

Peristaltic Pumps: An Open Loop Flow Control System

Chemical Mechanical Planarization (CMP) systems typically utilize an open-loop, peristaltic pump control system for delivering slurry to the point-of-use polishing pads (see Figure 1). In many cases, the polishing system flow rate is not directly measured or properly controlled, causing performance, maintenance and accuracy issues.

Fluctuations of slurry flow occur due to changes in supply pressure, the gradual deterioration of the peristaltic pump flexible tubing and other factors. As a result, most fabs report $\pm 10\text{-}20\%$ slurry fluid flow fluctuation as well as occasional no flow conditions that can lead to dry polish and catastrophic wafer loss.

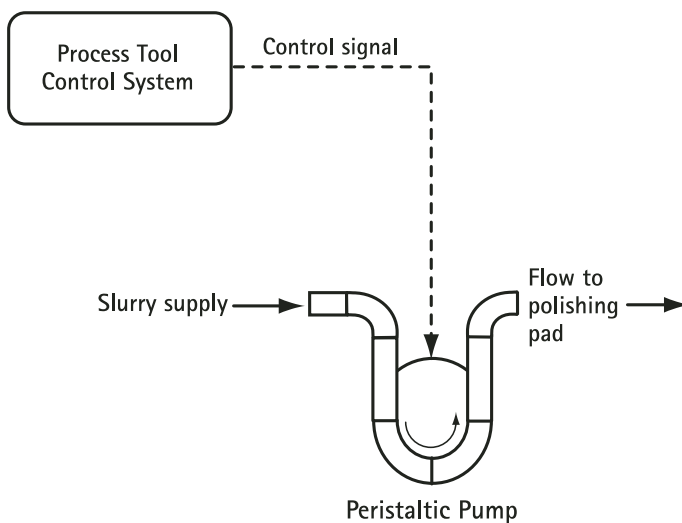


Figure 1. Typical open-loop peristaltic control system.

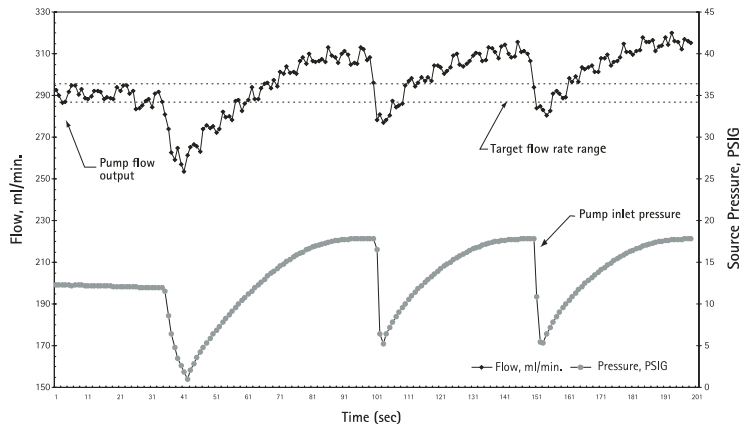
Performance Considerations

- **Defects.** Too little or too much slurry flow may lead to overpolishing or underpolishing, decreasing overall yield rates.
- **Accuracy.** Inconsistent slurry flow rate to the polishing pad due to variable facility supply pressure, resulting in process downtime, excessive slurry use and flow rate variations of 10-20%.
- **Chemical Consumption.** Using peristaltic pumps, many fabs use excess slurry flow to ensure that the minimum slurry flow is maintained, resulting in valuable slurry loss and chemical waste.
- **Yield.** Wafer scrap and loss due to catastrophic failure from the lack of feedback alarms on original manufactured CMP equipment.
- **Contamination.** Peristaltic pump tubing degradation and wear, resulting in particle shedding of the soft polymer tubing material and becomes a source for wafer defects.
- **Maintenance.** Pump repair and replacement time and costs, including tubing replacement and calibration issues.

