“Impact of Advanced Memory Technologies on CMP Industry”

CMPUG July 11, 2018

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Outline

• Introduction to Linx Consulting

• Semi Industry Outlook

• CMP in Advanced Devices

• Conclusions
Introduction to Linx Consulting
1. We help our clients to succeed by creating knowledge and developing unique insights at the intersection of electronic thin film processes and the chemicals industry on a global basis

2. The knowledge is based on a core understanding of the semiconductor device technology; manufacturing processes and roadmaps; and the global structural industry dynamics

3. This knowledge is leveraged to create advanced models, simulations and real-world forecasts

4. Our perspectives are by direct research and leveraging our extensive experience throughout the global industry value chain
MSI Breakdown & Forecasts
Linx Consulting Service Portfolio

- **Full Service**
  - Forecast Service
  - Technology Trends

- **Multi-Client Reports**
  - IC Materials
    - CMP
    - Deposition
    - Patterning
    - Cleaning
    - Gases
    - Bulk Chemicals
    - Packaging

- **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
  
  *With Hilltop Economics LLC*

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

  *With IC Knowledge, LLC*

- **Conference Production**
  - The Business of Clean & SPCC

- **Wafer Start Demand Forecasting**
  - Device type and technology node
Semi Industry Outlook
Market Inflections

Materials Market Drivers
- PCs and Internet
- Connected World
- AI / Machine learning
- IoT / Big data / VR / AR
- Autonomous vehicles / ADAS

Mfg. Inflections
- 10/7/5 nm foundry
- 3D NAND
- China

CMP Impact
- CMP Intensity Increases
- New Materials
Record Levels of Capex

Driven by NAND, DRAM and Foundry

NAND
- Samsung Pyeongtaek P1
- SK Hynix M14 3D NAND line
- Micron Building 60 (Lehi) and Fab 10X in Singapore
- Toshiba/Flash Alliance Fab 2, Fab 6 and new R&D Center
- Intel Fab 68 in China

DRAM
- Samsung Pyeongtaek P1 and Line 15
- Micron Fab 15 (Hiroshima) and Fab 16
- SK Hynix M14

Foundry
- TSMC Fab 12, Fab 14 and Fab 15
- Samsung S2 and S3
- GLOBALFOUNDRIES Fab 1, Fab 8 and Fab 11
- SMIC Beijing B2 and B3, new Shanghai 300mm fab and Shenzhen 300mm fab
- UMC Fab 12A P5 and Xiamen fab

Vertical scaling helps drive Materials Growth and CMP
Latest MSI Forecast by ESF Model

Semiconductor MSI Outlook

Annual Percent Change in MSI
11.4%  3.3%  2.9%  10.0%  7.9%  5.4%

History: Semi.org
Forecasts: Hilltop Economics, LLC

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Silicon Forecast

Advent of 3D

200mm growth

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Wafer Supply May Cause Disruption

300mm
- Brownfield Investment is being made by leaders
- 300mm contracts are in place for larger end-users.
- China producers still need 3 to 5 years to quality
- Expect 300mm wafer shortages for smaller end-users
- Suppliers may not be prepared for growth

200mm
- US and Europe have stronger than expected outlook
- Auto and IOT applications drive continued 200mm growth
- Fabs are using reclaim wafers for production
- 200mm shortages beginning in 3Q 2017
- Global Wafer has increased 200mm supply
- 200mm from China are of sufficient quality
Linx WFM Liquidity Index

YOY Change(%)
CMP in Memory
CMP is Aligned with WFM Trends

Increasing Chemical Consumption

Trends in Advanced Technology Wet Cleans

Wet chemical consumption per wafer is increasing

- Proliferation of single-wafer processing, higher number of layers
- Multi-step patterning, more complex process flows
- Defect reduction, less recycle

Larger volumes increase scrutiny on chemical cost ($)

Trend driven by:

- Increased # of interconnect and FEOL layers
- RMG process
- Multi-Patterning
- New materials integration

Bill of Materials – Si not Included

Source: Linx, IC Knowledge, Intel
Overall Processing & CMP Cost Per Wafer

Source: ICKnowledge, Strategic Model
CMP Costs are In-line with Wafer Processing Costs

Source: ICKnowledge, Strategic Model
CMP Intensity in Memory, 2020

The bar chart shows the number of CMP steps and wafer starts for ASIC 10nm, DRAM 15nm, and 3DN 96L. The line chart illustrates the number of CMP operations for each category.

The pie chart represents the percentage distribution of CMP operations among the three categories. ASIC 10nm accounts for 29%, DRAM 15nm for 34%, and 3DN 96L for 37%.

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Conclusions
Conclusions

- Sustainable strong growth outlook anticipated for several years

- 3D structures and new materials will continue to drive semiconductor technology advancement at 1Xnm and beyond.

- 200mm and older wafer fab is expected to remain at high levels of capacity utilization over the next several years. Productivity will be a major driver

- Memory will account for a greater share of 300mm CMP spend going forward