Monitoring Air Supply in Spin Coating Photolithography Process

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Photoresist film uniformity is one important factor among many when spin coating photoresist. To control the uniformity of the photoresist film, fluid flow at the dispense point plays an important role. To ensure uniform topography, fluid must form a straight, solid stream at the nozzle tip, and it must flow at a constant flow rate. Controlling fluid flow at the nozzle tip can be achieved by adjusting the open and close timing of a stop suckback valve that is usually installed between the dispense pump and nozzle. After the dispense pump dispenses the fluid, the stop suckback valve needs to open at the right time to enable the fluid to form a straight, solid stream. If the valve opens too early, there is not enough pressure to form a solid fluid stream and the fluid will drip out of the nozzle tip. If the valve opens too late, the flow rate will be compromised and too much fluid will flow at the beginning, and too little will flow at the end.

Equally important to opening at the right time, the valve needs to close at the right time as well. If the valve closes too early, there will be an insufficient amount of fluid to cover the whole wafer. If the valve closes too late, there may be a drop of fluid that dispenses after the main fluid stream stops flowing because the valve is not yet closed. To prevent these undesirable events, the open and close timing of the stop suckback valve must be precisely controlled.

Though most stop suckback valves are digitally controlled, some are pneumatically controlled and require air to open and close them. Air-operated valves need very consistent air pressure to control the valve actuation and avoid fluctuations between dispense cycles. Supplying consistent air pressure to lithography production processes is vital but not easy to achieve. Air pressure fluctuation is often inevitable, particularly when too many devices require air at the same time. In those instances, it is likely the stop suckback valve could receive insufficient air supply than is necessary to actuate it. This consequently leads to a delay in opening and closing the valve, which will eventually cause poor uniformity of photoresist film on wafers during the coating process.

To monitor photoresist dispense uniformity, Entegris offers a dispense pump with an integrated monitoring "confirmation tool". The confirmation tool confirms whether the last dispense has the same characteristic as the reference dispense that is recorded prior as a good dispense. If the stop suckback valve open and close timing varies due to fluctuating air pressure, the confirmation tool can detect the change in the fluid flow rate and alert the operator before wafers are compromised.

This application note introduces four of the nineteen tools in Entegris' confirmation tool that are responsive when air supplied to the external stop suckback valve is weakened.

FOUR RESPONSIVE TOOLS AND THEIR PRINCIPLES

Pressure Profile Compare (%)

Compares the pressure profile of the last cycle to the reference. The matching percentage enables user to identify if they can achieve the same quality of dispense in the last cycle as in the reference.

Maximum Dispense Pressure (psi)

Measures the maximum level of pressure in the dispense chamber. Observing a maximum pressure difference between the reference cycle and the last cycle enables user to control dispense quality.

Average Pressure (psi)

Monitors the average level of pressure in the dispense chamber during dispense. Observing the average pressure difference between the reference and the last cycle enables user to control the dispense quality and be aware when an abnormal event occurs.

Maximum Pressure Time (ms)

Monitors the timing of the peak pressure in the dispense chamber during dispense. Observing the timing difference between the reference and the last cycle enables user to be aware when an abnormal event occurs.

EXPERIMENT

Testing was performed in the Entegris laboratory using an IntelliGen® LV pump with firmware "V1005_987" installed with Impact® 2 OF UPE 3 nm filter. Isopropyl Alcohol (IPA) and 193 nm BARC were used as the process fluids.

The event of weak air supplied to the external stop suckback valve was created by installing a needle valve to the pneumatic line, and then incrementally closing the needle valve to decrease the amount of air going to the valve. The detailed test setup is shown in Figure 1.

Original air pressure supply to the external stop suckback valve was set at 350 kPa (50.76 psi), 300 kPa (43.51 psi) and 250 kPa (36.26 psi) using a pressure regulator. The needle valve was adjusted to the following four conditions at each pressure level: 1) Fully open, 2) ¼ closed, 3) ½ closed, and 4) ¾ closed. The actual air pressure was monitored by a Keyence pressure sensor and the test values of the four confirmation tools of the IntelliGen IG-ULV were observed and recorded.

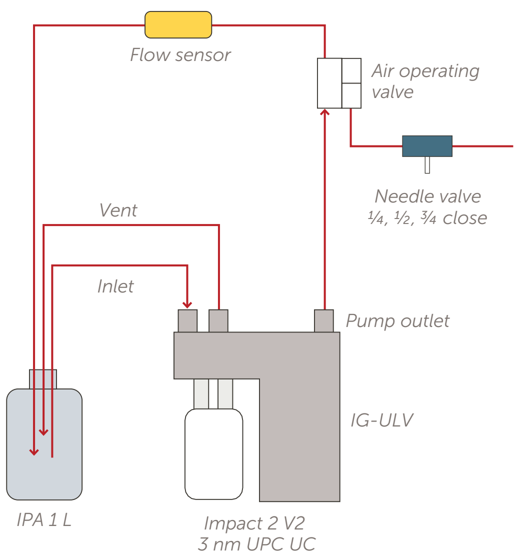


Figure 1. Test setup.

