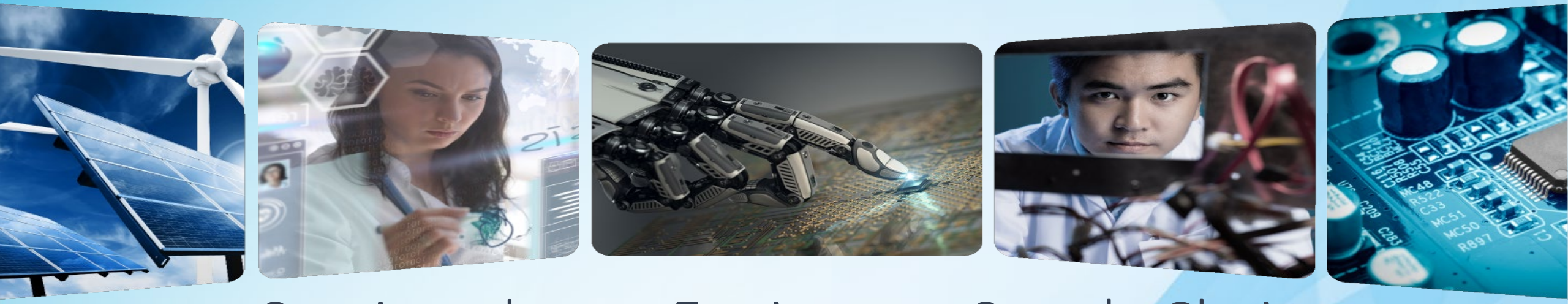

Semiconductor Equipment Supply Chain Ecosystem for Advanced Packaging

This Lecture is supported by the IEEE EPS Distinguished Lecturer Program

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EPS Junior Past President

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Agenda

- Supply Chain Landscape
- Semiconductor Eco-system Pyramid
- Traditional Semiconductor Fabrication Process
- Fabrication Process Adapted to Support Advanced Packaging
- Key Wafer Fabrication Processes - Dominant Equipment Suppliers
- Summary
- What”s Next

Supply Chain Landscape- Overview

Semiconductor market was 532 US B$ (FY 2023) [1] and increased to 611 US B$ in mid year 2024. [2]

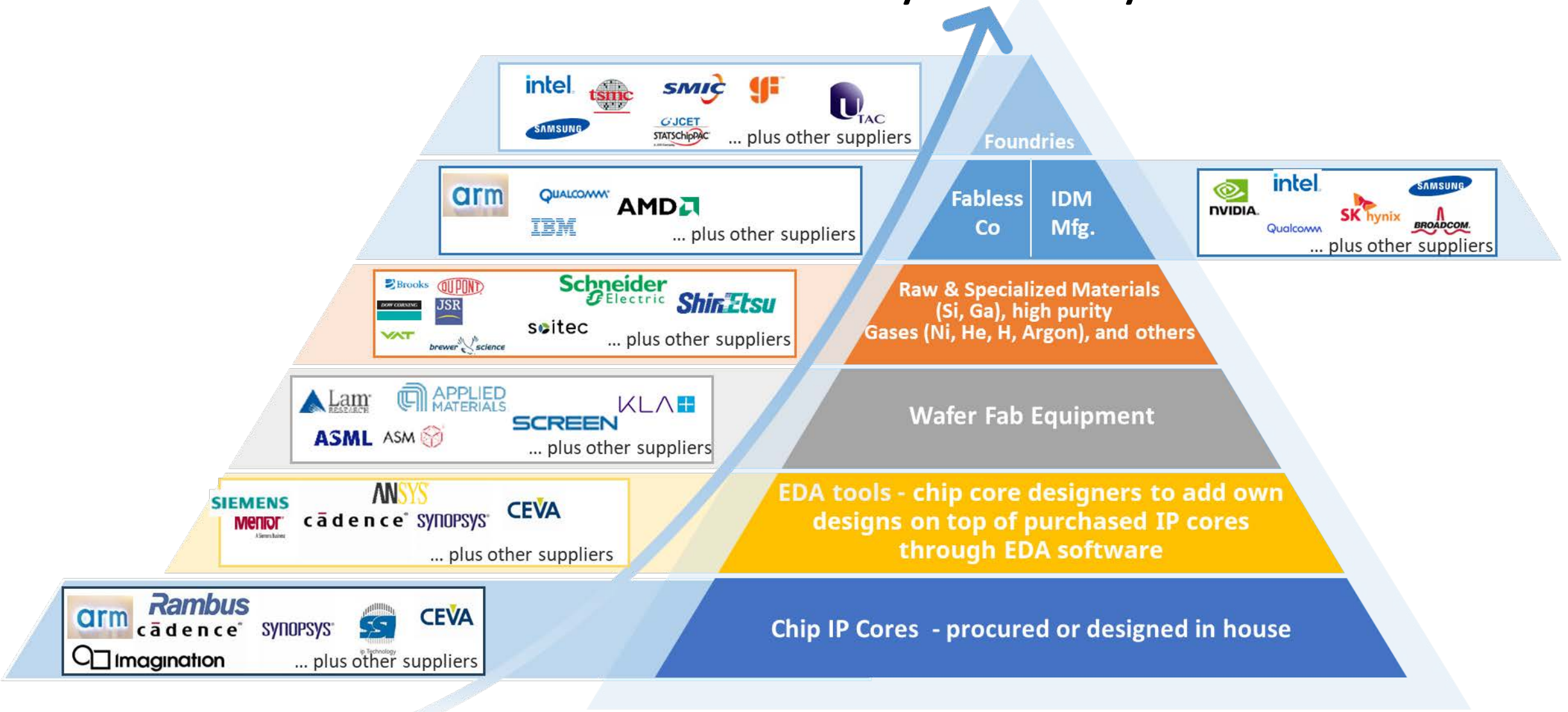
Semiconductor market anticipates 19% growth in 2024 ending with 630 US B$ and forecasts revenue to be 716.7 US B$ in 2025. [Gartner]

