



SWTEST

PROBE TODAY, FOR TOMORROW

2024 CONFERENCE

Advanced Packaging pushing the boundaries of the semiconductor probe card market



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OUTLINE

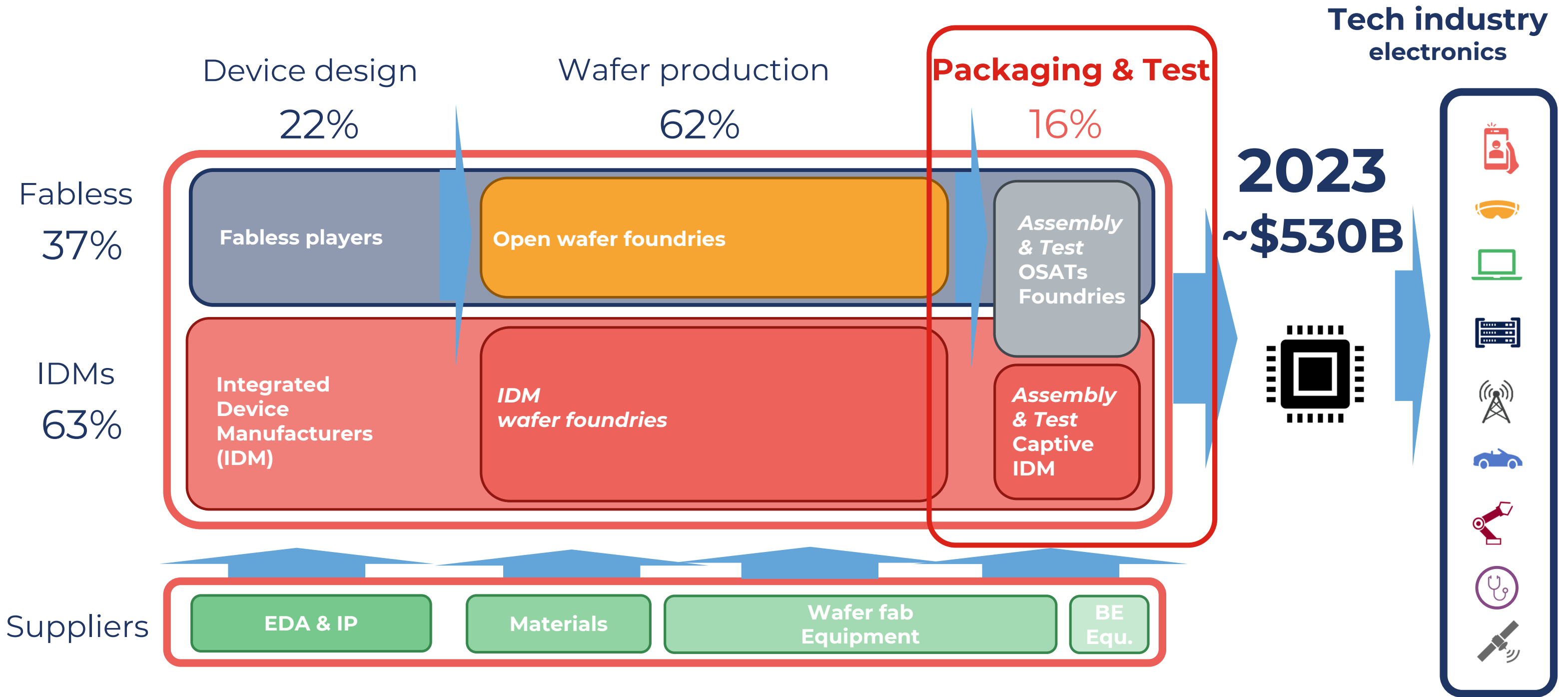


- Advanced Packaging Market Trends
- High-End Packaging: 2.5D and 3D Technologies
- Technology Trends: Pitch and I/O Density scaling
- HBM roadmap
- Automotive packaging
- Supply Chain, Players and Investments
- Conclusions

How is advanced packaging pushing the test and probe card industry?

2023 SEMICONDUCTOR INDUSTRY VALUE CHAIN

Value added (% of all semiconductor device revenues)

