Slurry Pump Affects on CMP

Leland Bauck, Robert Donis
CMP Department, LSI Logic Manufacturing Services, Inc.
Fab O1 Operations, Gresham, OR

E-mail : lbauck@lsil.com, rdonis@lsil.com

Abstract – Slurry pump types impact slurry particle size distribution as well as CMP process performance. This paper has two parts. Part 1 is a comparison of two slurry pump types tested on a production CMP oxide slurry distribution system. The performance of a Levitronix® bearingless pumping system (BPS) is compared to a bellows pump. Part 2 is a comparative study of the effects between a point of use bearingless pumping system and a point of use peristaltic pump system tested on a 200mm Novellus Momentum™ CMP oxide tool and a 200mm Applied Materials® MirraMesa™ copper CMP tool.

The BPS pump tested on the oxide slurry distribution system showed a 28 percent reduction in particles at 800nm and better than 50% reduction in particles greater than 1 micron. The BPS point of use system tested on the oxide CMP process showed flatter removal rates above 2000 Å/min than the peristaltic pump system. Blanket wafer non-uniformity results were less than 4.5% at slurry flow rates ranging from 20mL/min to 280 mL/min. BPS blanket copper removal rates at 50 mL/min were 2500 Å/min higher than the peristaltic pumps. Tantalum blanket wafer non-uniformities were less than 5.7% on slurry flow rates ranging from 50 mL/min to 250 mL/min.

Keywords : CMP, Levitronix®, Slurry, Pump

1. DISTRIBUTION PUMPS

1.1. Introduction

Pump types used in re-circulating CMP slurry distribution systems have a significant affect on the stability of particle size distribution in colloidal slurries. A study completed by CT Associates, Inc. show that BPS3 centrifugal pumps have little effect on large particle concentrations in colloidal oxide slurries in a typical production CMP distribution system [1].

Further studies show that BPS3 pumps generate significantly fewer particles than diaphragm or bellows type slurry distribution pumps. Tests completed on slurry distribution filter lifetimes show the rate of pressure drop across slurry filters in a slurry distribution system pressurized by diaphragm and bellows pumps were 9 and 23 times higher than a BPS3 pump [2].

Part 1 is a comparison between a Levitronix® bearingless pumping system (BPS) and a bellows pump tested on a production CMP oxide slurry distribution system to determine if the BPS system generates fewer particles.

1.2. Experimental

Figure 1 shows the oxide slurry distribution system configuration. A Mykrolis CMP9 filter was used. The pump outlet pressure was approximately 1.4 bar. Slurry samples were collected and analyzed once per week for 25 weeks to baseline the bellows pump performance.

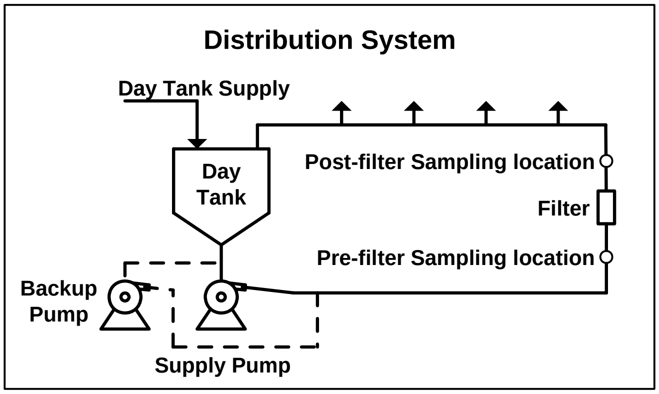

Figure 1. Slurry Distribution System Configuration

The distribution pump was then transferred over to a Levitronix® BPS3 pump in the backup location without taking the distribution system offline. Slurry samples were collected weekly for 14 weeks.

The slurry was sampled at the post filter sampling locations for both pump types. Slurry large particle data was analyzed on a PSS NICOMP Accusizer 7080A.

1.3. Results and Discussion

The 25 week average number of post filter slurry particles sampled during the bellows pump operation is shown in Figure 2. The 14 week particle average for the BPS pump is also shown. The bellows pump percent particle decrease is also shown.

