

# Developments in CMP and Impact on CMP Consumables

Mike Corbett

Semicon West CMPUG July 12, 2017

[mcorbett@linx-consulting.com](mailto:mcorbett@linx-consulting.com)

**LINX-Consulting**  
see beyond the horizon

Surface Preparation & Cleaning Conference  
External Disclosure Not Permitted

[www.linx-consulting.com](http://www.linx-consulting.com)

# Agenda



1. Introduction to Linx Consulting
2. Where Have We Been and Where are We Going?
3. Defects in CMP
4. Post-CMP Clean
5. Conclusions



# Introduction to Linx Consulting



# 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*
2. *The knowledge is based on a core understanding of the semiconductor device technology; manufacturing processes and roadmaps; and the 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, including:*
  - Experience in global electronics and advanced materials and thin film processing industries
  - Experience in the global chemicals industry
  - Experience at Device Producers
  - Experience at OEMs



# Linux Consulting Service Portfolio

- **Multi-Client Reports**

- IC Materials
  - CMP
  - Deposition
  - Patterning
  - Cleaning
  - Gases
  - Bulk Chemicals
- III-Vs, TSV, WLP, Solar

- **Proprietary Projects**

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

- **Econometric Semiconductor Forecast**

- Financial planning
- Sales and Operational planning
- Forecasting

**Hilltop Economics LLC**

- **Cost Modeling**

- Client demand modeling
- Product development
- Bill of Materials quantification

**IC Knowledge, LLC**

- |        |             |                      |
|--------|-------------|----------------------|
| – Semi | – Packaging | – Nano Technology    |
| – LCD  | – PV        | – LED/ Compound Semi |

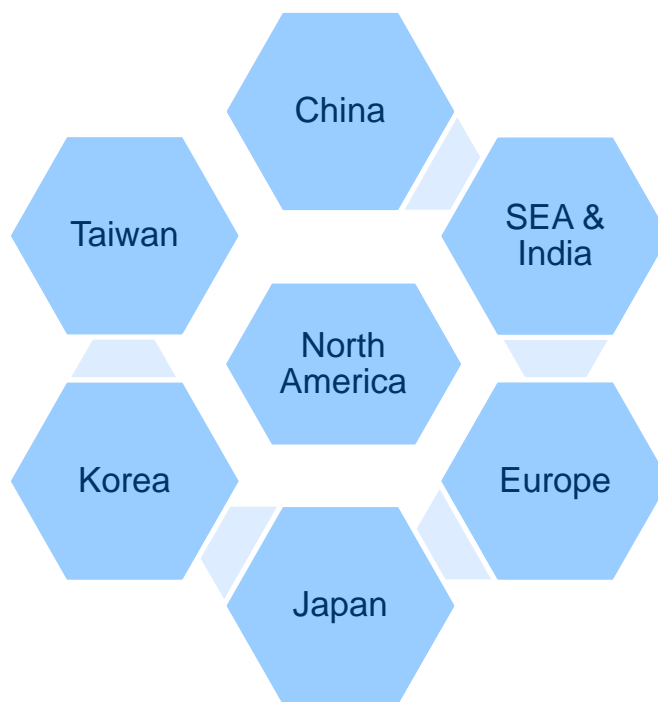
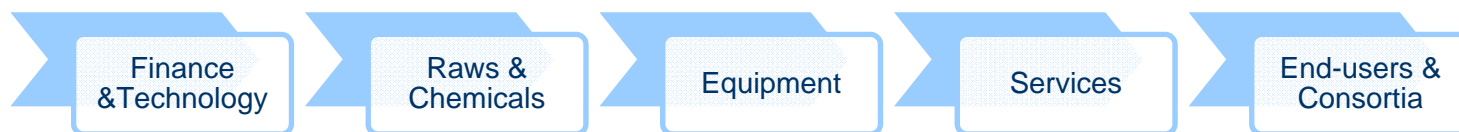
Conference Production - Surface Prep & Cleaning Conference & PCMP Cleans

[www.spcc2017.com](http://www.spcc2017.com)

[www.linx-consulting.com](http://www.linx-consulting.com)