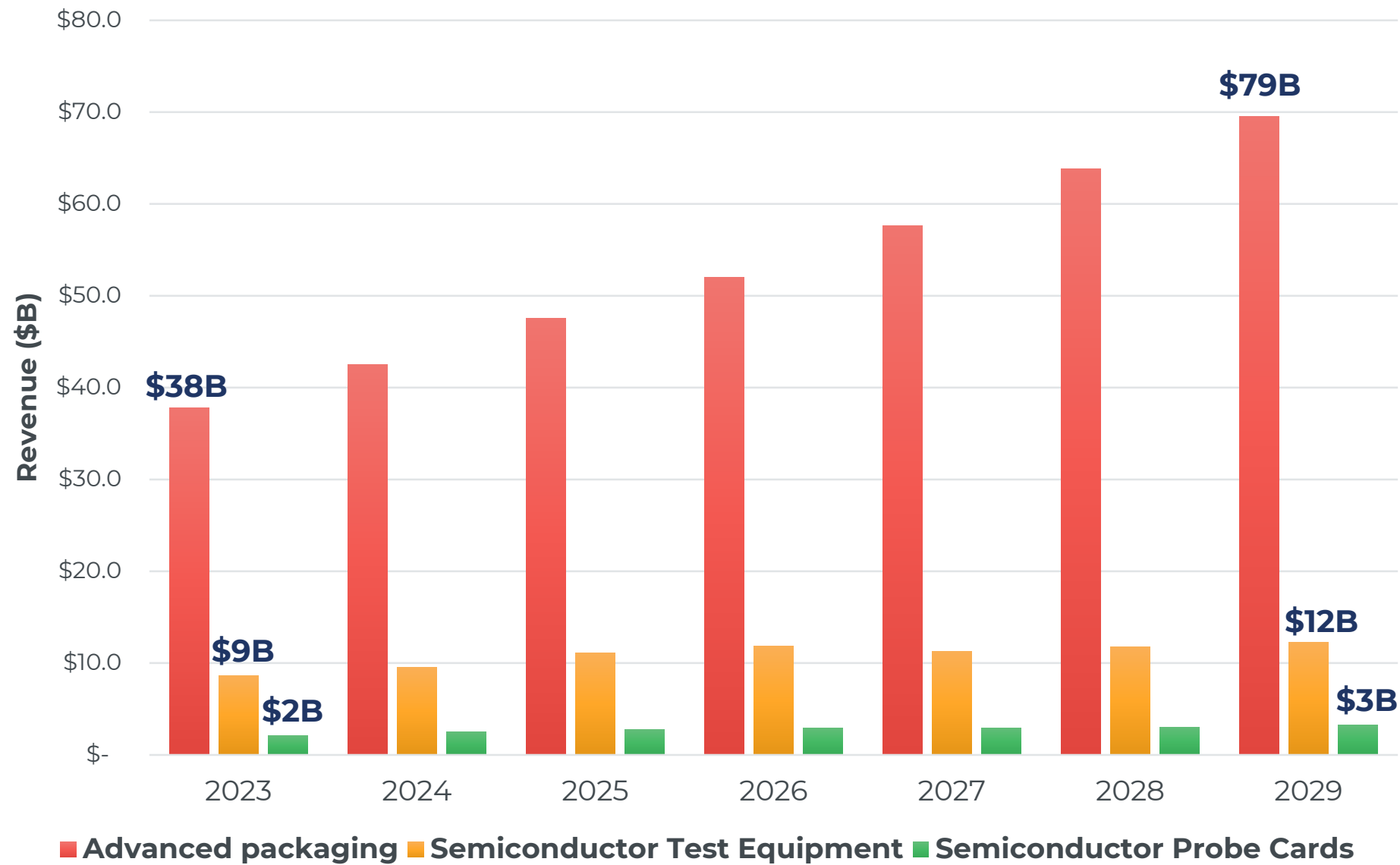


ADVANCED PACKAGING VS. TEST EQUIPMENT VS. PROBE CARD MARKET

Revenue Market Forecast 2023-2029 (\$B)



Advanced Packaging vs. Semiconductor Test Equipment vs. Semiconductor Probe Card Market Revenue (\$B)



