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

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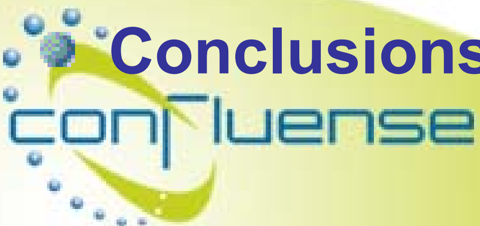
Outline

- 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

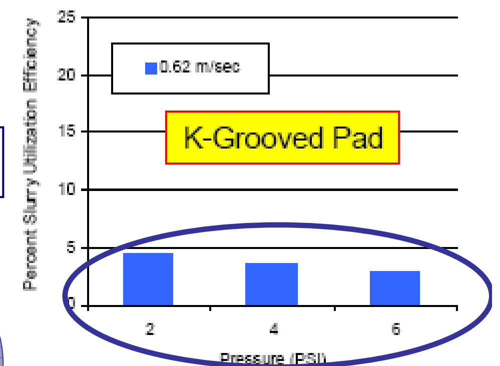
Facilities

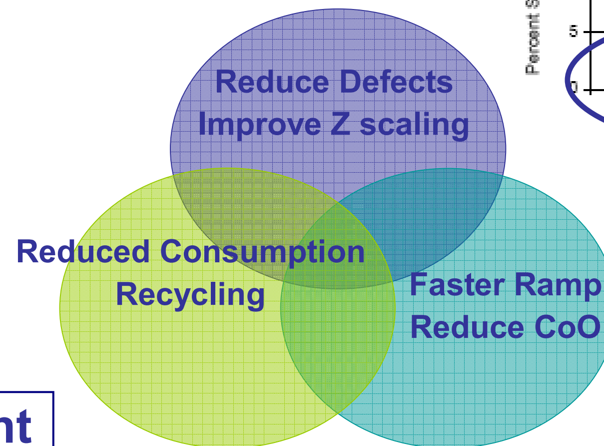
- We offer contract services for:
  - Material development
  - Process analysis
  - Process development
- Our technology is available to address your CMP problems!

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**

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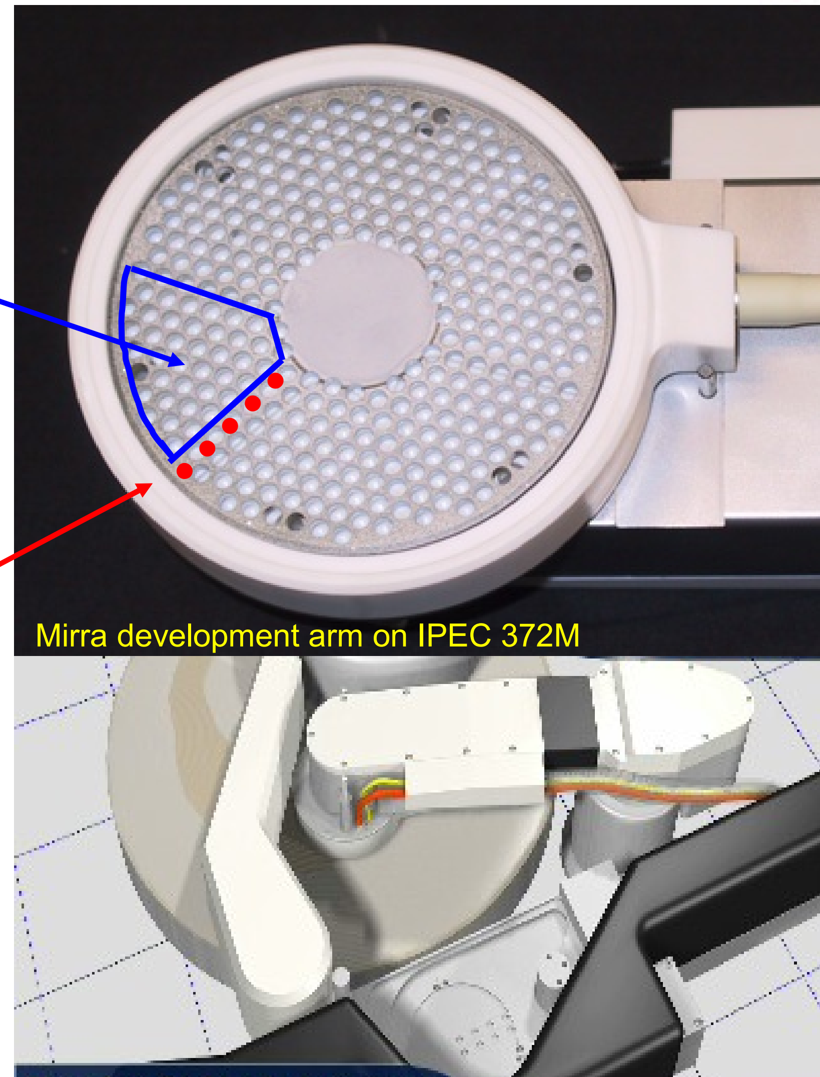
Pad Surface Manager

- *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



Pad Surface Manager

PSM
"OEM Cartridge"
Design provides common PSM subsystem for multiple OEM platforms, i.e., 200mm, 300mm, 450mm?

