Applications for Real-Time CMP Slurry Monitoring

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CMP Slurry Monitoring

• Large particle counts (LPCs) have been shown to correlate to wafer defectivity.
• Count and size of large slurry particles can be measured in real-time, at production strength.
• Continuous monitoring of slurry LPC is an effective way to identify/disqualify root causes of defectivity.
• Continuous slurry monitoring may be implemented at various stages of the slurry life cycle.
  – Slurry Supplier lot characterization and filter evaluation
  – Slurry Delivery Systems (SDS) in the sub-fab
  – SDS supply loop on the fab floor
  – Point-of-Use (POU) on the CMP tool
• **Chemical** (acidic/basic) **Mechanical** (abrasive) **Planarization** prepares the **wafer surface** for the next lithography step.

• The polishing process is affected by:
  - Polishing tool configuration/settings
  - Polishing pad
  - Polishing pad conditioning (and residue, CVD diamond)
  - Polishing slurry

**External factors**
- Flow rate, filtration, plumbing configuration
- Temperature, pressure

**Intrinsic Properties**
- Slurry chemistry (including additives)
- Physical properties (density, morphology)
Common Knowledge” that LPC contributes to wafer defectivity.
Filters are used to reduce LPC of incoming slurry.
LPC “spikes” occur for various reasons.
Shrinking device geometries are likely more sensitive to these LPC spiking events.
Experimental data clearly shows the correlation between LPC and wafer defectivity.

1. Baseline the slurry LPC using Vantage SlurryScope
2. Polish wafers and measure the corresponding defectivity
3. Add inert particles, stabilize, measure with SlurryScope
4. Polish new wafers and measure the new defectivity
Defectivity and LPC

Ref: Techcet February, 2012; M. Fury, Vantage Technology Corp.
Spiking slurry with alumina particles caused the entire particle distribution within the SlurryScope measurement range to increase.

Scratch count increased as measured particle count increased.

IC customers have since correlated in their fab between LPC growth and scratch count increase.
Slurry Particle Size and Count

Main Particle Size Distribution

Tail of Particle Size Distribution

10^{15} particles

Number of particles

Number of particles

Diameter (nanometers)

Diameter (microns)

Good slurry

Bad slurry

Tens to thousands of particles

SlurryScope target application: LPC in tail, continuously measured in real-time

Ref: Ceramic Industry Magazine, Nov. 2004, PSS
Continuous, real-time measurement @ 15 ml/min
Detection range 1-10µm in 0.2 m increments
Production-strength CMP slurry
**SPOS* Methods**

- Periodic sampling
- Sample size 0.25-1 ml
- Offline / near line
- Dilution to meet SPOS detector requirements

**SlurryScope System**

- Continuous monitoring
- Sampling rate 15 ml/min
- Real-time
- Undiluted at full POU concentration
- Integrates into SDS
- Integrates into polisher slurry lines at POU

*Single Particle Optical Sizing*
Continuous Slurry Monitoring

Ref: CMPUG July 2012; M. Fury, Vantage Technology Corp.
Slurry Path to Point-of-Use

Actual SlurryScope fab and sub-fab data

SlurryScope monitors the integrity of the entire slurry distribution loop

Slurry manufacturer
Concentrated slurry shipment

Slurry Delivery Systems
Slurry storage

 CMP Tools
Dilution and chemicals added

Loop 1

Loop n

Fab
Sub-fab

SlurryScope monitors the integrity of the entire slurry distribution loop.
Slurry Life Cycle Monitoring

• **Slurry and SDS Manufacturers:**
  - Lot characterization/comparison
  - Slurry turnover effects
  - Filter evaluation

• **Sub-fab slurry monitoring:**
  - Batch characterization
  - Day Tank event (mixing, filling) characterization
  - Filter change events

• **Point-of-Use (POU):**
  - Correlation of LPC spikes with wafer scratching
  - Correlation of LPC to on-tool events (pressure changes, flow stop/start)
Slurry and SDS Manufacturers

• Optimization of filter selection for each new slurry type
• Slurry turnover stability testing
• Optimization of various fab operations
  – Slurry replenishment
  – Slurry mixing
  – Filter replacements
  – System cleaning procedure

• QC monitoring of slurry barrel filling
• Ability to replicate customer SlurryScope data
Filter Efficiency Comparison

1µm filters (same manufacturer)
- F2 decreased LPC by 10X
- F1 decreased LPC by 30X
- F3 decreased LPC by 40X
- F4 decreased LPC by 80X

*average of three runs per filter
• Real-time monitoring of production-strength Ce slurry loop
• Strong correlation between LPC and turnover after 20h
• Slurry stability is degraded after 300 turnovers
Sub-Fab Slurry Monitoring

- **Batch Characterization**
- **Day Tank Event Characterization**
  - Mixing
  - Filling
- **Filter Change Events**

Ref: ASMC May, 2012; A. Kim, Mega Fluid Systems & M. Parkin, Vantage Technology Corp.
Sub-Fab Slurry Monitoring

Square wave caused by shift between SDS tanks A & B

Ref: CMPUG July 2012; M. Fury, Vantage Technology Corp.
Single Day Tank SDS

SlurryScope Measured Particles / ml

~10 hours

Day tank liquid level

Ref: Semicon West July 2013; M. Fury, Vantage Technology, C. Aparece, Global Foundries
SDS Comparison – 1 vs. 2 Tanks

1 Day Tank: average total 1,100 particles/mL

2 Day Tanks: average total <300 particles/mL

Lower LPC attributed to dump/flush capability with dual tanks
Fab Floor Monitoring

SDS Loop Monitoring

- Degradation of slurry quality in loop
  - Distance from source
  - Hardware design flaws
  - Hardware failure

- Root cause for defectivity differences between polishers

Point-of-Use (POU) Monitoring

- Correlation of LPC spikes with wafer scratching
- Correlation of LPC to on-tool events
  - Pressure changes
  - Flow Stop/Start
POU - Flushing of Slurry Line

4/24 13:59
Pre-flush level

4/25 14:27
Post-flush level

DI Water Flush
Hi Flow Rate

Measured at VMB out

Particles/mL > 1 micron

Time from start (hh:mm:ss)
Zoom-in of 4/25 Flush Event

4/25 14:27

~10 minute width
Challenges and Future Work

- Aggregation / Agglomeration / Gel Formation
- These causes of LPC are not well characterized
  - Dilution effects
  - Mechanical effects (valves/fittings, line transition, line lengths)
  - Chemical changes, including pH
  - Pressure changes
  - Temperature changes
Summary

- Slurry LPC monitoring has been correlated to wafer defectivity impact at multiple fabs, on different slurry types.

- Continuous monitoring of production-strength slurry by SlurryScope provides *new information* that allows LPC sources to be traced and eliminated, bringing CMP in line with 6σ process defect control principles.

- *You won’t know what’s happening in your slurry line until you look…*
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