

How the Evolution of the Supply Chain for CMP & Post-CMP Cleans Consumables has Overcome Challenges

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CMPUG

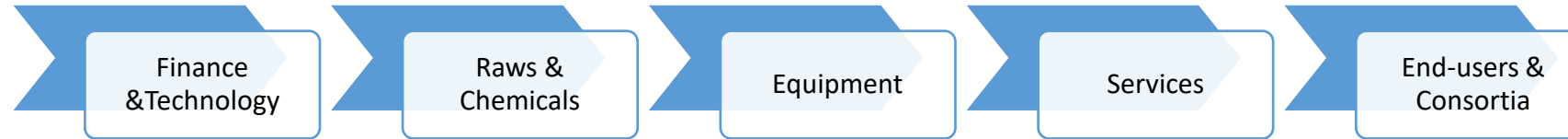
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AGENDA



- Introduction to Linx consulting
- Industry Developments
- Where Are We Going
- State of the Supply Base
- Conclusions

Linx Consulting Service Portfolio



• Multi-Client Reports

- CMP & Specialty Abrasives
- Advanced Deposition
- Patterning Materials
- Cleaning & Surface Prep
- Electronic Specialty Gases
- Bulk Chemicals
- ALE
- Photomasks

• 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 & Scenario development
- With Hilltop Economics LLC**

• Cost Modeling

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

• Semiconductor Technology & Market Conferences

- The Business of Cleans & SPCC
- Electronic Specialty Gases & Systems

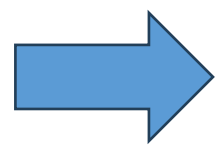
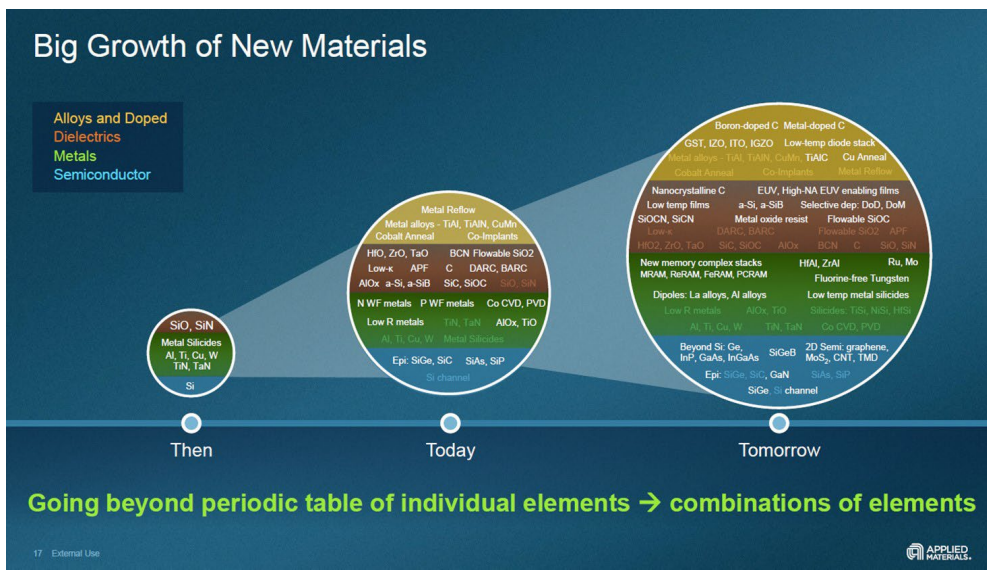
• Continuing Services