Design complexity is increasing with growth of AI and ML forcing innovation in processes and advanced simulation and verification tools. [1]

Revenue growth driven by AI and ML surge in demand.

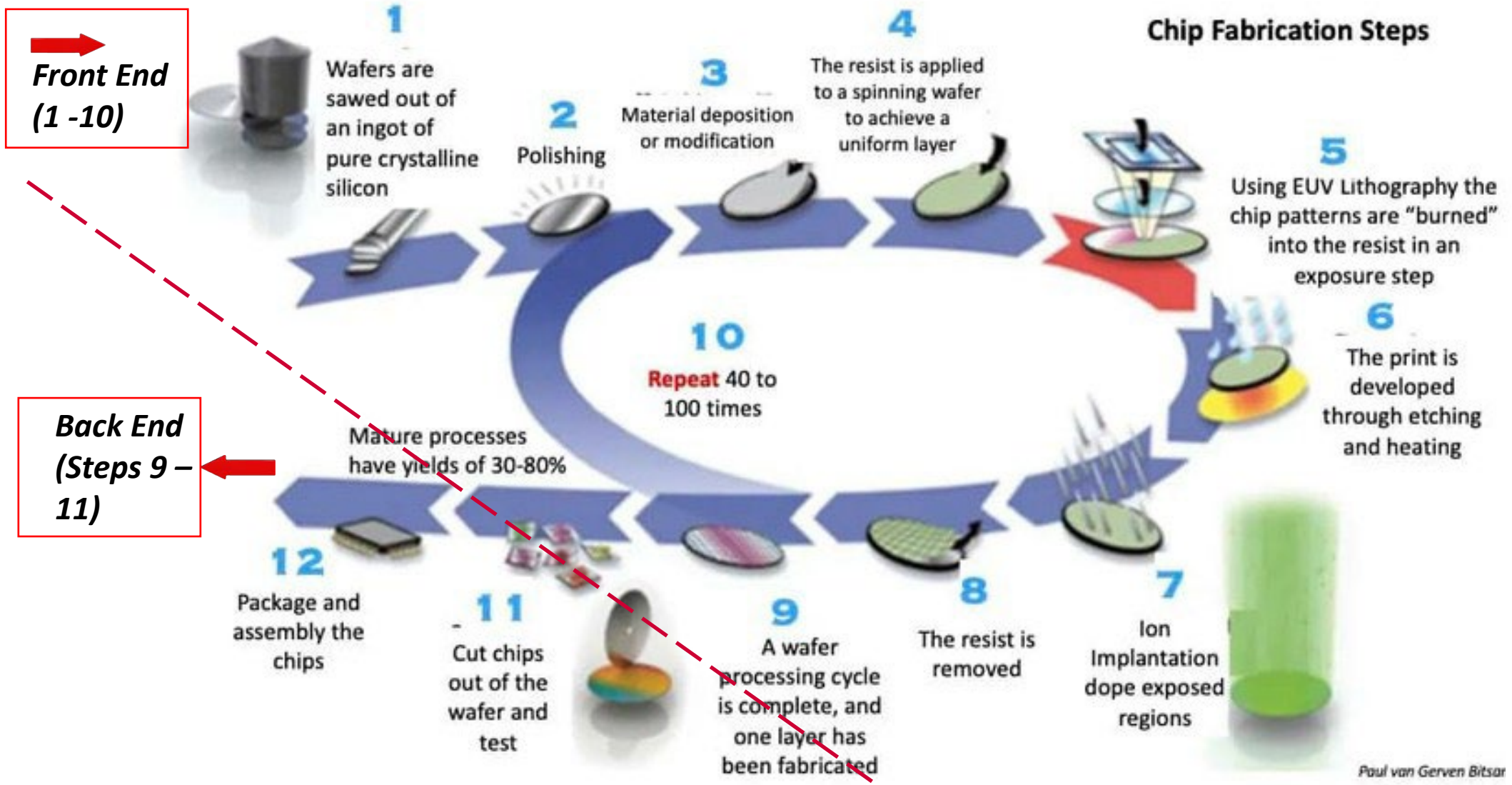
Automotive sector with eVehicles is also driving semiconductor demand.

