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

NCAVS CMPUG Meeting July 16, 2009

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

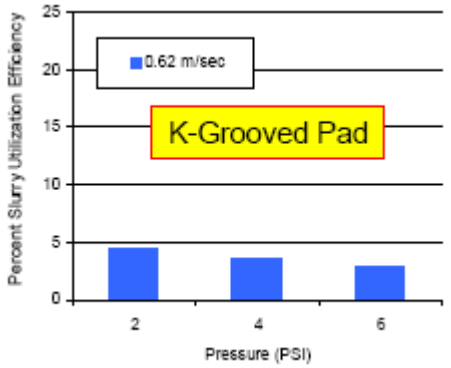
- Confluense was spun-off from TBW Industries in 2008
  - TBW's "Clean Through"™ abrasive designs enabled development of the Pad Surface Manager
- Confluense is a company dedicated to advanced abrasive surface finishing equipment and technology. We are guided by the following objectives:
  - Provide 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

Facilities

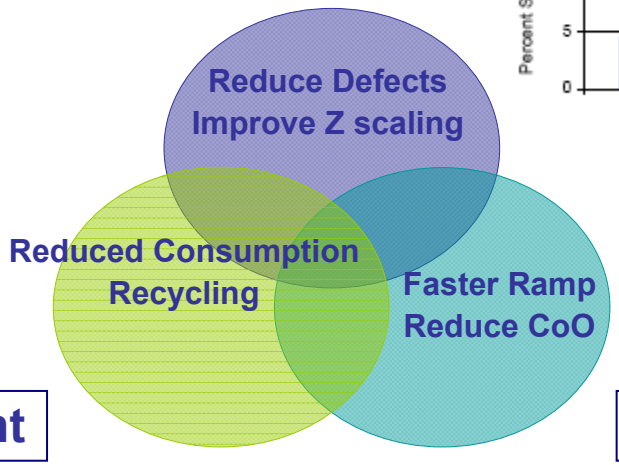
- We offer contract services for:
  - Material development
  - Process analysis
  - Process development
- Our technology is available to address your CMP problems!

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



Environment

Economics

Motivation

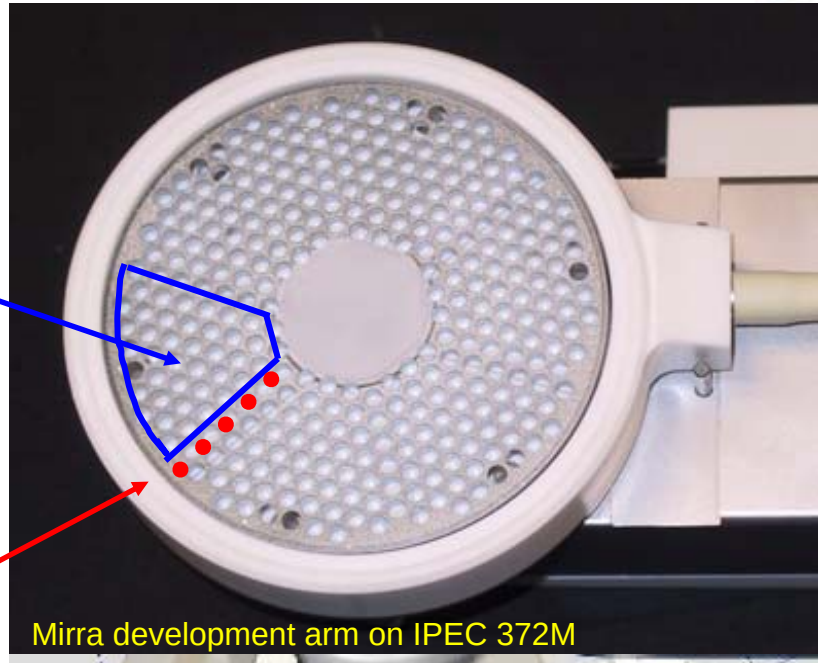
- 2009 ITRS revision has STI CMP metrics in the FEP tables (Table FEP14 CMP Process Technology Requirements)
  - Contains metrics on particles, scratches, RR uniformity, and WIW uniformity
    - Critical particle size – 25nm
    - Critical scratch length – 23nm
    - RR uniformity (3σ) – 8%
    - WIW 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