- Forecast Service
- Technology Trends

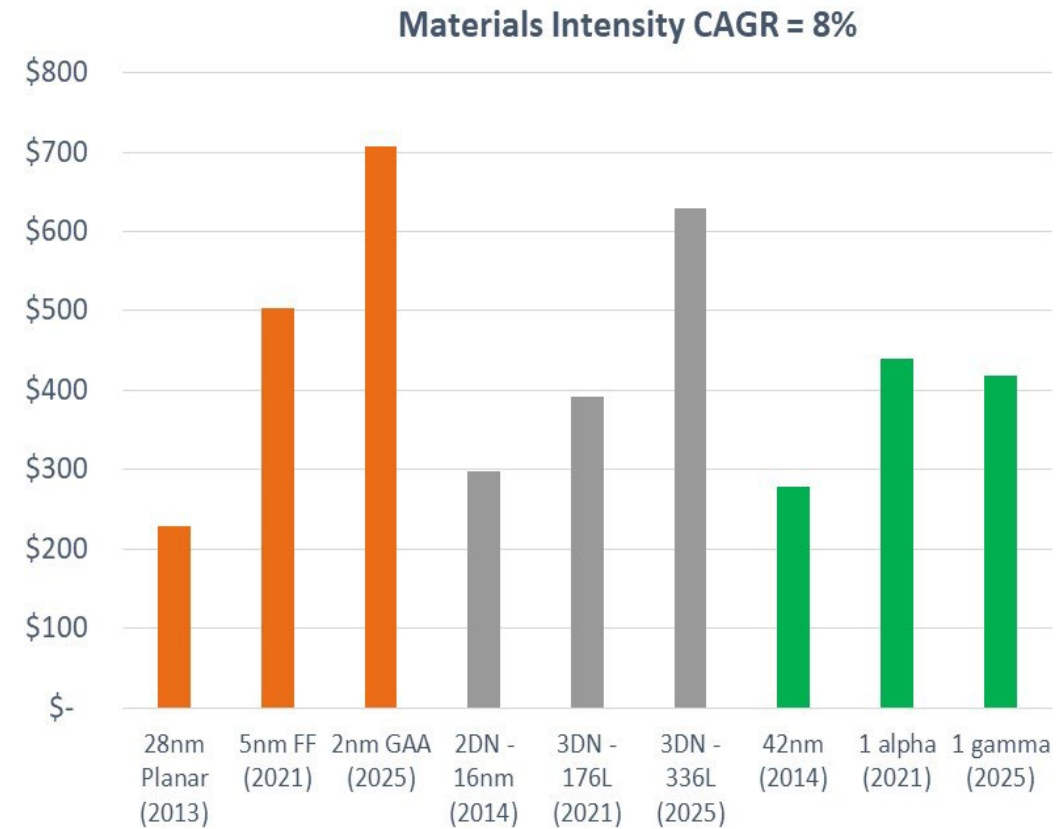


INDUSTRY DEVELOPMENTS

Novel Materials and Processes are Enabling



The development of new processes such as ALE, ALD, Selective etch, Cryo etch, ASD, etc.