Tubing configuration

Location	ID × length
Bottle to pump inlet	¼" 70 cm
Pump outlet to flow sensor	¼" 50 cm
Flow sensor to air operating valve	¼" 70 cm
Air operating valve to nozzle	2 mm × 100 cm
Vent line	2 mm × 50 cm

RESULT AND DISCUSSION

Test results are divided into two parts, 1) Confirmation whether air supplied to the external stop suckback valve is weakened when the needle valve is closed, and 2) Results of the four confirmation tools: Pressure Profile Compare, Maximum Dispense Pressure, Average Pressure, and Maximum Pressure Time.

1. Confirmation whether air supplied to the external stop suckback valve is weakened when needle valve is closed:

   350 kPa (50.76 psi) is the pressure specification. Normally, users are required to provide this level of pressure to the stop suckback valve. 300 kPa (43.51) and 250 kPa (36.26 psi) are the test cases when air supply is lower than the requirement.

   The confirmation shows that air supplied to the outlet valve starts to become weak when the needle valve (installed at the air line between the pressure regulator and pneumatic valve) is half closed. Figures 2 through 4 demonstrate the pressure monitored by Keyence pressure sensor.

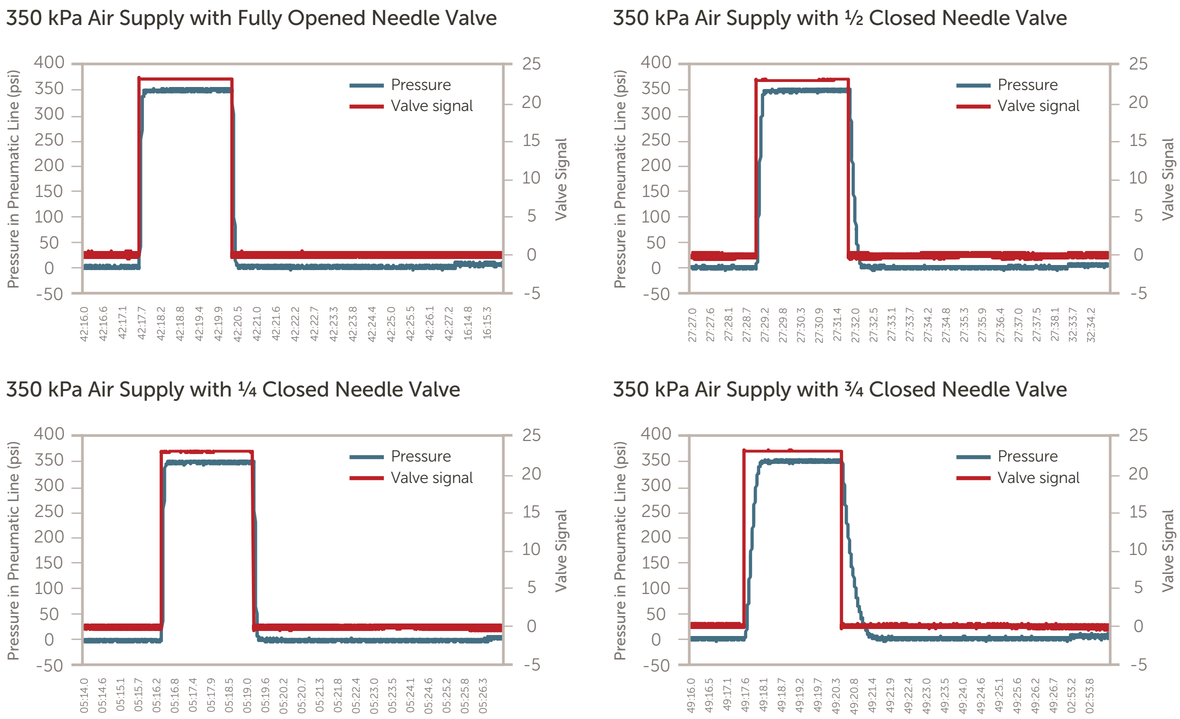


Figure 2. Actual pressure (blue) and valve signal (red) monitored by Keyence at air supply of 350 kPa.