Advanced Packaging

CAGR₂₀₂₃₋₂₀₂₉ ~10.7%

Semiconductor Test Equipment

CAGR₂₀₂₃₋₂₀₂₉ ~6.0%

Semiconductor Probe Card

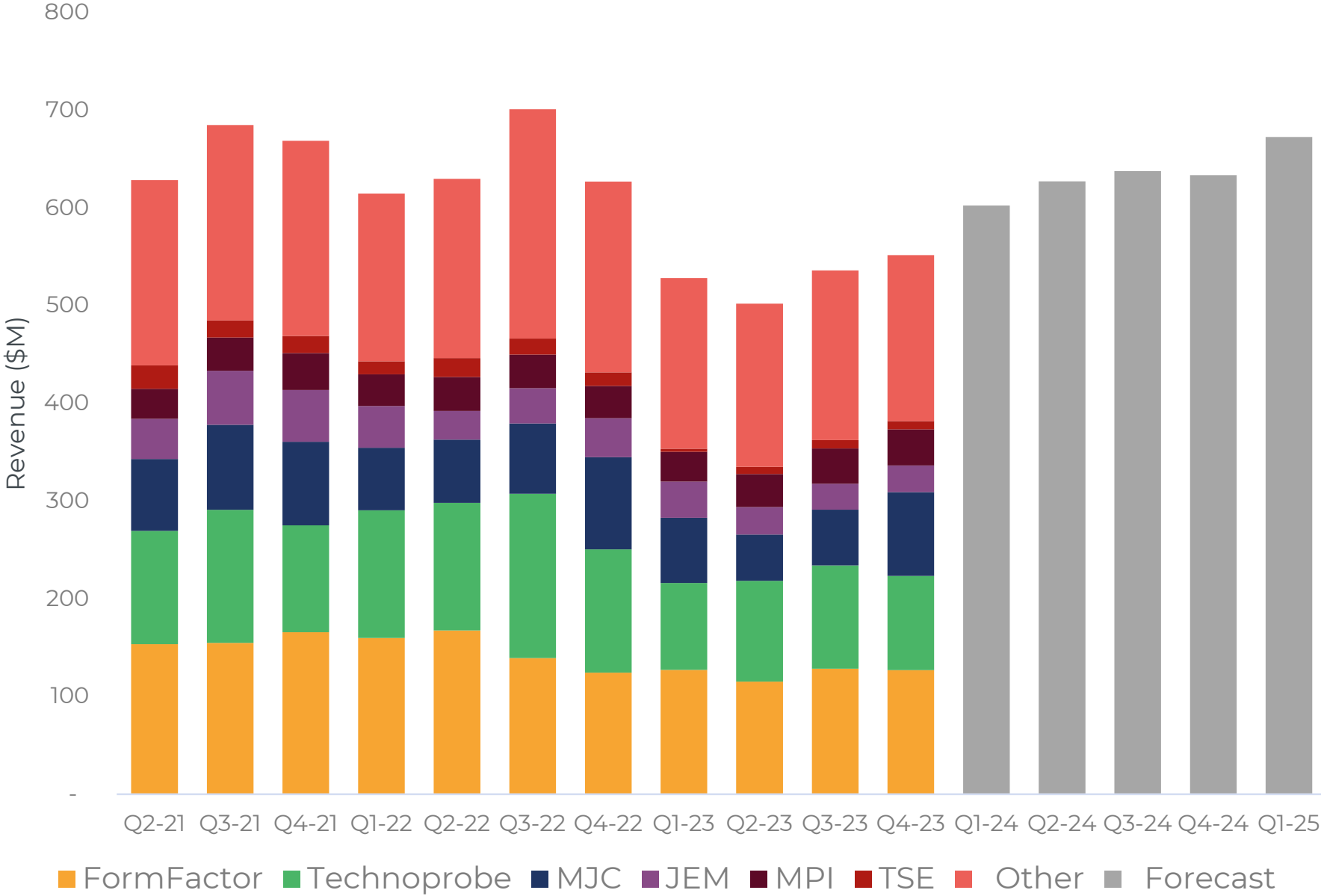
CAGR₂₀₂₃₋₂₀₂₉ ~7.4%

PROBE CARD QUARTERLY MARKET EVOLUTION

Breakdown by supplier



Probe card quarterly revenue by supplier (\$M)



Although 2023 was a down year, 2024 is set to be a year for recovery. Significant order activity indicates that the first half of 2024 was good, and the market is on track to grow steadily throughout the rest of the year.

Source: Semiconductor Test Consumables Market Monitor Q1 2024, Yole Group

ADVANCED PACKAGING MARKET TRENDS

What is driving advanced packaging adoption?



Industry megatrends are moving the semiconductor market and are pushing for more demanding system requirements



- More computing power
- Higher speed
- Higher bandwidth
- More system integration
- More sensors
- More memory



- Lower latency
- Lower power
- Lower cost

- CPUs, GPUs, SoCs, APUs, FPGAs
- ASICS, DSPs, MCUs
- MEMS/Sensors
- Power ICs/discretes
- Memory
- Optoelectronics

Opportunity for advanced packaging

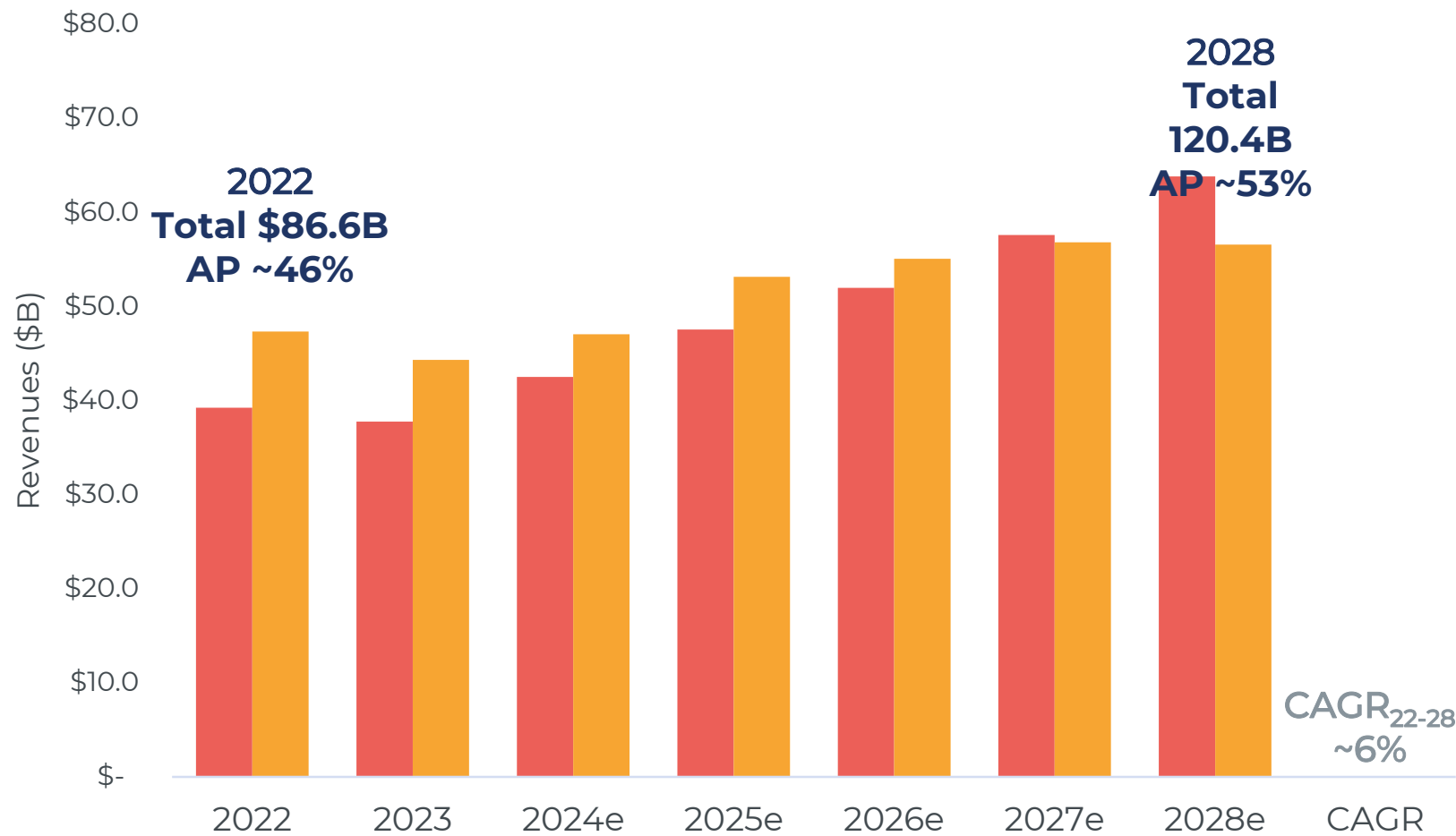
Test intensity and probe card demand increases as advanced packaging becomes widespread. This makes advanced packaging one of the main drivers for the probe card market.

