Confirmation Tools – Effective Solution For Robust Filter Clog Monitoring

Testing of filtration – average delta pressure and filtration – maximum upstream pressure

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Photoresists are light sensitive materials used in lithography processes that form particles or gels when they are exposed to light, elevated temperature, humidity, or a particular solvent such as isopropyl alcohol. This phenomenon, which we call *aging of photoresist*, occurs during storage or after the chemical bottle is opened to allow the chemical to be used in the chip production process. See Figure 1. Users can open the chemical bottle and put tubing into the bottle, then suck the bottle via the pump and dispense it onto the wafer. After the chemical bottle is opened, the chemical may potentially react to water molecules or other impurities in the environment leading to this *aging of photoresist* chemical phenomenon.

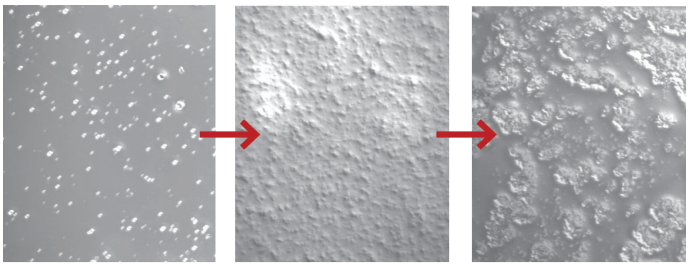

Figure 1. Appearance of more and more (from left to right) aged photoresist after coating: With increasing concentration and size, particle form conglomerates of clusters (each picture 500 µm × 500 µm). Source: www.microchemical.eu

Particles or gels formed during aging of photoresist cause the filter installed between the fill and dispense chambers of a two-stage dispense pump to become clogged.

To address this unfavorable situation, a new platform of IntelliGen® (IG) pumps (IG-LV, IG-ULV and IG-MV) was developed. The IntelliGen product family utilizes an advanced two-stage dispense technology that incorporates a robust alarm functionality called *confirmation tool*. The confirmation tool is based on the Fault Detect Control (FDC) software that compares the change in the recorded reference pressure profile with that of the last cycle. The FDC software first computes the average delta pressure by calculating the difference between the pressure inside the fill chamber and the pressure inside the dispense chamber. Next, it calculates the difference between the average delta pressure of the reference and the last cycle.

Figure 2 displays a configuration of pumps with two stages – the fill chamber to the left and the dispense chamber to the right. Pressure sensors are installed in both chambers enabling real-time pressure monitoring and the capability to calculate the average delta pressure.

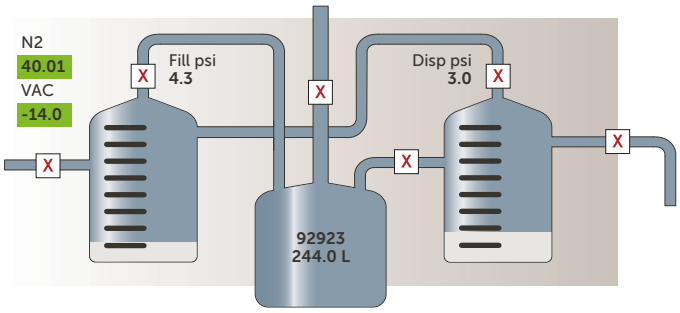

Figure 2. Demonstration of two-stage dispense pump: left is fill chamber and right is dispense chamber. Both chambers have pressure sensors installed inside enabling real-time pressure monitoring.

If the difference of the average delta pressure between the reference and the last cycle exceeds the alarm limit, the alarm will be activated. Both error and warning alarms are user-selectable. If the error alarm is enabled, the pumps can halt dispense activity after the error alarm is activated. Moreover, the confirmation tool can be used to estimate time to change the filter and also to monitor a filter clog condition. With this feature, it is no longer necessary to estimate filter life or monitor a filter condition manually by observing the delta pressure between filter upstream and filter downstream. Coater developer can automate the monitoring system by receiving an alarm signal sent by the dispense pumps. This automation saves time, cost, and manpower.

BACKGROUND – CONFIRMATION TOOLS

Two confirmation tools respond to a potential filter clog condition.