# Customer Base in Semiconductors



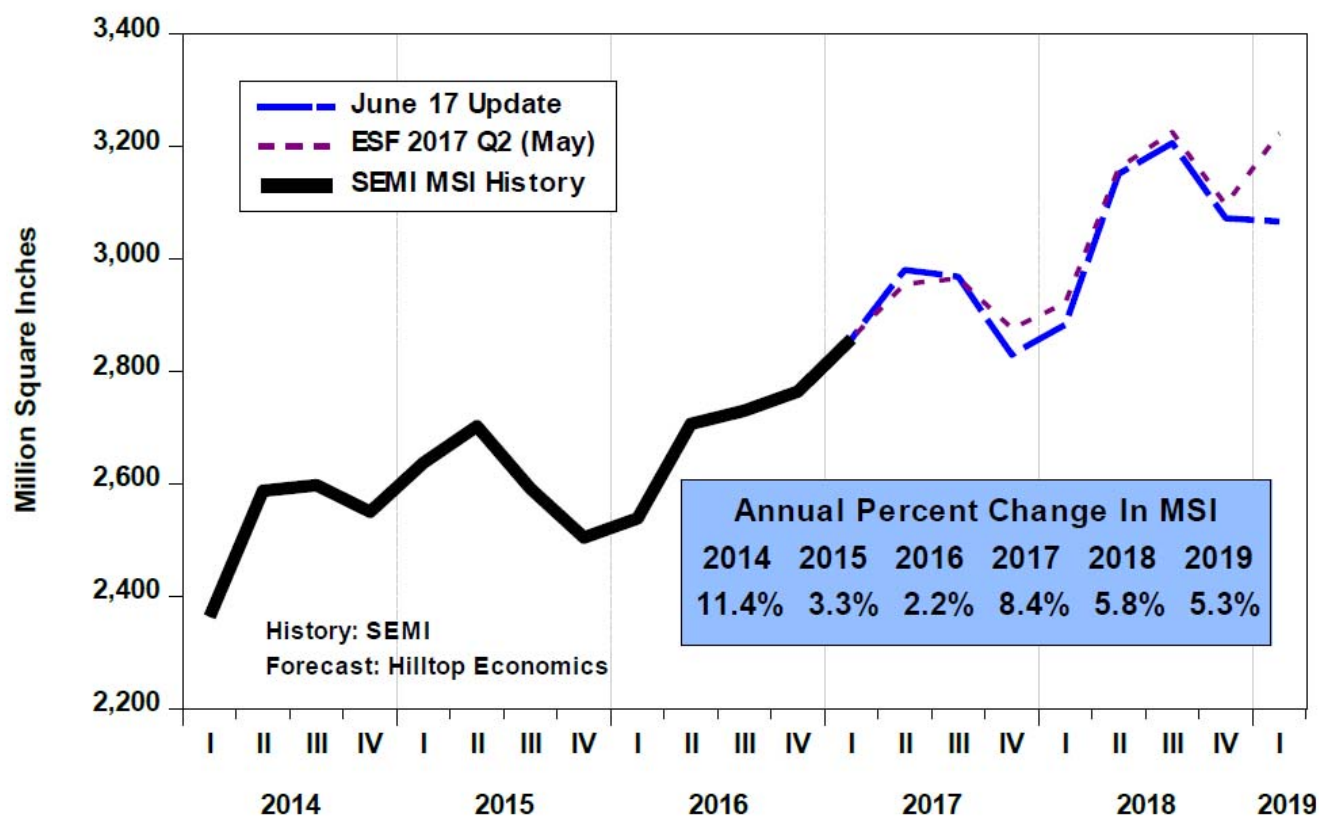


# Where Have We Been and Where are We Going?



# Strong Industry Outlook

## Semiconductor MSI Outlook



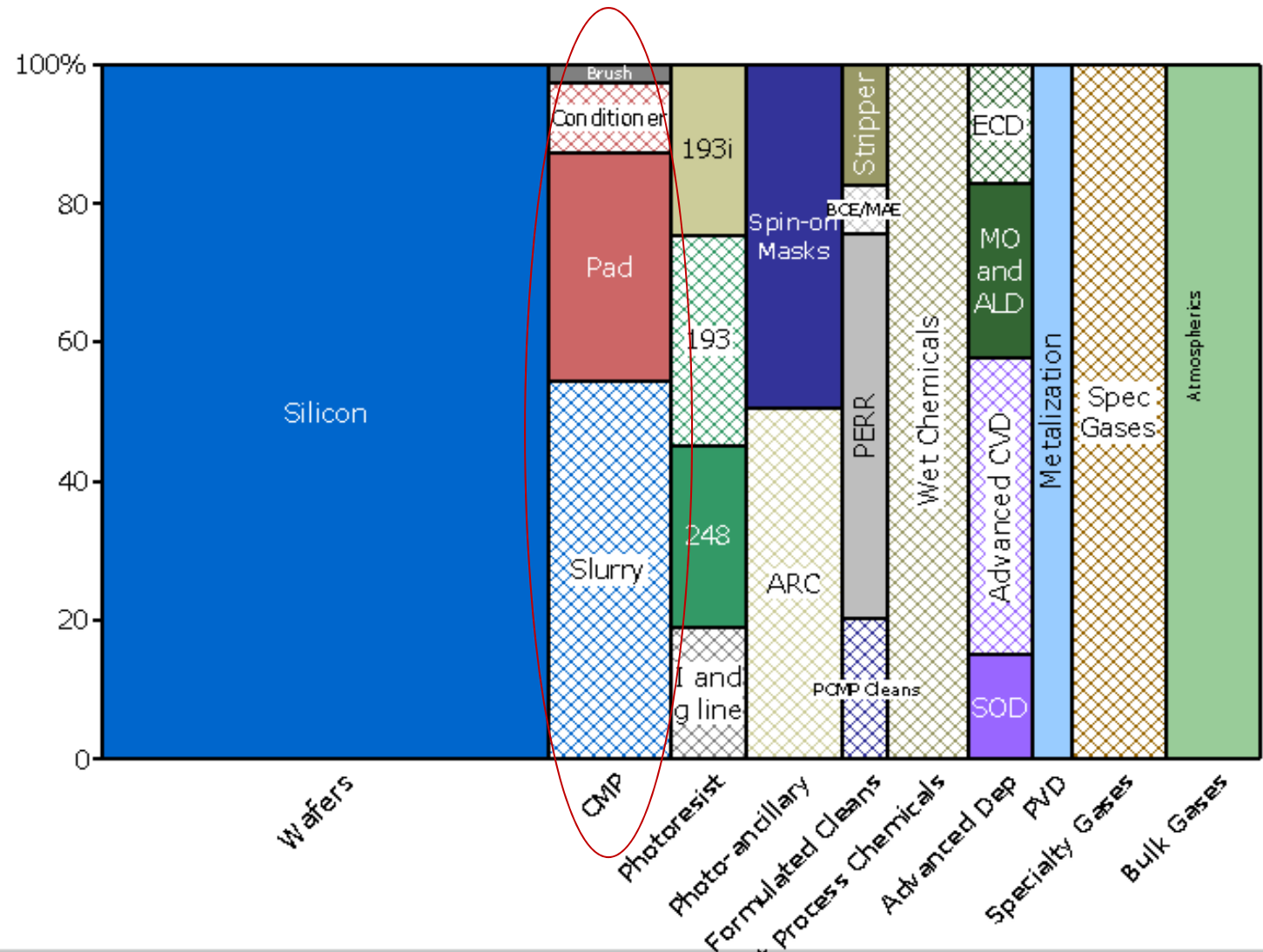
# Semiconductor Wafer Fab Materials (WFM) 2016



