OUTLOOK FOR CMP
CONSUMABLES

CMPUG April 12, 2018

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Linx Consulting Inc.
Outline

• Introduction to Linx Consulting

• Semi Industry Outlook

• Materials Challenges

• Impact on Suppliers

• 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.
Linx Consulting Service Portfolio

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

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

- **Econometric Semiconductor Forecast**
  - Financial planning
  - Sales and Operational planning
  - Forecasting

  *With Hilltop Economics LLC*

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

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

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

  *With IC Knowledge, LLC*

- **Wafer Start Demand Forecasting**
  - Device type and technology node
Semi Industry Outlook
Economic Drivers

**World** Real GDP Growth

- 2016: 2.3%
- 2017: 3.0%
- 2018: 3.1%

**World** Real Investment

- 2016: 3.4%
- 2017: -4.3%
- 2018: +4.2%
- 2019: +3.8%

U.S. Business Investment

- Percent Change
- History: U.S. Bureau of Economic Analysis, ($)
Linx WFM Equity Index

% Change in Equity Price

- Platform: -24
- Entegris: 54
- Versum: 27
- Cabot Micro: 44
- KMG: 42
- JSR: 23
- TOK: 6

Time Period 3/27/2017 to 3/27/2018
Latest MSI Forecast by ESF Model

Semiconductor Forecast: ESF 2018 Q1

MSI DRIVES CMP AND OTHER FAB MATERIALS
Record Levels of Capex

Fab Spending shows Records!

Construction $ Record of US$10B in 2018

Equipment $ Record of US$54B in 2018

Source: World Fab Forecast Report, May 2017, SEMI

Fab equipment spending includes new and secondary equipment; and facilities for such

Capacity Utilization for 200mm and 300mm fabs > 95% in 2017
Key Growth Drivers: NAND, DRAM and Foundry

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

3DN and Logic driving growth. Vertical scaling helps drive Materials Growth
Materials Challenges
Materials Challenges

Demand Drivers

• CuBS demand increasing in Logic Interconnect
  • Limitations of current architectures

• FinFET gate deposition
  • GAA Nanowire development
  • High mobility materials

• Memory technology extension
  • 3D-NAND growth
  • DRAM capacitor dielectric
  • Novel architectures

• Pitch doubling and quadrupling
  • Low temperature spacers

• Lithography aids

Opportunities

• Possible changes in conductor metal
  • Cu ⇒ Co Barrier ⇒ Co plating

• 3D-NAND aspect ratio
  • Hard mask technology
  • 2D stair-step

• Novel process development
  • Multi color, self aligning etch
  • CVD ⇔ Continuous etch
  • ALD ⇔ ALE

• Self Assembling Materials for selective processes

• Few new PVD applications
  • 3DXpoint / MRAM?

• Selective Deposition
  • Self Assembling Materials
  • Selective Deposition

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Trends - WFM Spend at Advanced Nodes

Increasing Chemical Consumption

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

Source: Linx, IC Knowledge, Intel
CMP Benefits from New Devices

# CMP Steps

- 3DN 96 Layer
- TSMC Fab 18 - 5nm

- Oxide (including STI)
- CuBS
- Cobalt
- Poly
- W (include MG)
- SiN
- SiGe

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Planarity Considerations in SADP for Advanced BEOL Patterning

- CNSE have shown the impact of gap-fill planarity on SADP process for advanced 7nm/5 nm technology
- Multiple patterning has been the main stream integration scheme in the sub 14 nm before the maturity of EUV lithography
- Among all the practical schemes, SADP not only simplified the overlay control, but also provides a better RC performance over the LELE scheme
- Therefore, minimizing the number of cuts in the SADP integration became important to HVM
- CNSE demonstrated that a robust SADP process through insertion of etch stop layer (ESL) between two coatings of organic polymer layers

Source: Albany Nanotech/IBM
Slurry, Pad & PCMPC Forecast ($M)
Impact on Suppliers
Regional & Structural Trends

Recent Transactions

- Cabot Microelectronics – NexPlanar
  - Fujimi Collaboration
- FujiFilm EM – Ultra Pure + Wako
- Wonik – Nova-Kem
- NATA - Kempur
- Air Liquide – AirGas + Voltaix
- Air Products – Versum Materials spinout
- SK - OCIM + Tri-Chem
- Dow Chemical – DuPont + Dow Corning
- Global Wafer - SunEdison
- Yoke – UPChem
- Versum - Dynaloy
- SK Holding – LG Siltron + OCIM
- Linde + Praxair
- Avantor - Gelest

China

- Leveraged government equity positions to enable significant sized acquisitions
- Continued acquisition activity from multiple companies.
- Acquisitions along the line of key product areas:
  - Silicon
  - Gases
  - Lithography materials
  - Advanced deposition materials

Korea

- Korean companies also looking to change business model
- Gain international market access
Top Tier WFM Suppliers
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

• Concentrated customer base and tool supplier base, along with increasing barriers to serve end-users will drive WFM consolidation

• New capacity in China will enable new suppliers who will initially compete with special commodities

• Expect Korea to focus more effort on specialty chemicals