Confirmation Tools – Advanced Monitoring of Photolithography Dispense Operations (IntelliGen® LV, ULV, and MV)

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Photolithography processes are among the most critical operations in semiconductor manufacturing. Semiconductor decision makers demand solutions that increase yield while minimizing wafer defects. Undetected errors, such as thickness or patterning inconsistencies during the liquid dispense phase can be too costly and time-consuming to correct. Therefore, integrating a system into the process that monitors for event abnormalities before transitioning to the next phase (wafer coating) is highly desirable. One such system is Entegris' confirmation tools.

Based on the Fault Detect Control (FDC) software, confirmation tools monitor the dispensing of liquids onto the substrate and then compare the change in the recorded reference profile with that of the last cycle. Confirmation tools monitor multiple steps of fluid dispensing onto the substrate. In addition, these tools detect malfunctions with the dispense system itself, the condition of the point-of-use filter, and the condition of the tubing that runs from the liquid source to the pump, the nozzle, and the processed liquid flow rate. This level of monitoring enables the user to catch abnormal events before wafer coating starts and helps improve the overall photolithography process to achieve higher yield and fewer wafer defects.

Figure 1 shows an advanced, two-stage dispense system configuration consisting of two chambers – left for fill and right for dispense. Pressure sensors are installed in both fill and dispense chambers to enable users to calculate the "delta pressure," which is the difference in pressure between the two chambers.

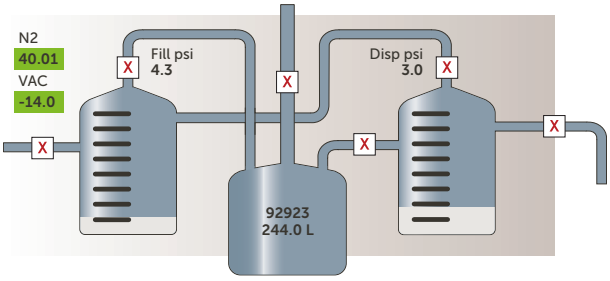

Figure 1. Two-stage dispense system configuration: left is fill chamber and right is dispense chamber

Laboratory tests concluded that the confirmation tool can detect small event abnormalities such as with motor position, with pressure detected inside both fill and dispense chambers, or with liquid flow rate in the outlet line. It then returns to normal after the abnormality no longer exists. Figure 2 and Figure 3 demonstrate how the pressure profile of the reference and the last cycle differ when the outlet valve of the last cycle either opens at the same time (Figure 2) or opens 100 ms later (Figure 3) than the reference cycle.

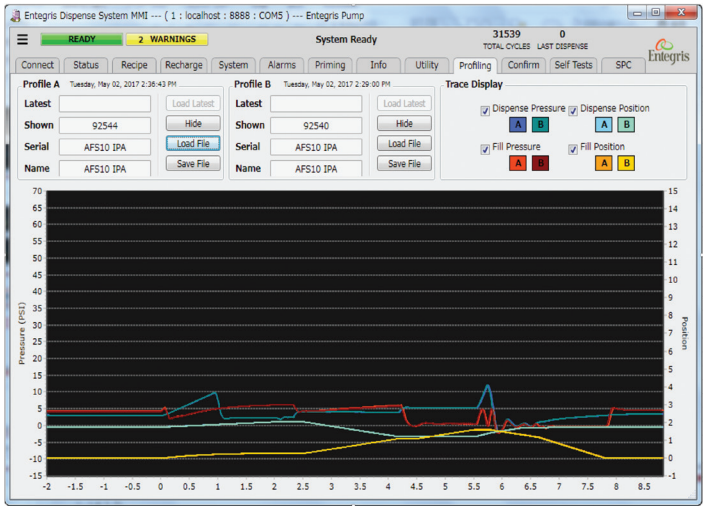

Figure 2. Demonstrates outlet valve opening at the same time as the reference cycle

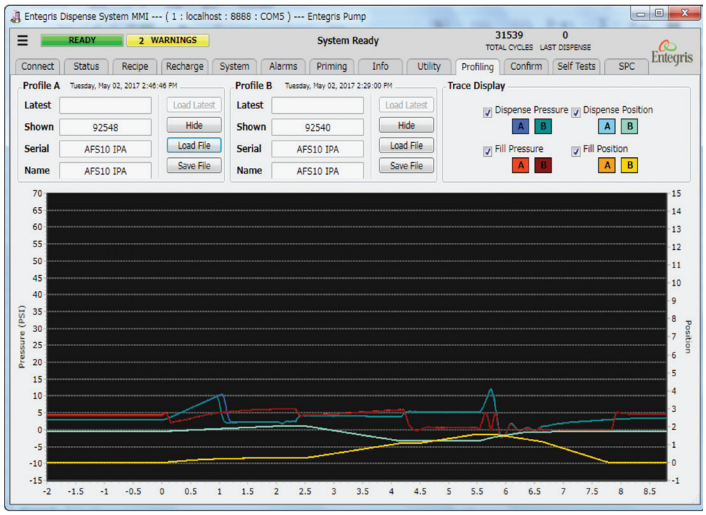

Figure 3. Demonstrates outlet valve opening 100 milliseconds after reference cycle

CONFIRMATION TOOL FUNCTIONALITY

The IntelliGen® dispense system incorporates 18 confirmation tool functions.