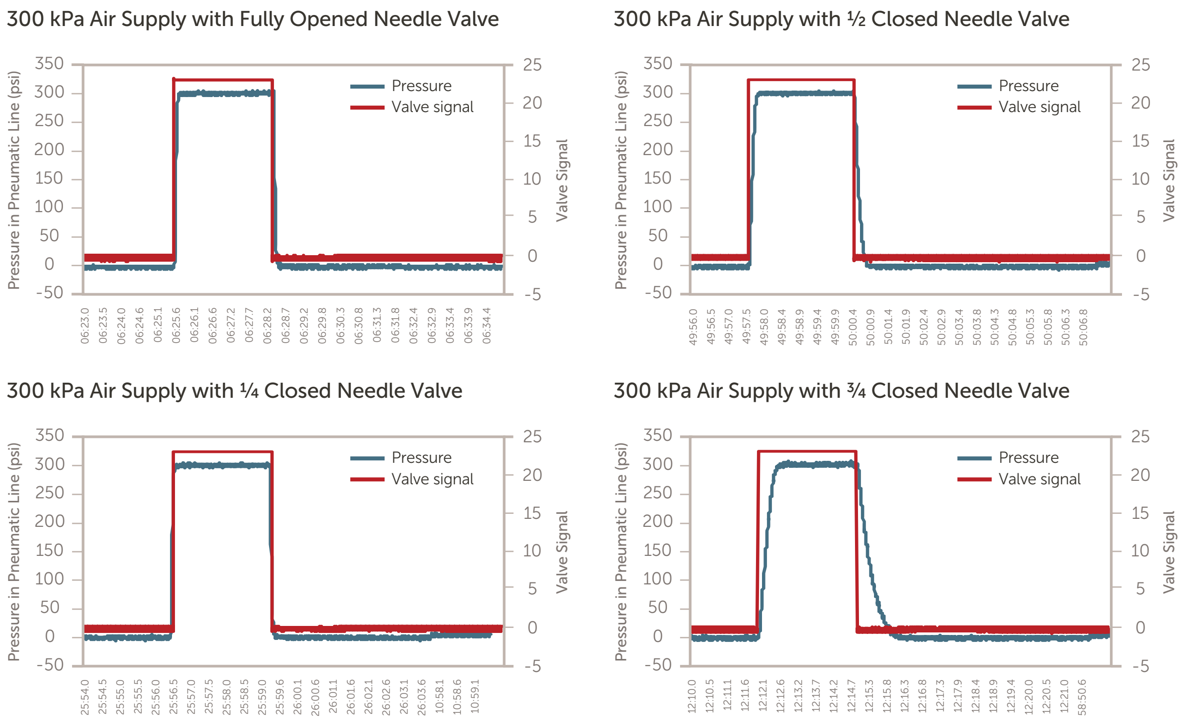


Figure 3. Actual pressure (blue) and valve signal (red) monitored by Keyence at air supply of 300 kPa.