Semiconductor “Eco-system” Pyramid



[3] Pyramid Concept - Steve Blank. Microsoft Word - The Semiconductor Ecosystem.docx (stanford.edu)

Traditional Wafer Fabrication Process Flow

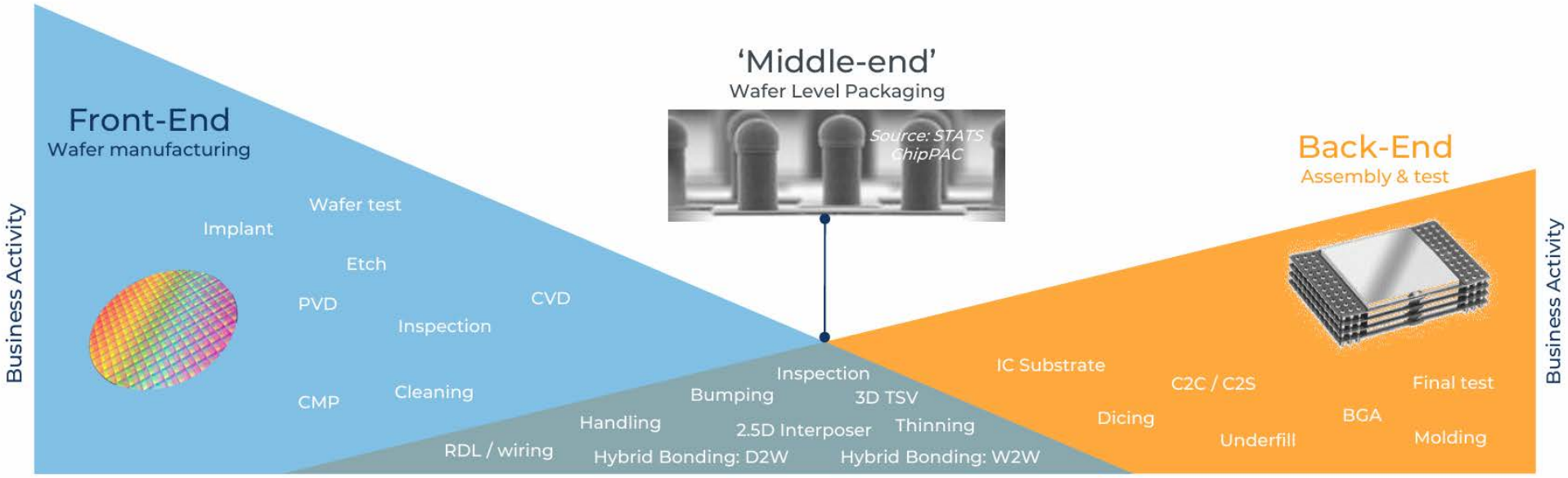


Advanced Packaging Fabrication Process Flow – Adapted [4]

