Keeping Your CMP Slurry From Being A Pain in the As-Probed Die Yield

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Background

Generalized Diagnostics

Examples

Summary
Components of CMP

Polisher
  + Polishing Pad
  + Slurry
    + Conditioning disk (usually)
    + Process recipe
  + Wafers
    + Deposited film(s)
    + Li’l bit o’ bloomin’ luck
And to make life even more fun …

Each new material or integration is likely a **new** puzzle!!
Background

- Process has been in manufacturing for >15 yrs
  - Excursions and deviations still occur regularly
  - Control limits on most wafer metrics keep shrinking
  - Downtime is costly … scrap is even more costly!

- Slurry is a key factor for all major CMP processes
  - Removal rate, selectivity, roughness, dishing, erosion, defect density, etc. can all be affected by slurry
  - Storage and distribution are critical
Why is slurry important?

Higher large particle counts (LPC) = higher defects

Slurry properties have a DIRECT connection to CMP defects.

Costs add up:
- Lower yield
- In-line scrap
- Down time
Fishbone Diagram

Things that make you go HMMM …

- A helpful brainstorming tool
- Results easily transfer to FMEA (if desired)
A familiar sequence to any fab process engineer ...

The key is to find root cause and get back on line as quickly as possible!
• Impact when CMP has a failure …
  Near end of line → High cost per scrap wafer
  Seldom enjoys overcapacity → Risks to die out schedule
  Consumables + wafers → Expensive troubleshooting

• CMP complexity requires many factors be checked

• Troubleshooting efficiency can be improved with a systematic diagnostic sequence
Diagnostic Sequence

Single Tool

- End of pad life
- Conditioner life
- Filter (if used)
- Peristaltic tubing
- Calibration drift
- Valve (post-loop)
- Pump (if present)

Fix and Verify
Example #1

Observations

- Toolset running stable
- One idle polisher was brought back on line and failed defect quals on successive tries
- LPC tail shows delta between slurry loop and sample at platen

Solution

- Perform PM on tool
- Returned to baseline so further action was not required
Diagostic Sequence

Single Tool
- End of pad life
- Conditioner life
- Filter (if used)
- Peristaltic tubing
- Calibration drift
- Valve (post-loop)
- Pump (if present)

Multi-Tool Commonality
- Sudden onset?
- Slurry lot change
- Loop filter change
- Test wafer lots
- Operating setpoints
- Pumps
- Valves

Fix and Verify
Example #2

**Observations**

- Oxide CMP
- Rate qual failure
- Simultaneous shift in uniformity
- Series of similar qual fails on multiple tools
- No shift in defects
Solution #2

Diagnostics

• Label possibly related events on chart
• Clear timing with new slurry lot (new tote)

Short Term “Fix”

• Purge / flush / refill
• Recharge with a different slurry lot

Long Term Improvements

• Improved control at slurry manufacturer
• In-line monitoring for pH and S.G. (% solids)
Example #3

Observations

- Particle monitor installed for passive data collection
- Small random spikes in 2um and 5um bins correlate with wafer level defect qual data
- No commonality to tool, pad changes, etc.
- Coincided with a fraction of drum changes
Solution #3

Diagnostics
- Loose commonality to certain lots of slurry
- Filtration tests promising

Short Term “Fix”
- Purge / flush / refill
- Transfer filter
- Continue monitoring

Long Term Improvements
- LPC and defect qual data correlation confirmed
- Early flag for engineering on any OOC data point at transfer
Diagnostic Sequence

Single Tool
- End of pad life
- Conditioner life
- Filter (if used)
- Peristaltic tubing
- Calibration drift
- Valve (post-loop)
- Pump (if present)

Multi-Tool Commonality
- Sudden onset?
- Slurry lot change
- Loop filter change
- Test wafer lots
- Operating setpoints
- Pumps
- Valves

Trend Analysis

Fix and Verify

SLURRY PARMS
- Slurry pH
- Density (or S.G.)
- Concentration [X]

WAFER DATA
- Rate / Uniformity
- Defects (qual)
- Defects (on product)

SERVICE OPERATIONS
- System settings
- Pump rebuild life
- Batch transfers
- Drum switchovers
Example #4

Observations

- Tungsten CMP
- Random qual failures
- Some recovery after pad changes

- Observed on multiple tools
- No shift in defects
Solution #4

**Diagnostics**
- Plot with trend line
- Assay slurry [H2O2]
  - Fresh mix
  - In loop

**Short Term “Fix”**
- Purge / flush / refill
- Manual [H2O2] monitor

**Long Term Improvements**
- Avoid excess day tank volume (keep turnovers reasonable)
- In-line monitoring for [H2O2] and auto-dose replenishment
[H2O2] Decay

**Bench Test**
- Single batch of tungsten slurry
- Target mix 3% H2O2
- Circulated in clean loop with data point taken every 10 min.

**Result**
- Strong [H2O2] decay observed over roughly 12 hours
- Similar effects occur in global loops, though possibly with different time constants depending on design
• Partially completed fishbone for particle qual failures

GROUPINGS OF POSSIBLE ROOT CAUSES

- Inadventent change
- Wrong slurry/chemical
- Data entry error
- Wrong recipe
- Valve or pump fail
- Peristaltic tubing
- Leaks
- Calibration drift
- Control system
- Poor process optimization
- Poorly designed loop
- PM frequency or scope
- Insufficient monitors
- Inadequate tool clean
- Contamination
- End of filter life
- Slurry pot life
- Pad / conditioner life
- Slurry lot

Things that make you go HMMM …
Summary

• Slurry is one of the most critical ingredients for maintaining a consistent CMP process
• When excursions occur (and they do), the key is to find the problem quickly
• Follow a systematic troubleshooting approach
• Design (or redesign) slurry delivery methods to minimize risks AND accumulate the proper data for efficient troubleshooting
## Design Inputs

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Thank you

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