

THE WAFER FAB CLEANS IN SEMICONDUCTOR INDUSTRY FROM A MATERIALS SUPPLIER PERSPECTIVE

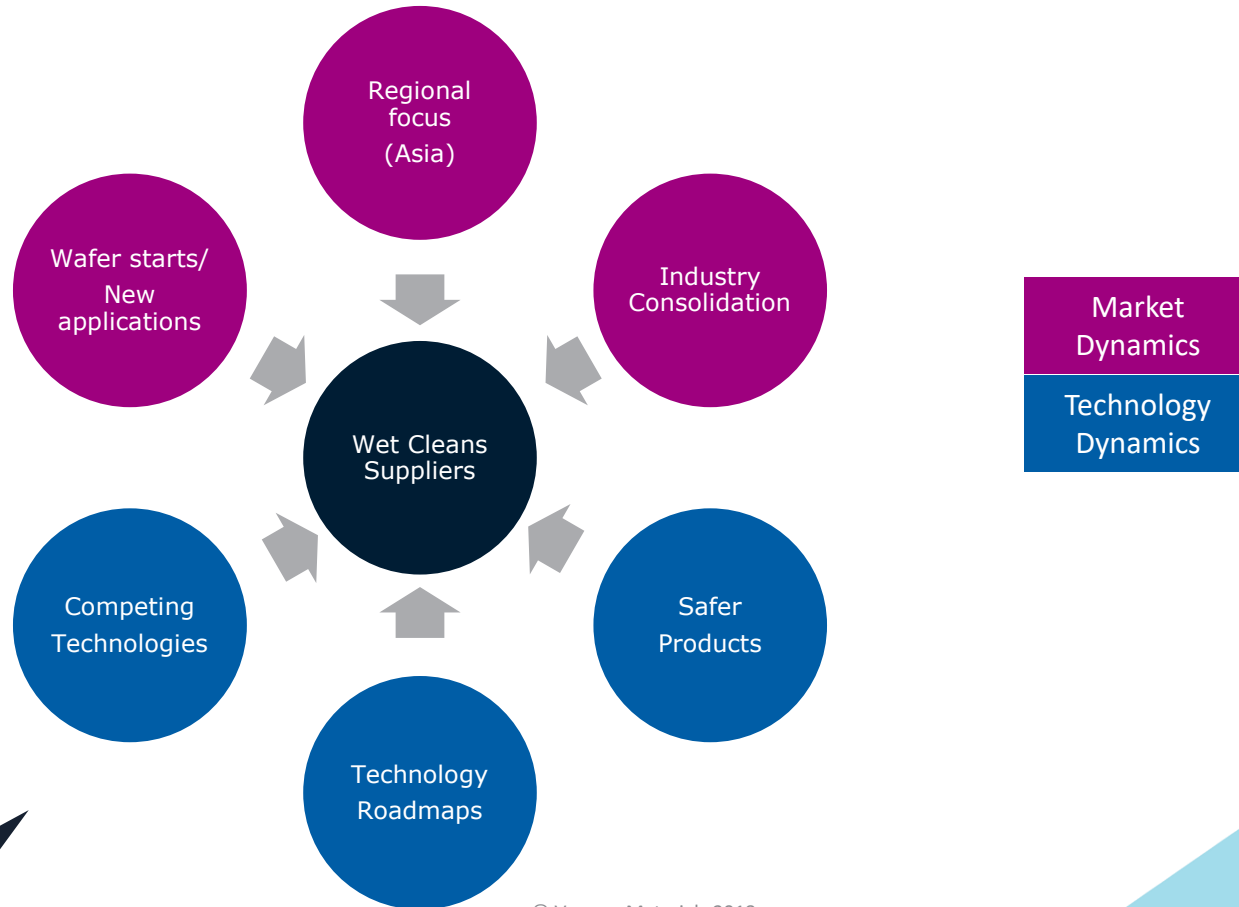
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SP&C Business (Surface Preparation & Cleans)



OUTLINE

- Market drivers and challenges
- Technology advancements and challenges
- Questions and answers