1. **Filtration – Average Delta Pressure:** The confirmation tool measures the average delta pressure between the pressure inside the fill chamber (filter upstream pressure) and the pressure inside the dispense chamber (filter downstream pressure) during the filtration segment. This measurement enables users to monitor a filter clog condition and determine the approximate filter life. The higher the average delta pressure is, the more severe the filter clog condition.
2. **Filtration – Maximum Upstream Pressure:** The confirmation tool measures the maximum pressure inside the fill chamber (filter upstream pressure) during the filtration segment. This measurement also enables users to monitor a filter clog condition and determine the approximate filter life. The higher the maximum upstream pressure is, the more severe the clog condition of the filter.

Figure 3 displays the profile page, which is the monitoring screen for the new platform pumps.

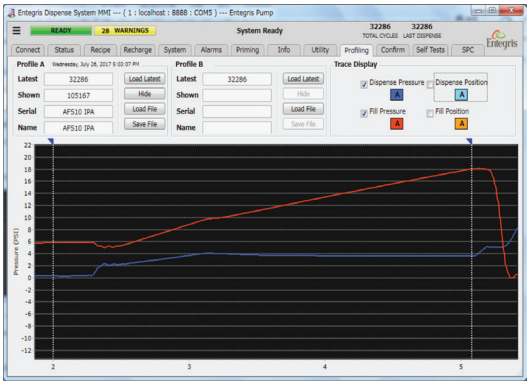

Figure 3. Profile page of the new platform dispense pumps differentiates the pressure inside the fill chamber (upstream – red profile) with the pressure inside the dispense chamber (downstream – blue profile) during the filtration segment.

The red profile displays the pressure inside the fill chamber (filter upstream pressure), and the blue profile displays the pressure inside the dispense chamber (filter downstream pressure); both profiles occur during the filtration segment. The average delta pressure is calculated from these two profiles – the average pressure inside the fill chamber minus the average pressure inside the dispense chamber during the entire duration of the filtration segment. The Y-axis represents pressure in psi units, and the X-axis represents time units (seconds).

EXPERIMENT

An experiment was performed using the "new pump".

NOTE: "New pump" refers to any of the new IntelliGen platform pumps – IG-LV, IG-ULV, and IG-MV, as well as model AFS10, which was actually used in the experiment and which has the same properties as the aforementioned IntelliGen platform pumps. Therefore, the test results can also be applied to any of the IntelliGen platform pumps after they are released and made available worldwide with the confirmation tool alarm capabilities.

Two conditions of gelatin solution were prepared and introduced into the dispense pump through the inlet port of the pump for 2,000 dispense cycles for condition 1 and 1,202 dispense cycles for condition 2, respectively. Test values of the "Filtration – Average delta pressure" confirmation tool and the "Filtration – Maximum upstream pressure" confirmation tool were observed.

Parameter settings used to test the new pump are summarized in Table 1.

Table 1. Parameter settings used to test the new pump

Parameter	Set value
Dispense volume	0.3 mL
Dispense rate	0.15 mL/s
Outlet valve open adjustment	730 ms
Outlet valve close adjustment	50 ms
Suck back volume	0.0 mL
Fill rate	1.0 mL/s
Filtration rate	0.5 mL/s
Filtration pressure setpoint	4.0 psi
Ready pressure setpoint	3.0 psi

TESTING SETUP

The testing setup is shown in Figure 4 with supplemental details provided in table 2.

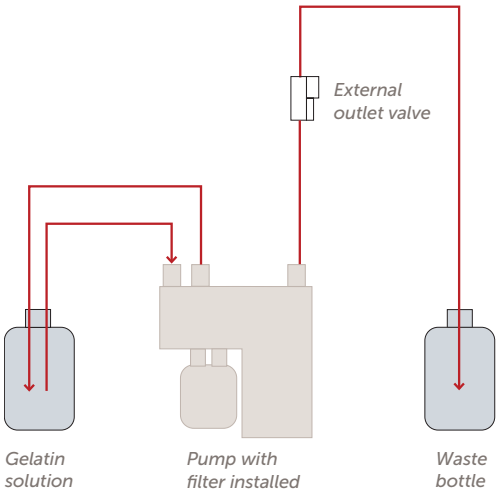

Figure 4. Testing setup

Table 2. Testing Details

No.	Tubing information	Length	Outer diameter	Inner diameter
1	Gelatin solution bottle to dispense pump inlet	500 mm (19.68")	6.35 mm (0.25")	3.96 mm (0.15")
2	Dispense pump outlet to external outlet valve	200 mm (7.87")	6.35 mm (0.25")	3.96 mm (0.15")
3	External outlet valve to waste bottle	500 mm (19.68")	—	2 mm (0.08")
4	Vent line	500 mm (19.68")	—	2 mm (0.08")

