“Great Recession” Legacy
CMP Consumables’ New Playing Field

NCCAVS CMPUG Semicon W Meeting
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The “Great Recession” Effects

- 2008-09 Very Dark and Scary Years: Materials markets fell as predicted, but no full bounce back in 2010.
- Some Materials less negative: CMP & Bulk Gases
- 2009 was even worse for equipment – the worst of times for Indirect Materials ~ - 40%
- 450 mm becoming a reality despite naysayers
- Cost of “Earth, Wind and Fire” continue to climb
Supply Constraints/Drivers
(IC Materials, not CMP Specific)

Market Drivers
- Portable Applications Driving Need for Smaller Geometry IC’s
- Cloud Computing Driving Demand for Simpler Technologies

Other Markets Demanding Same Materials

Raw Material Production Flexibility

Materials Business Growth/Profitability

Si/polySi Wafer Prices

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Cost Reduction Focus 2008-09

- All IC Materials Are Affected
- Cheaper Materials
  - Sputter Target Purity versus Price
  - CVD/ALD Precursors (Hf-organo versus HfCl$_4$)
- Do More with Less
  - Previously Undiluted Slurries Diluted
  - Self-Mix of Post-CMP versus Specialty Chemical
- Cost Pressure Throughout the Supply Chain
- New Entrants Focus on Cost of Ownership
Despite Recession: New Technologies and Growth Opportunities

Pre-1985

1000 nm
Two Al Metal layers, BPSG & TEOS

250 nm
Five Al metal layers, W Plugs, SiOF

Mid-1990’s

130 nm
one W & Six Cu Layer

Mid-2000’s

65 nm
Eight Cu Layer

2010’s

• SOG STI and pre-M1 Dielectric
• Hi K Dielectric & Metal Electrode Gates
• Hi K Memory Capacitors
• >8 layers of Cu Wire, 45nm
• AirGap @ ≤32nm
New High K-Metal Gate

Replacement Metal Gate Process

PMOS

NMOS

- Significant growth expected for Precursors, for 2015 Market Size in Expected to be <$100M
- Oh boy, more CMP (Al)

Pictures from Dec’07 IEDM

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<table>
<thead>
<tr>
<th>Year</th>
<th>Elements</th>
<th>Description</th>
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<tr>
<td>1980s</td>
<td>11</td>
<td>11 Elements</td>
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<tr>
<td>1990s</td>
<td>15</td>
<td>+4 Elements</td>
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<td>2000s</td>
<td>45</td>
<td>+45 Elements (Potential)</td>
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CMP Materials -
Still Accepting New Entrants

- A First? CMP Slurry Revenues Down 20% & 13% in 2008 & 2009
- Post-Recession, CMP Slurry Revenues Recover, Hoping to Match 2007 (2010 >1.20 x 2009)
- Numerous Slurry Suppliers Bring Price Competition, esp. Cu & Barrier and now Direct STI Slurries
  - Cu and Barrier not “one size fits all”
  - Direct STI (Ceria) growing, only one pass per wafer start ... new competitor takes signif share
- PCMP: Cu still a growth market, W niches below 45nm, Direct STI opportunities abound
- PVA brushes & Retaining rings – new suppliers, new designs, new materials
IC CMP Slurry Revenues

Annual Revenues ($M)

- Cu Barrier
- Cu Step 1
- Tungsten
- Oxide
- Ox-HKG
- AI-MGE
- Direct STI


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# Slurry Abrasive Suppliers Abound

<table>
<thead>
<tr>
<th>Company</th>
<th>Product Focus</th>
<th>Company</th>
<th>Product Focus</th>
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<td>Adcon Lab, Inc.</td>
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<td>Hitachi Chemical</td>
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<td>Mitsui Mining</td>
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<td>Nalco</td>
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Major Slurry Suppliers

- Cabot CMP still largest revenue market share
  - Tungsten, ILD, Al, some STI
  - Eternal Acquisition good for Cu
  - CMP Pads making progress (see Mike’s presentation)
- Five Suppliers ~ 10% each:
  - Dow Chemical, no longer with Eternal
  - Fujimi, Strong is Si Wafer, Share of Cu & ILD
  - DA Nanomaterials ... more barrier and Cu
  - Hitachi, Direct STI strong ... New competitor
  - Planar Solutions ... less barrier and more Cu
What’s New?

Metal Gate Electrode
- **Finally Al CMP is back**
- Small % of overall CMP at 45nm & 32nm

![Pie chart showing the breakdown of 2009 revenues: Cu Step 1 (32%), Cu Barrier (21%), Tungsten (25%), Oxide (14%), Direct STI (8%).]
What’s New?

- Direct STI (Ce)
  - Expensive abrasive, reduced abrasive content has large impact
  - New Entrant made progress when Fabs were most $ conscious

% 2009 Revenues

- Cu Barrier 21%
- Cu Step 1 32%
- Oxide 14%
- Tungsten 25%
- Direct STI 8%

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What’s New?

Copper & Barrier
- Reduced abrasive content reduces cost/wafer pass
- Highly fragmented and competitive market
- Will “Rule of Three” ever materialize?

% 2009 Revenues

- Cu Barrier 21%
- Direct STI 8%
- Oxide 14%
- Cu Step 1 32%
- Tungsten 25%

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What's New?

- Direct STI
- Oxide
- Cu Step 1
- Tungsten

% 2009 Revenues

- Tungsten
  - Effect of recent court battle TBD
  - W not large growth market
  - Slurry dilution & competition erode margins

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Post Copper CMP is still largest segment

Post Direct STI is becoming more and more important

Post Al Gate Electrode CMP could become next critical clean

% 2009 Revenues
Slurry Disposal

- Lower tech applications abound
- Recycle for CMP?
- Reclaim and re-use of spent CMP slurries
  - Concentrate used slurry
  - Reduce heavy metal contamination
- Road filler or ??
- Does it pay to be green?

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Future is Looking Bright

- **CMP Slurry**
  - Pricing pressure with numerous players and dilutions
  - But IC developers find us new applications

- **Post CMP Clean**
  - Pricing pressure as some Fabs mix their own
  - But IC yield pressures find us new customers

- **Korea and China**
  - They are buying lots of products that use Ics
  - Local materials suppliers are making headway, in many IC materials.
Techcet Group

- Techcet Critical Material Reports*

  - High K & Metal ALD/CVD Precursors
  - Interconnect Materials Beyond 65nm
  - Solar Cell Process Materials
  - Solar Cell Equipment Consumables
  - Polysilicon Market and Supply Chain
  - Ceramics
  - Ion Implant Sources
  - Liquid Dopants
  - Low Temperature Dielectric Precursors

  - CMP Consumables
  - Gases
  - Graphite
  - Masks and Reticles
  - Photoresists and Photoresist Ancillaries
  - Quartz
  - Silicon Carbide
  - Sputter Targets
  - Wet Chemicals

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