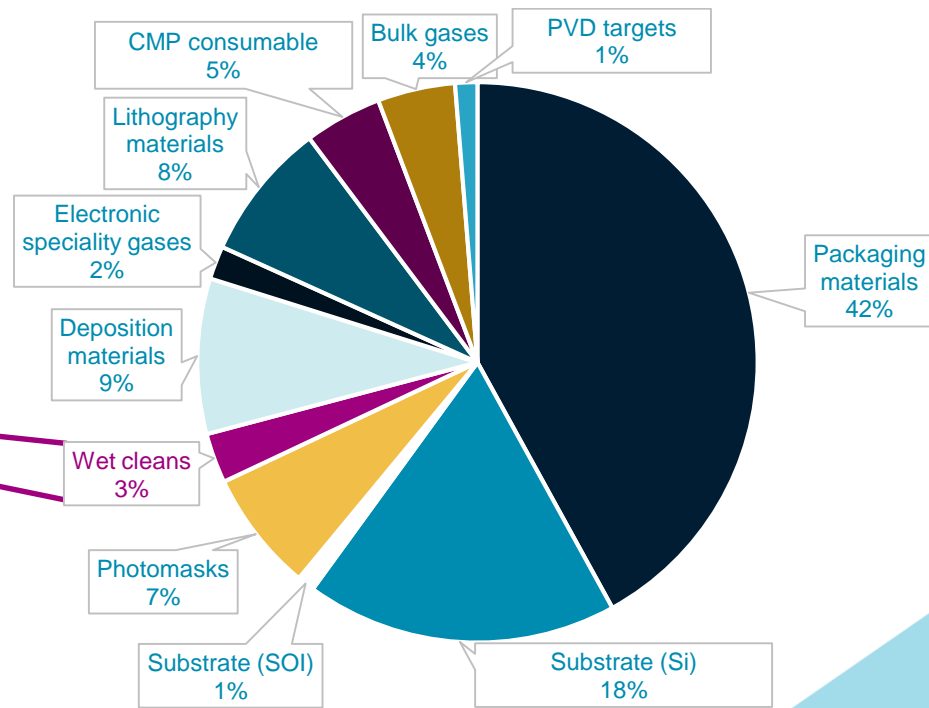
THERE ARE FORCES ACTING ON MATERIAL SUPPLIERS



IC INDUSTRY VALUE CHAIN

Wet cleans (excluding pCMP)

- Sales ~\$1.5B in 2018
- ~3% of total materials and ~7 of wafer fab materials (excluding substrates and photomasks) sales
- Growing at a CAGR of 5%
- Core to SEMI Innovation and Productivity



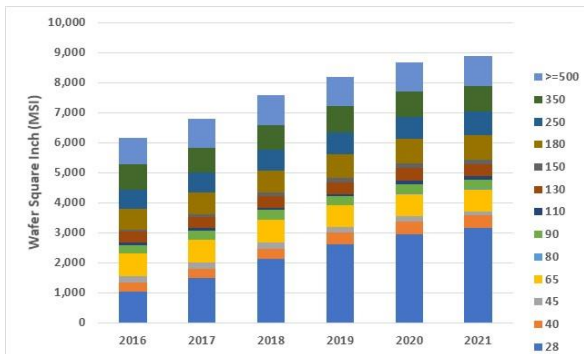
Source: SEMI, Linx consulting

WHAT DRIVES WET WAFER FAB CLEANS?

Industry Volume Growth

- Silicon MSI/Wafer Starts
 - 4.8% CAGR of MSI (2015 -2017)

>70% Of All Wafer Starts at 28nm and above



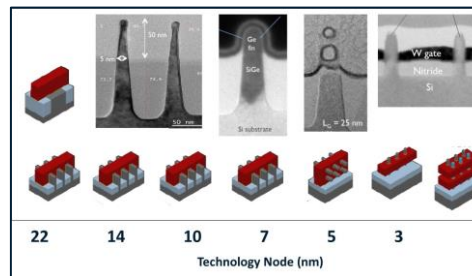
Source: IHS MARKIT



Technology Changes Due to New Device Architectures

- Next Generation Nodes (New Materials)
- 3 Dimensional Structures (More materials and More processing steps)