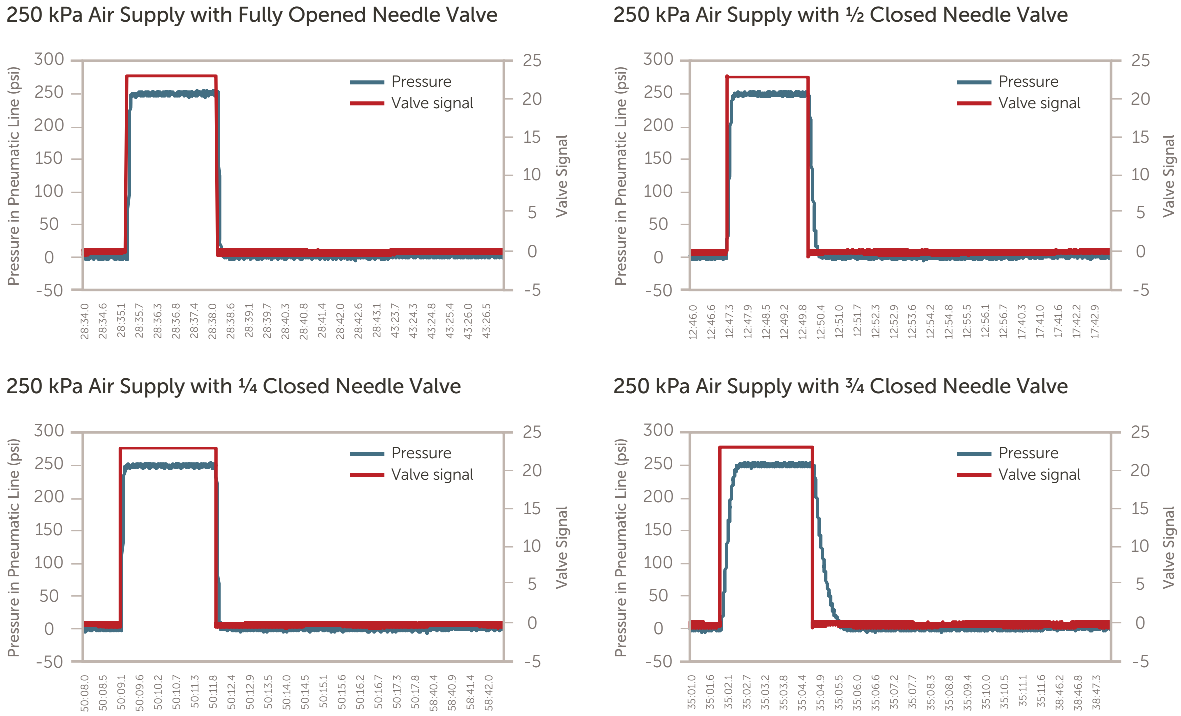
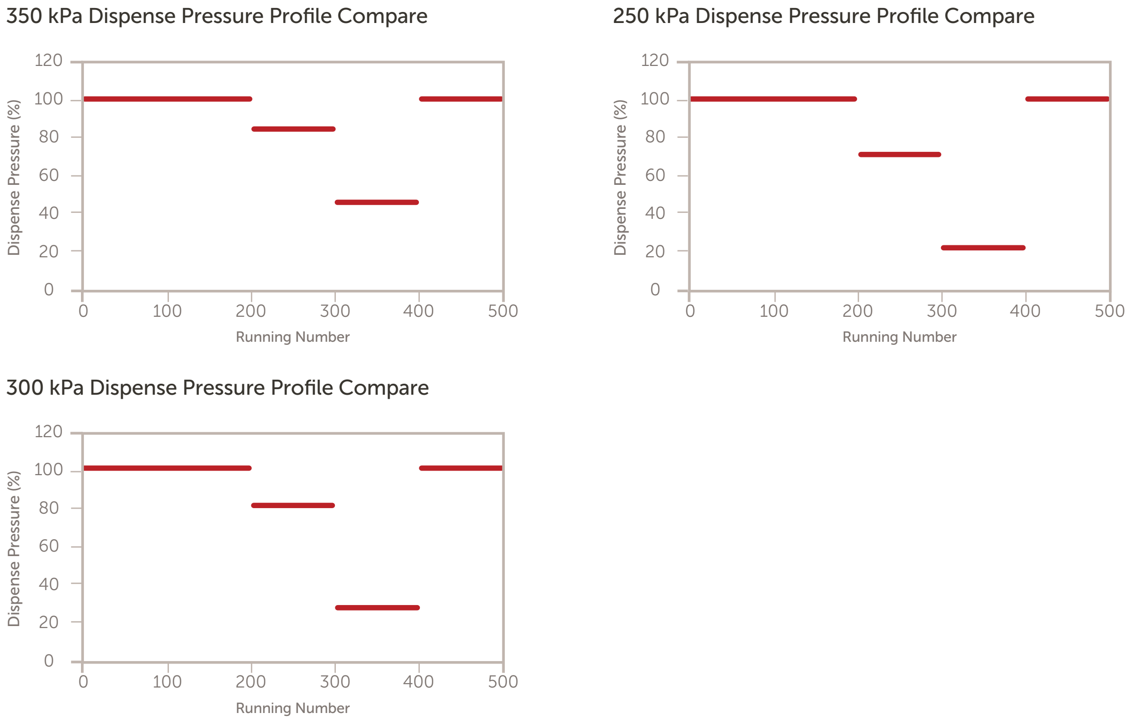


Figure 4. Actual pressure (blue) and valve signal (red) monitored by Keyence at air supply of 250 kPa.

2. Test results of four confirmation tools: Pressure Profile Compare, Maximum Dispense Pressure, Average Pressure, and Maximum Pressure Time.

   Results show that the four confirmation tools give a reliable response to the situation when air supplied to the external stop suckback valve is weaker than the reference situation. Figures 5 through 8 show the test results of Pressure Profile Compare, Maximum Dispense Pressure, Average Pressure, and Maximum Pressure Time at the air supply of 350 kPa, 300 kPa, and 250 kPa, respectively. Figures 9 through 11 show the pressure profile when the needle valve is fully opened, ¼ closed, ½ closed, and ¾ closed, respectively.