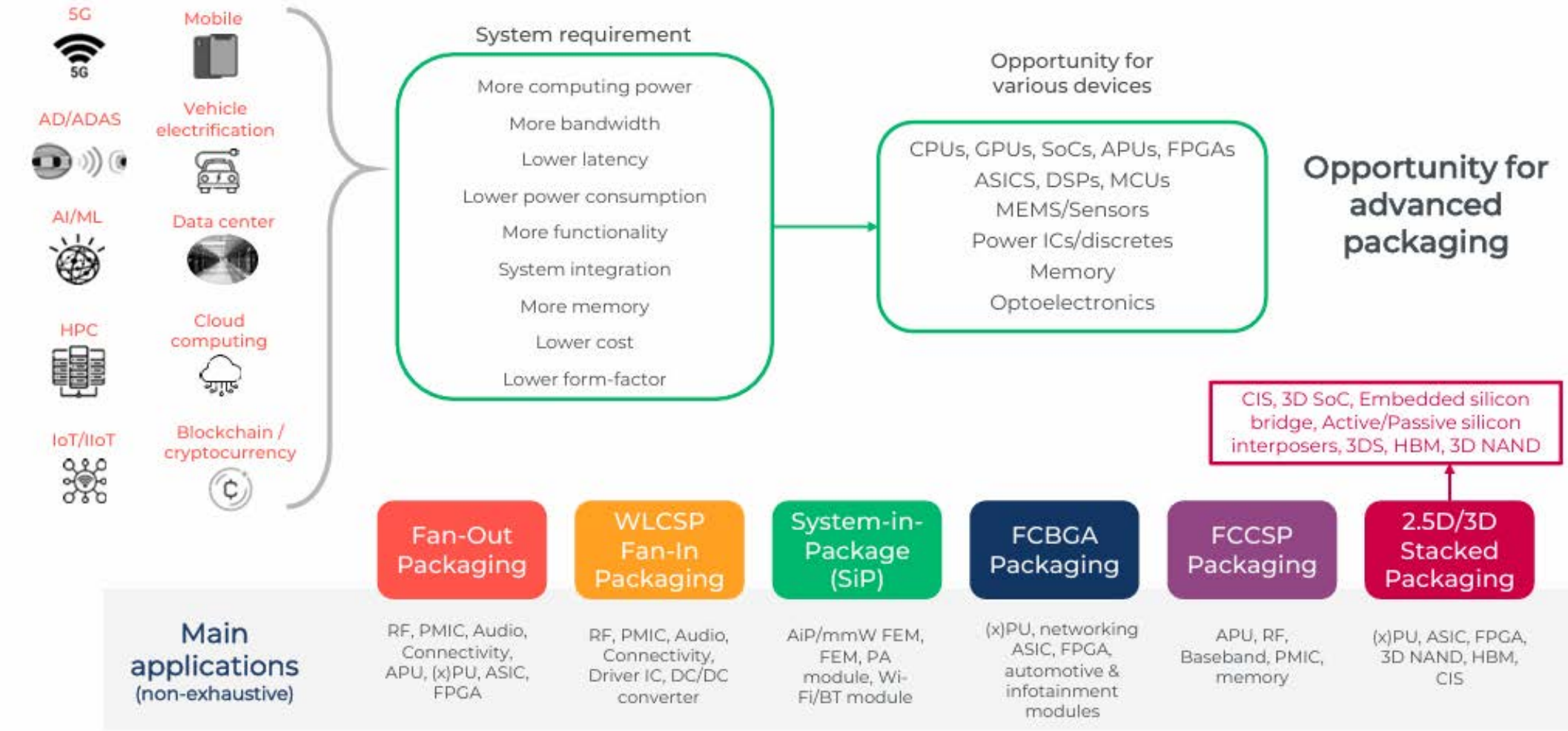
FOCUS ON ADVANCED PACKAGING (2/2)

WFE adaptation

- With packaging at wafer-level, players dedicated to front-end but having wafer equipment are now able to go further along the manufacturing chain.
- With the same objective of enlarging their scope, OSATs can go further in their processing steps, since 'packaging' can start earlier in the manufacturing chain, at the wafer-level.
- A 'middle-end' zone between front-end and back-end, where bumping and packaging can be executed at the wafer-level, can be reached by OSATs, WLP Houses, and IDMs.

