Outline

1. Overview of Linx Consulting
2. CMP Outlook/Drivers for 450
3. Conclusions
The Value We Bring To Clients

1. We create knowledge and develop unique insights at the intersection of advanced thin film processes and the chemicals industry

2. We help our clients to succeed through our:
   • Experience in global electronics and advanced materials and thin film processing industries:
     - Semi
     - Packaging
     - Nano Technology
     - LCD
     - PV
     - Other
   • Experience in the global chemicals industry
   • Experience at Device Producers
   • Experience at OEMs
   • Global network and capabilities
   • Advanced modeling capabilities
WE PROVIDE HIGH CONFIDENCE DECISION SUPPORT SERVICES – SINGLE CLIENT

PLANNING
- Business Analysis
- M&A / Due Diligence
- Diversification / Expansion Planning

IDEAS TO MARKET
- IP Development
- Value Chain Analysis
- Technology Assessment and Commercialization

OPERATIONS
- Cost Benchmarking
- Competitive Intelligence
- COO Models and Assessment
- Process Technology Assessment

MARKETING & SALES
- Market Analysis/Monitoring
- Market Forecasting and Modeling
- Competitive Intelligence
- Customer Perceptions
Analysis Reports - Services Offered

CURRENTLY AVAILABLE INDUSTRY ANALYSIS REPORTS

1. CMP Technologies and Markets

2. Advanced Thin Films for FEOL and BEOL Applications

3. Advanced Materials and Chemicals for Photovoltaic Cells and Modules

4. Emerging Materials Opportunities for Advanced Semiconductor Devices

5. Advanced Cleaning and Surface Preparation: Technologies and Markets

6. Opportunities in Imprint Lithography

7. Specialty Abrasives in CMP

8. Advanced Patterning

9. Semiconductor Industry Direct Consumables Model
CMP Outlook/Drivers for 450
CMP Growth Remains Strong

Thousands of unit operations

14% Long Term CAGR

Source: Linx Consulting
CMP Tool Base - Current

Source: Linx Consulting and Gartner

Linx Consulting
See Beyond The Horizon
The new "Silicon Valley"

Business model changes required / desirable?

Notes:
1. Bottom axis is on a percentage basis
2. Size of box is proportional to # wafer starts
3. Source: Semico and Linx estimates

Materials innovations required
New Industry Structure, 2018

Notes:
1. Bottom axis is on a percentage basis
2. Size of box is proportional to # wafer starts
3. Source: Semico and Linx estimates

“Silicon Valley” extends
Notes:
1. Bottom axis is on a percentage basis
2. Size of box is proportional to # wafer starts
3. Source: Semico and Linx estimates
CMP Wafer Distribution in 2018

- 250nm - 32nm: 39%
- 22nm - 12nm: 61%
# Opportunities for CMP Keep on Increasing

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Reference: **Chemical Mechanical Polish: The Enabling Technology**, Steigerwald
Wafer Costs Keep Increasing

- Processing costs increase over the next five years as follows:
  - DRAM – 59%
  - MPU – 50%
  - NAND – 34%

- Although some of this can be blamed on the costs associated with double, triple and quadruple patterning, device producers will still have problems passing these increases along.

Source: IC Knowledge
CMP Tool Base Extended View

Source: Linx Consulting, IC Knowledge and Gartner
Tool Distribution, 2020

Tools by Wafer Size

- 450mm
- 200mm
- 300mm

LINX CONSULTING
SEE BEYOND THE HORIZON
450mm Trends

**Trends Impacting Consumable Suppliers:**

- Leading platforms are looking at 42” pads
- Pad composition is relatively similar between 300mm (30”) and 450mm applications
- Slurry composition is also expected to be relatively stable with conversion to 450mm
- 450mm wafer is ~ 900 to 925 microns thickness; where as the 300mm wafer is 775 microns. This increases wafer bowing
- ROI/NPV concerns

**Trends Impacting Tool Suppliers:**

- Early tool development efforts are targeting 2015/2016 for HVM
- The number of zones per head may increase upwards from 5 zones for better control of uniformity
- Possible move from single point to multi-point dispensing systems to ensure uniformity of slurry distribution
- Potential within wafer variations may lead to multi-point endpoint detection
450mm Trends

Trends Impacting End-users:

- Greater emphasis on *truly* collaborative driven solutions will be required due to increased development expense
- Not all semiconductor producers can or will invest in 450mm technology
- Transition to 450mm will necessarily limit the supplier base over time, as not all suppliers can afford investment or will be selected to for PORs.
  - In addition, suppliers need large volumes for learning curve driven cost reductions
Conclusions

- 200mm is set and done -> work toward productivity improvements

- 300mm still has a long way to go
  - Work toward productivity improvements
  - Work towards innovation

- 450mm is coming, but is still a way off
  - Be sure to place bets at an appropriate time and not too early
  - Select the right partnerships

- 450mm may impact supplier selection criteria (need fewer, large suppliers) and supplier industry structure

- Collaborations and consortia become more important
Acknowledgements

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QUESTIONS?

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