\$19 billion market in 2016

100's of material categories

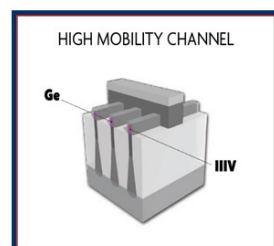
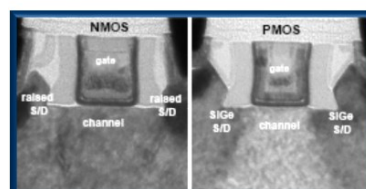
1000's of SKUs



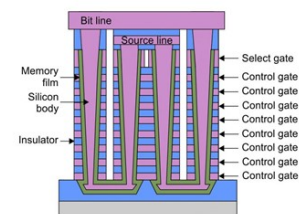
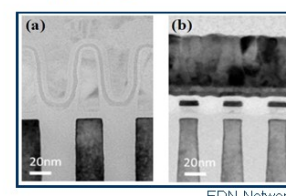


# CMP is an Enabling Process

Logic



NAND

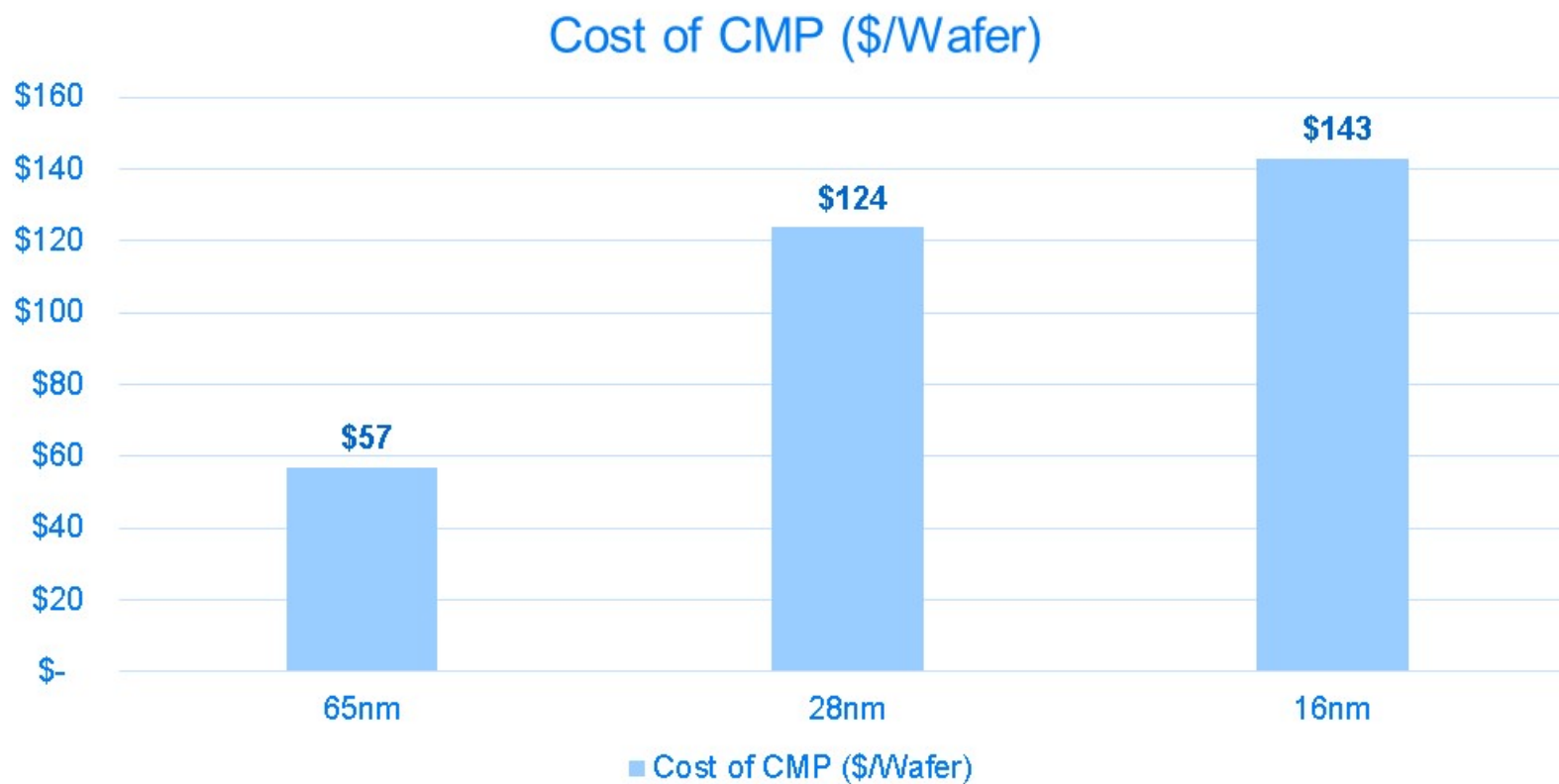


Copyright © 2015, IC Knowledge LLC, all right reserved

Trend	Impact on Deposition	Impact on CMP
High aspect ratio front end structures	Low temperature Gap fill	CMP for dielectrics and poly Novel selectivity
High-k / metal gate	Work function adjustment	More specialty metals ALD RMG CMP
Copper Barrier Seed technology limitations	New structures	ALD of Cu, Co, Ta, Ru, Mn, etc LKD Novel CMP - MHM
3D NAND	New structures	Advanced oxides W CMP
DRAM Scaling problems	Capacitor films TSV	CMP ALD



