CMP OPTIMIZATION AND CONTROL THROUGH REAL-TIME ANALYSIS OF PROCESS EFFLUENTS

S.J. Benner and D.W Peters
Allentown, PA 18106
610-395-7840
dwpeters@confluense.com
www.confluense.com
Outline

Introduction
- Company introduction
- Motivation (CMP cost, defectivity, process stability, ITRS CMP metrics, environmental footprint, etc.)

Pad Surface Manager
- Concept of *in-situ* tribology management

Data
- Conductivity and pH versus time for STI polish effluent
- Tribology alteration during an ILD polish
- Conductivity versus time for Cu polish effluent
- Particles from an ILD polish effluent
- Wafer particle reduction during an ILD polish

Conclusions
Company Background

Confluense was spun-off from TBW Industries in 2008

TBW’s “Clean Through”™ abrasive designs enabled development of the Pad Surface Manager

Confluense is a company dedicated to advanced abrasive surface finishing equipment and technology. We are guided by the following objectives:

- Provide the lowest CoO
  - Efficient use of consumables, reduced defectivity, improved throughput
- Provide real-time management of polishing tribology
  - Active measurement and control of material removal kinetics
- Provide in-situ endpoint capabilities
  - Endpoint detection through effluent analysis, end-state control through polishing film management (Friction, Lubrication, Charge)
- Provide sustainable technology
  - Effective consumption of materials and waste separation/treatment
We offer contract services for:
- Material development
- Process analysis
- Process development

Our technology is available to address your CMP problems!
Motivation

- CMP has a large environmental footprint
- High defectivity
  - Random – Particles, scratches
  - Systematic – Process variation, thickness, non-planarity
  - Parametric – Layout related x-y-z
- High cost per wafer pass
  - Inefficient use of consumables
- End user led integration
  - Multi-material, -scale, -step
- Fragmented supply chain
  - No one-stop shops
- Long development cycles
  - e.g., low-K

Moore’s Law

Economics

- Faster Ramp
- Reduce CoO

Environment

- Reduced Consumption
- Recycling

- Percent Surly Utilization Efficiency

- K-Grooved Pad

NCAVS CMPUG Meeting July 16, 2009
2009 ITRS revision has STI CMP metrics in the FEP tables (Table FEP14 CMP Process Technology Requirements)

- Contains metrics on particles, scratches, RR uniformity, and WIW uniformity
  - Critical particle size – 25nm
  - Critical scratch length – 23nm
  - RR uniformity (3σ) – 8%
  - WIW uniformity (3σ) – 6%

- CMP will require improvements to meet these metrics
Outline

Introduction
- Company introduction
- Motivation (CMP cost, defectivity, process stability, ITRS CMP metrics, environmental footprint, etc.)

Pad Surface Manager
- Concept of in-situ tribology management

Data
- Conductivity and pH versus time for STI polish effluent
- Tribology management during an ILD polish
- Conductivity versus time for Cu polish effluent
- Particles from an ILD polish effluent
- Wafer particle reduction during an ILD polish

Conclusions
**Pad Surface Manager**

*In situ* exchange of materials – at the “*working interface*”

- Vacuum waste through the abrasive conditioner
  - Actively remove polishing wastes: film, slurry, pad – *enables replenishment, removes defect sources*
  - Analyze process effluent – *feedback, control, treatment*
  - Direct effluent to reprocessing or waste

- Fluids introduced over entire area
  - Pad cleaning agents
  - Process tuning; Surfactants, Inhibitors

- Clean pad and conditioner between wafers
  - Use oxalic or citric acid solutions

*Mirra development arm on IPEC 372M*
Pad Surface Manager

- PSM “OEM Cartridge” Design provides common PSM subsystem for multiple OEM platforms, i.e., 200mm, 300mm, 450mm?
- “Shoulder” provides mechanical interface to OEM SWEEP drive sub-system.
- “Dresser coupling” provides mechanical interface to OEM abrasive rotation.