1. **Ready – Ready Pressure (psi):**
   The confirmation tool measures the pressure inside the dispense chamber during the ready segment. This measurement enables the user to detect system leakage, a motor drive issue and others factors that could lead to a change in pressure during the ready segment.

2. **Ready – Ready Correction Volume (mL):**
   The confirmation tool measures the motor advances that establishes the ready pressure setpoint before the dispense cycle starts. This measurement enables the user to predict the amount of air inside the dispense chamber, the increase in motor advances, and the higher volume of air.

3. **Dispense – Pressure Profile Compare (%):**
   The confirmation tool compares the pressure profile of the reference with the last cycle. The matching percentage enables the user to assess whether the quality of the dispense is the same as the reference.

4. **Dispense – Flow Profile Compare (%):**
   The confirmation tool compares the flow rate profile of the reference with the last cycle. The matching percentage enables the user to monitor the change in flow rate. This is one of the most important factors that can lead to good dispense quality.

5. **Dispense – Maximum Dispense Pressure (psi):**
   The confirmation tool measures the maximum pressure in the dispense chamber. Evaluating the difference in maximum pressure between the reference cycle and the last cycle enables the user to control the dispense quality and to detect when an abnormal event occurs. Typically a change in maximum pressure leads to a corresponding change in average pressure.

6. **Dispense – Average Pressure (psi):**
   The confirmation tool monitors the average level of pressure in the dispense chamber during dispense segment. The observation of the difference in average pressure between the reference and the last cycle enables the user to control the dispense quality and to detect when abnormal event occurs.

7. **Dispense – Cutoff Pressure (psi):**
   The confirmation tool monitors the level of pressure during the final segment of the dispense cycle, which lasts for only 200 ms after the outlet valve closes. This capability enables the user to effectively control the quality of liquid cutoff at the nozzle tip.

8. **Dispense – Average Motor Rate (mL/s):**
   The confirmation tool observes the average rate of dispense motor movement, and monitors the difference in average motor rate between the reference and the last cycle. This capability gives the user visibility to a potential hardware problem.

9. **Dispense – Total Motor Volume (mL):**
   The confirmation tool observes the total volume of motor movement, and monitors the difference between the reference cycle's total volume and the last cycle. This capability enables the user to control the volume of resist and to maintain a consistent coating of resist on the wafer substrate.

10. **Dispense – Average Air Detect Volume (mL):**
    The confirmation tool detects the existence of air in the tubing downstream of the dispense system and, if so, alerts the user.

11. **Dispense – Total Flow Volume (mL):**
    The confirmation tool measures the total volume of dispensed fluid using the data collected from the flow sensor combined with the dispense system. This measurement enables the user to observe dispensed fluid volume during production.

12. **Filtration – Average Delta Pressure:**
    The confirmation tool measures the differential pressure between the filter upstream and the filter downstream during the filtration segment. This measurement enables the user to monitor for a filter clog condition and estimate a filter's lifetime.

13. **Filtration – Maximum Upstream Pressure:**
    The confirmation tool measuring the maximum pressure inside the fill chamber during the filtration segment. This measurement enables the user to monitor for a filter clog condition and estimate a filter's lifetime.

14. **Vent – Total Volume:**
The confirmation tool measures the volume of fluid and the venting frequency during the vent segment. This measurement enables the user to monitor the volume of fluid being vented.

15. **Fill – Minimum fill Pressure (psi):**
The confirmation tool measures the minimum amount of pressure in the fill chamber during the filling segment. It alerts the user to factors that cause excessively high negative pressure due to an increase in viscosity or a tubing kink.

16. **Fill – Average Motor Rate (mL/s):**
The confirmation tool measuring the average rate (mL/sec) of the fill motor movement, and monitors the difference in the average motor rate between the reference and the last cycle. This capability gives the user visibility to a potential hardware problem.

17. **Fill – Total Time (sec):**
The confirmation tool measures the time it takes to complete the fill segment. It alerts the user to factors that could extend the fill segment time such as due to an increase in viscosity.