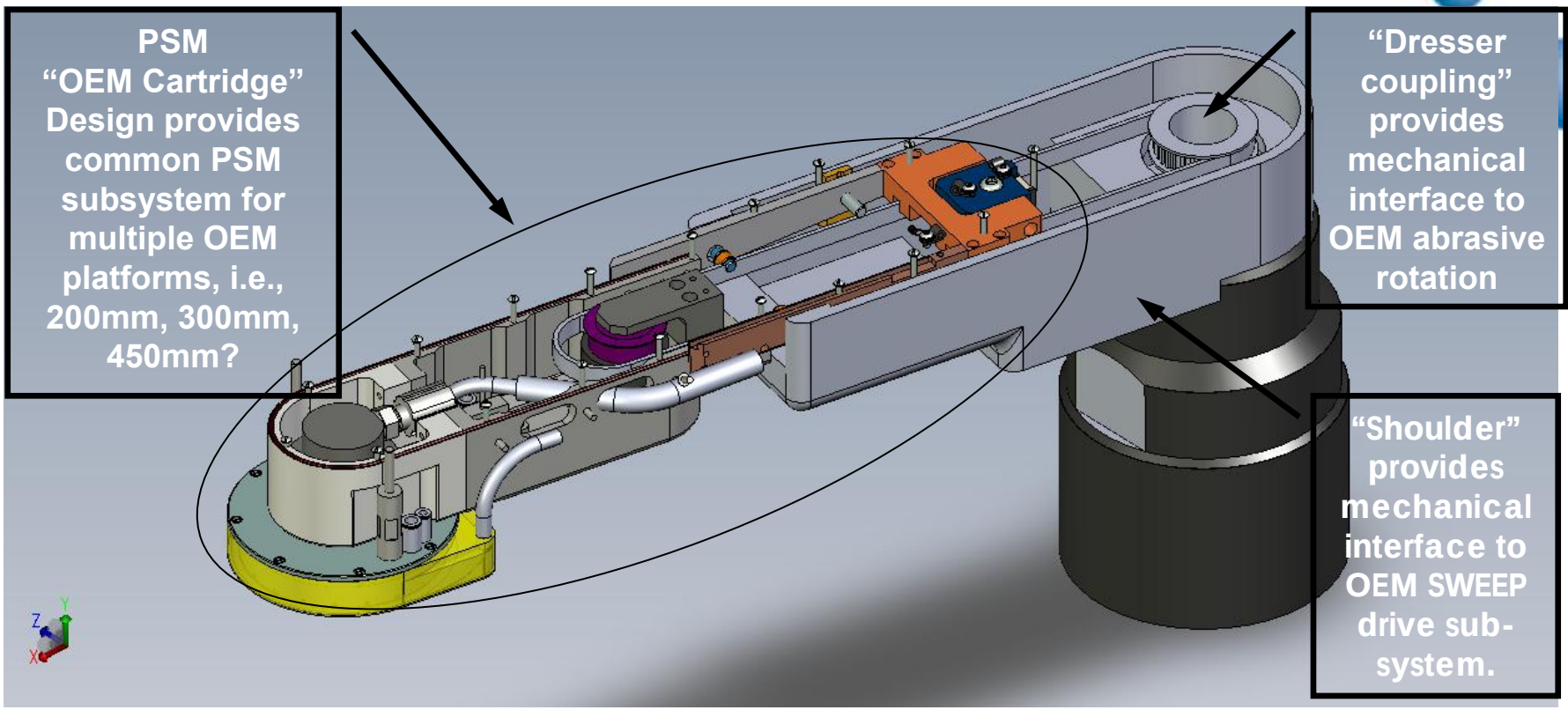
Pad Surface Manager

- *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

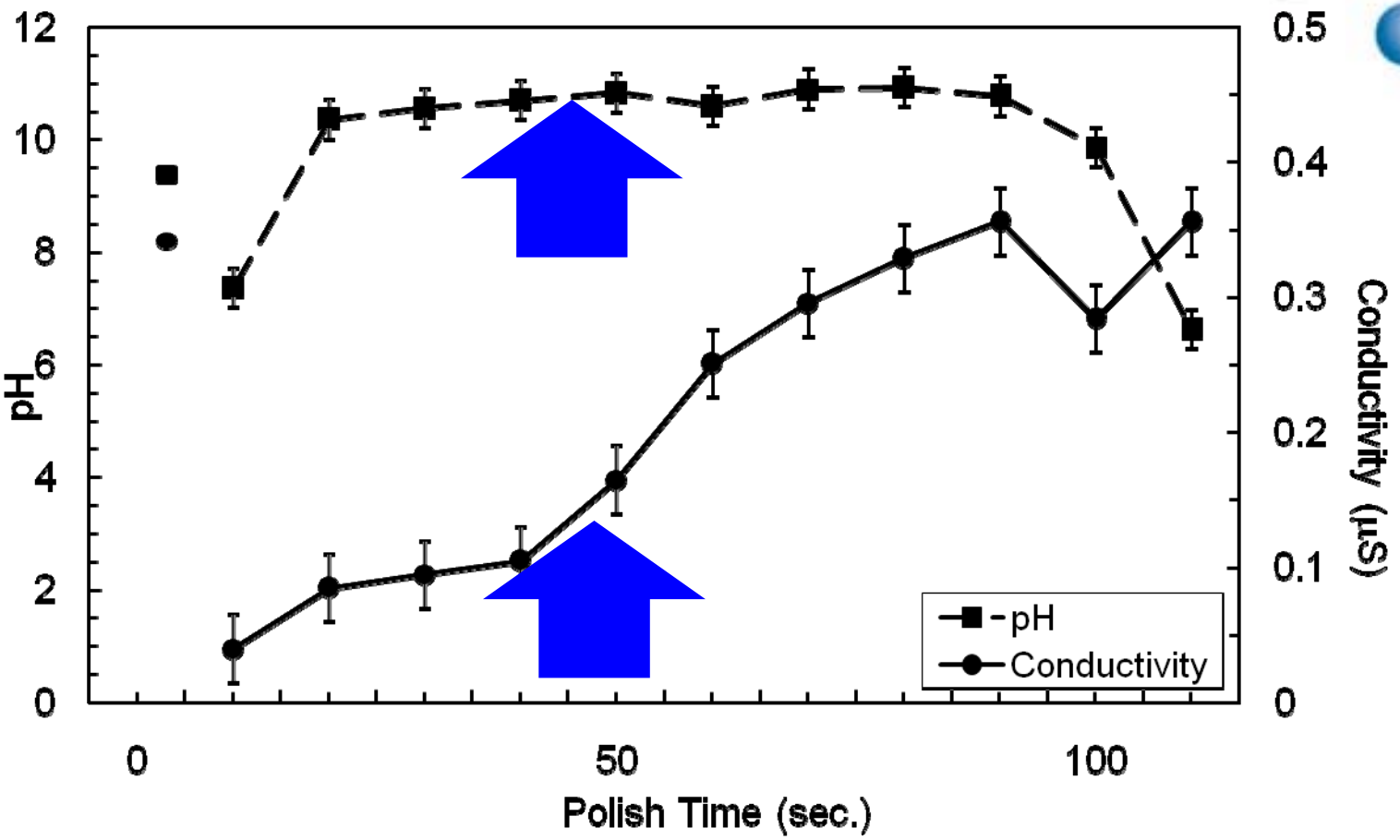