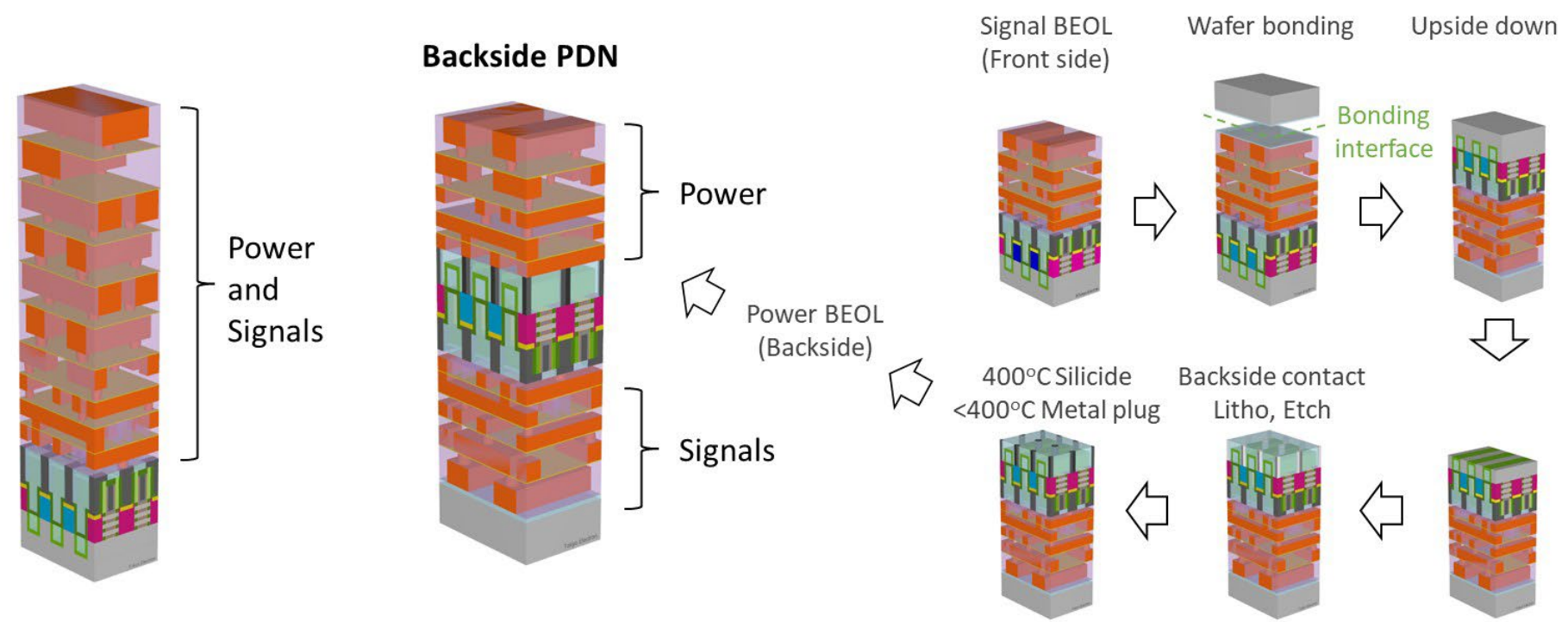


Does not include silicon wafers or advanced packaging

Source: B. Haran, SMC 2023

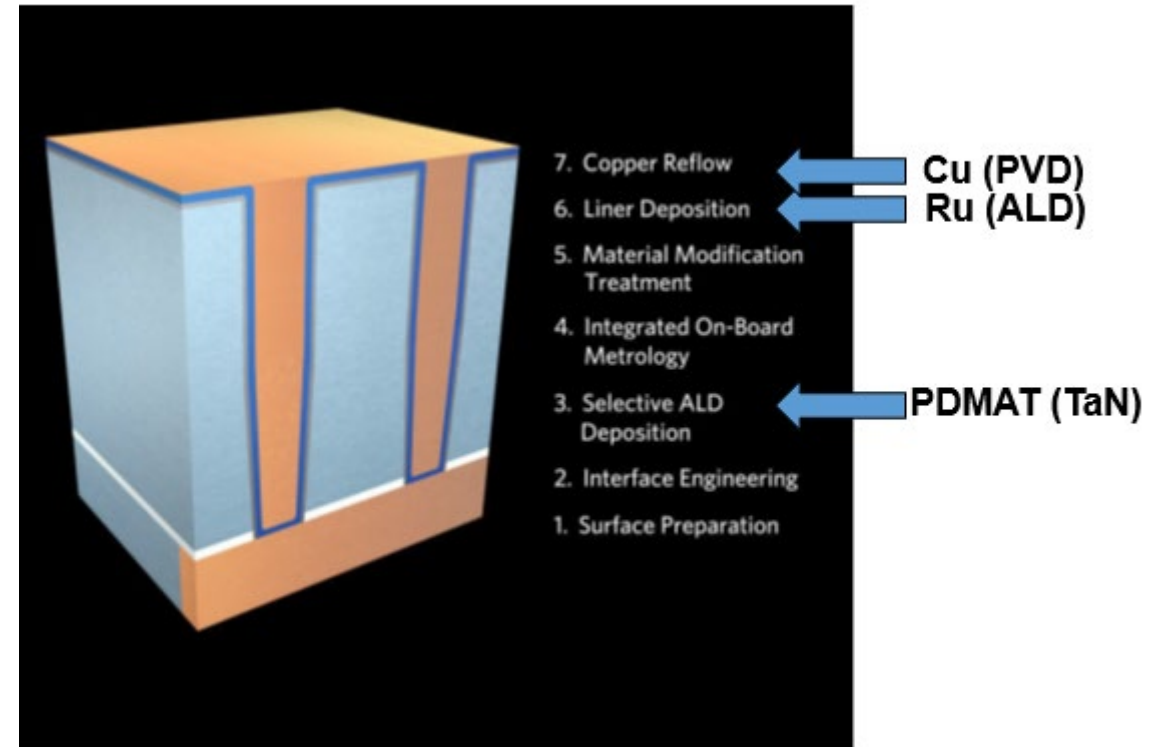
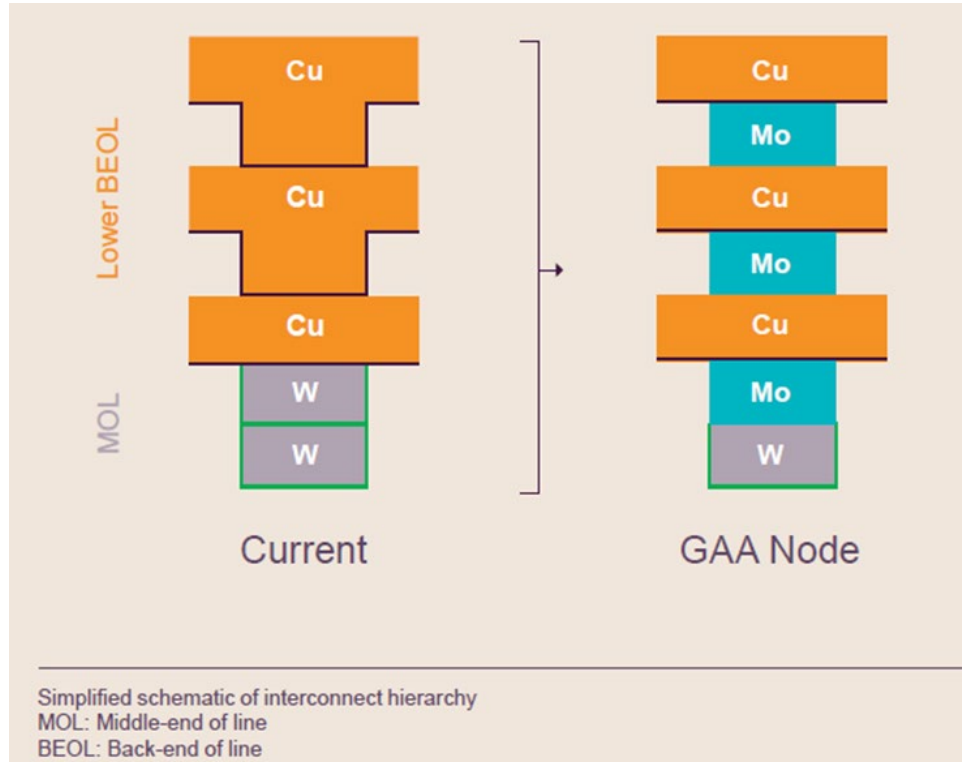
Source: Techinsights