- Modular unit adaptable to different wafer sizes and tool configurations
Outline

Introduction
- Company introduction
- Motivation (CMP cost, defectivity, process stability, ITRS CMP metrics, environmental footprint, etc.)

Pad Surface Manager
- Concept of in-situ tribology management

Data
- Conductivity and pH versus time for STI polish effluent
- Tribology management during an ILD polish
- Conductivity versus time for Cu polish effluent
- Particles from an ILD polish effluent
- Wafer particle reduction during an ILD polish

Conclusions
Variation of Conductivity and pH

- An order of magnitude variation in conductivity
- Indicates a significant variation in ionic content
- The pH changed by ~ 4 units
- Could alter chemical activities

200mm TOX blanket wafers, Cabot SS11, IC1010 K groove pad
Oxide removal rate vs. slurry flow - IPEC POR

- Equivalent or better MRR with reduced slurry flow

Conventional PSM @ 9" Hg
- MAX 1989 A/min
- Average 2020 A/min

WIWNU

- 200mm TOX, Cabot SS12, IC 1000 perforated pad
Inflection points at 200 and 300 seconds correspond to the end points for Cu and Ta, respectively.
Particles Removed from the Pad

- Pad effluent sampling
- Filtration membrane with 800nm pores
  - High vacuum, low slurry

- Particles in the effluent included slurry, agglomerates, and pad debris
- Carbon peak from SEM EDS identified pad debris

![Image](image-url)
Wafer Particle Reduction

Post CMP clean, Mirra POR

Particle counts

LPC were reduced 30% at mid range; 50% at high vacuum

200mm TOX blanket wafers, Cabot SS11, IC1010 K groove pad
# PSM CoO Benefits

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wafer layers per machine - hour</td>
<td>45</td>
<td>WWK CoO model*</td>
</tr>
<tr>
<td>Production hours per machine - year</td>
<td>7460</td>
<td>7 x 24 – 15% down</td>
</tr>
<tr>
<td>Wafer layers per machine year</td>
<td>335,700</td>
<td>Result 45 x 7460</td>
</tr>
<tr>
<td>Annual Dielectric CMP savings</td>
<td>$1,436,796</td>
<td>$4.28 savings/polish*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$7.65 CoO/polish baseline</td>
</tr>
<tr>
<td>Annual Copper CMP savings</td>
<td>$3,336,858</td>
<td>$9.94 savings/polish*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$17.65 CoO/polish baseline</td>
</tr>
</tbody>
</table>

Prepared by Daren L. Dance  
VP, Technology  
Wright Williams & Kelly, Inc.  
26 Oct 2005  
Revised 23 Dec 2005
Outline

- Introduction
  - Company introduction
  - Motivation (CMP cost, defectivity, process stability, ITRS CMP metrics, environmental footprint, etc.)

- Pad Surface Manager
  - Concept of \textit{in-situ} tribology management

- Data
  - Conductivity and pH versus time for STI polish effluent
  - Tribology management during an ILD polish
  - Conductivity versus time for Cu polish effluent
  - Particles from an ILD polish effluent
  - Wafer particle reduction during an ILD polish

Conclusions
Conclusions

- Enables real-time control of polishing process through tribology management
- Offers endpoint detection through analysis of effluents
- Reduced wafer LPC by 30% - 50%
- Enables CMP to be a sustainable HV manufacturing technology
  - Reduces the environmental footprint
  - Allows separation of solids from liquids to simplify the waste stream and/or allow recycling
- Can yield a 45% improvement in CoO with an ROI of ≥ $1M/tool/yr from model outputs based on real data inputs
Confluense was selected as one of the four finalists for the “SEMICON West 2009 Sustainable Technologies Award”

The award winner will be announced in August
References

THANK YOU FOR YOUR ATTENTION!

Visit us at the TBW booth, #2209 in the South Hall
Contact Information

Stephen Benner, President  
sjbenner@confluense.com

Darryl Peters, Ph.D., Process Technology VP  
dwpeters@confluense.com

Confluense  
7277 William Ave., Suite 300  
Allentown, PA 18106  
(610) 395-7840