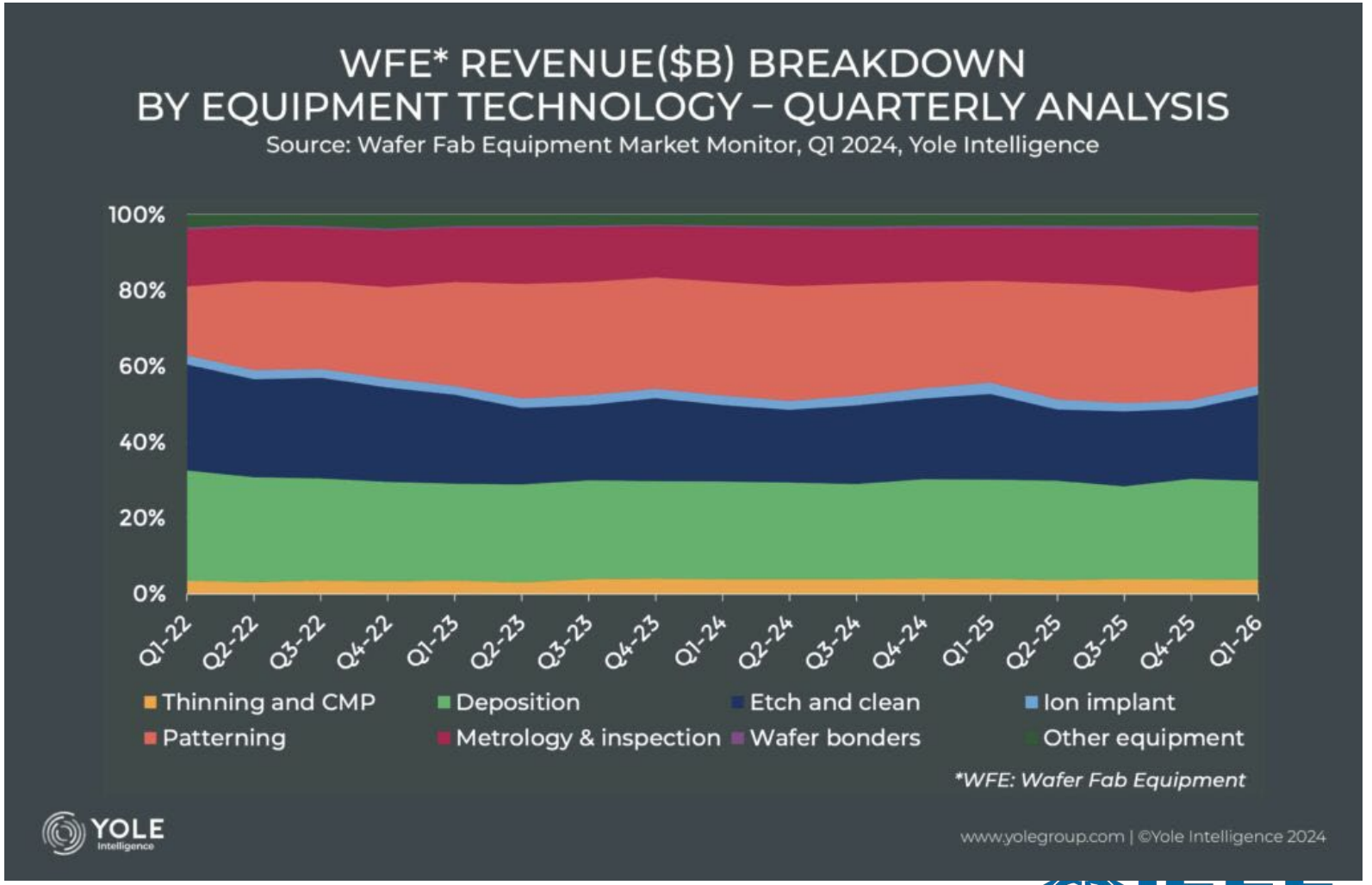


NEW TRENDS & DRIVERS: OPPORTUNITY FOR ADVANCED PACKAGING [5]



Front-end Key Fabrication Processes Reviewed

High-level Semiconductor Equipment WFE Market [6]



High-level Semiconductor Equipment WFE Market

The global WFE market size was 76.6 B US$ in 2023 and is projected to reach 183.6 B US$ by 2032, expanding at a CAGR of 9.33% [ ]

Deposition, Etch and Clean, and Patterning equipment proved the greatest WFE revenue.

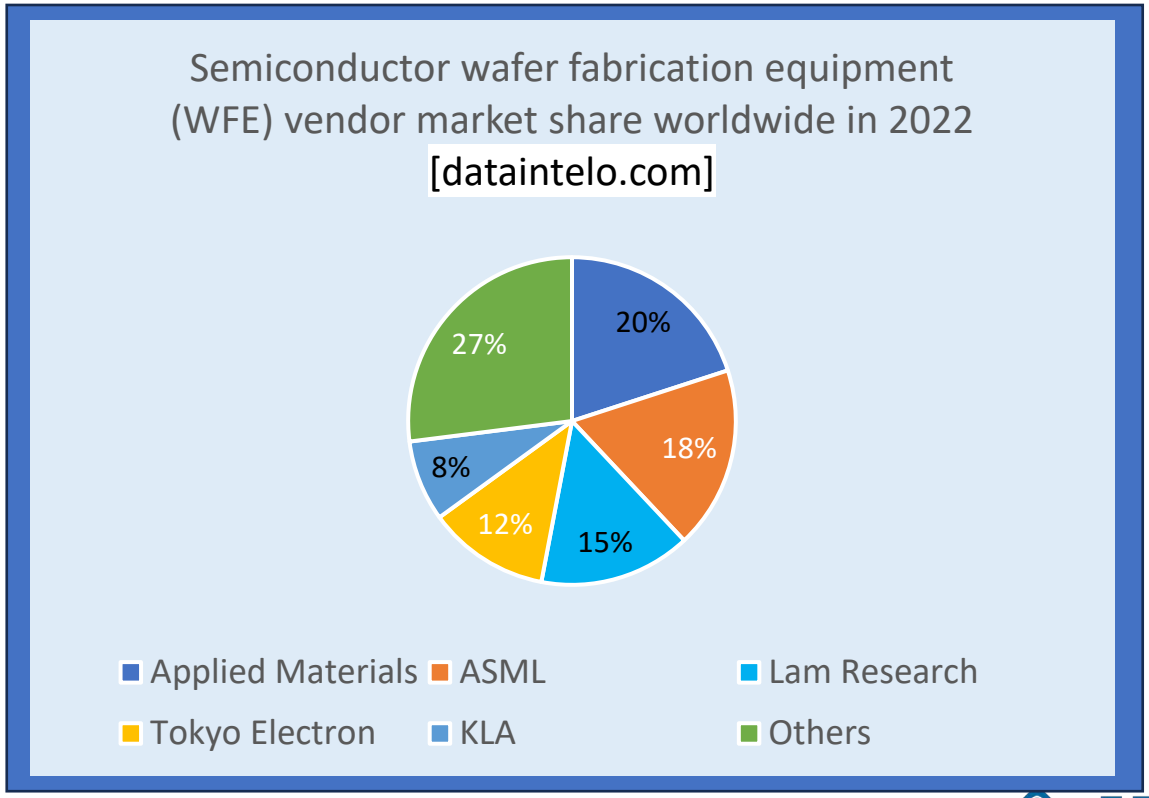
Together, they account for nearly 75% of the WFE market.