TOTAL PACKAGING MARKET – ADVANCED VS. TRADITIONAL PACKAGING

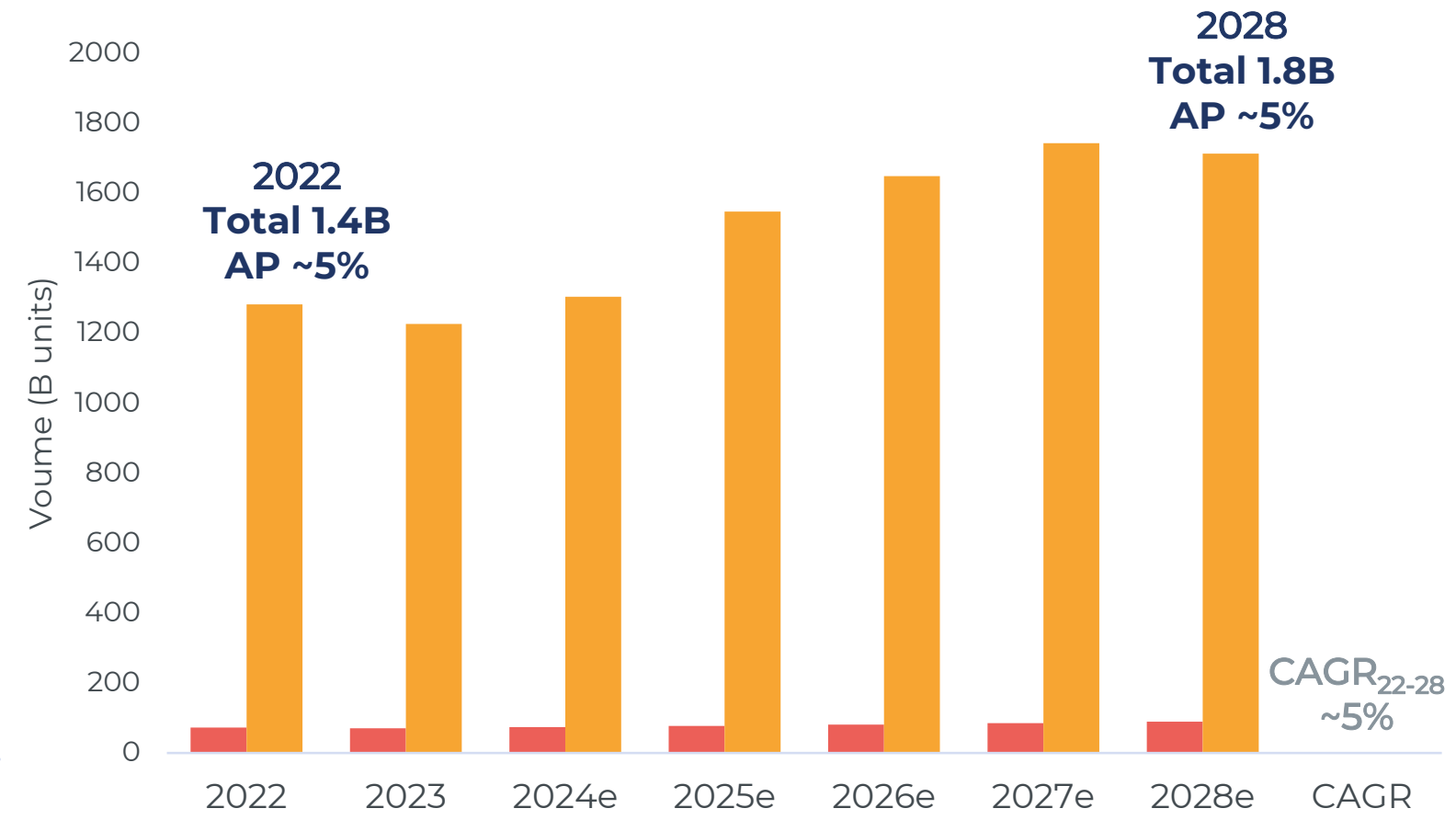
Revenues and Units Forecast 2022-2028



Total semiconductor packaging market revenues (\$B)
Breakdown of advanced vs. traditional packaging



Total semiconductor package units (B units)
Breakdown of advanced vs. traditional packaging



