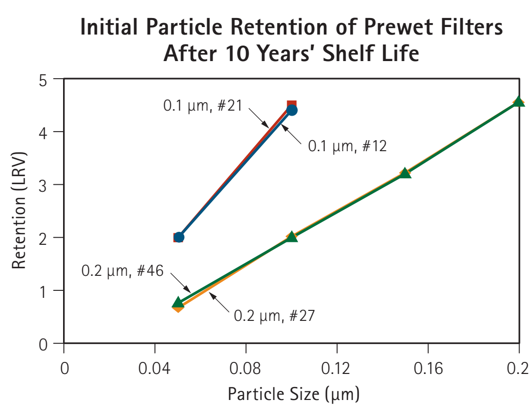

Figure 12. Initial particle retention of prewet filters after 10 years' shelf life: Fluorogard TP (CWFG01TPE, CWFV01TPE); prewet, autoclaved and sealed in a bag for 10 years.

Summary

- QuickChange filters are provided "water-wet" in a PTFE FEP bag and are nondewetting.
- The filters start quickly out of the bag, having rapid TOC recovery and providing low particle counts in chemicals.
- QuickChange filters can reduce equipment downtime by allowing the equipment to come back online sooner after filter changeout, by reducing filter changeout due to the elimination of dewetting, and by reducing stress on pumps.
- QuickChange filters may improve the bath performance by lowering particle counts, maintaining high flow rate and allowing the use of tighter membranes.

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