TRENDS IN CMP AND IMPACT ON CONSUMABLES

CMPUG USA MAY 2, 2024
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# Linx Consulting Service Portfolio

## Multi-Client Reports
- CMP & Specialty Abrasives
- Advanced Deposition
- Patterning Materials
- Cleaning & Surface Prep
- Electronic Specialty Gases
- Bulk Chemicals
- ALE
- Photomasks

## Proprietary Projects
- Market Planning
- M & A
- Growth and Diversification
- Supply Chain Optimization
- Technology Commercialization
- Strategic Planning
- Voice of the Customer
- Market Diligence

## Econometric Semiconductor Forecast
- Financial planning
- Sales and Operational planning
- Forecasting & Scenario development

*With Hilltop Economics LLC*

## Cost Modeling
- Client demand modeling
- Product development
- Bill of Materials quantification

## Semiconductor Technology & Market Conferences
- The Business of Cleans & SPCC
- Electronic Specialty Gases & Systems

## Continuing Services
- Forecast Service
- Technology Trends

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**Global Economic Background**

**World* Real GDP**

- 2021: 6.1%
- 2022: 3.0%
- 2023p: 2.7%
- 2024f: 1.8%
- 2025f: 2.5%

*Hilltop Economics, 85 Consensus Economics countries
World Bank History, 2015 Constant US$, March 2024
Long term trend (1994-2019) 3.1%/Yr

**Regional GDP Growth Forecasts**

<table>
<thead>
<tr>
<th>March Update vs ESF 23Q4</th>
<th>2023 November</th>
<th>2023 ESF</th>
<th>2024 November</th>
<th>2024 ESF</th>
<th>2025 November</th>
<th>2025 ESF</th>
<th>2026 November</th>
<th>2026 ESF</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>2.4</td>
<td>2.5</td>
<td>(0.3)</td>
<td>1.2</td>
<td>1.8</td>
<td>1.6</td>
<td>3.3</td>
<td>2.9</td>
</tr>
<tr>
<td>Asia-Pacific</td>
<td>4.1</td>
<td>4.2</td>
<td>3.1</td>
<td>3.4</td>
<td>3.6</td>
<td>3.6</td>
<td>4.5</td>
<td>4.4</td>
</tr>
<tr>
<td>Europe</td>
<td>0.5</td>
<td>0.4</td>
<td>0.2</td>
<td>0.2</td>
<td>1.4</td>
<td>1.3</td>
<td>2.4</td>
<td>2.3</td>
</tr>
<tr>
<td>Latin America</td>
<td>1.9</td>
<td>2.1</td>
<td>0.8</td>
<td>0.8</td>
<td>2.5</td>
<td>2.4</td>
<td>3.1</td>
<td>3.0</td>
</tr>
<tr>
<td>Total World</td>
<td>2.6</td>
<td>2.7</td>
<td>1.3</td>
<td>1.8</td>
<td>2.5</td>
<td>2.5</td>
<td>3.5</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Source: Hilltop Economics

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Outlook for MSI is Still Strong

<table>
<thead>
<tr>
<th>Year</th>
<th>Y-on-Y Growth</th>
</tr>
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<tbody>
<tr>
<td>2023</td>
<td>-14 %</td>
</tr>
<tr>
<td>2024</td>
<td>4 %</td>
</tr>
<tr>
<td>2025</td>
<td>15+ %</td>
</tr>
</tbody>
</table>
New Technology Challenges

Technology Challenges
• EUV /HNA EUV pattern transfer
• Metrology gaps
• 3D Structure challenges
• Logic transistor architectures
• Backside power delivery
• Vertical DRAM stacking
• Heterogenous Integration

Novel Materials and Processes
• High NA EUV
  • Patterning approaches and materials
• CVD & ALD Metals for interconnect and power
• Atomic Layer Etch
• Area Selective Deposition
• Selective dry or wet etch, and subsequent cleans
  • GAA transistors
  • 3D NAND
  • Vertical DRAM
CMP Aligns With Advanced Nodes

Growth of CMP Processing in Advanced Logic Nodes
- Litho DOF - Higher NA requires flatter surfaces
- Metal damascene
- Dielectric trench
- Smoothening
- Etchback does not sufficiently planarize
- Advanced patterning / grating
- TSV
- Power via
- BPR
- Wafer bonding
- Bridges
CMP Consumables ~ CMP Tools ($ basis)
Challenges Facing Materials Suppliers
Materials Supply Challenges

**Geopolitical Influences**

- Materials supply chain is becoming less efficient and more costly due to dual supply chain and localization (De-risking)
- Upstream raw materials uncertainties have caused interrupted supply
- Alternative sources and new source requalification process may cause higher raw material cost

**Environmental Control Regulations**

- Continued efforts to develop alternative greener chemistries for restricted materials such as GHG, PFAS, TMAH, NMP…etc.
- New ways for looking at shipping and container costs
- Recycling considerations
- Green inflation may be caused by extra resource requirements and high switching cost of alternative solutions
Materials Supply Challenges

Limited Supplier Options

- Longer supply lead time and possibly interrupted supply due to insufficient capacity on critical materials
- Quality system knowledge limitation of tier 2 suppliers
- Post-M&A concentrated supplier base in critical segments without alternative choices
- Increasing bargaining power of dominant suppliers and possibly price increase

Governmental Support

- Global leading-edge semiconductor manufacturing has been recognized as a critical geo-political imperative, and national governments are incentivizing domestic capability for economic and strategic reasons.
- How will government support for advanced production in Korea, Japan, Europe, China and USA impact market?
- Impact on Materials Suppliers - Suppliers must balance technical capability and infrastructure with localized customer support
## Challenges - Localization Barriers

<table>
<thead>
<tr>
<th>Raw Mats Supplier Breadth</th>
<th>R&amp;D CT Criticality</th>
<th>Infrastructure : Revenue Cost</th>
<th>Applications Support Intensity</th>
<th>Supplier : Customer Density</th>
<th>Ease of Localization</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Wet Chemicals</td>
<td>Broad</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Regional</td>
<td>Easy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Specialized Permitting Required. Costly to ship long distances.</td>
</tr>
<tr>
<td>Slurry</td>
<td>Unique</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium High</td>
<td>National/ Site</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Local Support Costs. Local Manufacturing Preferable.</td>
</tr>
<tr>
<td>Photoresist Advanced</td>
<td>Unique</td>
<td>High</td>
<td>High / Unaffordable</td>
<td>High</td>
<td>Site</td>
<td>Difficult</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Innovation Costs Require Scale. Centralized R&amp;D and Manufacturing</td>
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Outlook - CMP Consumables Grow Above MSI

CMP consumables CAGR at 11+% will outpace MSI growth of 8% due to 3DN and Logic CMP intensity and inflation impacts on materials.

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Summary

Over the next decade per capita semiconductor demand will rise at double the global GDP growth rate, and increasing materials intensity for advanced chips will compound this growth to 10-15% AAGR for materials used in sub 5 nm technologies.

Global leading-edge semiconductor manufacturing has been recognized as a critical geopolitical imperative, and national governments are incentivizing domestic capability for economic and strategic reasons.

2023 and 2024 will be challenging for both materials and equipment supply chains.

Government regulation may have an impact on materials availability for legacy and leading edge manufacturing.