Key CMP Issues & Their Causes

- Three key CMP issues encountered in field:
  - High defects/microscatches on wafers
  - Change in polishing performance (removal rate, nonuniformity)
  - Short filter lifetime or reduction in lifetime

- Associated causes of these three key issues:
  - Large particles in slurry
  - Change in slurry particle size distribution
  - High gel content in slurry
Terminology of Particles Observed with SEM, ESEM & Light Microscope

- **Particle**: single solid sphere or other geometry
- **Aggregate**: multiple particles chemically attached to each other (chain), primarily via siloxane bonds
- “**Agglomerate**”: particles and aggregates come together into close-packed clumps due to entanglement, drying, and coagulation, denser than the surrounding solution
- **Microgels**: aggregates link together and form three dimensional network with water trapped within; same density and refractive index as the surrounding solution (Filter Plugging Problem)

Potential Defect Causing Agglomerates & Large Particles
Silica slurry was diluted with pH adjusted water, then filtered through a 3 micron Isopore membrane.
Possible Sources of Large Particles & Gels:

- Agglomeration
- Local drying in shipping container, tank, and fittings
- Settling
- pH shock during dilution
- Temperature fluctuation during shipping and storage
- Shearing (i.e. certain valves, pumps, piping design)
- Improper Mixing
- Large # of Turnovers
- Lack of PM’s on Distribution System
- Lack of proper slurry conversion protocols from one slurry type to another, including flushing and system sterilization protocols.
Oxide Defects “Large Particles” in Slurry Create Micro-Scratches & Embedded Particles on Wafers

Typical defects in oxide CMP
Ref.: C. Dennison, KLA-Tencor, Micro, February 1998
Nine types of tungsten CMP defects

Ref.: C. Dennison, KLA-Tencor, Micro, February 1998
Large Scratch
Cu-CMP Defects

Image Courtesy of Mic Lab

Brightfield

Darkfield

SEM
Bar = 2μ

20x DF
Large Chatter Marks
Cu-CMP Defects

Optical image (Compass®)

SEM images (SEMVision™)

AFM (Veeco)
Optical image (Compass)

AFM (Veeco)

SEM images (SEMVision)
Micro Scratch
Cu-CMP Defects

Optical image (Compass)  SEM images (SEMVision)

AFM (Veeco)
Slurry Troubleshooting Takes Detective Work
# Slurry Trouble Shooting Methods

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Analytical Labs Play Key Role for Slurry Handling, Troubleshooting and Filtration

- Total % Solids
- Density / Specific Gravity
- pH
- Conductivity
- Viscosity
- Mean Particle Size
- Large Particle Size
- Filtration Testing & Optimization (Source, Post Mix, Global Loop & POU)
- Zeta Potential
- Percent Assay & Assay Development
- Slurry Characterization, Distribution & Handling Evaluations, Slurry Conversion Protocols
Drum Contamination

- Clean drum surface to remove dust particles before opening.
- When removing lids bung holes should be carefully cleaned before pouring out slurry.
- Carefully clean the slurry container lids & bung holes before closing left over slurry pails or drums to prevent introducing dry slurry particles.
- Dip tubes should be clean before introducing into new slurry container.
Proper Mixing of Slurry

Some Mixing Factors

- Size of Tote
- Age of Slurry
- Number of Propellers
- Type of Mixer and Propeller
- Direction of Mixing
- RPM
- Propeller Scraping Side of Drum

Note: Slurry allowed to remain undisturbed for several weeks for Time 0 sample.
Minimizing Particle Growth

- Humidification
- Need to humidify the air pockets that come in contact with the slurry with >95% humidity.
- Need to avoid drying of the slurry which can result in formation of agglomerations and aggregates.

