Leveraging Outsourced CMP Foundry Capabilities for Process-level Development through Full Production

by

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Outline

• Why outsource CMP?

• Development
  - Technology issues and financial impact
  - Example: CMP Pad Supplier

• CMP Integration and Qualification
  - Technology issues and financial impact
  - Example: Small Device Manufacturer

• Production Outsourcing
  - Technology issues and financial impact
  - Example: Major IDM

• Comments and conclusions
Once prized as a competitive advantage ... now CMP is recognized a necessary process for most advanced IC designs and many emerging technologies.

- CMP is more available, no longer kept behind a black curtain
- Still high cost and long implementation time
- Requires extensive process and integration expertise
- Now “mainstream” on oxide, W, STI, Cu ... others underway
- Critical to achieving acceptable yield on many device flows
Why Outsource CMP?

• Lower Risk
  - Leverage technical expertise and known baseline processes

• Faster Execution
  - Tap into existing facility, equipment, and process technology
  - Reduce implementation time by 12 months or more

• Lower Cost
  - Zero capital required
  - Much lower unit costs for low to moderate volume production
Who Needs CMP?

- CMP Packaging
- ICs
- Specialty Substrates
- CMP Consumables
- MEMS
- Photonics
- Emerging Devices
Three Example Scenarios:

• Development
  - Technology issues and financial impact
  - Example customer: psiloQuest, Inc.* (CMP pad supplier)

• Integration and Device Qualification
  - Technology issues and financial impact
  - Example customer: Medtronics, Inc.* (Medical device supplier)

• Production
  - Technology issues and financial impact
  - Example customer: Current CMOS fab needing more capacity

* Company names used with permission.
All other names of Entrepix customers are withheld.
Typical needs for a CMP development project:

- Credible wafer-level data on all major metrics
- Screening trials
- Process optimization and sensitivity to major variables
- Stability tests over multiple trials
- Extended life tests and inputs into failure mode analysis
- Honest technical feedback from an independent perspective
- Complete data package for market launch

All of these can be obtained from a properly equipped CMP outsource provider
**CMP Project Comparison**

### Internal Development:
- **Capital Invest:** $1.5 M
- **Several Engrs + Staff:** $1.0 M/Yr
- **Time to Develop:** 18-24 mo.
- **Multiple learning cycles**

### Outsourced Development:
- **Capital Invest:** $0
- **One Sr. Engineer:** $150K/Yr
- **Time to Develop:** 6-9 mo.
- **Leverage existing processes, staff, experience, and consulting**

**Total Time Savings:** 12 months or more
Development: Example Customer

- **psiloQuest, Inc.**
  - CMP pad supplier trying to penetrate mainstream market
  - Previously invested in their own internal apps lab
  - Needed additional capability, esp. for cleans and defectivity

- **Results**
  - Improved product characterization (verified by customers)
  - Through joint efforts, pad was qualified for use with 3rd party mainstream production wafers
  - Recent decision to shut down internal lab and outsource all applications work through Entrepix
Date: March 2004
Polisher: IPEC 472
Pad: psiloQuest
Slurry: Cabot SSW-2000 (diluted 1:1 + 4% H2O2)
Conditioning: None

Note: Rate offset due to difference in test wafer lots
Typical needs for CMP integration and qual:
- Technical inputs into composition and thickness of layers
- Feedback to design team on CMP module sensitivities
- Guidance on consumables choices
- Starting point CMP processes
- Short process runs for prototype devices
- Honest technical feedback from an independent perspective
- Optimized CMP processes with ability to ramp when needed

All of these can be obtained from a properly equipped CMP outsource provider
Internal:
- Capital Investment: $2.2-3.3M
- Multiple Engrs + Staff: $1.0 M/Yr
- Time to Develop: 18-24 mo.
- Multiple learning cycles

Outsourced:
- Capital Investment: $0
- One Sr. Engineer: $150K/Yr
- Time to Develop: 6-9 mo.
- Leverage existing processes, staff, experience, and consulting to reduce risk and learning cycles.

### Time to Implement:

#### Typical Internal Integration Project (first pass):
- Equip. Purchase
- Delivery & Qual.
- Development
- Qual.
- Prod. Ramp

#### Typical Integration Project with TFS:
- Total Time Savings: 12-24+ mos
- 3 mos 6 mos 9 mos 12 mos 15 mos 18 mos 21 mos 24 mos 27 mos 30 mos

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[Image: Diagram showing project phases and time savings comparison between internal and outsourced integration projects.]
Example CMP Integration and Qual:

• Medtronics, Inc.
  - Small production fab for medical devices
  - Unique device integration, including thin CrSi resistor layer
  - Running 0.6-0.8 um and desires to shrink to 0.35 um
  - Extreme focus on reliability

• Results
  - Straight to 3-level CMP integration with both ILD and W CMP
  - Debugged on existing mask set using < 50 product wafers
  - Less than 8 months total from concept to first silicon out
  - First lot to reach probe floor yielded working devices
  - Design team now working on new masks and qual plans
Integration: Reflow BPSG Contact

- **BPSG Reflow**
  - Smooth Step but not planar

- **Hot Metal Dep.**
  - Acceptable metal step coverage at 50%

- **SOG Gap Fill**
  - Acceptable planar surface, but not good enough to shrink
Integration: CMP Planarized Contact

- Good Contact to Substrate
- Ultra Flat BPSG
  - Photolithography is improved.
  - Planarization is improved
Integration: Non-planarized M1-M2

Thinning over step.