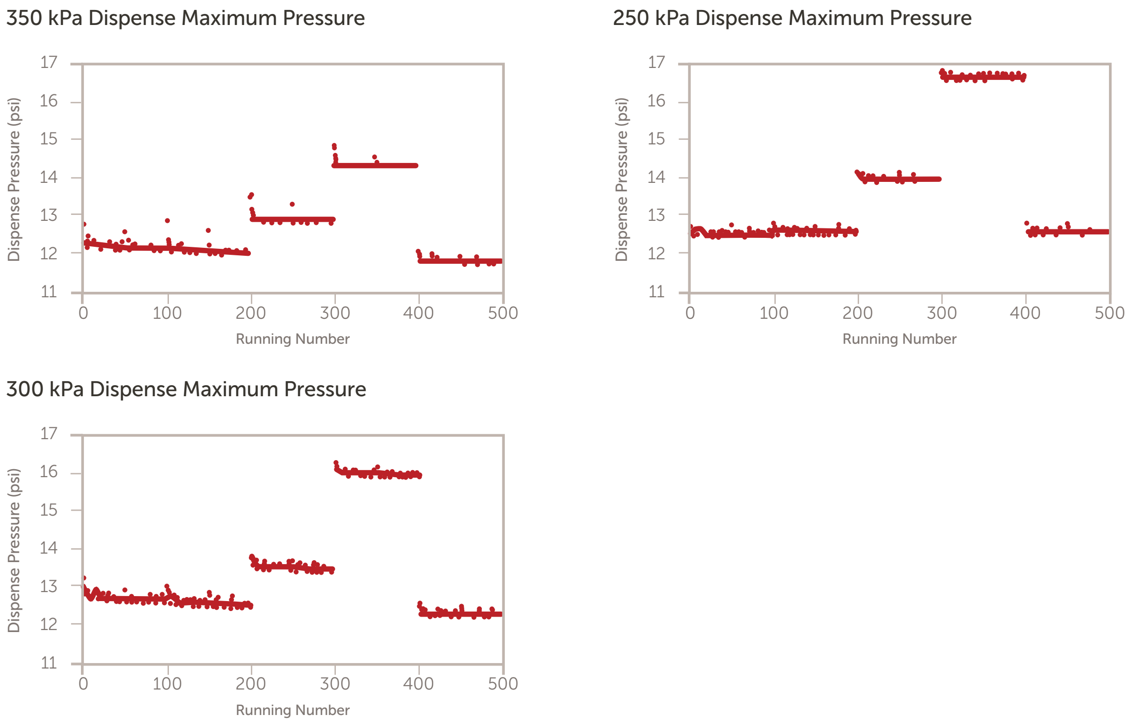


Top: Original air supply is at 350 kPa

Top: Original air supply is at 250 kPa

Bottom: Original air supply is at 300 kPa

Figure 5. Test results of Pressure Profile Compare Confirmation tool; Running No. 1 to 100: needle valve is fully opened, Running No. 101 to 200: needle valve is ¼ closed, Running No. 201 to 300: needle valve is ½ closed, Running No. 301 to 400: needle valve is ¾ closed and Running No. 401 to 500: needle valve is fully opened again.



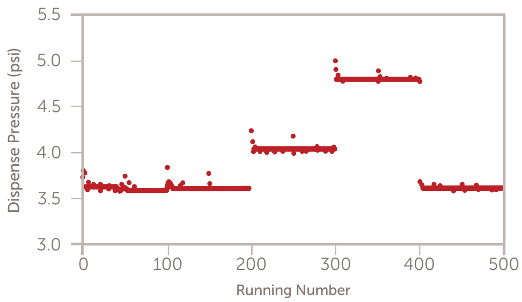
Top: Original air supply is at 350 kPa

Top: Original air supply is at 250 kPa

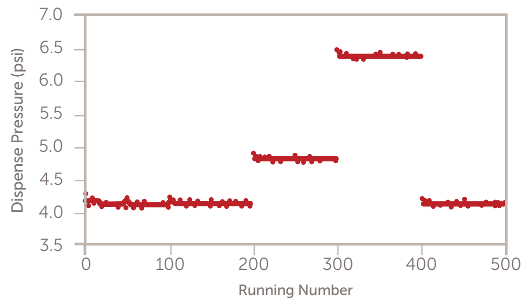
Bottom: Original air supply is at 300 kPa

Figure 6. Test results of Maximum Confirmation tool; Running No. 1 to 100: needle valve is fully opened, Running No. 101 to 200: Needle valve is ¼ closed, Running No. 201 to 300: Needle valve is ½ closed, Running No. 301 to 400: needle valve is ¾ closed and Running No. 401 to 500: needle valve is fully opened again.