■ Advanced Packaging

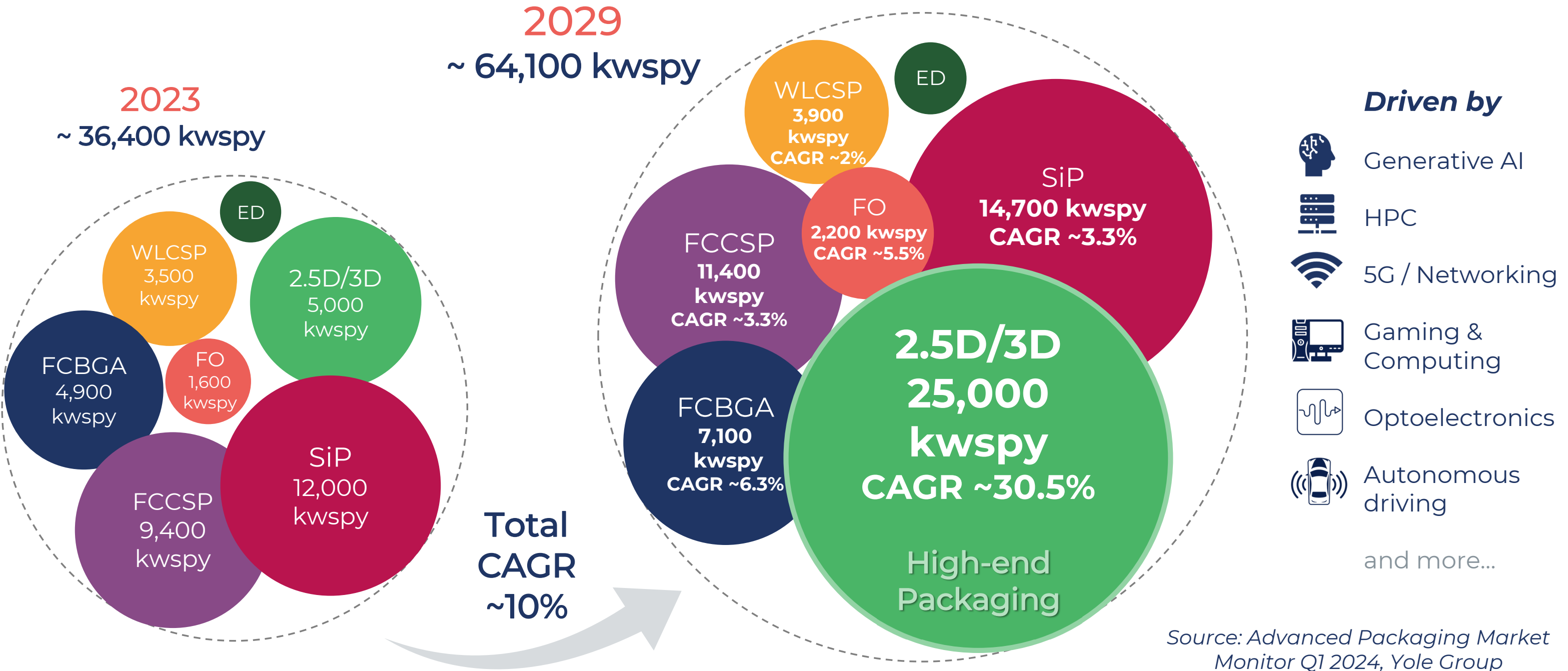
Fan-Out, WLCSP, FCCSP, FCBGA, SiP, 2.5D, 3D

■ Traditional Packaging

Wirebond, Leadframe-based, Ceramic-based
WB-BGA/LGA, QFN/QFP, COB/BOC, SOIC, TSOP, LCC, DIP, HTCC/LTCC, etc.

ADVANCED PACKAGING WAFER MARKET EVOLUTION 2023-2029

Breakdown by packaging platform, 300mm wafer equivalent (KWSPY)



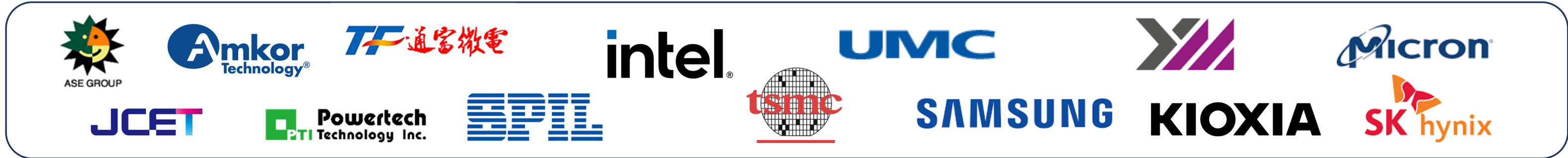
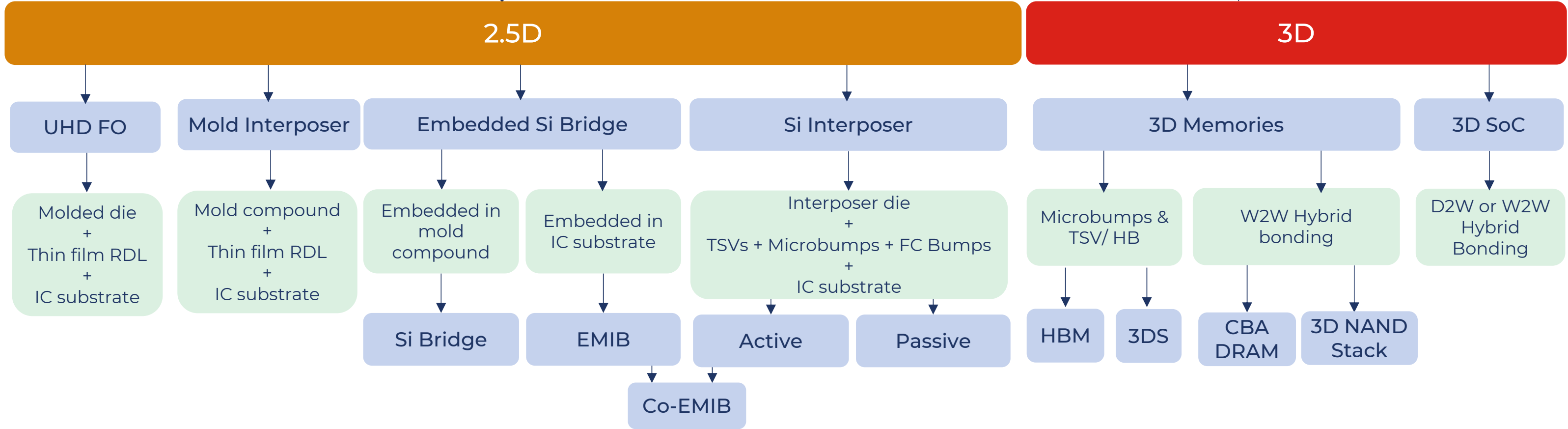
Source: Advanced Packaging Market Monitor Q1 2024, Yole Group