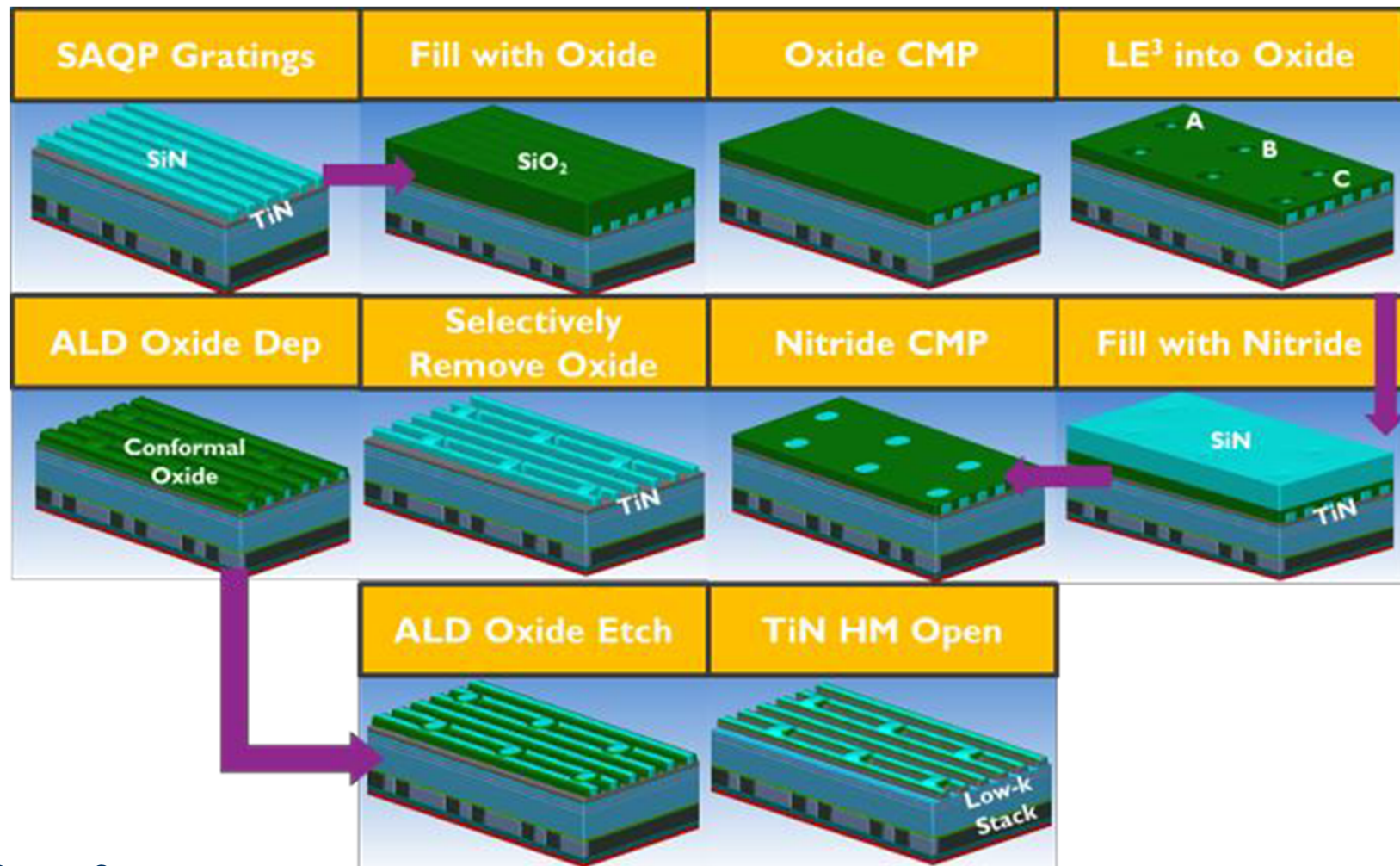
# Cost of CMP Consumables



Illustrative example based on ASIC production at leading edge foundry fab



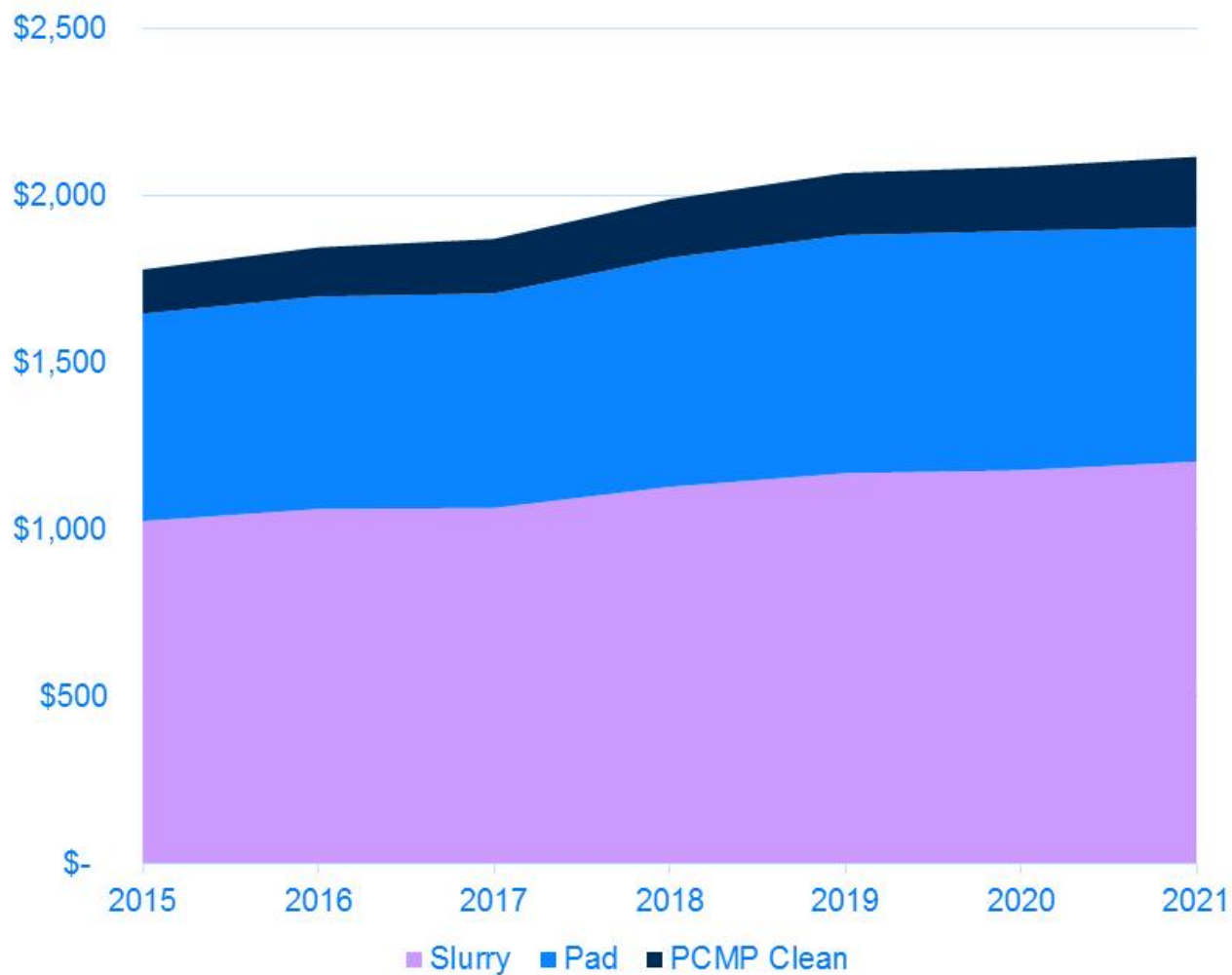
# Advanced Litho Processes & CMP



Source: Coventor



## Slurry and Pad Forecast (\$M)



### Issues impacting Revenue Growth:

- Lower polish times
- Price down of slurries and pads
- Increased dilution rates
- Pad life extension
- Better processes
- Lower abrasives contents



# Expect Consolidation to Continue

## Recent WFM Acquisition Landscape

- KMG - OMG + General Chemical + Nagase