Key Processes For Backside Power Delivery



Key Enablers Are Low Distortion Wafer Bonding And <400°C Silicide And Metal Plug Modules

New Materials are Enabling for MOL / BEOL



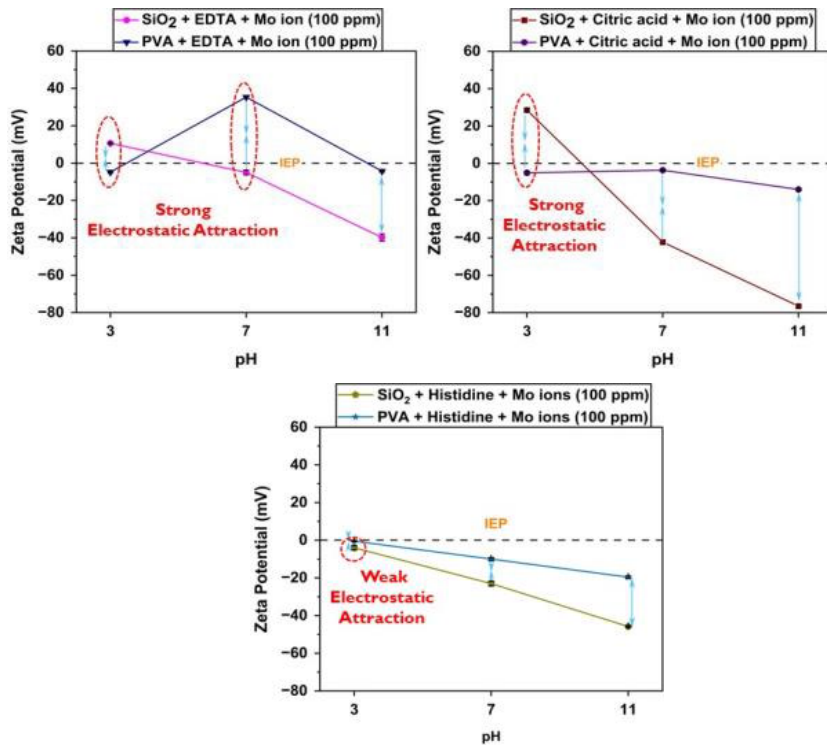
The contact may actually be a combination of W and Mo

Selective ALD deposition of TaN (Step 3)
The Ru liner (Step 6) is deposited by ALD
Copper is then deposited by PVD (Step 7)

Molybdenum PCMP



- As described previously, molybdenum is increasing in importance as both a primary conductor metal and a barrier material for Cu in advanced IC design
- The study highlighted here examines a series of chelants in Mo pCMP formulations, focusing on PVA brush interactions.