HIGH-END PERFORMANCE PACKAGING: ALL PLATFORMS

Yole's classification for 2.5D and 3D



2.5D and 3D Packaging

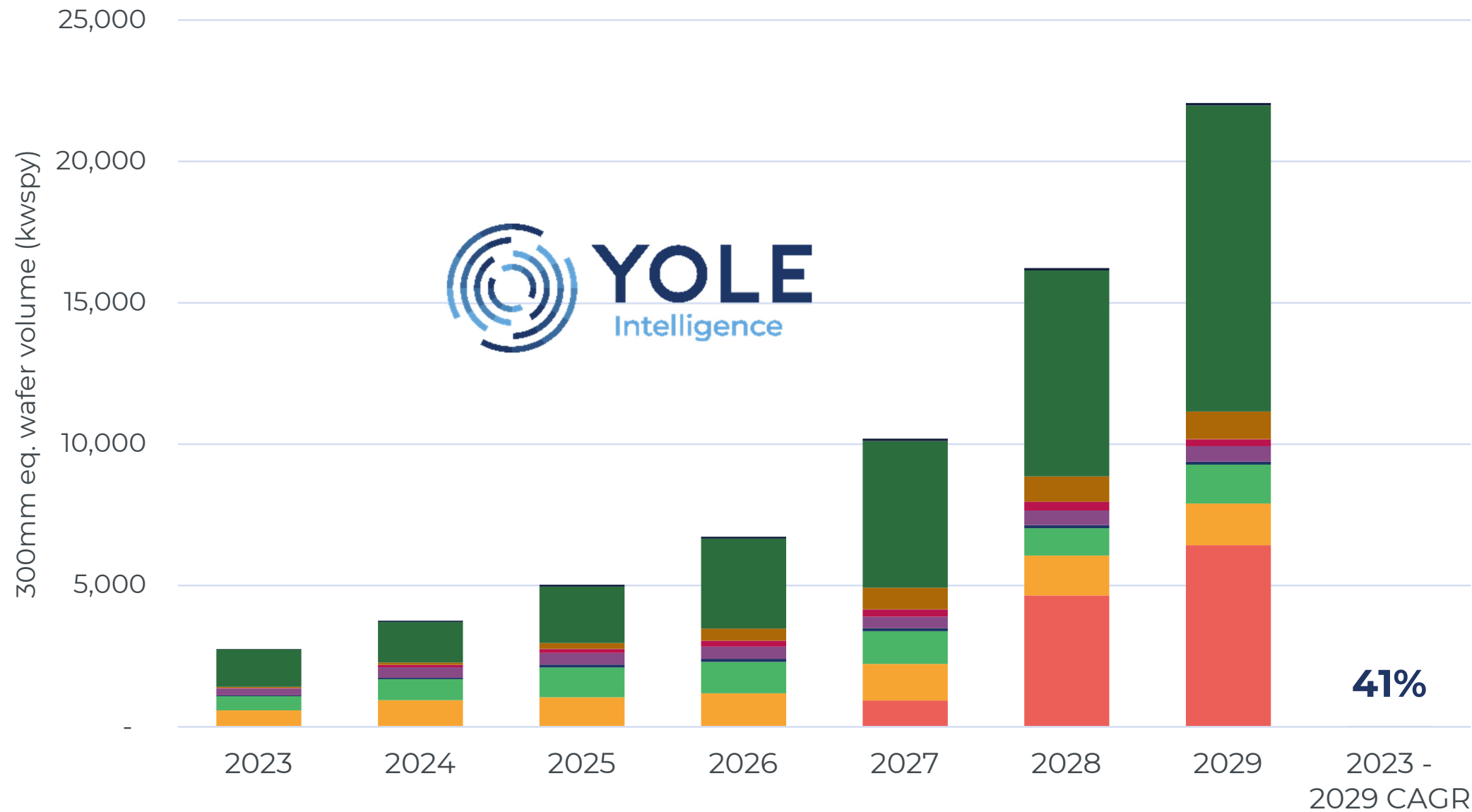


2.5D / 3D-STACKED IC PACKAGE 300MM EQUIVALENT WAFER DEMAND

Split by technology, excluding CIS stack



2.5D/3D Stacked wafer forecast (300 mm eq.) KWSPY
(without CIS)



Technology	CAGR ₂₀₂₃₋₂₀₂₉
CBA DRAM	655%
HBM	17%
3DS	18%
3D NAND	42%
3D SoC	71%
Active Si Interposer	68%
Co-EMIB	11%
Passive Si Interposer	14%
Embedded Si bridge	37%
Mold Interposer	27%
Total	41%

Source: Advanced Packaging Market Monitor Q1 2024, Yole Group



MARKET DRIVERS FOR 2.5D/3D HIGH-END PACKAGING

Generative AI growth dependent of high-end packaging capabilities



5G



Edge data center



Social networks



Cloud gaming



Enterprise digitalization



Autonomous driving



AI inference



AI training



AI accelerator – GPU/AI ASIC

2.5D/3D packaging for datacenter AI processors reached ~\$800M in 2023 and is set to grow to ~2.4B in 2029.



