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MFI™ for CMP Slurry Outlier Analysis

Chemical-Mechanical Planerization (CMP) requires precise control of the size distribution and morphology of particles contained in polishing slurries. A critical aspect affecting slurry performance is the presence of minute concentrations of large particles that can cause defects, such as micro-scratches, on the wafer during CMP.

These particles can originate either during the original manufacture or subsequently by aggregation during storage or use. The size, shape and degree of compaction of these large outlier particles will determine their scratching behavior. Micro-Flow Imaging™ (MFI™) is a new technique which employs digital imaging of a flowing sample stream for analyzing outlier particles in CMP slurries. MFI™ instruments provide highly sensitive detection, counting, and sizing of each individual particle combined with automatic image capture and shape analysis. This feature set results in instruments which can contribute to process yield enhancement both through more rigorous incoming and in-process inspection and, through the additional insight gained for process development and troubleshooting.

The MFI™ Advantage

When compared with alternative technologies for analyzing outlier populations in CMP slurries (principally light-blocking and light-scattering techniques as well as ultrasonic spectroscopy), MFI™ has a number of unique advantages including:

- **Detection Sensitivity**: Each particle is individually detected and measured using a highly sensitive pixel-based imaging technique. This sensitivity allows very low concentrations of outlier particles to be detected and measured. MFI™ is particularly well suited for the critical 0.75 to 10 µm range, accurately measuring outlier concentrations less than 0.001% by volume that are difficult to detect using existing techniques.

- **Material and Shape Independence:** Unlike many indirect particle size measurement technologies, measurements are insensitive to shape and composition making MFI™ well suited for highly heterogeneous outlier populations commonly found in CMP slurries.

- **Comprehensive Morphological Analysis**: Images of outlier particles within the slurry population can be automatically stored and analyzed using the MFI™ morphological analysis module, providing measurement of equivalent circular diameter, Feret's diameter, area, perimeter, circularity and transparency. These additional parameters can be conveniently presented in the form of histograms or scatterplots. This analysis provides further insight into the nature of the outlier particles as well as their propensity for damaging wafers.

- **Speed and Convenience:** MFI™ analyzers are easy to operate and provide full population analysis in less than 5 minutes.

- **Direct Observation**: During analysis, image frames are displayed providing immediate visual feedback on the nature of a particle population. Software assisted filtering can save particle images meeting user-defined characteristics.

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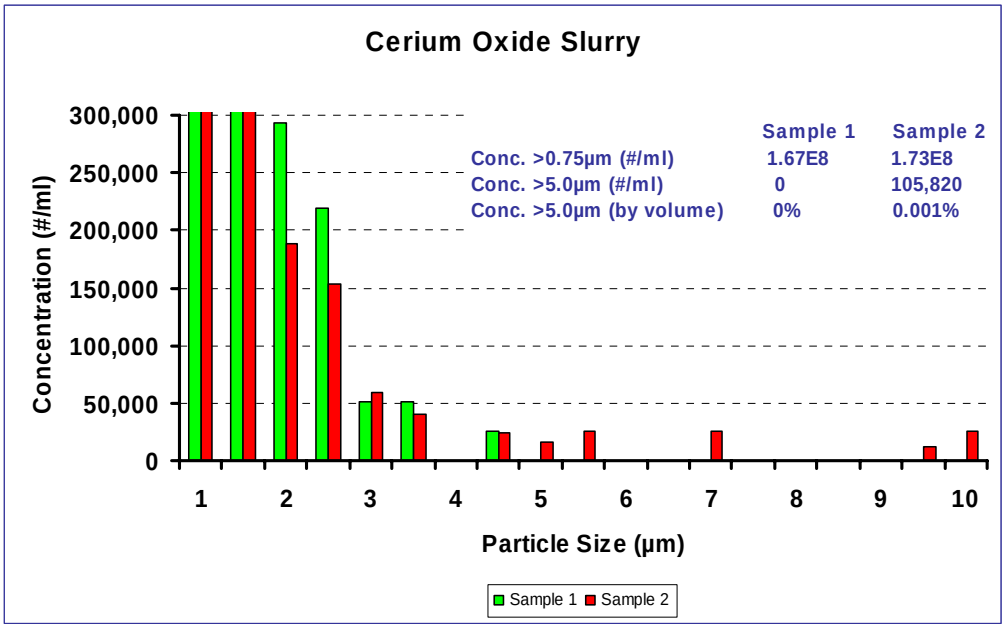
MFI™ Sizing, Counting, Image Capture

The DPA4100 MFI™ system supports operation at two different magnification set points depending on the size range of interest (0.75µm to 100µm), or (2.25µm to 400µm). Images can be stored selectively based on detection of particles falling into user-specified size ranges, or sequentially as a function of time. The results below are an example of the DPA4100 analysis of two different cerium oxide slurry samples where one is known to be more problematic in terms of wafer damage. The system was found to be capable of measuring very small concentrations of particles larger than 5µm (0.001% by volume).



MFI™ Morphology Analysis

In addition to measuring the size and concentration of outlier particles, MFI™ can measure the morphological characteristics of the suspended particulate (equivalent circular diameter, Feret's diameter, area, perimeter, circularity, and transparency) using the captured images. Powerful software tools including variable thresholding, histograms, scatter plots, and fully exportable data sets permit comprehensive comparisons of samples and more advanced diagnostics of yield-affecting slurry lots.

Summary

As the complexity and value of silicon wafer fabrication increases, it is critical to ensure that the CMP polishing process utilizes slurries of narrow and highly uniform size and shape distributions. MFI™ provides a better method of characterizing particle size distribution outliers in slurries with consequent benefits to slurry manufacturers in quality and process control and, to end-users for inspection and diagnostic purposes.