- Entegris - ATMI
- Merck – AZ + Sigma Aldrich & Solmet
- Cabot Microelectronics - NexPlanar
- FujiFilm EM – Ultra Pure and 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
- NSIG – Okmetic
- Yoke – UPChem
- Linde and Praxair

## China

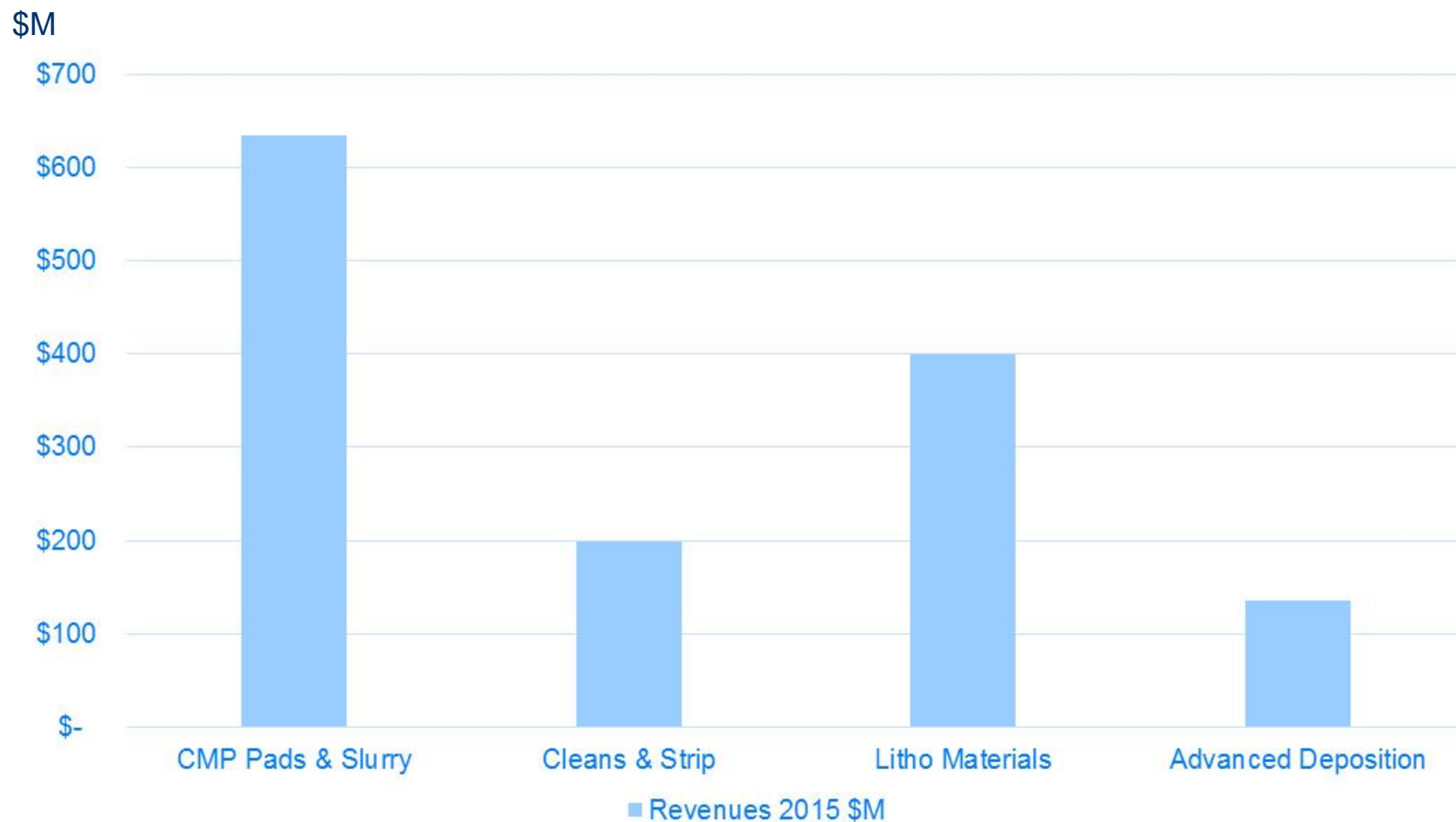
- Leveraged government equity positions to enable significant sized acquisitions
- Continued acquisition activity from multiple companies.
- Acquisitions along the line of key product areas:
  - Silicon
  - Gases
  - Lithography materials
  - Advanced deposition materials