18. **Cycle – Total Time (sec):** The confirmation tool measures the total time it takes to complete one cycle, from the start of the dispense segment to the end of the purge segment. It alerts the user to factors that could extend the cycle time such as a change in filtration rate.

CONFIRMATION TOOL DEFINITION SUMMARY

The following table summarizes the confirmation tools' product functionality.

Table 1. Summarization of the definition of each confirmation tool

Item	Name of confirmation tool	Description	Detector	Detectable event
1	Ready – Ready pressure (psi)	Averages the pressure inside the dispense chamber during a ready segment (estimated 200 ms duration).	Pressure sensor in the dispense chamber	1. Air in the system 2. System leak 3. Change in the ready pressure setpoint
2	Ready – Ready correction volume (psi)	Measures the correct volume of dispense motor advances before the dispense cycle starts to establish the ready pressure setpoint.	Pressure sensor in the dispense chamber	1. Air in the system
3	Dispense – Pressure profile compare (%)	Performs a standard RSQ calculation (%) comparing the pressure profile of the reference with the cycle of interest. If both pressure values are equal, then the calculation will be 100%.	Pressure sensor in the dispense chamber	1. Air in the system 2. Valve timing 3. Motor drive issue 4. Change in the recipe parameters
4	Dispense – Flow profile compare (%)	Performs a standard RSQ calculation (%) comparing the flow rate of the reference with the cycle of interest. If both flow rate values are equal, then the calculation will be 100%	Flow sensor	1. Change in the flow rate 2. Air in the system

Table 1. Summarization of the definition of each confirmation tool (continued)

Item	Name of confirmation tool	Description	Detector	Detectable event
5	Dispense – Maximum pressure (psi)	Records the maximum pressure in the dispense chamber during dispense.	Pressure sensor in the dispense chamber	1. Air in the system 2. Valve timing 3. Motor drive issue
6	Dispense – Average pressure (psi)	Averages the pressure in the dispense chamber during dispense.	Pressure sensor in the dispense chamber	1. Air in the system 2. Valve timing 3. Motor drive issue
7	Dispense – Cutoff pressure (psi)	Averages the pressure in the dispense chamber for 200 ms during the cutoff period (after the outlet closes).	Pressure sensor in the dispense chamber	1. Outlet valve closing condition 2. Change in the recipe parameters
8	Dispense – Average motor rate (mL/s)	Averages the rate (mL/sec) of the dispense motor during dispense.	Encoder of the dispense motor	1. Change in the recipe parameters
9	Dispense – Total volume (mL)	Measures the total volume (mL) of dispense motor movement.	Encoder of the dispense motor	1. Change in the recipe parameters
10	Dispense – Air detect volume (mL)	Measures a rise in pressure based upon a specific motor movement.	Pressure sensor in the dispense chamber	1. Air in the outlet line
11	Dispense – Total flow volume (mL)	Measures the liquid flow rate using the flow sensor.	Flow sensor	1. Change in the actual liquid flow rate 2. Air in outlet line
12	Filtration – Average delta pressure (psi)	Averages the delta pressure between the fill chamber and the dispense chamber during filtration.	Both pressure sensors in the fill chamber and in the dispense chamber	1. Clogging condition of the filter 2. Change in the filtration rate
13	Filtration – Maximum upstream pressure (psi)	Records the maximum pressure in the fill chamber during filtration (specifically to avoid skipping a step).	Both pressure sensors in the fill chamber and in the dispense chamber	1. Filter clogging condition 2. Change in the filtration rate 3. Change in the filtration pressure setpoint
14	Vent – Total time (sec)	Records the total time (sec) of the vent segment.	Encoder of the fill motor	1. Change in the setting for vent volume
15	Fill – Minimum pressure (psi)	Records the minimum pressure in the fill chamber during the fill segment.	Pressure sensor in the fill chamber	1. Change in the viscosity 2. Kink in the inlet tube
16	Fill – Average motor rate (mL/s)	Averages the rate (mL/sec) of the fill motor during the fill segment.	Encoder of the fill motor	1. Change in the fill rate setting 2. Motor drive issue

Table 1. Summarization of the definition of each confirmation tool (continued)

Item	Name of confirmation tool	Description	Detector	Detectable event
17	Fill – Total time (psi)	Records the total time (sec) of the fill segment.	Clock	1. Increase in the liquid viscosity 2. Change in the dispense volume
18	Cycle – Total time (sec)	Records the total time (sec) of the cycle.	Clock	1. Change in the filtration rate 2. Incomplete cycle issue

SUMMARY

Consistency in every dispense cycle is of utmost importance in photolithography processes. Maintaining consistently high yield with minimal wafer defects remains a high priority. Therefore, the benefits of incorporating the IntelliGen dispense systems, coupled with the advanced confirmation tools, far outweigh the costs associated inferior wafer quality.

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