- Modular unit adaptable to different wafer sizes and tool configurations

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

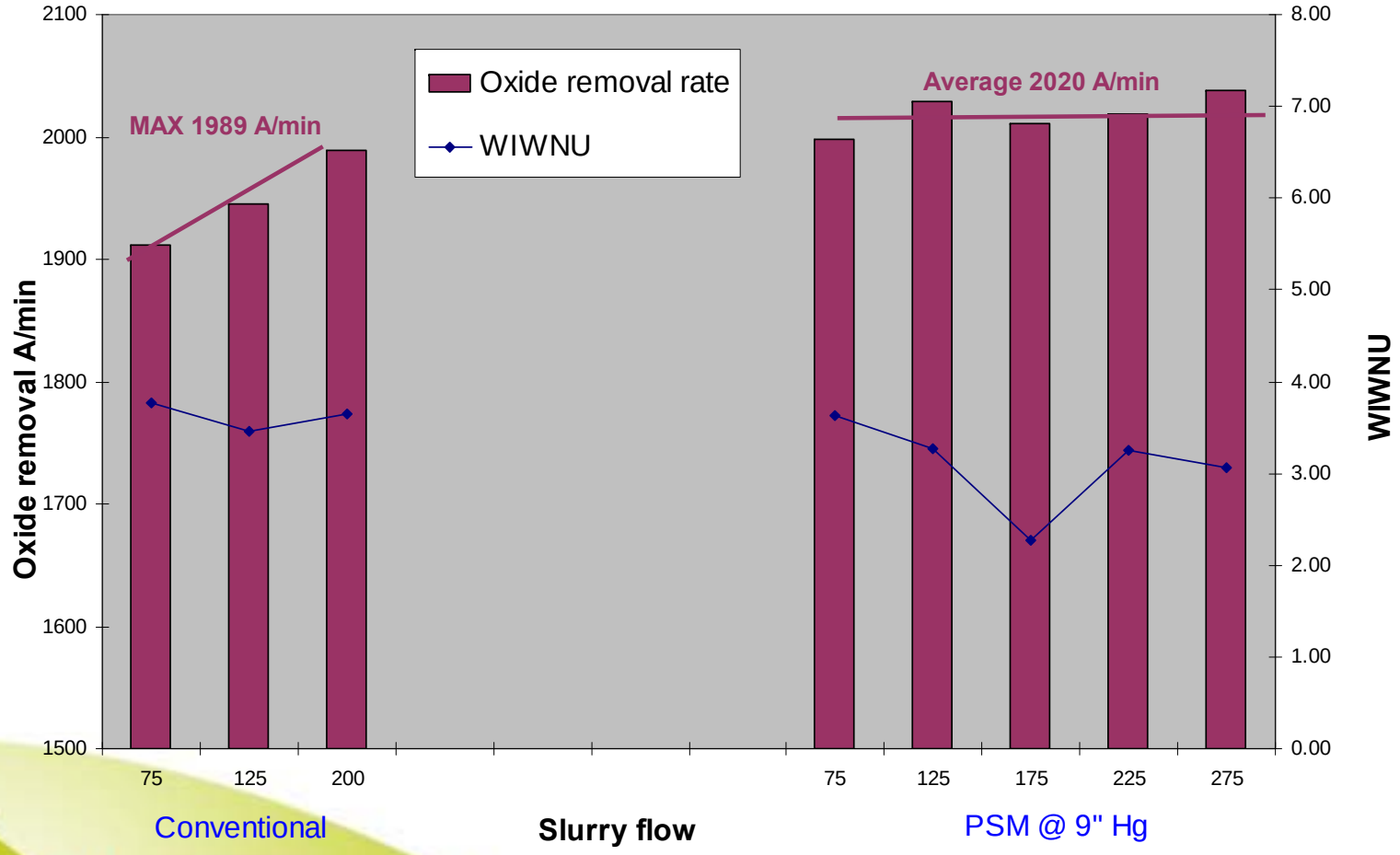


- An order of magnitude variation in conductivity
  - Indicates a significant variation in ionic content
    - The pH changed by ~ 4 units
      - Could alter chemical activities