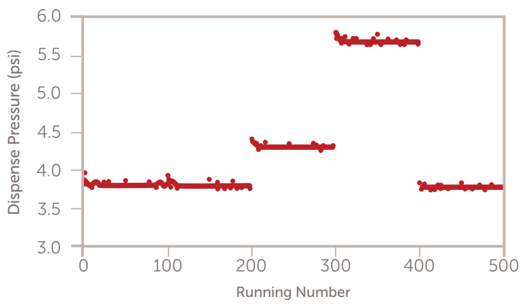
350 kPa Dispense Average Pressure



250 kPa Dispense Average Pressure



300 kPa Dispense Average Pressure



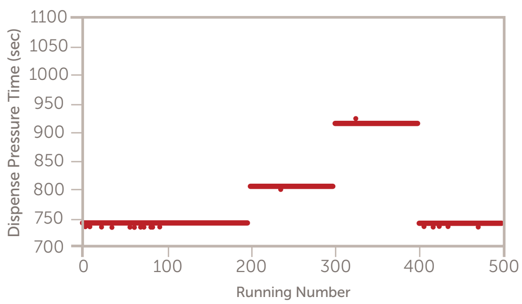
Top: Original air supply is at 350 kPa

Bottom: Original air supply is at 300 kPa

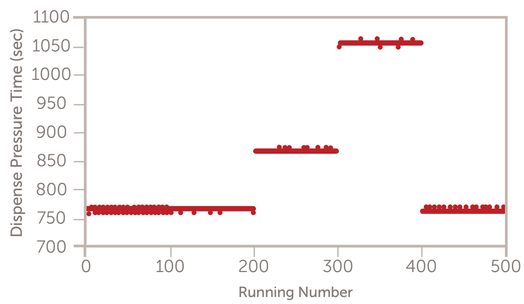
Top: Original air supply is at 250 kPa

Figure 7. Test results of Average Pressure Confirmation tool; Running No. 1 to 100: Needle valve is fully opened, Running No. 101 to 200: needle valve is ¼ closed, Running No. 201 to 300: Needle valve is ½ closed, Running No. 301 to 400: needle valve is ¾ closed and Running No. 401 to 500: needle valve is fully opened again.

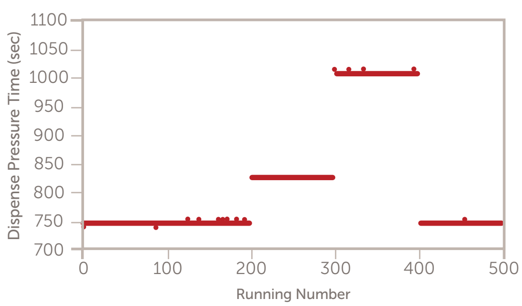
350 kPa Dispense Maximum Pressure Time



250 kPa Dispense Maximum Pressure Time



300 kPa Dispense Maximum Pressure Time



Top: Original air supply is at 350 kPa

Bottom: Original air supply is at 300 kPa

Top: Original air supply is at 250 kPa

Figure 8. Test results of Maximum Pressure Time Confirmation tool; Running No. 1 to 100: needle valve is fully opened, Running No. 101 to 200: needle valve is ¼ closed, Running No. 201 to 300: needle valve is ½ closed, Running No. 301 to 400: needle valve is ¾ closed and Running No. 401 to 500: needle valve is fully opened again.

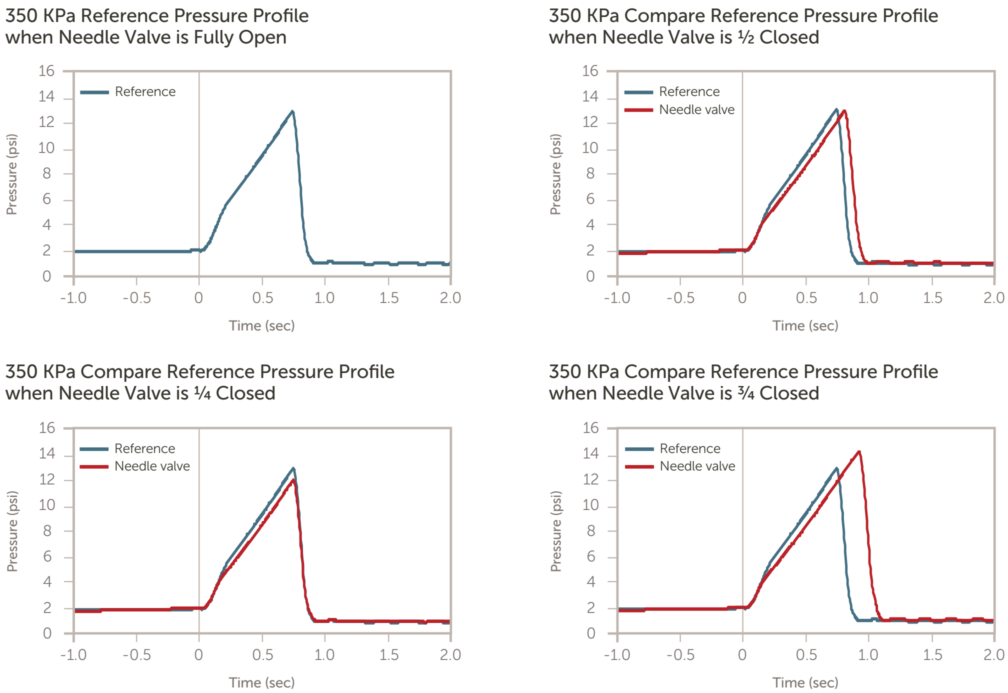


Figure 9. Pressure profile when original air supply is at 350 kPa.