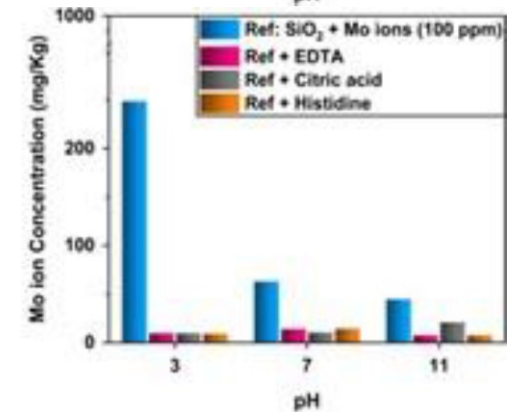
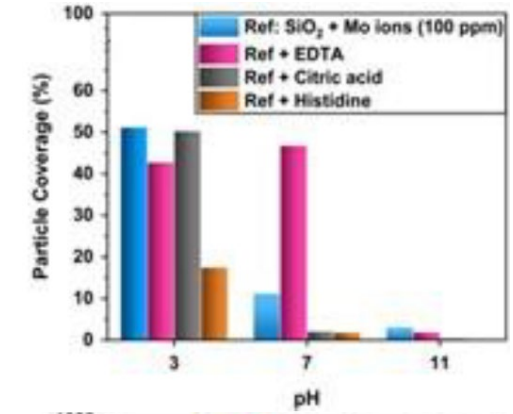
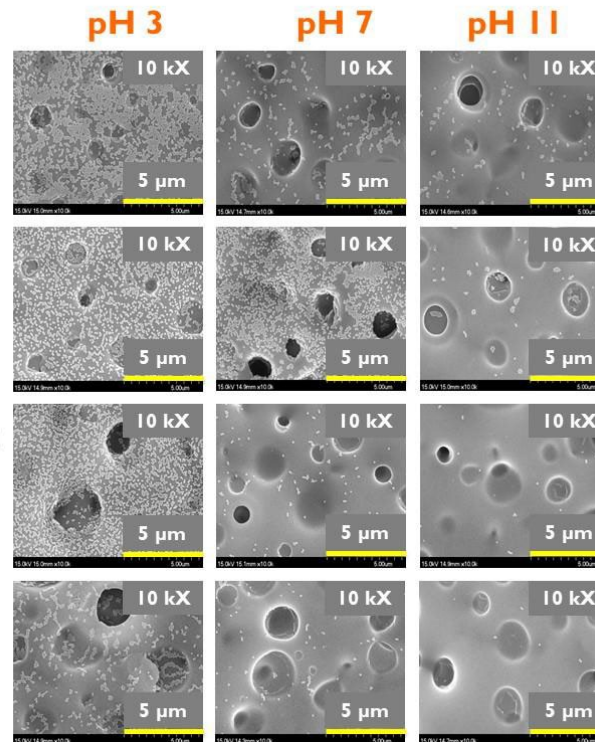


SiO₂
+
Mo ions
(100 ppm)

SiO₂ + EDTA
+
Mo ions
(100 ppm)

SiO₂ + Citric acid
+
Mo ions
(100 ppm)

SiO₂ + Histidine
+
Mo ions
(100 ppm)



Zeta potential of SiO₂ and PVA interactions with Mo ion & three chelating agents

Silica on PVA brushes as a function of chelant & pH by SEM

Chelant effect on SiO₂ brush coverage (top) and [Mo ion] (bottom)