200mm TOX blanket wafers, Cabot SS11, IC1010 K groove pad

Tribology Management

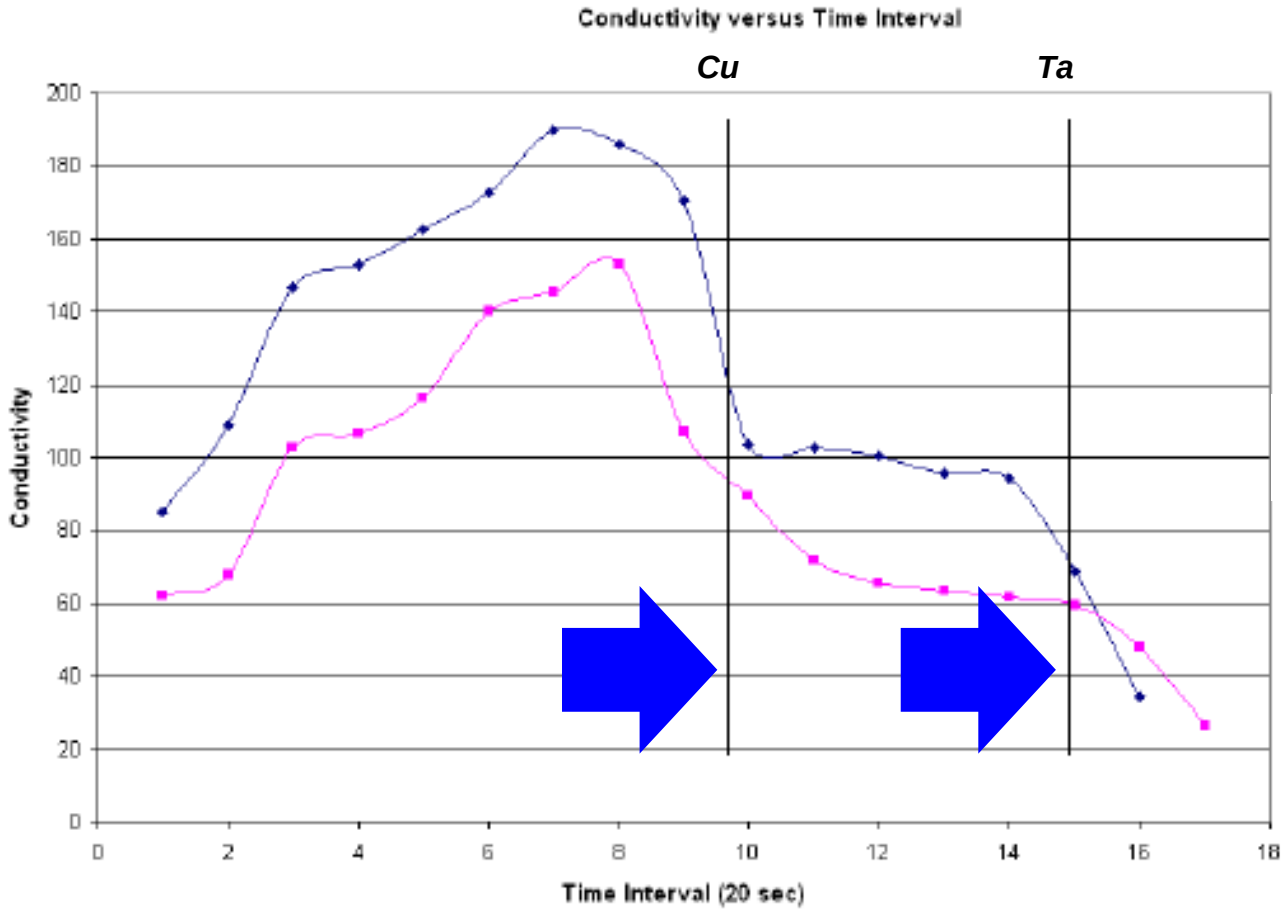
- Oxide removal rate vs. slurry flow - IPEC POR