And, more than half of the 75% is attributed to deposition and patterning (lithography) equipment.

High-level overview for Deposition and Patterning processes' equipment follows.

Semiconductor WFE Market

- Growth attributed to rising demand of wafers to support miniaturization, electric vehicles (EVs), etc.
- Sophisticated machinery essential for foundries to fabricate chips efficiently during front-end processes.



*Wafer Fab Equipment(WFE) Market Size, Share Report | 2032 [7]

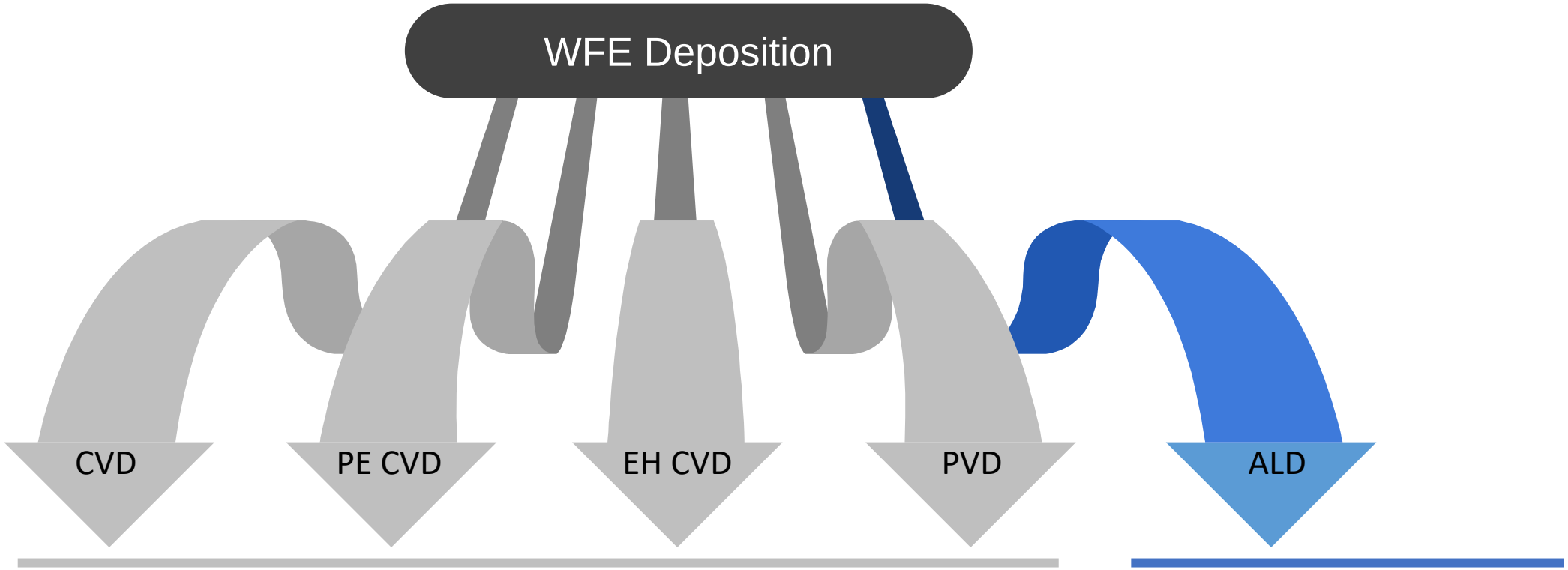
Semiconductor WFE Deposition Market

Deposition is critical in entire chip production process (front-end and back-end)

- Processes include CVD, EHCVD, PEPVD, ALD plus others.
- Chemical Vapor Disposition (CVD) is the dominate deposition process.
- Each requires high dollar, complex equipment for chip fabrication

  - Deposition equipment market is predicted to rise to 25.77 B US$ in 2023, growing at a CAGR of 13.75%. [8]
  - CVD market size estimated at 22.35 B US$ in 2023 and projected to grow at a CAGR of 9.0% from 2024 to 2030. [9]
  - PVD (physical vapor deposition) Equipment Market was valued at 27.1 B US$ in 2023 and is expected to by a CAGR of 8.9% for 2024 to 2032 forecast period. [10, 11]
  - PECVD (Plasma Enhanced) is expected to be the highest growing segment in coming years.