Moore's law continues

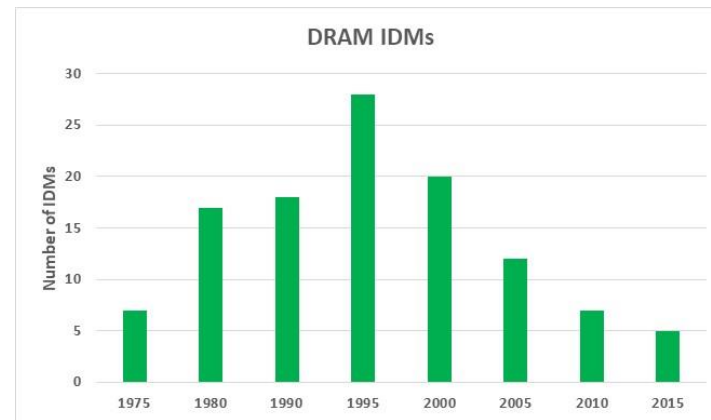
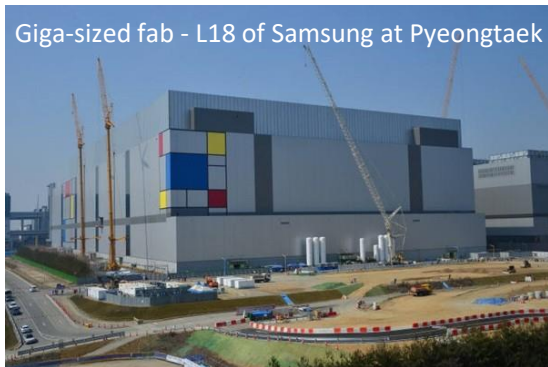


Source: IMEC

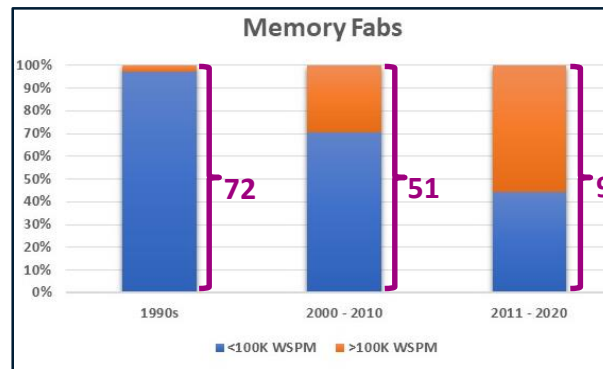
CUSTOMERS ARE CHANGING

Fewer and much larger customers...

- Too many suppliers for shrinking customer base
- Increased ramp complexity, volume and variability
- Higher expectations/pressure
- Access is critical for more limited POR opportunities
- Implications of winning/losing
- Customer centric vs. market centric model



Source: VLSI Research

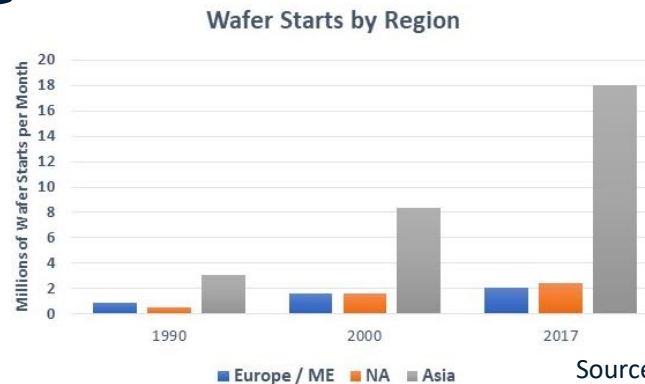


Source: SEMI

CUSTOMERS ARE CHANGING

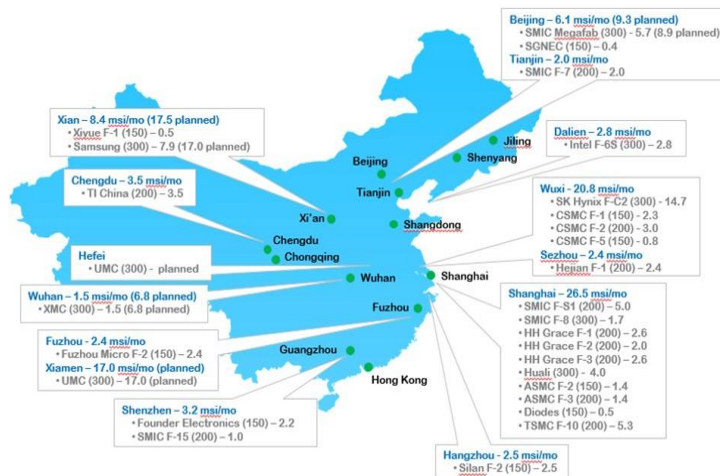
Shift to Asia requires footprint changes

- New customers
- Supply
- Operation
- Innovation infrastructure

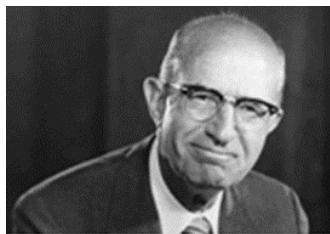


The Emergence of Si China

- Multinational vs. domestic fabs
- Localization vs. globalization



COMPETITORS ARE CHANGING



Air Products and Chemicals acquired Ashland Specialty Chemical Company's electronic chemicals unit.



