Effective management of CMP distribution systems to minimize slurry filtration cost of ownership

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Topics

- Overview of CMP slurry filtration in the Fab
- Some of our experiences in the subfab
  - A typical result (ceria slurry)
  - The effect of shear induced agglomeration
    - LPC growth
    - Filter life
  - A proper result (silica slurries)
  - A model of particle retention in a recirculating system
- Case study in the fab
- The effect of poor LPC management in the subfab on
  - POU defectivity
  - POU filter life
- Methods to address cost of ownership at the Point of Use
The Driving Need for Better Filtration

ITRS showing as feature size shrinks so does critical particle size

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</thead>
<tbody>
<tr>
<td>Technology Node (nm)</td>
<td>50</td>
<td>45</td>
<td>40</td>
<td>36</td>
<td>32</td>
<td>28</td>
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<td>Critical Particle Diameter (nm)</td>
<td>25</td>
<td>22.5</td>
<td>20</td>
<td>18</td>
<td>16</td>
<td>14</td>
<td>12.5</td>
<td>11</td>
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I TRS showing as feature size shrinks so does critical particle size

GOAL : REDUCE DEFECTS

30% reduction in microscratch defects on an STI Process

30% reduction in CMP defects on a Copper CMP Process
Melt blowing is a process by which molten polymers are converted to fibrous media through melt extrusion, fiber attenuation, and controlled lay down.
Typical CMP Slurry Distribution and Dispense System

Filtration Recommendations

1. Single Pass Filter (Tote to Mixing Station)
   - Currently Available

2. Recirculation Filter (Distribution/Global Loop)
   - New Product

3. POU Filter (Polishing Tool Dispense)
   - In Development

Polishing Tool
Typical results for global loop filtration (recirculation) Using a 0.2 micron depth filter

Testing with ceria slurry

Counts/mL > 0.53 micron

Lot 1, #1 Lot 1, #2 Lot 2 #1 Lot 2, #2

Filter

Influent
one turnover
15 turnovers
30 turnovers
50 turnovers
Silica Slurry Recirculation Test Results with 4.5 micron Pall filter (HOPEFULLY NOT SO TYPICAL!!)
Pump causes LPC growth:
Rotary Peristaltic vs. Levitronix Pumps

* LPC’s increased 2.5X over a period of 3 hours (45 turnovers) when using the rotary peristaltic pump. There was no appreciable change in LPC’s using the Levitronix pump under the same conditions.
Silica Slurry Recirculation Test Results with 4.5 micron Pall filter

Results for > 0.53μm

Results for > 1.01μm

Fumed Silica slurry testing with Levitronix Pump

Fumed Silica slurry testing with Levitronix pump

Particle Counts (>0.53μm)

Particle Counts (>1.01μm)
Summarizing the Recirculating System Filtration Model

Retention in a recirculating system
See next slides for details

Graph to left shows experimental data from silica slurry used in recirculation vs. calculated values from model. (percent retention was at 0.56 um using Accusizer)

- Key point is majority of particle removal comes in first few passes
- Therefore, when only loop filtration is used the required filtration is nearly the same (in terms of grade) as in a single pass operation (like POU)
- When used in a complementary manner the filter in the loop can be quite a bit coarser and still provide adequate particle removal (4.5 micron filter was used in silica slurry noted to the left).
A theoretical analysis yields the equation: \( C_t = C_0 e^{K(Qt/v)r} \)

where:
- \( C_t \) = concentration of particles at time \( t \)
- \( C_0 \) = concentration of particles at the start of the test
- \( Q \) = recirculation flow rate
- \( V \) = volume of the system
- \( r \) = a constant that is defined is the mixing efficiency (with a range between 0 and 1 with 0 corresponding to no mixing and 1 perfect mixing)
- \( K \) = a constant that incorporates the remaining contributing factors. One of these is the filter’s geometry (including pore size)

The above equation was derived from the differential equation that describes the particulate removal process in the system:
Particle Removal in a Recirculating System (Results)

\[ C_t = C_0 e^{K(Qt/v)^r} \]

Ceria Slurry using 0.2μm Depth Filter

Fumed Silica Slurry using 4.5μm Depth Filter

*The mixing efficiency component (r) in both examples are nearly the same*
Customer stated they were having a filter life issue at the POU. They tried various Pall filters and could not prevent flow decay below limits.

The issue:
- Start flow to platen 1 reaches 200 cc/min no problem (remains stable)
- Start flow to platen 2 reaches 200 cc/min and both 1 and 2 remain stable
- Start flow to platen 3 and all three platens drop to roughly 190 cc/min

In discussions with customer I found out the system pressure (feeding the tools) was limited to roughly 4 - 5 psi.
Depth filters have a differential pressure associated with them (even a relatively coarse 10 micron filter will have 1-2 psid)

It is not uncommon to use two filters in series (so double that value)

More aggressive (finer) filtration is possible with many of these newer slurries. Finer filters have even greater dP.

If possible this needs to be considered in future bulk slurry distribution systems

Immediate solution was to use a product with greater surface area but that limits you in terms of retention.
Defects can be reduced using effective loop filtration.

Distribution Loop Test Results (Silica Slurry)

KLA Detected Microgouges by Optical Review 05AC1

Average Defects By Lot

- 5 micron loop filter
- 3 micron loop filter
POU Filter life for various grades of Pall filters

SS12 POU testing performed on the CMP Applications Test Stand

- Unfiltered: 20884 LPC's
- 0.3 micron: 915 LPC's
- 0.5 micron: 1104 LPC's
- 1.0 micron: 1698 LPC's
- 3.0 micron: 3419 LPC's
- 5.0 micron: 5956 LPC's

Life = 2.0x
Life = 1.4x
Life = 1.0x
Life = 0.55x
Life = 0.25x
Roadmap of CMP Slurry Filters

Loop and POU filtration that is complementary

<table>
<thead>
<tr>
<th>Technology Node (nm)</th>
<th>2013 Present</th>
<th>2016 Next Requirements</th>
<th>2018 Future</th>
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<tr>
<td>R&amp;D (Production)</td>
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<td></td>
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<tr>
<td>Requirements</td>
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<td>14 (22)</td>
<td>10 (14)</td>
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<td>Profile® II (1.0 µm) Profile® II (0.2 µm)</td>
<td>Profile® II (1.0 µm) Profile® Nano 100</td>
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<td>Profile® II (0.5 µm) Fibrous Membrane</td>
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<td>Profile® Nano 100 Profile® Nano 50</td>
<td>Profile® Nano 100 Fibrous Membrane</td>
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Notice:
Silica (5:1 or 10:1) Loop/POU
Ceria (3:2) Loop/POU
The effect of increased filter area on life based upon testing with a fumed silica slurry

$y = 1.0395x^{1.8891}$

$R^2 = 0.9997$

- Should note data is from a limited sample
- Testing was done on SS12 by altering both surface area and flux rates
How else are we addressing the filter life / CoO issue? (Mechanically)

Lowering Cost of Ownership – Gradient Optimization

(Using this for the basis of all CMP product development today)
How are addressing the Filter Life /CoO issue ?
(at the particle/filtration media interface)

The issue - Why do abrasives types filter so differently?

- Is the mechanism for interaction between filtration medium and ceria particle different than filtration medium and silica?

Influences both loop and POU filtration

Silica retention is much greater than ceria