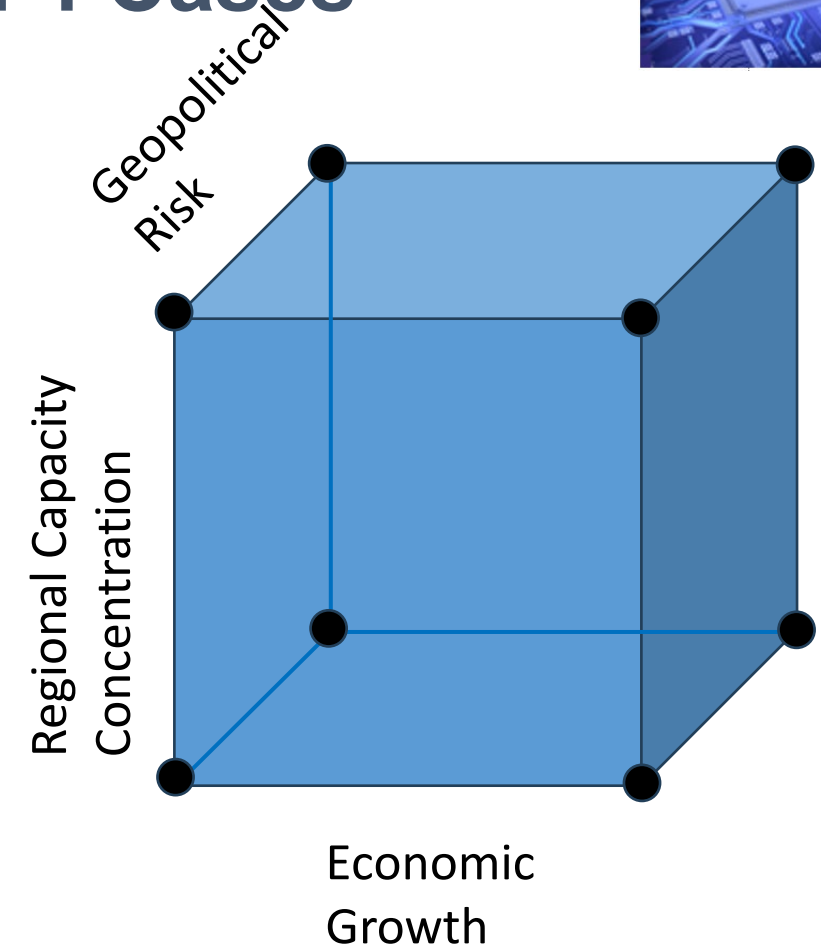


WHERE ARE WE GOING?

Interactive Scenario Plan with 4 Cases



| | Variable | Levels |
|---|---|-----------|
| A | Economic growth - MSI | Low, High |
| B | Geopolitical Risk | Low High |
| C | Technical Complexity – Materials Intensity | Low, High |
| D | Regional Capacity Concentration – Economic Cost | Low, High |