- Equivalent or better MRR with reduced slurry flow

200mm TOX, Cabot SS12, IC 1000 perforated pad

Cu and Barrier Polish Endpoints



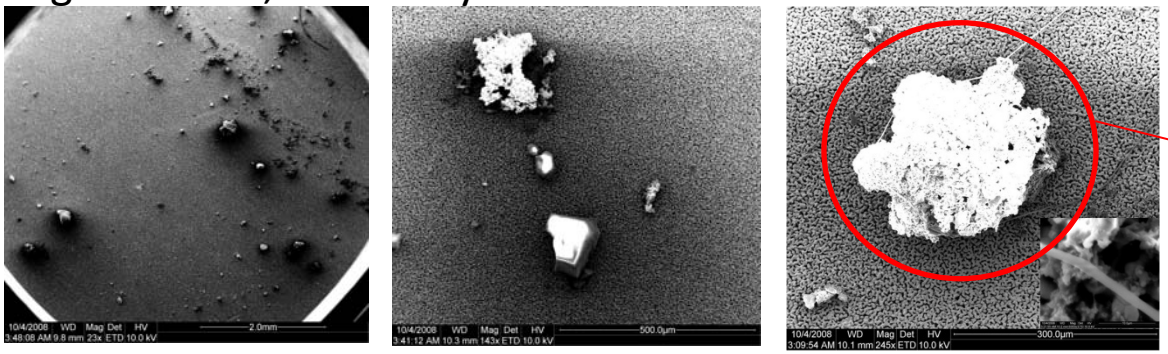
- **Inflection points at 200 and 300 seconds correspond to the end points for Cu and Ta, respectively**

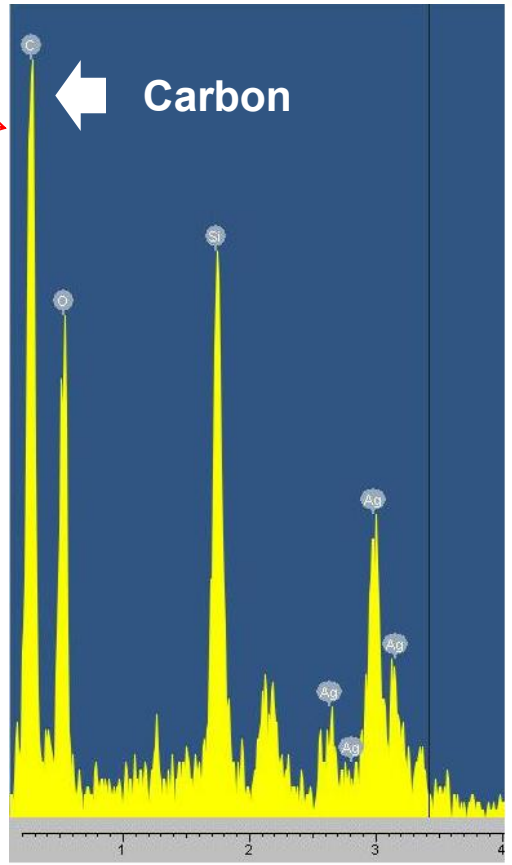
200mm Cu/Ta blanket wafers, PPG experimental slurries, IC1010 K groove pad

Particles Removed from the Pad

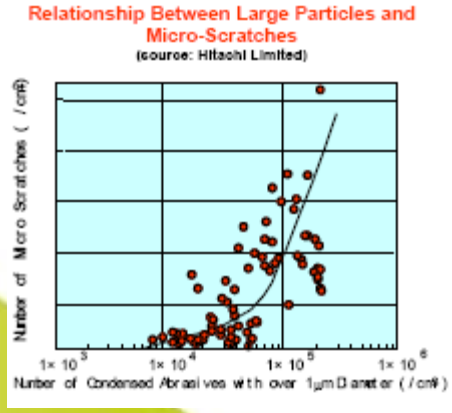
- **Pad effluent sampling**
  - **Filtration membrane with 800nm pores**