- Less than 20% coverage on corners

Poor ILD Planarization.

- Has negative impact for photolithography
- Limits design flexibility
Integration: CMP Planarized M1-M2

- Step coverage no longer an issue.
- Ultra flat surface.
  - Enhances photolithography.
  - More flexibility in design.
Cost per wafer comparison:

Bottom Line: Low volume cost differential is enormous
High volume cost differential is minimal
Production outsourcing: Technology issues

Typical needs for production outsourcing:
- Ability to match process outputs of in-fab toolset
- Equivalent yield
- Consistent day-to-day performance
- SPC and acceptable quality standards
- Systems and infrastructure to handle wafer flow
- Properly trained staff
- Ability to ramp quickly .... Up or down!

All of these can be obtained from a properly equipped CMP outsource provider.
### Internal CMP Production:
- Capital Invest: $1.5 M
- Ox-CMP capacity: $4.9 M
- W-CMP capacity: $2.5 M
- Cu module: $4.6 M
- Staff: $1.0 M/Yr
- Time to implement: 18-24 mo.

### Outsourced CMP Production:
- Capital Invest: $0
- One Sr. Engineer: $150K/Yr
- Time to Develop: 3-6 mo.
- Leverage existing production capacity, processes, staff, experience, and consulting

### Time to Implement:

<table>
<thead>
<tr>
<th>Project Phases</th>
<th>Time Savings: 6-9 mos</th>
</tr>
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<tbody>
<tr>
<td>Equip. Purchase &amp; Delivery</td>
<td></td>
</tr>
<tr>
<td>Qualification</td>
<td></td>
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<tr>
<td>Production Ramp</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Typical CMP Capacity Ramp with TFS:</th>
</tr>
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<tbody>
<tr>
<td>Qualification</td>
</tr>
<tr>
<td>Prod. Ramp</td>
</tr>
<tr>
<td>3 mos</td>
</tr>
<tr>
<td>6 mos</td>
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<tr>
<td>9 mos</td>
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<tr>
<td>12 mos</td>
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Example of Outsource Production:

• **Major IDM**
  - Production fab running at full CMP capacity
  - Strong desire to ramp wafer starts, but bottleneck at CMP
  - Ordered more CMP tools, but timing delayed from starts ramp
  - Willing to consider outsource CMP

• **Results**
  - Close monitoring of contamination proved comparable to fab
  - Qualified both tungsten and oxide CMP at 3 levels
  - Yield was equivalent to in-fab toolset on first 1000 wafers
  - Outsource CMP enabled fab to achieve die out targets that would otherwise have been missed
- Now over 125 production lots
- Yield equivalent to in-fab process tools
- Extremely low scrap rate
- Proven process repeatability
Impact of Development Cycles

• Internal development requires additional investments for each node:
  - Dedicated development teams for each node
  - Increasing investment in new equipment and facilities dedicated to new materials: Oxide, W, STI, Cu…

Or...

• Outsourcing development leverages processes and integration expertise of the outsource provider:
  - Reduces time to qualify new process by 6-18 months
  - Eliminates capital investment
  - Reduces risks by using proven solutions
## Repeated Development Cycles Impact

<table>
<thead>
<tr>
<th>Node</th>
<th>Key Technology</th>
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<tbody>
<tr>
<td>45 nm</td>
<td>High-K, Ir &amp; Pt, ...</td>
</tr>
<tr>
<td>65 nm</td>
<td>Cu CMP w/UL-k</td>
</tr>
<tr>
<td>90 nm</td>
<td>Cu CMP w/CDO or Low-k</td>
</tr>
<tr>
<td>130 nm</td>
<td>Cu w/ FSG</td>
</tr>
<tr>
<td>180 nm</td>
<td>STI/ PMD/ Cu CMP</td>
</tr>
<tr>
<td>0.25 um</td>
<td>W-CMP</td>
</tr>
<tr>
<td>0.35 um</td>
<td>TEOS-CMP</td>
</tr>
<tr>
<td>0.5 um</td>
<td>Lmt'd Oxide &amp; W-CMP</td>
</tr>
<tr>
<td>0.8 um</td>
<td>Pre-CMP</td>
</tr>
</tbody>
</table>

**Legend:**
- Prototype
- Development
- Qualification
- Prod. Ramp

Potential Time Savings of 3-6 months per Node using Outsourced CMP Development
Summary: Reasons to outsource CMP

• **Lower Risk**
  - Immediate access to proven process technology and expertise
  - Minimize complexity associated with polishers, cleaners, chemical delivery, filtration, metrology, consumables, etc.

• **Faster Execution**
  - Rapid prototyping, development projects or process qualification
  - Reduce implementation time an average of 12 to 18 months

• **Substantial Cost Benefits**
  - Reduce or eliminate capital expenditures
  - Lower unit costs

• **Production Impact**
  - Perform engineering trials without taking your polishers off line
  - Flexible manufacturing capacity when you need it
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