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Effect of pump-induced particle agglomeration on CMP

EXECUTIVE OVERVIEW An investigation of pump-induced large particles and their impact on computer hard drive substrate CMP (chemical mechanical polishing) is summarized. Experiments have been performed to measure the particle agglomeration tendency during various pumping processes. The surface quality of NiP/Al substrates after CMP has been directly linked to the presence of these particles. The mechanism for formation and growth of these large particle sizes is elucidated in this study.

With low operating height of reading head to disks, microscratches, pits, and other micro defects on media surfaces, which may damage the data stored on the disk's magnetic coating, should be decreased to minimum in order to avoid read head crash [1]. A myriad of factors, such as strong chemical effect, pad, and polisher settings, are involved in producing defects on substrates in the CMP process.

Recently, the correlation between oversized particles contamination in slurry and formation of microscratches and pitting has been reported in semiconductor device fabrication [2]. Although a detailed mechanistic understanding of this process remains elusive, a clear link has been established between the presence of large particles and the level of defects. To quantify such a correlation, a series of new analytical methods and techniques for the characterization of the abrasive particles and other consumables in CMP slurries has been invoked [3]. To minimize the negative effect of oversized particles on CMP, slurry manufacturers and end users have started to pay attention to the slurry delivery and handling [4,5]. However, reports on the direct correlation between pump-induced oversized particle and specific defects in CMP have been scattered. The objective of this study is to illustrate the effects of a magnetically levitated centrifugal (MLC) pump and a bellows pump on particle agglomeration. Moreover, the performance of treated slurry is tested in NiP/Al rigid disk substrate polishing. The results reveal that use of a bellows pump leads to a significant increase in the number of oversized particle in the slurry during circulation. In polishing tests, the pump-induced oversized particles are directly linked to microscratches on disk substrates.

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Pump-induced particle agglomeration

Magnetically levitated centrifugal (MCL) pumps, which transfer energy to a fluid through a spinning impeller, impart kinetic energy to the fluid handled. This is converted into pressure through diffusive action in the pump casing. MCL pumps have the advantage of seal-less design due to their air floating magnetically levitated impeller design.

After it was circulated for a certain period of time with a pumping system, the slurry was analyzed with particle sizing instruments, including light scattering [6] and acoustic spectroscopy [7]. To quantify the number of large particles, we used Accusizer or single particle-optical sizing technique (SPOS). SPOS exhibits the high sensitivity required to quantify the fraction of slurry particles constituting the large particle count of a CMP slurry [8]. In addition, we used the Micro-Flow Imaging (MFI) system from BrightWell Technologies Inc. The MFI platform integrates micro-fluidics, optical assemblies, digital image acquisition, and image analysis algorithms to rapidly and accurately measure the physical properties of cell or particle populations (size, shape, transparency, count, and concentration). Post-processing and filtering capabilities are available, and results are displayed or exported in a variety of formats [9].

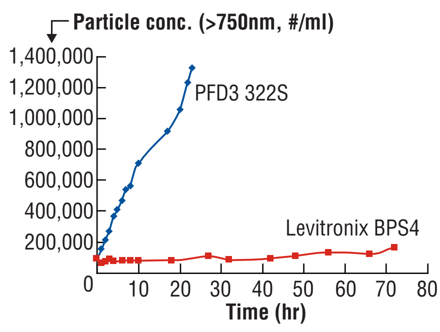

Figure 1. Increase of oversized particle in 12.5% SemiSperse25 (Cabot, Diameter: ~160 nm) processed with different pump (Levitronix BPS4 VS. PFD3 322S).