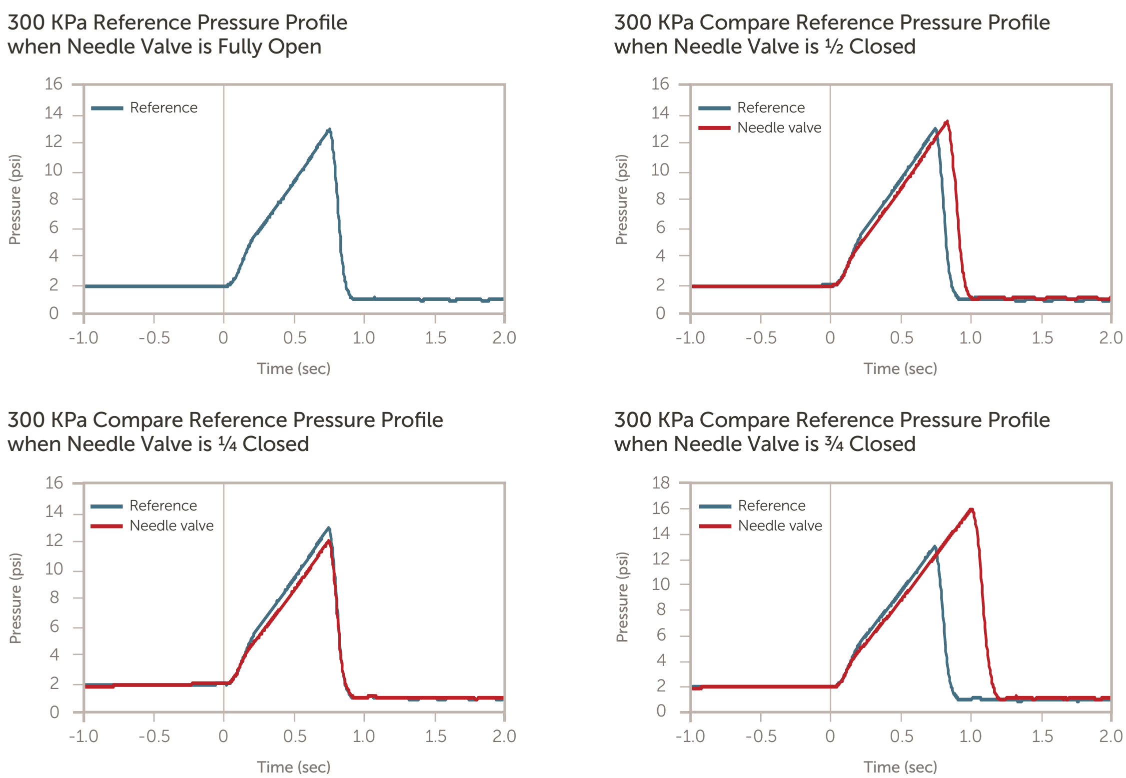


Figure 10. Pressure profile when original air supply is at 300 kPa.