"Dresser coupling" provides mechanical interface to OEM abrasive rotation

"Shoulder" provides mechanical interface to OEM SWEEP drive sub-system.

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

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Variation of Conductivity and pH

pH
Conductivity (µS)
Polish Time (sec.)
-■- pH
-●- Conductivity

- 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

Slurry flow	Oxide removal A/min (approx.)	WIWNU (approx.)
Conventional 75		
Conventional 125		
Conventional 200		
PSM @ 9" Hg 75		
PSM @ 9" Hg 125		
PSM @ 9" Hg 175		
PSM @ 9" Hg 225		
PSM @ 9" Hg 275		

MAX 1989 A/min

Average 2020 A/min

Legend: Oxide removal rate; WIWNU

Oxide removal A/min: 1500, 1600, 1700, 1800, 1900, 2000, 2100

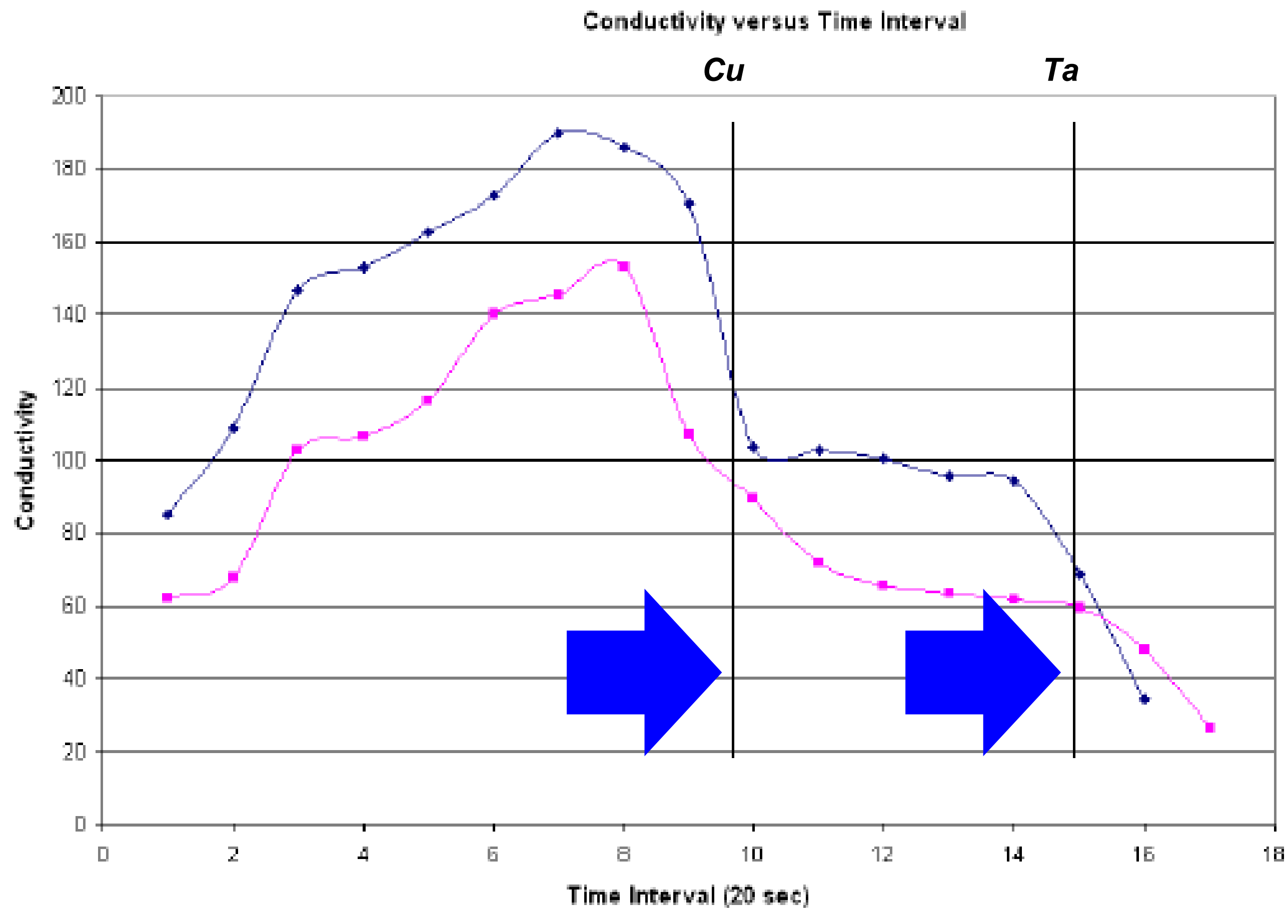
WIWNU: 0.00, 1.00, 2.00, 3.00, 4.00, 5.00, 6.00, 7.00, 8.00