Based on these 4 variables, we developed 4 scenarios

Survey Outputs



Economic Impact

Good: 62%
Poor: 38%

Geopolitical Risks

Low Risk: 3%
High Risk: 97%

Localization

Low Impact: 32%
High Impact: 68%

Technology Trends – Macro

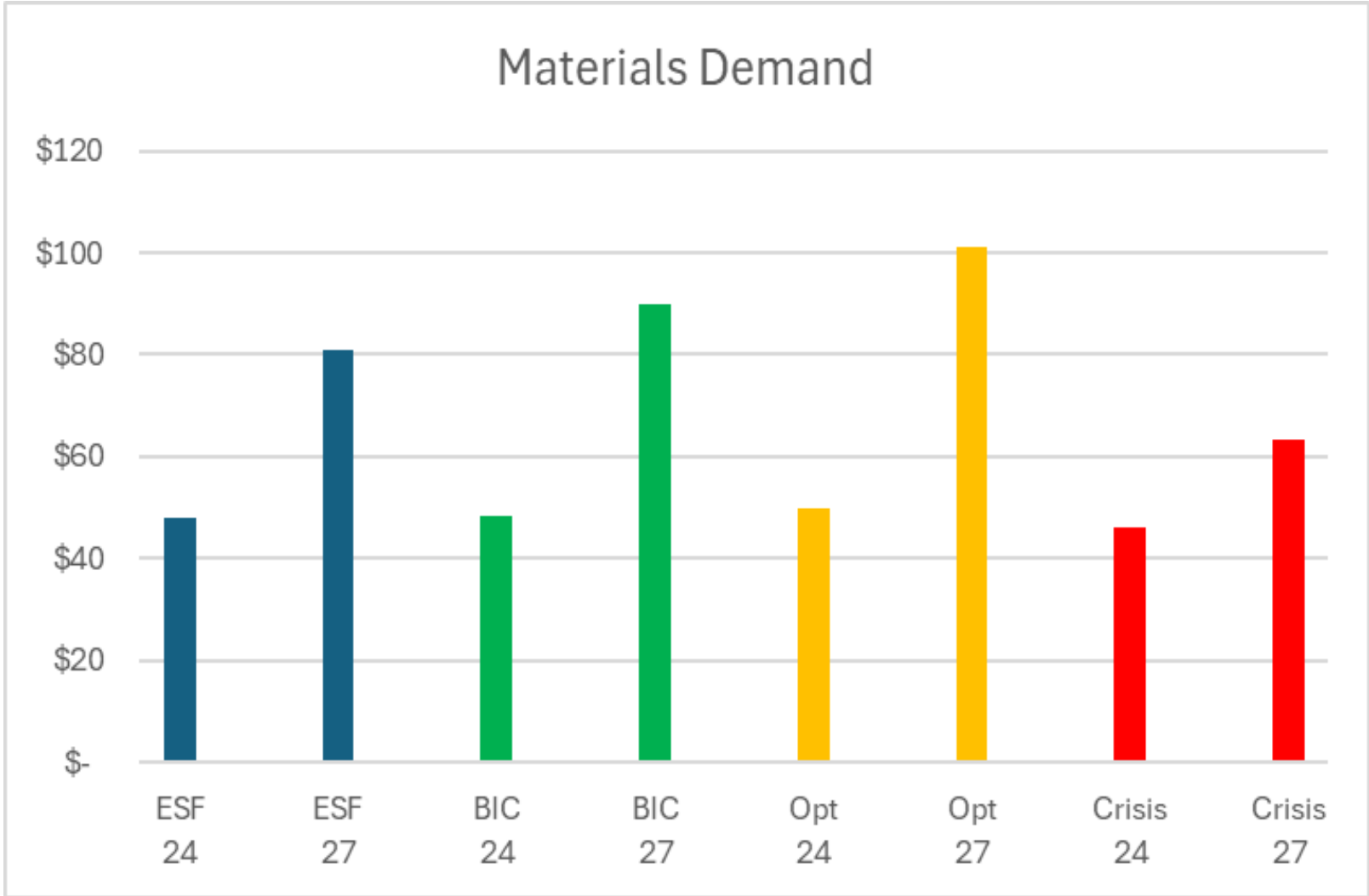
Low Risk: 91%
High Risk: 9%

Materials Intensity Impacted by Scenarios



Four Scenarios Developed:

- 1. **ESF** Base Case
- 2. **BIC** Case – based on BIC/ SPCC attendee input <https://www.linx-consulting.com/spcc/>
- 3. **Optimistic** case – based on strong alignment of industry growth drivers
- 4. **Crisis** – based on high levels of geopolitical challenges