Figure 1 shows the growth of oversized particles in 12.5% Semi-Sperse 25 (Cabot Microelectronics Corp.) during a circulation process using two types of pumps. With the PFD3 322S bellows pump system, the concentration of oversized particle (>750nm) increases from 8.5×10^4 particle/ml to 1.3×10^6 particle/ml after 23 hours. The oversized particle count increases almost linearly with circulation time. With the Levitronix BPS-4 system, the number of oversized particle count is relatively stable even after 72-hour circulation, lower than 2×10^5 particle/ml for

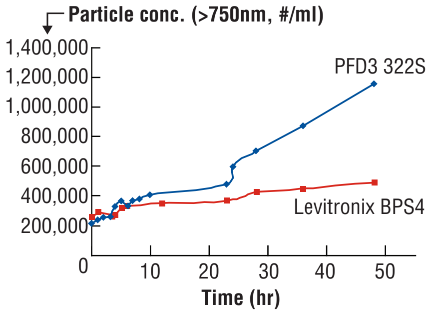

Figure 2. Increase of oversized particle in 20% BindZil EF70515 (Eka, Diameter: 70-80 nm) processed with different pump (Levitronix BPS4 VS. PFD3 322S).

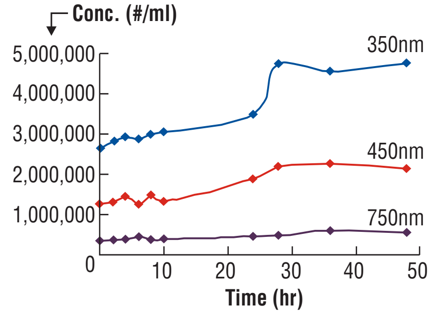

Figure 3. Increase of large particle with different thresholds in 20% BindZil EF70515 (Eka, Diameter: 70-80 nm) pumped with PFD3 322S.

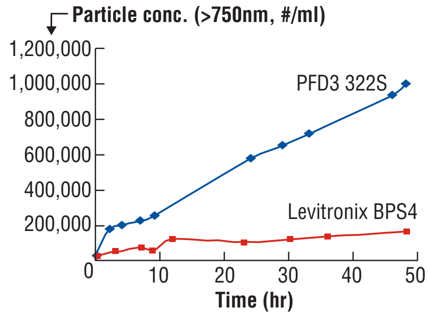

Figure 4. Increase of oversized particle in 15% NexSil 12 (NYACOL, Diameter: 30-40 nm) processed with different pump (Levitronix BPS4 VS. PFD3 322S).

particles larger than 750nm. When you use BindZil EF70515 as a model slurry, the higher growth rate of oversized particle was also observed in the PFD3 322S bellows pump system (**Fig. 2**).

Upon closer examination of the trends for large particle growth at different thresholds (350nm, 450nm, 750nm), a higher growing rate is observed for lower thresholds, as shown in **Fig. 3**. During 48-hour circulation, concentration of particles larger than 350nm increases from 6×10^5 p/ml to 4.8×10^6 p/ml. Growth rates for 450nm and 750nm particles are slower, from 1×10^6 to about 2.2×10^6 and 4×10^5 to 5×10^5 separately. This difference reveals that the growth of oversized particles in slurry from small particles may be a stepwise process.

For NexSil 12 colloidal silica from NYACOL, the oversized particle (750nm) in a bellows pump system goes up to 1×10^6 p/ml, while this number in the Levitronix BPS-4 system stays below 2×10^5 p/ml (**Fig. 4**).

As shown in **Fig. 5**, large particle counts with thresholds of 350nm and 450nm for NexSil 12 show similar trends. More specifi-

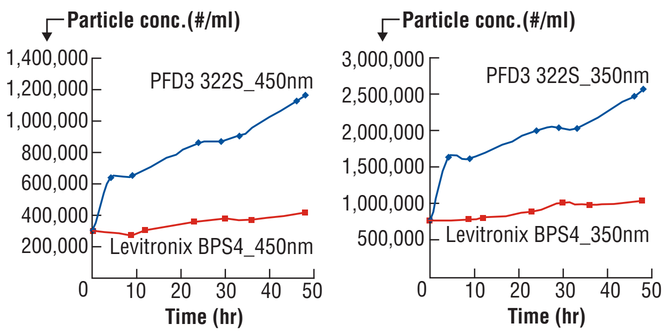

Figure 5. Increase of large particle with different thresholds in 15% NexSil 12 (NYACOL) processed with two pump systems (Levitronix BPS4 VS. PFD3 322S).

cally, there is a significant increase in large particles >350nm or 450nm using the Bellows pump while the numbers stay low in the Levitronix BPS4 system.