## Korea

- Korean companies also looking to change business model
- Goal to get away from commodity cycles and focus more on specialties

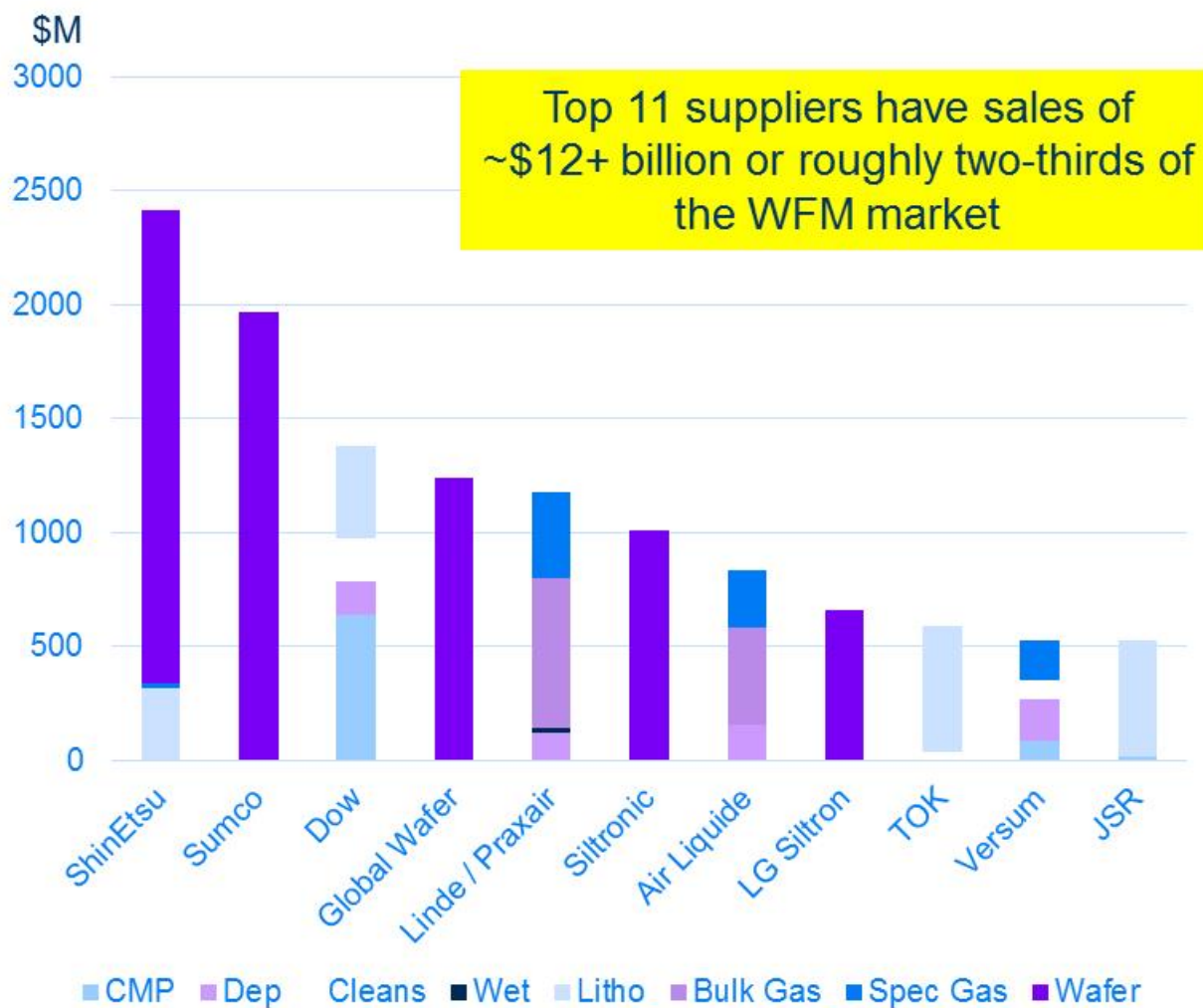


## Impact of M&A on WFM – Dow and DuPont





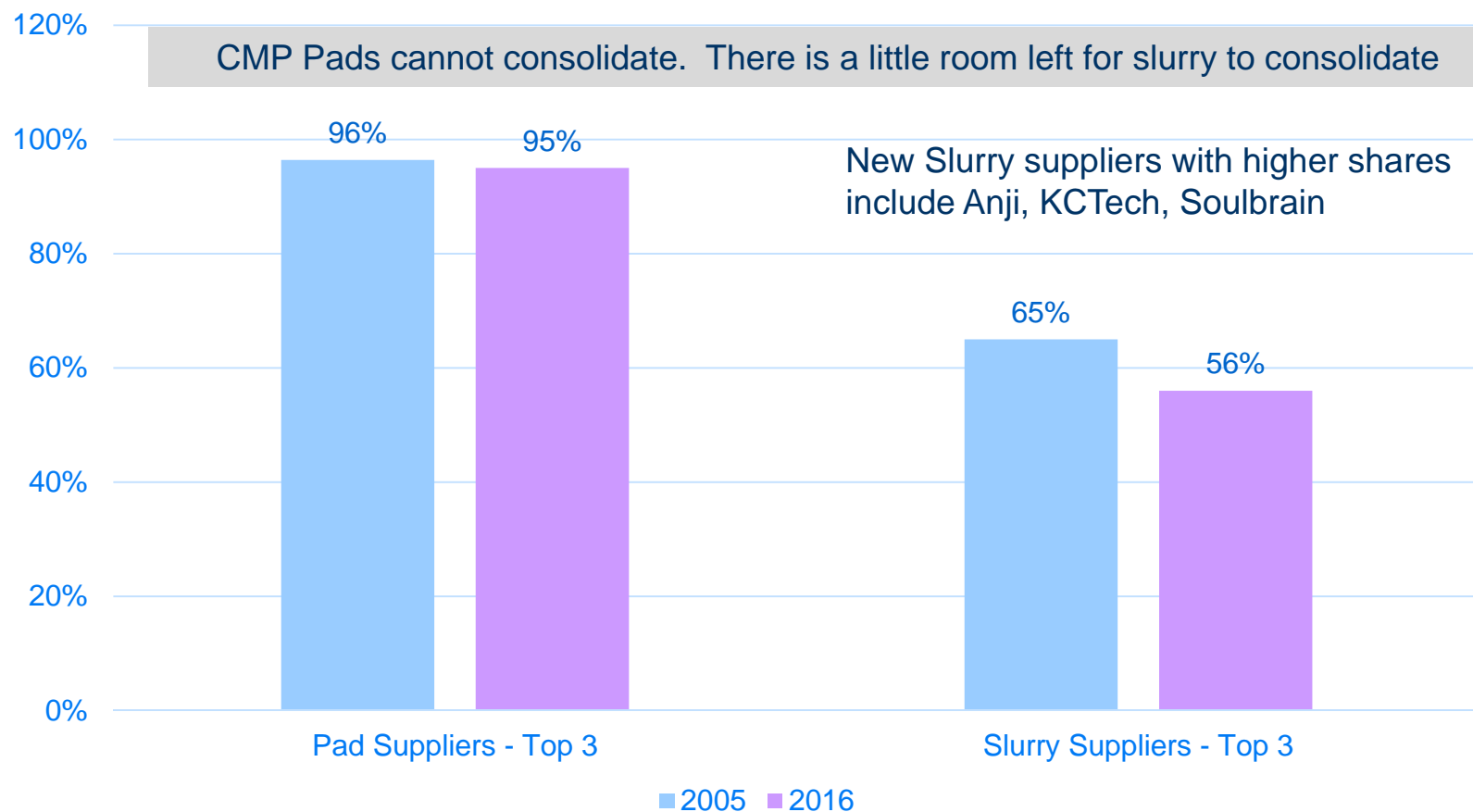
# Portfolios of Top Tier WFM Suppliers





# Will CMP Consolidate ?

## Supplier Share Evolution Over the Last 10 Years



Pads include Cabot Micro acquisition of NexPlanar

[www.linx-consulting.com](http://www.linx-consulting.com)



# Defects in CMP

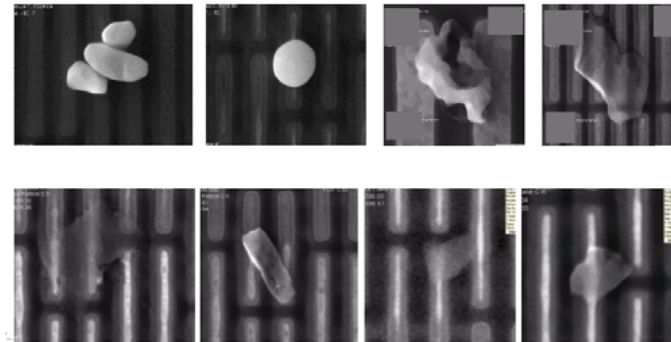
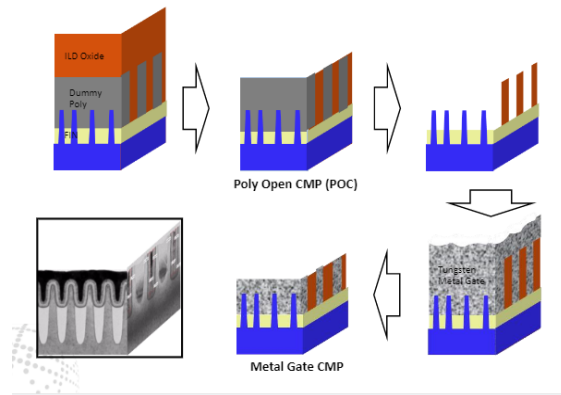


# Defectivity Paradigm Shift at 20nm and Beyond

1. Pursuit of Moore's Law is driving ever increasing design innovation, process sensitivity & complexity
2. Paradigm shift in thoughts about what we did not care about earlier in >20nm era & what we care to control now!
  - Complex Chemistry: Compatibility Issues
  - New Defect Sources, increase Defect Sensitivity
3. Metrology techniques of all types are challenged to provide sufficient sensitivity for early detection & prevention
  - Supplier Infrastructure Development needed for better defect detection & characterization
  - Metrology and Quality Control
4. Proactive engagement and collaboration across the supply chain are essential to HVM readiness

Source: A. Sengupta, Intel. Semicon West 2015

# RMG Process Flow in FinFET Structure



## Typical Source of Surface Particle Defects

- Organic Residue
  - Surface Particle
  - Scratching
  - Surface Flaking
  - Grain Roughness
  - Pattern Damage
- 
- Due to limited redundancy, each defect directly has an impact on the device performance or yield
  - leads to all kinds are potential killer defect
  - Organic residues and surface particles are the most frequently observed