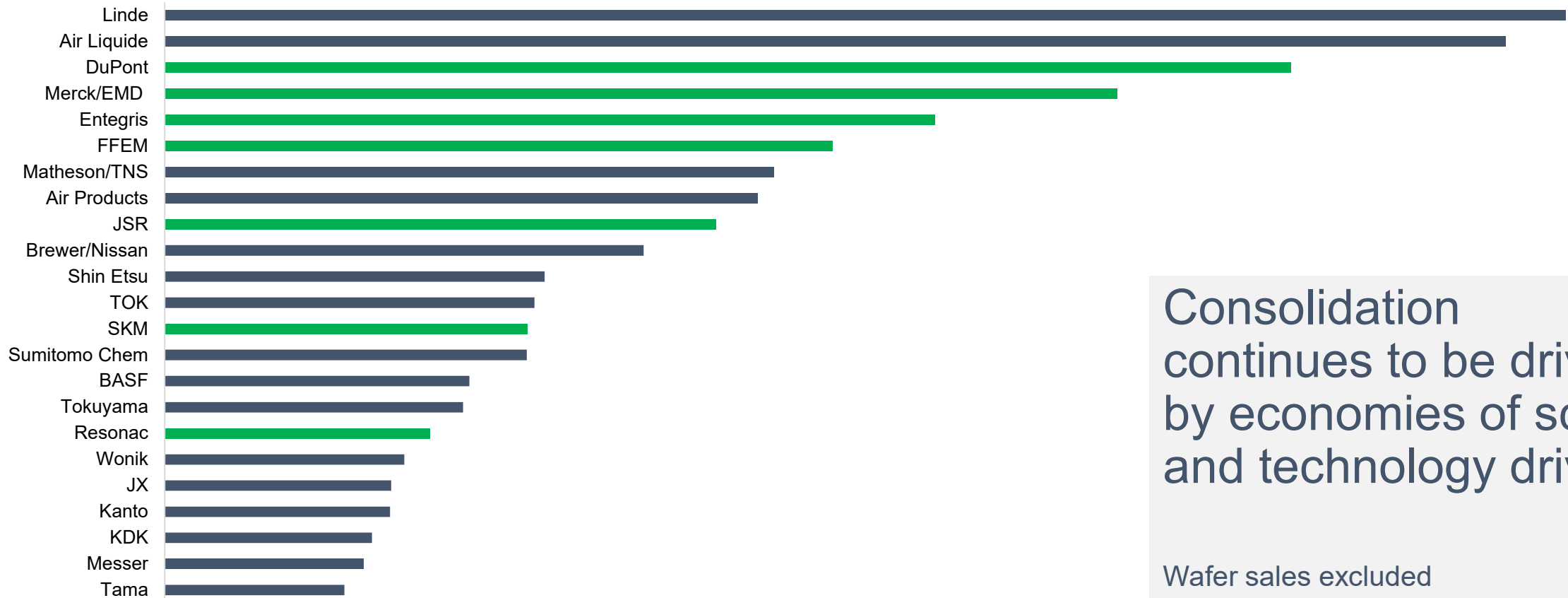


State of the Supply Base

Top Wafer Fab Materials Suppliers



Direct Materials Revenues 2023 \$Million



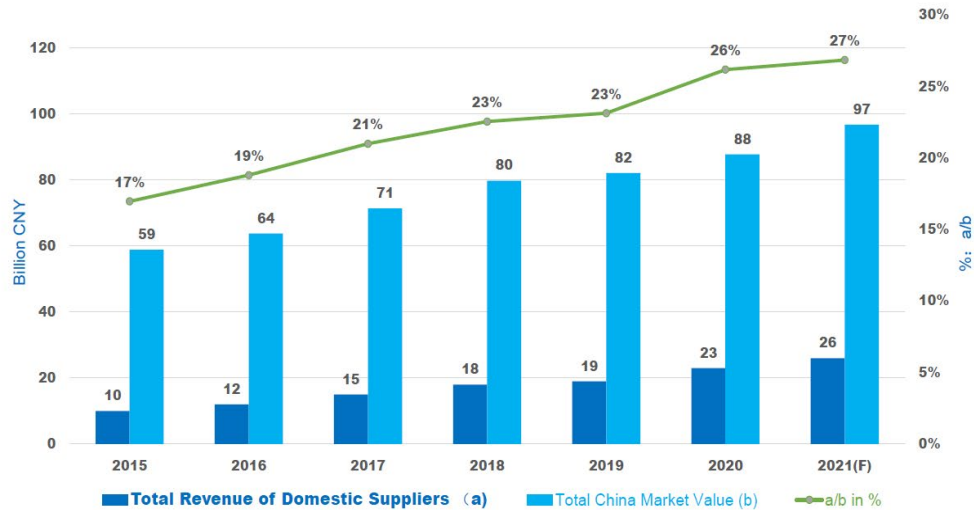
Consolidation continues to be driven by economies of scale and technology drivers

Wafer sales excluded

Challenges - Greater Localization Success in China



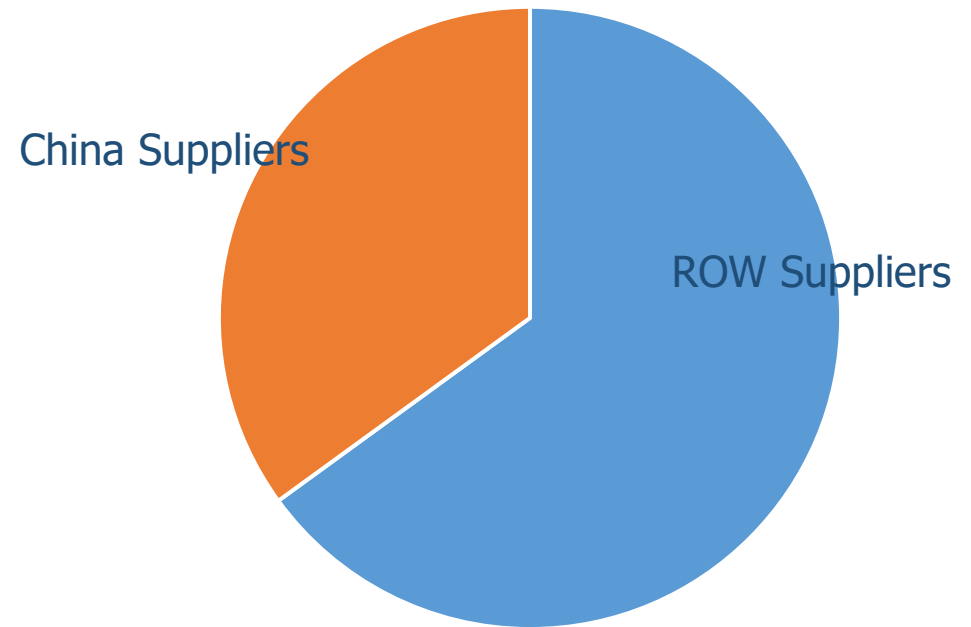
ANJI Semi-Materials Revenue of the Mainland China Suppliers



Domestic suppliers steadily gaining market share Data Source : ICMTIA



China CMP Consumables - % Local Content \$ Basis



Source: Shumin Wang, Anji Micro, Semicon Korea 2022

Conclusions



New materials and new processes are enabling next generation scaling. However, their ramp to HVM can be challenges and poses many risks



Aggressive and challenging technology roadmaps across all devices.



Geopolitics can have a huge impact on materials demand in semiconductor industry



Geopolitical risk leads to materials supply chains becoming less efficient and more costly due to dual supply chain and localization (De-risking). Alternative sources and new source re-qualification process may cause higher raw material costs