Flow Variation Causes

Fluid flow fluctuations affect accuracy, yield, defects, chemical consumption, contamination and maintenance. The factors that cause fluctuations in slurry flow from peristaltic pumps include:

- Changes in supply pressure
- Tubing degradation

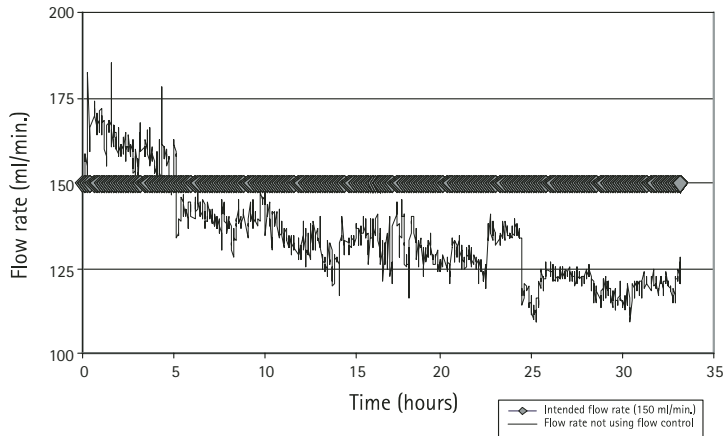


Graph 1: Flow rate varies due to inlet pressure changes while the peristaltic pump operates at constant speed.

Changes In Supply Pressure

Graph 1 illustrates the instantaneous variation of fluid flow due to inlet pressure changes while a peristaltic pump operates at a constant speed. Notice the variation from the target flow rate.

In turn, these pumps require frequent calibration to correlate flow rate and pump speed, while flow of slurry to the polishing pad may vary as much as 10-20% due to variations in facility operating pressures.



Graph 2: Flow rate varies due solely to peristaltic pump tubing wear while the pump speed and feed pressure remain constant.

Tubing Degradation

Graph 2 illustrates the long term deterioration of the fluid flow due solely to gradual deterioration and deformation of the peristaltic pump tubing flexible during the first 30+ hours of use. The pump speed and feed pressure remained constant during the 30+ hours of operation.

The Solution: A Closed-Loop Flow Control System

Installing a closed-loop flow control system enables users to increase the reliability and performance of the CMP slurry delivery system and process tool overall performance.

Using an automated flow control system with direct flow and pressure measurements provides the following advantages:

- Eliminates the need for frequent pump calibrations and increases tool uptime
- Maintains a constant flow of slurry to the polishing pad at the desired flow rate
- Allows for process optimization during each process step by controlling slurry flow
- Provides process alarms for low- or no-flow conditions
- Provides process alarms for low inlet pressure
- Minimizes slurry, chemical and DI water waste



NT® Integrated Flow Controllers.

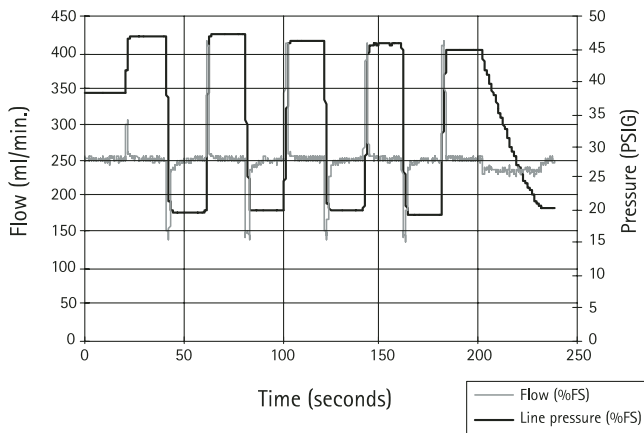
NT® Integrated Flow Controller – Closed Loop Control System

The NT® Integrated Flow Controller uses direct flow and pressure measurement for automated dispense control. It comprises three sub-components: a differential pressure flowmeter with no moving parts, a stepper motor actuated diaphragm control valve that minimizes movement, and control software that regulates valve position based on the desired flow and actual flow conditions.