Acquired Dynaloy LLC, a leading supplier of formulated cleaning solutions from Eastman Chemical Company (NYSE: EMN).

1940

Air Products founded in Detroit, Michigan, based on Leonard Pool's revolutionary on-site gas supply concept.

2003



2016

Air Products' EMD (Electronic Materials Division) spun off As Versum Materials on October 4, 2016

2017



Sustainable Growth

Recent M&As

- Cabot Microelectronics - NexPlanar
- Entegis - ATMI
- Fujifilm EM - Ultra Pure
- Wonik - Nova-Kem
- NATA - Kempur
- Air Liquide - AirGas + Voltaix
- SK - OCIM + Tri-Chem
- Dow Chemical - DuPont + Dow Corning
- Yoke - UPChem
- FFEM - Wako
- SK Holding - LG Siltron
- Linde + Praxair
- Infineon - Mentor
- Avantor - Gelest
- Global Wafer - SunEdison

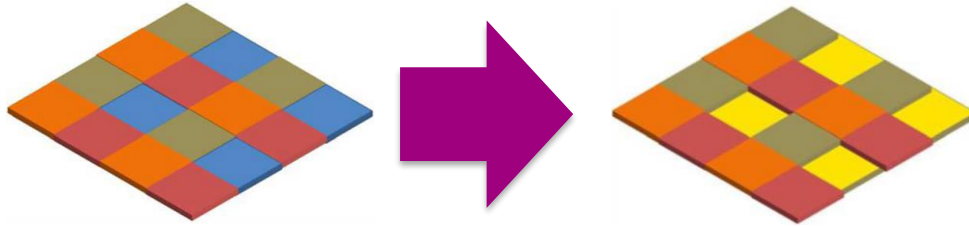
China

- 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

South Korea

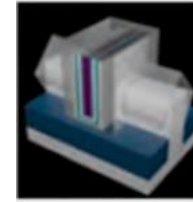
- Korean companies also looking to change business model
- Gain international market access

GREATER NEED FOR INNOVATION – SELECTIVE CLEANS

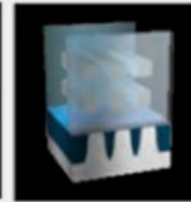


Source: Carver, C. et. Al. *ECS Journal of Solid State Science and Technology*, 4 (6) N5005-N5009, 2015.

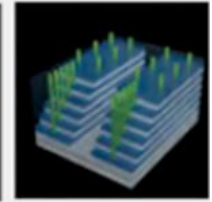
New materials challenges



FinFET



GAA
transistor



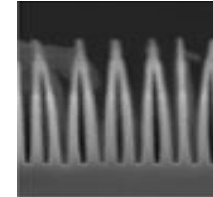
3D
NAND

Source: AMAT

Vertical geometry challenges



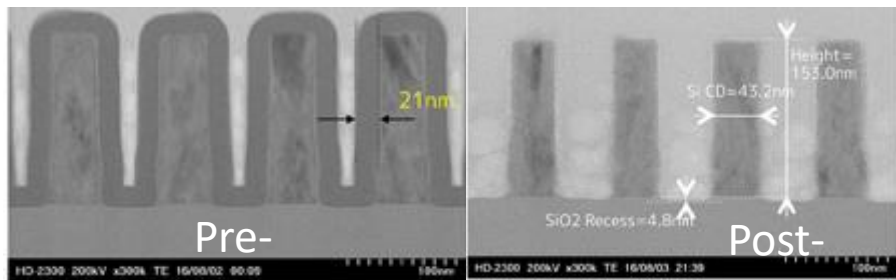
Tight space



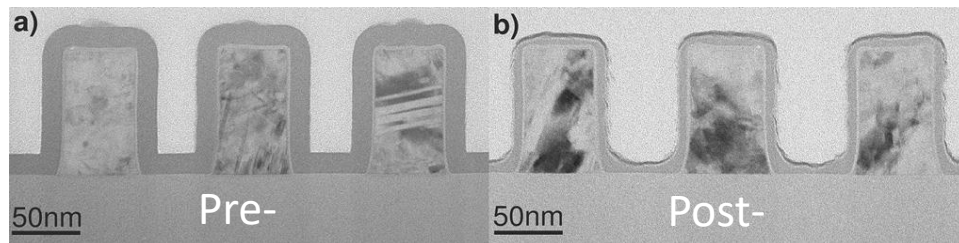
High A/R

GREATER NEED FOR INNOVATION – SELECTIVE CLEANS (CONTINUED)