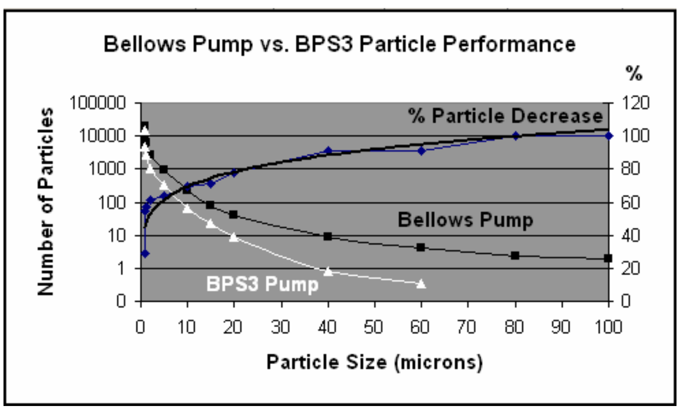

Figure 2: Average Post Filter Large Particle Data of Bellows and BPS3 Oxide Slurry Distribution Pumps

For each particle size measured, the BPS slurry pump generated fewer particles. The BPS pump showed a 28 percent reduction in particles at 800nm and better than 50% reduction in particles greater than 1 micron.

Slurry filters were replaced during scheduled maintenance only. The filter was not changed when the pump was upgraded. Post filter particle data did not shift as a result of filter changes.

2. Point of Use Slurry Pumps

2.1. Introduction

Point of use slurry pumps are used to provide the mechanical force necessary to accurately deliver slurry from a slurry supply to individual wafer polishing modules. Peristaltic pumps are typically used for POU CMP wafer polishing applications. Peristaltic pumps are also used for applications where chemical cleanliness, low volume, and accurate fluid flows are required. Peristaltic pumps are also self priming, and work well in high viscosity applications.

Figure 3 shows how a peristaltic pump works. Fluid enters the pump through a soft flexible tube on the inlet side. Fluid is forced through the tube to the outlet side by a squeezing action created between the pump housing

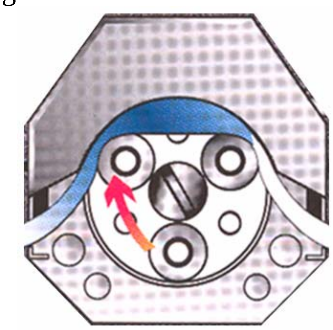

Figure 3. Peristaltic Pump [3].

and a set of rotating rollers. Fluid flow rate is controlled by the RPMs of a motor drive shaft connected to the rollers, or pump head.

Peristaltic pumps present many drawbacks for CMP applications. As technology nodes become smaller, CMP tool recipes are more dependent on precise slurry flows. Slurries are also one of the more expensive consumable items for any wafer manufacturing facility. Significant cost savings can be achieved by lowering CMP slurry flow rates. To achieve this, flow accuracy becomes extremely important.

Peristaltic pumps are not well suited for the high accuracy low slurry flow CMP applications. It is true peristaltic pumps generate accurate flow rates. However, flow rates are usually measured over a very long time frame, typically 30 to 60 seconds. This is a considerable timeframe on a CMP tool polishing at a 2500 Å/min material removal rate. If slurry flow is measured once per second for 60 seconds, the flow accuracy change is cyclical, and only accurate 3 times during one revolution of the pump head. This is called flow surging, and is created as each roller squeezes a short burst of slurry through the tube, followed by the roller, another burst of slurry, and so on. This flow surging causes a non-uniform slurry delivery to the wafer surface.

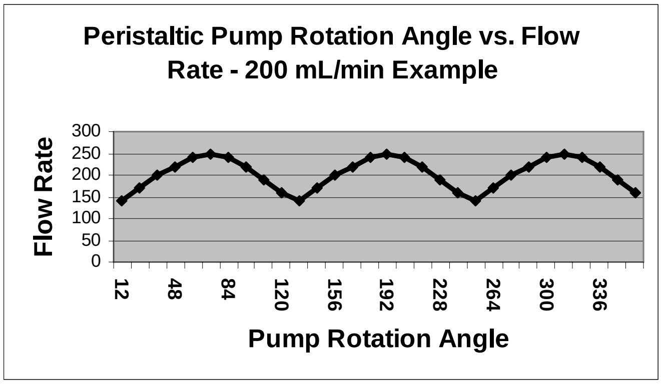

Figure 4. Peristaltic Pump Flow Rate vs. Pump Angle

Figure 4 shows an example of what the output flow rate might look like at 200 mL/min. The magnitude of the surging is a function of inlet pressure and pump speed. Even if smaller peristaltic pump heads are used with smaller diameter tubes, the flow rate will still be cyclical, not constant.

Peristaltic pump flow rates are also dependant on slurry inlet pressures. A small change in inlet pressure can create a significant change in the output flow rate. Depending on the pump head, tubing size used, and initial inlet pressure, a pressure variation of only 80 millibar at the pump inlet can cause a 4% shift in process flow rates measured for 60 seconds.

Peristaltic pump flow rates also increase as the pump tubing wears. As a result, peristaltic pumps require frequent calibrations and tubing changes to maintain their flow rates.

Part two of this paper is a study of the effects a constant slurry flow bearingless pumping system has on CMP removal rates (RR) and post polish wafer non-uniformity (NU) in comparison to peristaltic pumps.