The flow controller receives the same control signal that is used to control the peristaltic pump, thus the process upgrade is easy to perform and is not intrusive.

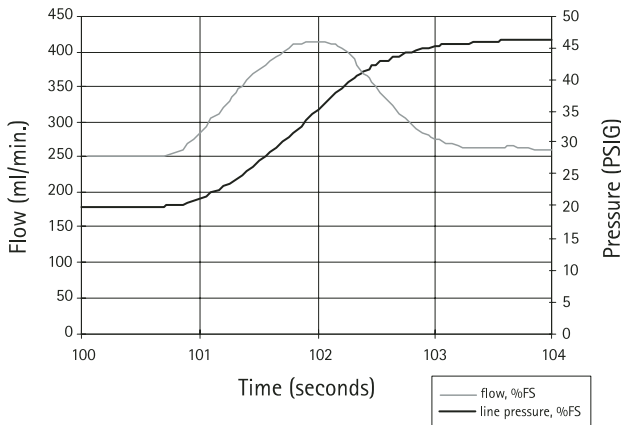
Without manual calibration, the NT® Integrated Flow Controller achieves the desired flow rate at the user's flow set-point during inlet pressure changes (see Graph 4). The unit has 1% full scale flow accuracy and response time to set-point changes or feed pressure changes within <3 seconds.

NT® Integrated Flow Controller Response to Step Change in Line Pressure



Graph 4: Flow rate is controlled within a three second response time despite significant changes in feed pressure.

NT® Integrated Flow Controller Response to Step Change in Line Pressure (Close-up of one transition point)



Graph 5: Close-up of one transition point from Graph 4.

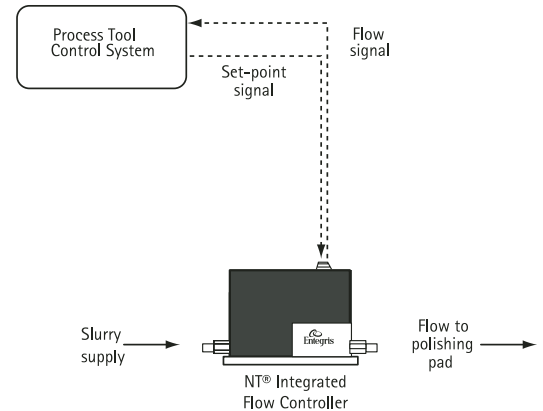


Figure 2: NT® Integrated Flow Controller replacing the peristaltic pump for closed loop slurry flow control.

Sensing And Control Solutions

Experienced in sensors, electronics and process instrumentation, Entegris utilizes proven measurement techniques, cleanroom product assembly and Class 100 work surfaces for all measurement products. Also, for protection against corrosive fumes, the internal electronics are fully encapsulated.

Entegris designs and manufactures measurement instruments for the high purity and corrosive chemical environments of the semiconductor industry. Our products measure flow, pressure and level for the various acids, caustics, solvents and slurries used in the industry.

For More Information

For more information on CMP filtration products or our complete line of fluoropolymer fluid handling solutions, contact your local Entegris distributor or Entegris, Inc.

To review our complete line of sensing and control product solutions or to calculate your labor, materials and slurry savings by replacing peristaltic pumps, visit Entegris' Web site at www.entegrisfluidhandling.com or contact Entegris Customer Service.

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ENTEGRIS, INC.

Corporate Headquarters / 3500 Lyman Boulevard / Chaska, Minnesota 55318 USA
Customer Service Tel. 763-502-0200 or Toll Free 877-503-0200 / Customer Service Fax 763-502-0300
www.entegris.com / www.entegrisfluidhandling.com

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