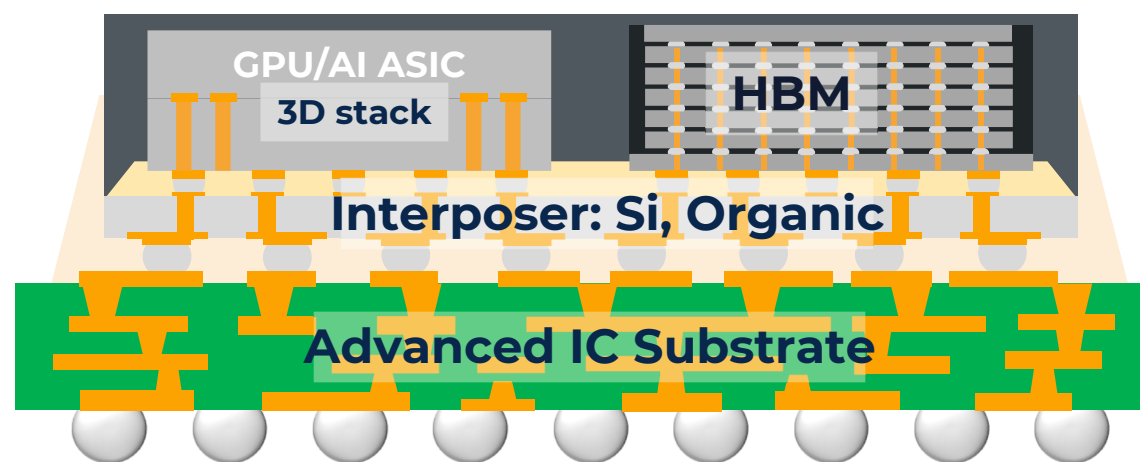
Requirements for AI accelerators

High computing power

High data flow

Large storage capacity

Optimal power consumption



- HBM
- 2.5D Interposer
- Chiplets / 3D stack
- Substrate



TECHNOLOGY TRENDS FOR 2.5D/3D HIGH-END PACKAGING

HPC/AI technology requirements for packaging

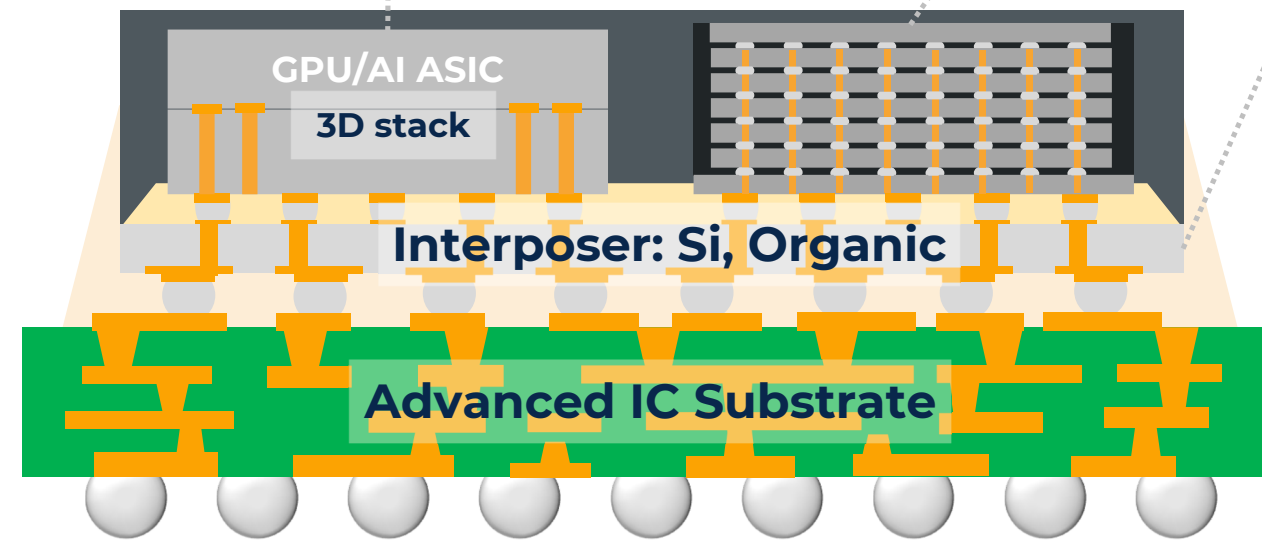
3D stacking

- Logic + Logic / Logic + memory / others



Memory

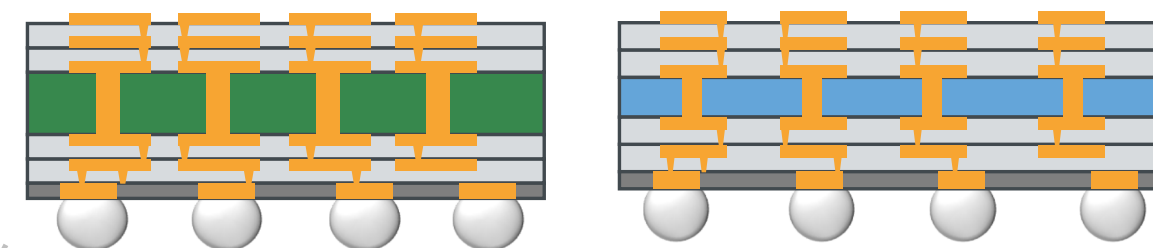
- HBM, 3D DRAM



2.5D Interposer



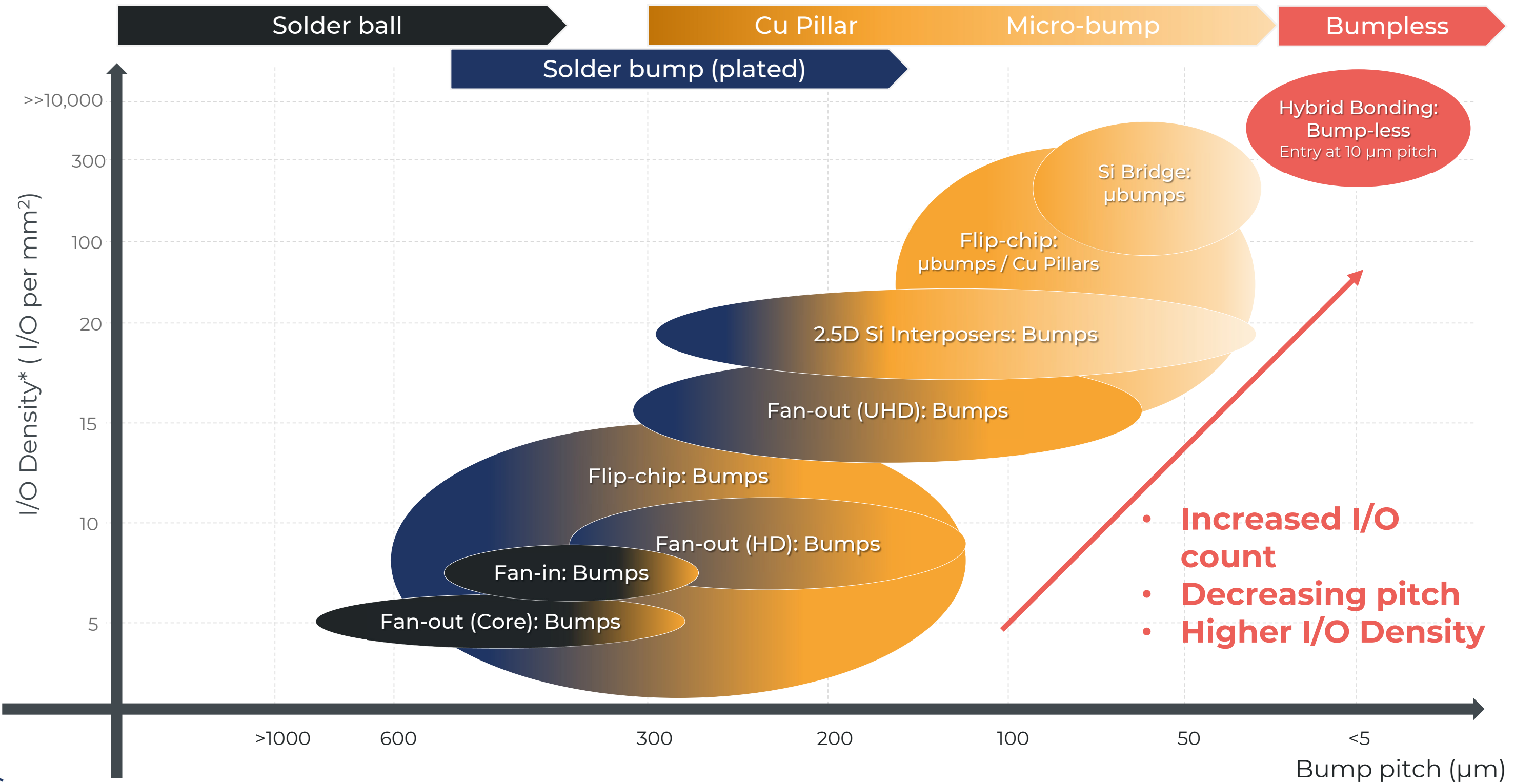
Advanced IC Substrate



Organic core

Glass Core

HIGH-END PACKAGING – TECHNOLOGY EVOLUTION



HBM PRODUCT DEVELOPMENT – OVERVIEW



HBM Generation	HBM	HBM2	HBM2E	HBM3	HBM3E / HBM3P ⁽¹⁾	HBM4 / HBMNext ⁽²⁾ (expected)
Number of dies per stack	4Hi	4-8Hi	4-8Hi	8-12Hi	8-12Hi ⁽³⁾	12-16Hi
Main packaging approach	TSV & Microbumps	TSV & Microbumps	TSV & Microbumps	TSV & Microbumps	TSV & Microbumps	12 Hi - TSV & Microbumps 16 Hi - Cu-Cu hybrid bonding