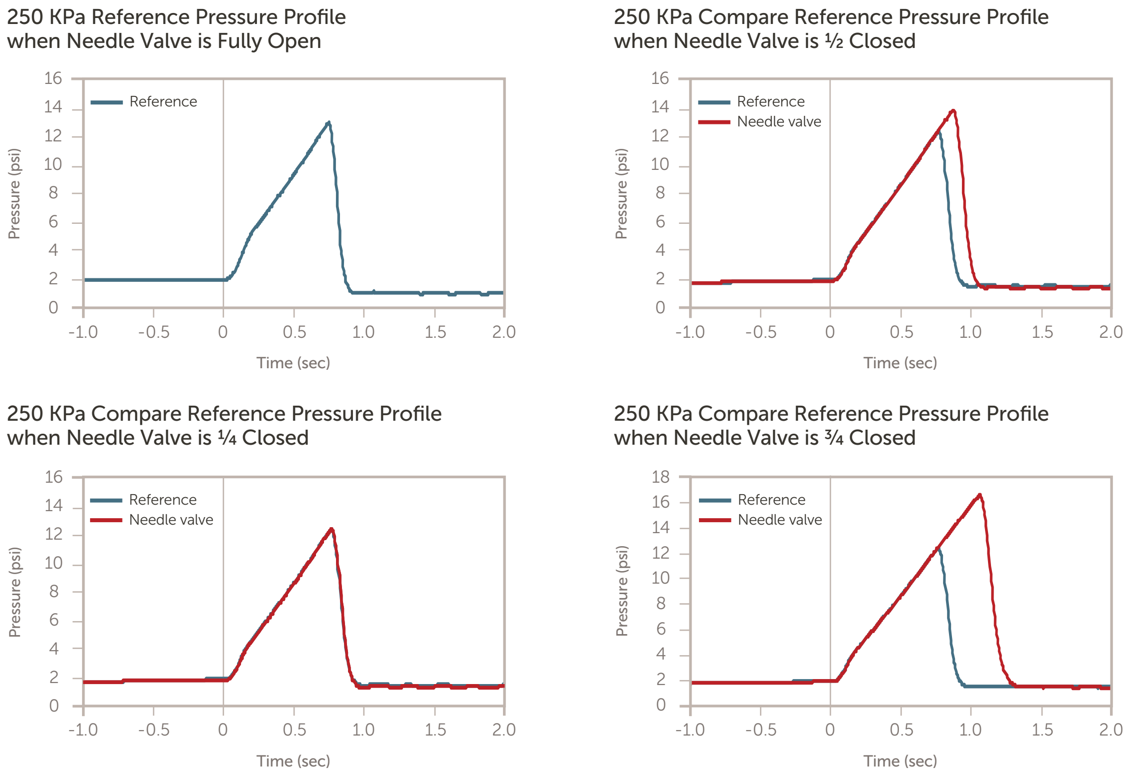


Figure 11. Pressure profile when original air supply is at 250 kPa.

SUMMARY

Among the four pressure sensor based tools, the Pressure Profile Compare showed the most sensitive response when air supplied to the stop suckback valve is weakened. The percentage of Pressure Profile Compare test results drop to 80% from 100% of reference level when air supplied is half of the original level, and 20% – 40% when air supply is one quarter of the original level. Though the setting limit for alarm activation depends upon the user, in general the warning limit is usually set between 80% – 90% and the error limit is between 70% – 80%. The 80% test result is sufficient to activate the alarm, and the 20% – 40% test result is definitely able to activate the alarm.

One can confidently use the Pressure Profile Compare confirmation tool to accurately monitor air supply fluctuations. Figure 12 shows the overall dispense system setup.

Even though they are not the most responsive, the Maximum Pressure, Average Pressure, and Maximum Pressure Time pressure sensor based tools showed a reliable response to this abnormal event. Test results show an obvious and stable change when air supplied to the stop suckback valve is weakened. These three tools could also be used to monitor air supply fluctuations.

SYSTEM LAYOUT

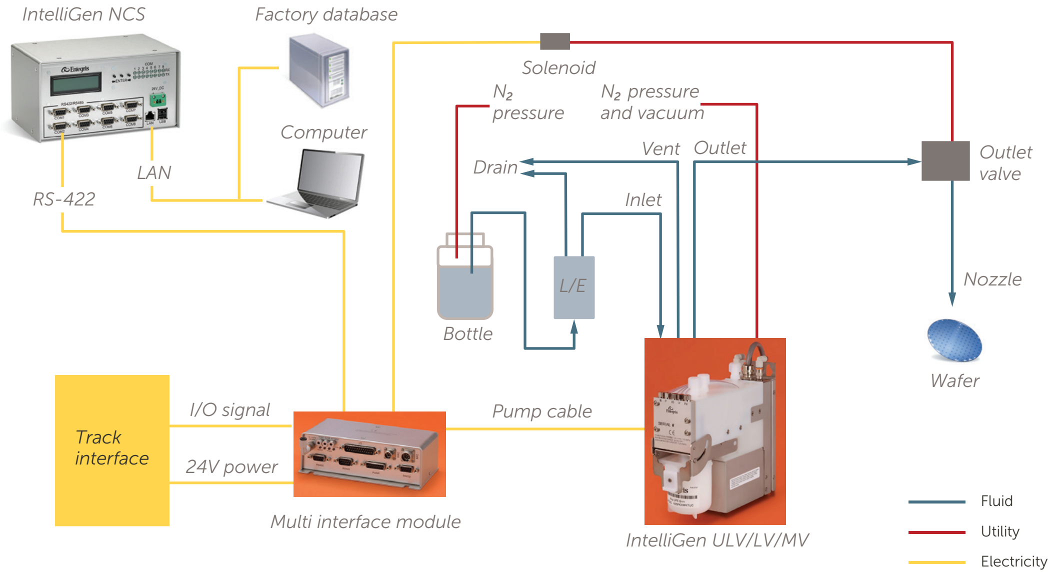


Figure 12. Dispense system setup.

CONCLUSION

Consistent air pressure is critical in maintaining high quality control over chip manufacturing processes. However, it is not easy to establish. Adding an air pressure confirmation tool can help manufacturers better control the wafer coating process. When the ability to monitor and control air pressure increases, wafer yield also increases.

Entegris has an innovative photochemical dispense pump with an integrated pressure sensor. User-friendly MMI software with robust confirmation tools simplifies recipe programming and provides real-time status. The integrated Pressure Profile Compare confirmation tool is featured in the IG-Mini and new pumps IG-ULV, IG-LV and IG-MV, and enables reliable monitoring and control in numerous applications. Implementing a dispense pump with a pressure sensor confirmation tool can help minimize costly wafer defects.

ACKNOWLEDGEMENT

The author would like to thank Entegris colleagues Mitsutoshi Ogawa, application engineer, for engineering the test setup, Tomohiro Wagatsuma, field service engineer, for participating in useful discussion, and Keigo Yamamoto, product manager, for guiding the experiment to completion.

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