Slurry flow: Conventional (75, 125, 200); PSM @ 9" Hg (75, 125, 175, 225, 275)

- Equivalent or better MRR with reduced slurry flow

200mm TOX, Cabot SS12, IC 1000 perforated pad

Cu and Barrier Polish Endpoints



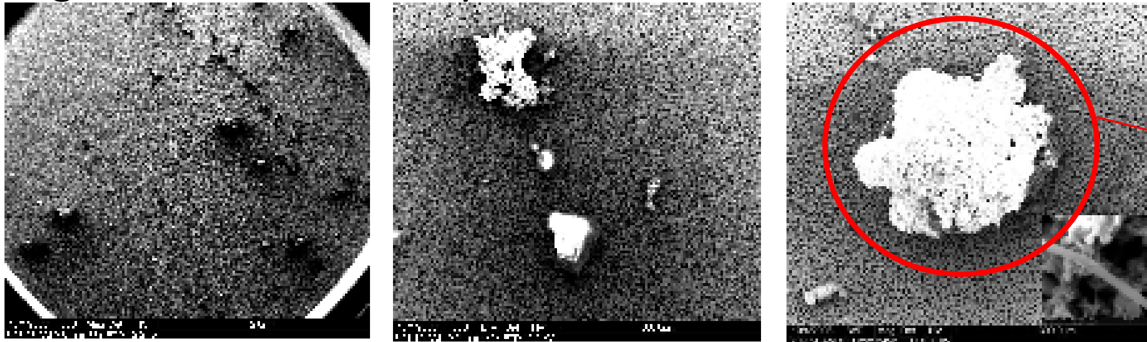
- **Inflection points at 200 and 300 seconds correspond to the end points for Cu and Ta, respectively**

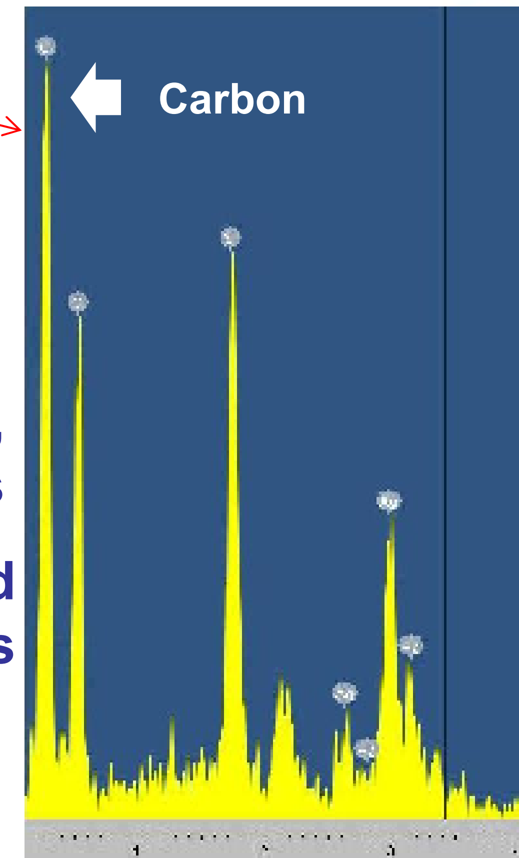
200mm Cu/Ta blanket wafers, PPG experimental slurries, IC1010 K groove pad

Particles Removed from the Pad

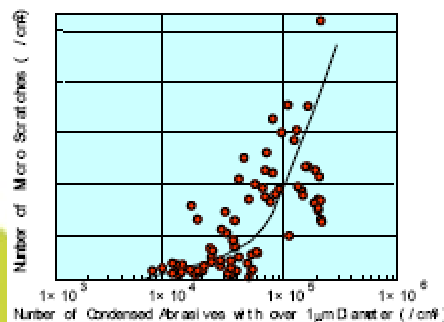
- **Pad effluent sampling**
  - **Filtration membrane with 800nm pores**

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

Vacuum	Total	Bin 1 - 5	Bin 6 - 10

Chart labels: Particles (y-axis); Vacuum (x-axis): 0, 6.1, 13.4; Legend: Total, Bin 1 - 5, Bin 6 - 10, Linear (Total), Linear (Bin 6 - 10); AKrion

- 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

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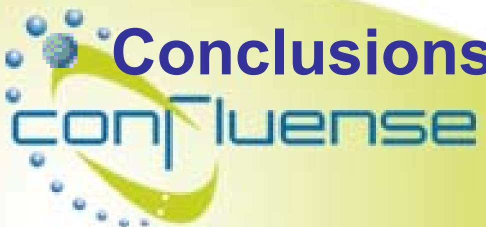

Conclusions

- **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

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

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