![Population Distribution Chart](Image)

- Effect of Humidification in CDM’s
  - Non-Humidified
Effect of CDM’s on Slurry Health

Large Particle Population Distribution

Counts

Particle Diameter (µm) ->

Control
CDM-I
CDM-II
CDM-III
Levitronix Pump Study

- Magnetic Levitation Technology

Fluid Handling without Bearings & Seals!
Dynamic Levitronix Pump Study

Storage Tank Turnovers

- Total Percent Solids
- Viscosity (cP)
- Density (g/mL)

Klebosol® 1501-50
Days

Klebosol 1501-50

Dynamic Levitronix Pump
The graph displays the Mean PSD (nm) over Days for a Dynamic Levitronix Pump, designated as "Klebosol 1501-50". The x-axis represents the number of days, ranging from 0 to 14, while the y-axis shows the Mean PSD in nanometers (nm), ranging from 0 to 150. The data points for the pump operation remain relatively stable across the observed period.
Klebosol 1501-50 Dynamic Levitronix Pump Study

Particle Diameter (microns)

Cumulative Number (# Part ≥ Diameter)

T0hrs
T24hrs (122 TO)
T144hrs (730 TO)
T336hrs (1700 TO)
Klebosol 1501-50 Dynamic Levitronix Wafer Removal Rate Response

Normalized RR Data

Polisher Head #

STANDARD (0 Turnovers) RR
LEVITRONIX (1700 Turnovers) RR
Klebosol 1501-50 Dynamic Levitronix Pump Defectivity Response

- **Head 1**
  - STANDARD (0 Turnovers): 2.0
  - LEVITRONIX (1700 Turnovers): 0.8

- **Head 2**
  - STANDARD (0 Turnovers): 1.2
  - LEVITRONIX (1700 Turnovers): 0.9

- **Head 3**
  - STANDARD (0 Turnovers): 1.5
  - LEVITRONIX (1700 Turnovers): 1.0

Normalized Defect Data (> 0.1 µm)
Filtration

Wonder if this filter will work?
Possible Filter Locations

- Shipping Container
- Dilution
- Day Tank
- Polishing Tool
- Water Track
- Cleaning Chemical Filtration
- DI Filtration
- Post CMP Cleaning
- Intake Filtration
- Post Dilution Filtration
- Recirculation Loop Filtration
- POU Filtration
- Recirculated DI Filtration
Filter Retention Curves

- Filter Ratings Are Not All Created Equal
  - Filter Retention Curves are Very Useful to Determine Effective Micron Size of the Filter at various Percent Retentions

Retention Efficiency Curves for Planargard CMP Filters

![Graph showing retention efficiency curves for various filters with different colored lines representing each filter type. The x-axis represents particle size in microns, and the y-axis represents percent retention.](image-url)
Large Defectivity Improvement Seen with Global Loop and POU filters.
If the filter is optimized for the slurry, there is no RR loss.
Foreign Materials Found On Filter

Foreign Materials
- Can Decrease Filter Life
- Such as Plastic Shavings/Misc.
- Some Foreign Materials Staticallly
- Attracted to PFA Tubing

Some Other Possible Sources
- Unclean Source Container
- Mixing Blade Improperly Adjusted &
- Scrapes Side of Drum
- Dirty Dip Tubes
- Unclean Environment where Drum Opened
- Improperly Cleaned Delivery System
Filtration Summary

- CMP slurry filtration may reduce defects and improve process consistency
- POU slurry filtration allows the use of more retentive filters
- Higher retention provides better defect reduction
- Filtration in slurry delivery systems will extend POU filter’s lifetime
- Filter lifetime is highly slurry and process dependent
- Lifetime can be monitored by pressure drop and/or flow rate
Conclusion

- Understanding slurry characteristics, handling properties and filtration is key for maintaining distribution systems, troubleshooting and minimizing large defect causing particles.

- Rohm and Haas Electronic Materials actively seeks to collaborate with distribution system suppliers, filter companies & others to provide the best solutions for the customer.

- Together as suppliers we can achieve optimized solutions to fit customer needs and to keep them on target.
Acknowledgements

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- Levitronix® – Provided Pump for Evaluation

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