2.2. Experimental

Peristaltic pumps were compared to BPS1 closed loop flow control pumps on two separate polishing machines and applications. Experiments were performed on a 200mm Novellus Momentum™ oxide polisher, as well as an Applied Materials® 200mm MirraMesa™ copper polisher.

The Momentum™ polisher is an orbital polishing system where slurry is delivered up through the center of the pad. This allows slurry to be delivered directly to the process area. Each polish module is independent and consists of one wafer head and one polish head.

Tool Type	Pump Type	Variable	Process	Output
NVLS	PP	Flow Rate	Oxide	Process Curves
AMAT	PP	Flow Rate	Copper	Process Curves
AMAT	PP	Flow Rate	Barrier	Process Curves
NVLS	BPS1	Flow Rate	Oxide	Process Curves
AMAT	BPS1	Flow Rate	Copper	Process Curves
AMAT	BPS1	Flow Rate	Barrier	Process Curves

Table 1. Experimental Setup

The MirraMesa™ is a 3-platen polishing system with four wafer heads. Slurry is delivered on the top of the pad. Grooves in the retaining ring and polish pad, along with rotating platens move slurry to the process area. For this copper application, each wafer head polishes on each platen one time during the process.

The BPS1 pump operating in flow control mode provides each polish module a constant slurry flow source with 1% flow accuracy.

Blanket wafer experiments were initially performed on each tool set to determine a baseline data set for the peristaltic pumps. Both tool sets were then upgraded with Levitronix® BPS1 closed loop flow control systems. The blanket wafer experiments were then repeated. Table 1 shows the experimental setup. Multiple wafers were processed to verify the accuracy of the results.

2.3. Results and Discussion

The experimental results comparing the peristaltic pump performance to the BPS1 pump on the Novellus Momentum™ polisher are shown in Figure 5.

The BPS1 non-uniformity (NU) curve is very flat in comparison with the peristaltic pump NU curve. The removal rate curves are very similar. However, the BPS1 removal rate is slightly flatter and more consistent than the peristaltic pump removal rate curve above a flow rate of 60 mL/min.

The major point of interest in this data is the almost flat BPS1 NU curve from 20mL/min to 280mL/min. Although the flow rates were identical, the peristaltic pump NU rises sharply at the low end and begins to steadily climb at 160mL/min.

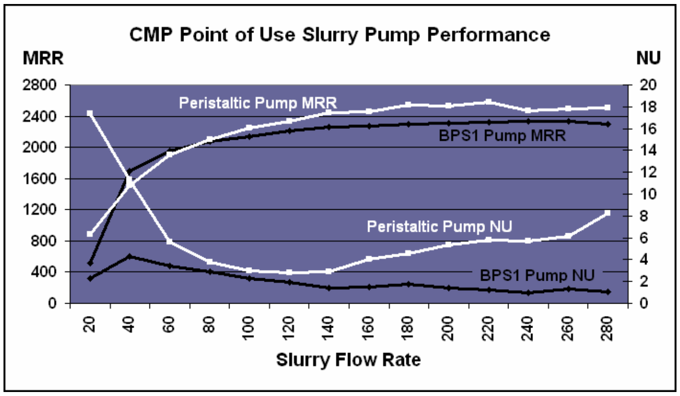

Figure 5. Peristaltic vs. BPS1 Novellus Momentum™ Oxide Process Results

A theory that could explain this phenomenon is the flow surging caused by the peristaltic pump. At low RPMs, the peristaltic pump is turning too slow to delivery slurry at a constant rate to feed the process. In this case, the polishing process would be subject to slurry starvation at regular intervals, which align with the pump head angle delivering the minimum output. In this case, the NU cutoff flow rate is approximately 60mL/min with a peristaltic pump. This is unfortunate, because the removal rate curve is still high enough to achieve a low slurry flow process.

Since the BPS1 is a constant slurry flow source, slurry is delivered to the process area uniformly at the lower flow rates. This causes the wafer to polish uniformly, even at 20mL/min. This allows a larger process window with respect to flow rates, because the process is not limited by a high NU curve at lower flow rates.

At the other end of the NU curve, the peristaltic pump NU acts opposite of the BPS1 NU curve. A high surging pressure caused by the peristaltic pump at high flow rates is one explanation for this. When the peristaltic pump angle delivers a surge of slurry, the slurry pressure under the wafer can possibly become high enough to create a small separation between the pad and the wafer surface. Any such separation could force more slurry particles between the wafer and the polish pad. This would explain the higher more inconsistent removal rate of the peristaltic pump at the higher flow rates.