Dominant Deposition Equipment Suppliers



Advanced Energy Industries, Inc. (Germany)
Angstrom Engineering (Canada)
Veeco Instruments Inc. (US)
Applied Materials Inc. (US)
Platit AG (Switzerland)

ASM International (Netherlands)
Tokyo Electron Limited (Japan)
Applied Materials Inc. (US)
LAM Research Corporation (US)
Veeco Instruments Inc. (US)

Semiconductor WFE Lithography Market

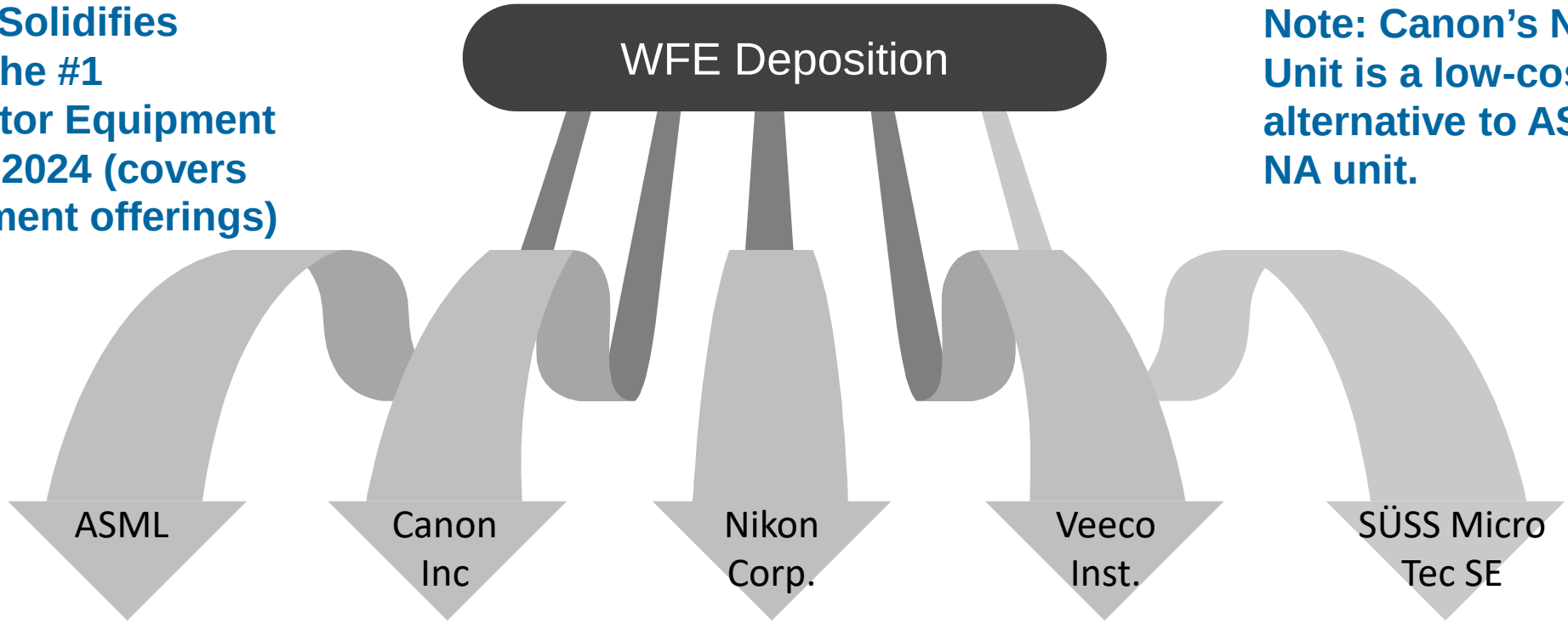
The global semiconductor lithography equipment market size was estimated at 26.48 B US$ in 2024 expected to reach 37.81 B US$ by 2029, at a CAGR of 7.3% during the forecast period (2024–2029). [12]

- Greater than 59 % of semiconductor fabrication costs due to equipment and tools
- Asia Pacific accounts for largest market share in all Semiconductor Lithography Equipment
- Applied Materials and ASML account for more than 53% of the WFE Revenue
- DUV (deep ultraviolet lithography) and EUV (extreme ultraviolet lithography) represent the 2 types
- ASML only supplier of High Numerical Aperture (NA) EUV lithography [13]
- Canon offers a “nanoprint” lithographic scanner to compete with ASML
- Sept 2022 Canon Inc. launched the "Lithography Plus1" solution platform for lithography systems
- Jun 2022 - Samsung and ASML agreed to collaborate on developing High-NA EUV Lithography equipment, which will be available next year. [14]

Dominant Lithography Equipment Suppliers

Note: ASML Solidifies Position as the #1 Semiconductor Equipment Company in 2024 (covers all its equipment offerings)

Note: Canon's Nanoprint Unit is a low-cost alternative to ASML High NA unit.