High vacuum, low slurry





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

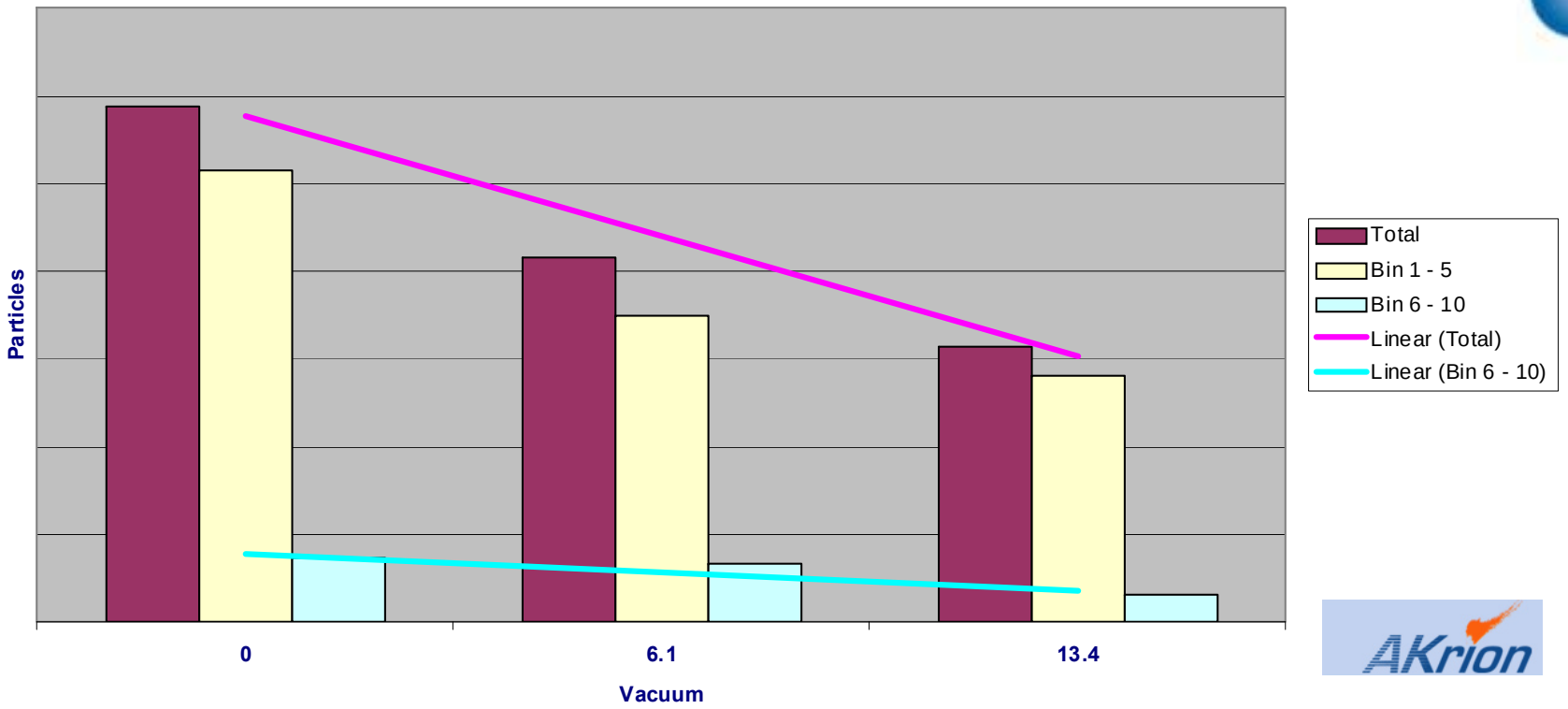


200mm TOX blanket wafers, TEOS POR ,Klebosol II, 1501-50

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

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

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 *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

Sustainable Technologies Award

- 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

- Y. Gotkis, "A Couple of Considerations on the Dynamics of Defectivity Generation in CMP Technology", NCAVS CMPUG Meeting (April 2007)
- J. G. Park, "CMP Process: Its Challenges and Future", SPCC (March 2009)
- C. L. Borst, "A Case Study: Topographic and Spectroscopic Analysis of Slurry Particle Retention for Cu CMP", Levitronix CMP Users Conference (2007)
- A. Philipossian and A. Mitchell, "Mean Residence Time and Removal Rate Studies in ILD CMP", J. Electrochem. Soc. 151, (6) 6402-6407 (2004); A. Philipossian, et al, "Analytical & Functional Evaluation of Fresh, Spent & Reprocessed Fumed Silica Slurries in ILD CMP", 1st International Workshop on Nanoscale Semiconductor Devices (2004)
- S. J. Benner and D. L. Dance, "CMP Productivity Improvement Using Pad Surface Management", ISIM Symposium on Equipment-Related Productivity Improvement Activities (March 2006)
- C. Burkhard, J. Zhao, P. Wu, M. Fox, S. V. Babu, and Y. Li, "Wafer Characterization and Spent Slurry Evaluation with a Novel Pad Conditioner", CMP-MIC (2004)

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