The experimental results comparing the peristaltic pump performance to the BPS1 flow control system on the Applied Materials® MirraMesa™ polisher are shown in Figures 6 and 7.

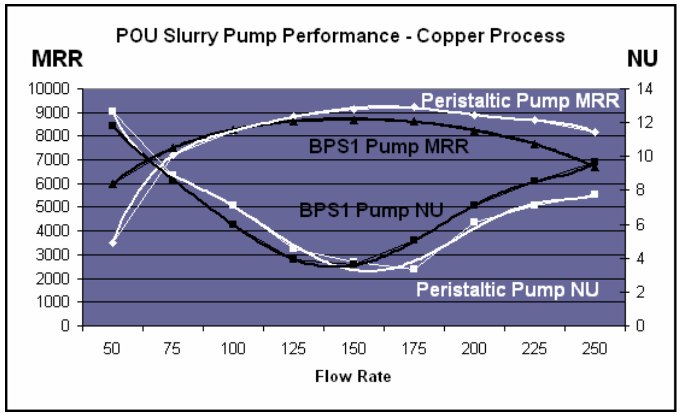

Figure 6. Peristaltic vs. BPS1 Applied Materials® MirraMesa™ Copper Process Results

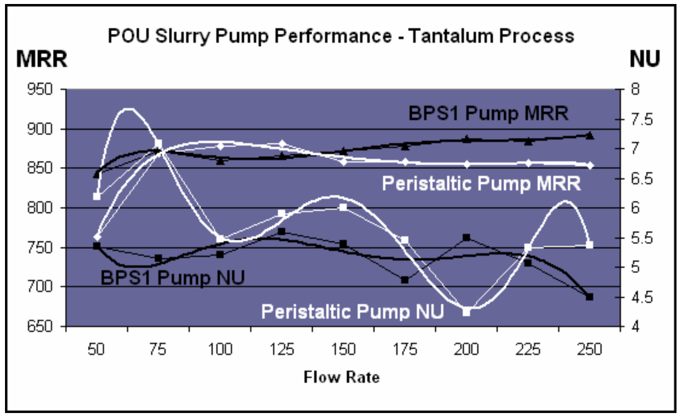

Figure 7. Peristaltic vs. BPS1 Applied Materials® MirraMesa™ Tantalum Process Results

The results between the peristaltic pump and the BPS1 pump on the MirraMesa™ copper process (Figure 6) are very close. At 50mL/min, the BPS1 removal rate is approximately 2500 Å/min higher. Like the Novellus tool, the low slurry flow high removal rate is only achievable with a constant flow pump. In this case, the flow rate cutoff point is determined by the process NU curve, which is about 75mL/min.

The results between the peristaltic pump and the BPS1 pump on the MirraMesa™ tantalum nitride process differ, especially the NU process curve. Like the other cases, the BPS1 removal rate is higher at the lower flow rate. The BPS1 NU process curve is also more stable than the peristaltic pump curve.

3. CONCLUSION

The BPS3 slurry distribution pump was shown to generate less post filter particles than a bellows pump in a recirculating production oxide slurry distribution system. Compared to a bellows pump, the BPS3 pump generated 28 percent fewer particles at 800nm and 50% few particles greater than 1 micron.

The BPS1 slurry pumps tested on a Novellus Momentum™ CMP tool were shown to create flatter removal rates above 2000 Å/min than the peristaltic pump system. Blanket wafer non-uniformity results were less than 4.5% at slurry flow rates ranging from 20mL/min to 280 mL/min. The material removal rates were almost identical. However, the improved process NU allows the capability for a lower flow rate process due to a larger process window.

BPS1 pumps tested on the Applied Materials® CMP tool had blanket copper removal rates 2500 Å/min higher than peristaltic pumps tested at 50 mL/min.

BPS pumps benefit recirculating slurry distribution systems as well as point of use slurry systems for CMP applications. Fewer particles in a slurry distribution system can help reduce CMP scratching. For the point of use systems tested, improvements in the process NU and removal rate curves existed. Maintaining a constant process operating point on the NU and removal rate curves is important. The BPS pumps are better suited for accurate and repeatable results.

ACKNOWLEDGEMENTS

The authors would like to thank Levitronix® for providing technical support and installation of the bearingless pump systems. Technical expertise and installation from Gary Rawson is also acknowledged.

REFERENCES

[1] M. Litchy, D. Grant, “The effect of a Levitronix BPS-3 Bearingless Pump System of SemiSperse® 12 particle size distribution,” CT Associates, Inc., March 2003.
[2] M. Litchy, R. Schoeb, “Effect of Particle Size Distribution on Filter Lifetime in Three Slurry Pump Systems,” CT Associated, Inc., Levitronix GmbH, (nd).
[3] Available at: http://www.coleparmer.com.