OVERALL TEST RESULTS

Test values for the "Filtration – Average delta pressure" confirmation tool and the "Filtration – Maximum upstream pressure" confirmation tool observed during the experiment are plotted with respect to the number of dispense cycles. The results are shown in Figure 5 and Figure 6, respectively.

Graphs demonstrate test value of Filtration – Average Delta Pressure confirmation tool with respect to number of dispense cycle when the solution of gelation is 0.098 g in 500 mL DIW

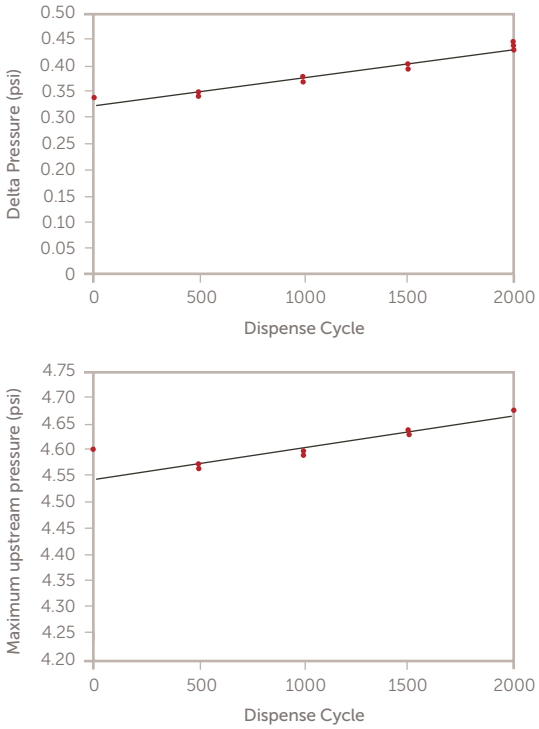

Figure 5. "Filtration – Average delta pressure" confirmation tool

Figure 5 illustrates the test results for the following condition: (1) Top: Test value of Filtration-Average delta pressure confirmation tool with respect to number of dispense cycles and bottom: Test value of Filtration – Maximum upstream pressure confirmation tool with respect to number of dispense cycles.

Graphs demonstrate test value of Filtration – Average Delta Pressure confirmation tool with respect to number of dispense cycle when the solution of gelation is 5.009 g in 500 mL DIW

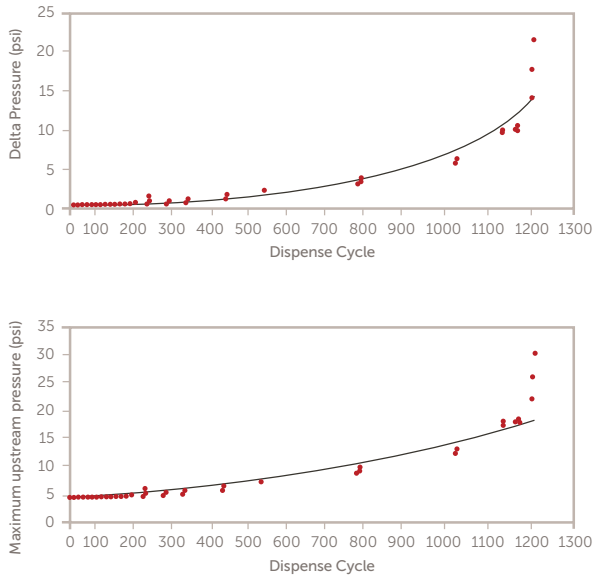

Figure 6. "Filtration – Maximum upstream pressure" confirmation tool

Figure 6 illustrates the test results for the following condition: (2) Top: Test value of Filtration-Average delta pressure confirmation tool with respect to number of dispense cycles and bottom: Test value of Filtration – Maximum upstream pressure confirmation tool with respect to the number of dispense cycles.