Competing technology of wet cleaning – ALE (Atomic Layer Etching) of SiNx



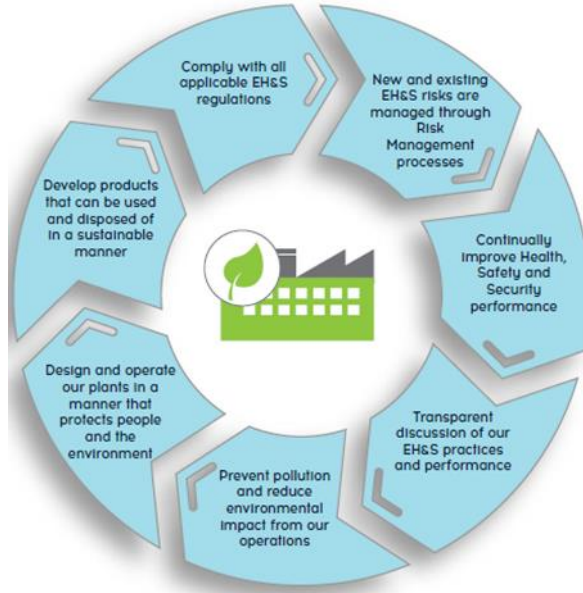
Source: Hitachi, The 232nd Electrochemical Society (ECS) Meeting ,
October 1 to 5, **2017**, National Harbor, Maryland.



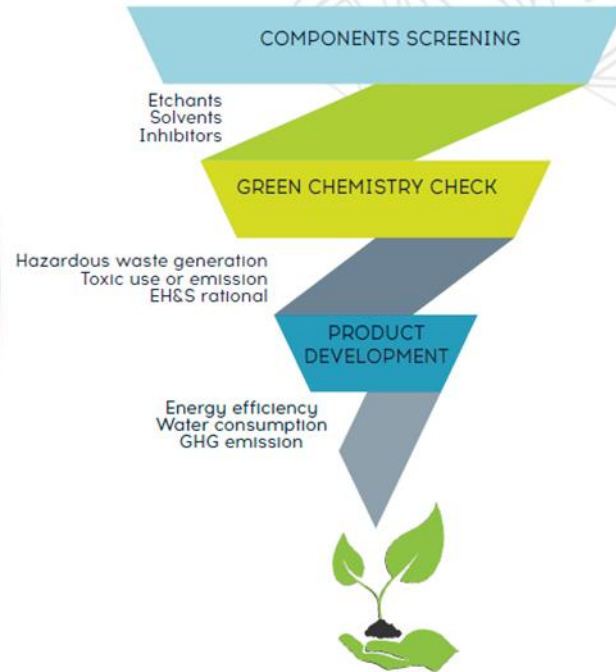
Source: Sherpa, S., et. al. Journal of Vacuum Science & Technology
A: Vacuum, Surfaces, and Films 35, 05C310, **2017**.

OUR COMMITMENT TO SAFER PRODUCTS

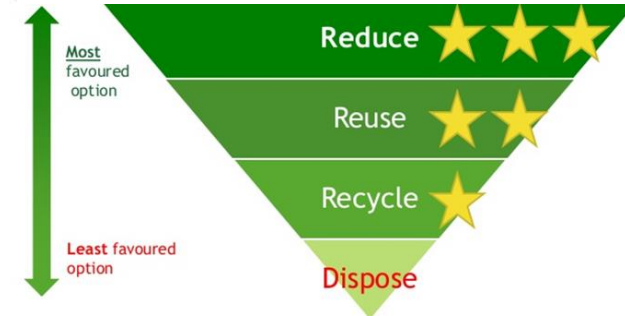
Our Principles



Our Strategy



Our values



CRITERIA FOR SUCCESS GOING INTO THE 2020S

- Customer Relationships
- Innovation Capabilities and Intellectual Property
- Global Infrastructure and Reliable Supply
- Diversified Portfolio

SEMI
Next
Generation
Specialty
Materials
Supplier



*Grace, Elegance...
and Fortitude*

THANK YOU

Wednesday, April 11th, 2018, 10:40 AM:

“Development of Wet-Etch Chemistries for Tungsten Word-line Recess”
by C.K. Ge, Versum Materials