Source: Hong Jin Kim, GF, CAMP 2016

# Consumables and Defectivity

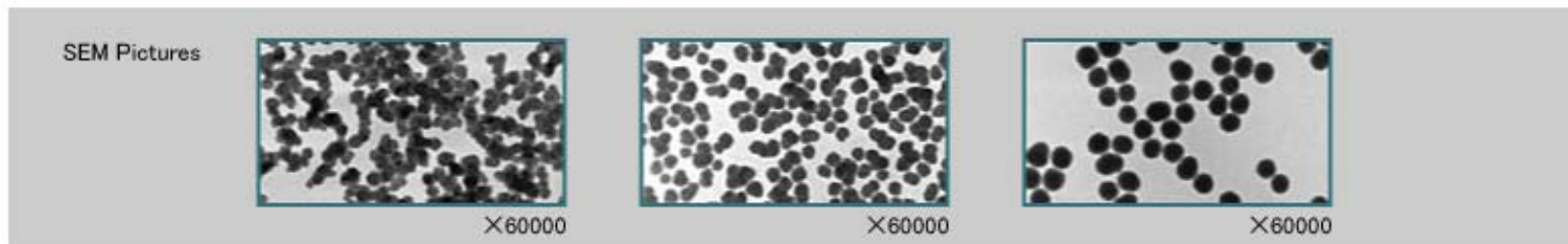


- For advanced nodes, the industry needs to have extremely tight control on the slurries and pad quality
- Greater use of high purity particles and chemicals to minimize contamination and increase reproducibility
- In advanced slurries, quality and morphology of the slurry particles will be critical
  - No agglomerations and angular particles
  - Need mostly spherical particles and to minimize the number of edges
- Trend to low abrasives or abrasive free – 0.5% or lower solids content as the slurry formulation trend is to greater chemo effect than mechanical effect
- Galvanic corrosion needs to be controlled in-situ – this is controlled by using the correct ingredients/formulations
  - Advanced slurry formulations may utilize 10 to 15 distinct ingredients
- Buff slurries.
  - In general colloidal silicas are preferred for buffing and there appears to be a trend towards ultra high purity colloidal silica buffs
  - Greater use of soft pads without sacrificing planarity with mild conditioning with proper pad surface roughness
- Once the polishing process is complete, a post-CMP cleaning process must not only remove residual slurry particles but also trace levels of metal ions, which otherwise could significantly decrease yield. In-situ clean from CMP tool is the most effective for clean wafer since it cleans wafer with wet state

# Ultra High Purity Colloidal Silica (UHPCS)



- Leading abrasive supplier can prepare high purity colloidal silica by particle growth method using hydrolysis and condensation with high purity alkoxysilane as a starting material
- Compared with colloidal silica starting from sodium silicate, this product is more pure, spherical shaped and stable at neutrality
- The purity of the product excluding nonionic and ionic dispersing agent is 99.9999% or more
- It is believed that, based on customer's requirement, it's possible to control particle size, degrees of the particle shape and select the dispersing agent, water, alcohol, glycol, etc.





## Abrasives Selected to Enhance Yield



Abrasives that do not drive optimized cost and yield solutions are transitioned away and replaced

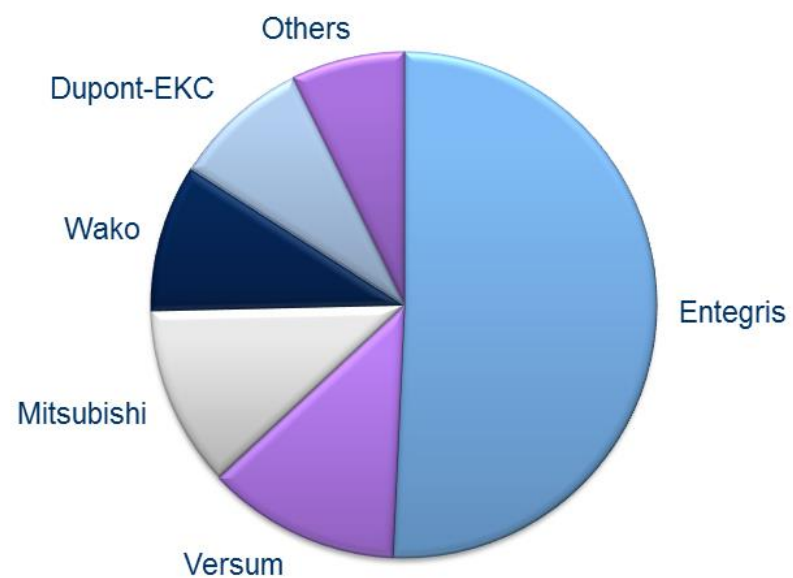
# Post-CMP Cleaning Chemistries Evolution



- Post-CMP cleaning solutions can have a large effect on wafer defectivity levels. The primary function of these chemicals is to protect the planarized metals and dielectrics, preventing corrosion while providing a smooth defect free wafer surface
- PCMP cleaning chemistry effectively removes organic residues, provide corrosion protection (static etch rate), galvanic corrosion protection, dendrite protection, and minimize oxide formation by protecting the surface layer from oxidation
- In addition, the desired level of surface roughness can be tuned by selecting different cleaning chemistries by choosing right concentration and dispensed volume for post-CMP cleaning
- Industry moving away from TMAH on PCMP cleans. The aqueous based chemistry consists of cleaning agents, chelating agents and corrosion preventing compound and other proprietary chemicals during and after the cleaning process
- Typically, proprietary formulations are used to increase performance, reliability and yield with reduced contamination and increase in queue time
- PCMP use significant levels of dilution – 50 to 150X, reducing post-CMP COO



## Leading Suppliers – pCMP Clean



Post CMP cleaning market – around \$150M in 2016

# Conclusions



- 3D structure and new materials will continue to drive semi conductor technology advancement at 1Xnm and beyond.
- CMP process technologies constantly evolve to meet a variety of new semiconductor manufacturing requirements for both logic and memory devices.
- CMP spending will remain to be a key part of overall wafer fab material cost stack and continue to increase node-by-node on a per-wafer basis.
- The CMP materials supply base is highly concentrated today and many of the leading semi material suppliers are involved in CMP. However it's expected to see significant changes in CMP consumables supplier landscape as industry continues the consolidation trend.
- Key CMP upstream material like abrasive plays a more critical role to achieve better polishing performance while controlling defects. New development to move to high purity colloidal type abrasives are taking place in both silica and ceria segments
- Close collaboration among CMP materials supply chain players is required to meet advanced CMP process requirements at 1Xnm and beyond through more precise defect control and end-to-end quality management