ANALYSIS OF RESULTS

The results show that test values for Filtration – Average delta pressure confirmation tool and Filtration – Maximum upstream pressure confirmation tool are consistent with each other and both types of test values exponentially rise with respect to the number of dispense cycles. This implies that only a slight change in average delta pressure and maximum upstream pressure occurred in the initial stage of the filter clog condition. However, there is a dramatic change in the later stage. A rapid increase in pressure was detected after the clog condition reached its threshold.

ALARM FUNCTIONALITY IN NEW PLATFORM PUMPS

Pumps provide alarm functionality that can be activated by the test value of the confirmation tools. The alarm limits are user-selectable based on the engineer's judgement. After the test values of the confirmation tools exceed alarm limits, the applicable alarm will be activated. The warning alarm detects that the test value is close to the setting limit, whereas the error alarm indicates that the test value has reached a severe level where the potential for defective wafers exists. Users can set the alarms to halt dispense activity to avoid adverse conditions.

Table 3 and Table 4 summarize the test values of Filtration – Average delta pressure confirmation tool and Filtration – Maximum upstream pressure confirmation tool of condition (2) respectively.

Table 3. Summary of test value of Filtration – Average delta pressure of condition (2)

Dispense cycle	Average delta pressure of last cycle	Average delta pressure of reference	Test value	Warning limit	Error Limit	Alarm supposed to be alerted
10	0.34 psi	0.33 psi	0.01 psi	1.00 psi	1.50 psi	No alarm
100	0.50 psi	0.33 psi	0.17 psi	1.00 psi	1.50 psi	No alarm
500	2.33 psi	0.33 psi	2.00 psi	1.00 psi	1.50 psi	Error alarm
1160	10.02 psi	0.33 psi	9.69 psi	1.00 psi	1.50 psi	Error alarm
1202	21.60 psi	0.33 psi	21.27 psi	1.00 psi	1.50 psi	Error alarm

Table 4. Summary of test value of Filtration – Maximum upstream pressure of condition (2)

Dispense cycle	Maximum upstream pressure of last cycle	Average delta pressure of reference	Test value	Warning limit	Error Limit	Alarm supposed to be alerted
10	4.65 psi	4.65 psi	0.00 psi	15.00 psi	18.00 psi	No alarm
100	4.82 psi	4.65 psi	0.17 psi	15.00 psi	18.00 psi	No alarm
500	7.68 psi	4.65 psi	3.03 psi	15.00 psi	18.00 psi	No alarm
1160	18.04 psi	4.65 psi	13.39 psi	15.00 psi	18.00 psi	No alarm
1202	30.47 psi	4.65 psi	25.82 psi	15.00 psi	18.00 psi	Error alarm

Figure 7 through Figure 11 show the change in pressure inside the fill chamber and the dispense chamber during the filtration segment of the 10th cycle, the 100th cycle, the 500th cycle, the 1160th cycle and the 1202nd cycle, respectively.

Graph demonstrates pressure inside fill chamber and dispense chamber during filtration segment of the 10th dispense cycle

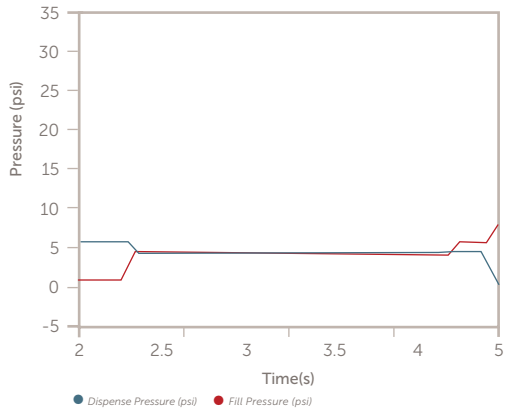

Figure 7. Filtration segment of the 10th cycle

Graph demonstrates pressure inside fill chamber and dispense chamber during filtration segment of the 100th dispense cycle