- GEO: Netherlands
- High NAEUV Twinscan EXE:5000
- Intel has 2 units
- TSMC assembling a unit

- GEO: Japan
- Nanoprint lithography FPA-1200NZ2C
- Texas Institute of Electronics (UT Austin)

- GEO: Japan
- DUV dry Arf and KrF scanners
  - NSR-322F
  - NSR-S220D

- GEO: US
- Superior overlay, resolution & side wall profile performance, …

- GEO: Germany
- Micro and Nanoimprint Solutions for SUSS Mask Aligners

Advanced Packaging Semiconductor Ecosystem Summary

Semiconductor market anticipates 19% growth in 2024 ending with 630 US B$ and forecasts revenue to be 716.7 US B$ in 2025 [Gartner]

EDA software and hardware tools continue to reduce time needed to develop complicated ICs, cutting manufacturing costs, and eliminating manufacturing defects design simulation and verification in early chip design.

Mergers and acquisitions are still at the top-of-the-list for increasing a company's competitive edge.

Semiconductor market trends include - increased R&D, rise in nanotechnology applications, technology advancements in processes and equipment.

Dominant lithography equipment suppliers are located in Netherlands, Japan, US, and Germany

Dominant deposition equipment suppliers Netherlands, Japan, US, Germany, Canada, and Switzerland

What's Next??

Add middle-end and back-end process equipment to current piece of work.

Semiconductor landscape changes rapidly due to dynamic and shifting geopolitics. Necessary to understand and define impact of the following on the ecosystem in 2025 and on:

1. Protection Laws – Taiwan [Taipei Times Nov 2024]
   - Protection rules limit domestic chipmakers that are at "least one generation less advanced than their fabs at home." TSMC is restricted from producing 2nm chips overseas, thus guaranteeing their "core" technology stays in Taiwan.
   - Volume production of 2nm chips at TSMC planned for 2025.
   - TSMC's A-16 chip enters volume production in 2026.
   - TSMC production of its 2nm chips not expected in US to ~2030.

2. Tariffs can result in two ways (very basic interpretation):
   - High tariffs can result in no imports to US
   - Low tariffs can result in diverting a portion of the trade

What's Next??

3. Reshoring Driven by: [What Is Reshoring? Benefits, Challenges, and Solutions]

Government Policies

- CHIPS and Science Act of 2022
- Inflation Reduction Act, (2022)
- IRA and CHIPS Act helped boost reshoring to an all-time high, up 53% from the previous year [Supply Chain Resources Group]

Geopolitics

- Trade Wars
- Pandemics
- Military Events

Automation and Technology Advancements

- China losing its competitive edge
- Automation make domestic production more affordable

4. Recent funding to Intel and grants to US companies from Chips Act (Nov 4, 2024)

- Awarded up to $7.86 billion in direct funding to advance their commercial semiconductor mfg. and advanced packaging projects in Arizona, New Mexico, Ohio and Oregon.
- Award is coupled with a 25% investment tax credit - Intel's plans to invest more than $100 billion in the U.S.

References

[1] Laurence Goasduff, Gartner Media Contact, Gartner Forecasts Worldwide Semiconductor Revenue to Decline 11% in 2023 , April 26, 2023

[2] European Semiconductor Industry Association. “Worldwide semiconductor market expected to recover strongly and hit $611 billion in 2024”, June 6, 2024

[3] Steve Blank. Microsoft Word - The Semiconductor Ecosystem.docx (stanford.edu)

[4] Wafer Fab Equipment Status, Yole Analyst Thursday Report. PowerPoint Presentation

[5] Yole

[6] need to add reference

[7] Wafer Fab Equipment(WFE) Market Size, Share Report | 2032 (dataintelo.com)

[8] Global Deposition Equipment Market Expected to Reach US$25.77 Billion in 2023, Surging at a CAGR of 13.75% - ResearchAndMarkets.com | Business Wire

[9] Chemical Vapor Deposition Market Size, Share Report, 2030 (grandviewresearch.com)

[10] PVD (physical vapor deposition) Equipment Market was valued at 27.1 B US$ in 2023 and is - Search (bing.com)

[11] PVD Equipment Market - Share, Manufacturers & Size (mordorintelligence.com)

[12] Semiconductor Lithography Equipment Market - Companies, Growth & Share (mordorintelligence.com)

[13] Intel completes assembly of first commercial High-NA EUV chipmaking tool — addresses cost concerns, preps for 14A process development in 2025 | Tom's Hardware (tomshardware.com)

[14] Samsung and ASML Announce Joint Plans for High NA EUV Equipment Implementation | Semiconductor Materials and Equipment (abachy.com)

Thank You for Your Attention!