Effect of oversized particle on NiP/Al polishing

Limited reports can be found in literature on the correlation between the number of oversized particles in slurry and CMP defects [11,12]. These particles have been identified as micron-size, hard, and irregularly shaped aggregates of abrasive particles. It should be noted that the researcher artificially added these extra large particles into the system; they were not part of the original slurry. It is highly questionable if the conclusion based on such a data set can be realistically generalized.

In our study, for the first time, a correlation between large particle count and scratch count found on an NiP surface after polishing has been established. More specifically as shown in **Figs. 6 and 7**, fresh slurry and the slurry treated with the Levitronix BPS4 pump show excellent surface finish (essentially scratch-free). However, slurry after it has been processed using a PFD 3 pump causes severe scratches on an NiP disk. It is worthwhile to emphasize that the large particles

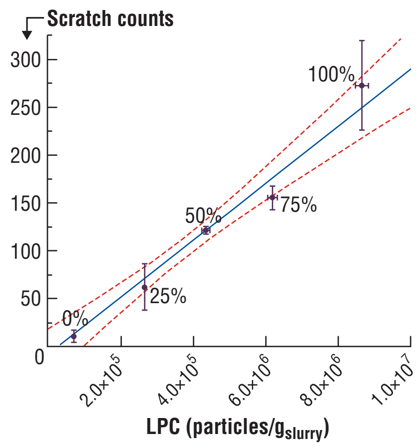

Figure 6. Correlation between scratch counts and LPC determined for particles with diameter _0.469 _m _S03 + S05_ with mixtures of slurry A _0 wt % slurry B_ and slurry B. Weight% slurry B for the mixtures is labeled at the corresponding data point. The weighted linear regression fit to the data set and 95% confidence limits are represented by the solid line and the dashed lines, respectively. Error bars correspond to ±1 standard deviation.

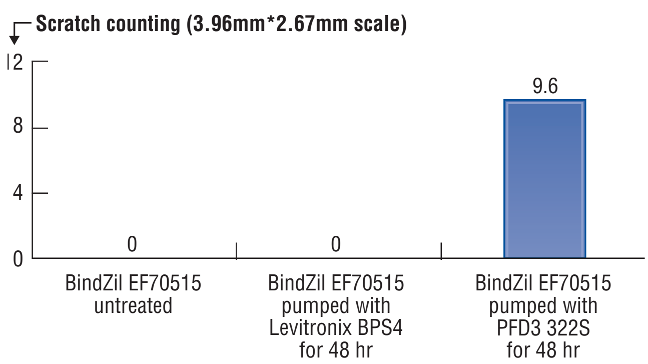

Figure 7. Scratch counting on NiP disks polished with pump-treated slurry.

found in the Bellows pump system are significantly higher than those found in a BPS4 pump system.

Conclusion

There is a profound difference between the Levitronix (MCL) pump and traditional pumps in terms of their impact on the growth of large particles. For the first time, a direct link between such a difference and the scratch count has been established for NiP CMP. Thus, it can be said with confidence that a proper selection of pumping systems is critically important in minimizing the polishing defects. ■

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Acknowledgment

Micro-Flow Imaging system is a trademark of BrightWell Technologies.

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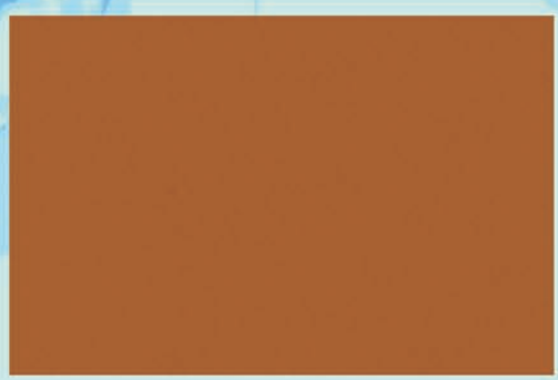
With Bellows Pump

ULK wafer polished with slurry which was recirculated 1000x with a bellows pump

AFM image of wafer surface polished with slurry which was recirculated 1000x with a bellows pump

With Levitronix Pump

ULK wafer polished with slurry which was recirculated 1000x with a Levitronix pump



AFM image of wafer surface polished with slurry which was recirculated 1000x with a Levitronix pump

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