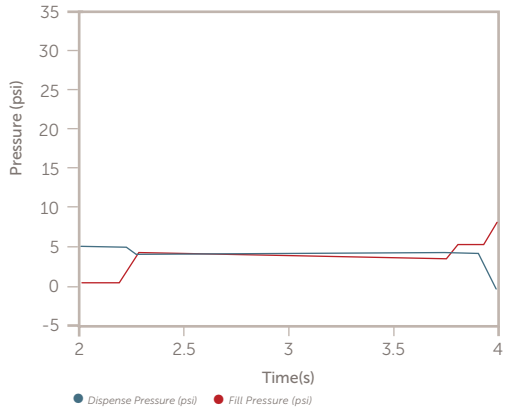

Figure 8. Filtration segment of the 100th cycle

Graph demonstrates pressure inside fill chamber and dispense chamber during filtration segment of the 500th dispense cycle

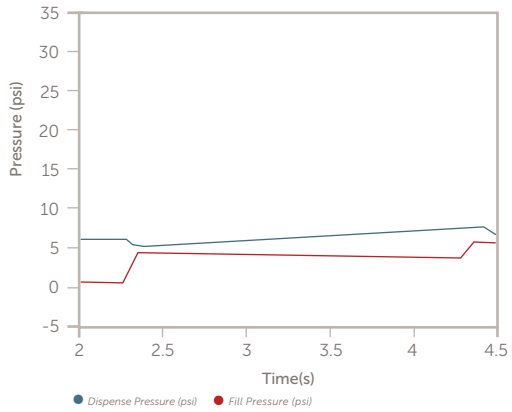

Figure 9. Filtration segment of the 500th cycle

Graph demonstrates pressure inside fill chamber and dispense chamber during filtration segment of the 1160th dispense cycle

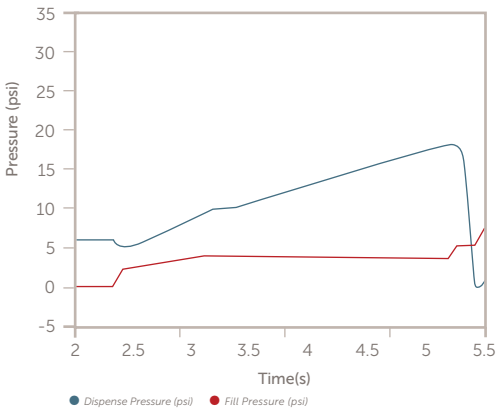

Figure 10. Filtration segment of the 1160th cycle

Graph demonstrates pressure inside fill chamber and dispense chamber during filtration segment of the 1202nd dispense cycle

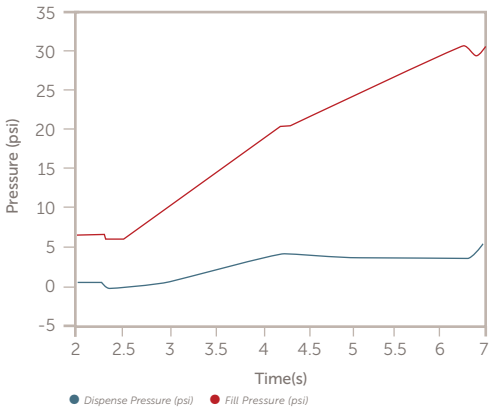

Figure 11. Filtration segment of the 1202nd cycle

Figure 7 through Figure 11 display an observable increase in average delta pressure and maximum upstream pressure. The two-stage dispense pumps are designed to have a constant downstream pressure (dispense pressure), as shown by the red line. During the filtration segment, the piston of the fill chamber moves upward to achieve the filtration rate that is set by users.

When a filter clog occurs, flow resistance increases. Because the filtration is set at a constant rate, upstream pressure (fill pressure), as shown by the blue line, increases to the level that fluid is allowed to flow at a set filtration rate.

CONCLUSION

The IntelliGen product family provides many opportunities that benefit the lithography process with its advanced two-stage dispense technology coupled with its robust monitoring and alarm capabilities of the confirmation tools. The filtration – average delta pressure and the filtration – maximum upstream pressure confirmation tools are documented to be able to monitor a filter clog condition and warn users when the clog condition is close to a severe level (warning alarm), as well as to halt dispense activity if the clog condition reaches an unacceptable level (error alarm). Users can also utilize confirmation tools to predict filter life, estimate time to change a filter without allowing the unacceptable events to occur. These capabilities help to prevent potential wafer loss or defects and to promote enhanced wafer processing.

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