Suppliers	SAMSUNG 	SAMSUNG 	SAMSUNG 	SAMSUNG 	SAMSUNG 	SAMSUNG

Bump Pitch

> 22 μm

< 20 μm; <10 μm HB

Technology evolution

↑ Bandwidth ↑ Capacity ↑ Thermal dissipation ↑ TSV & Bump Count ↓ TSV & Bump pitch ↓ Die thickness

Test

↑ **Test Intensity and test complexity**

HBM is a big driver for test and probe card market

- ↑ number of dies stacked → ↑ total silicon area
- High test intensity → High number of probe cards required
- High test complexity, raising the performance requirements for each probe card



HBM MANUFACTURING

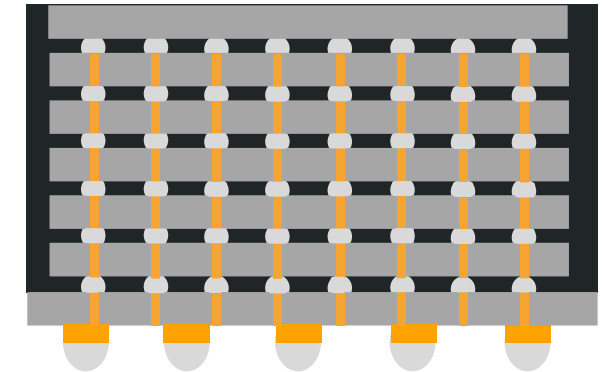
The HBM process comprises fab process, bumping/stacking processes and testing

HBM process flow

TCB/MR – bump technology



HBM manufacturers probe and test each DRAM die before stacking and then probe and test the multi-die DRAM stack at various points during the assembly process



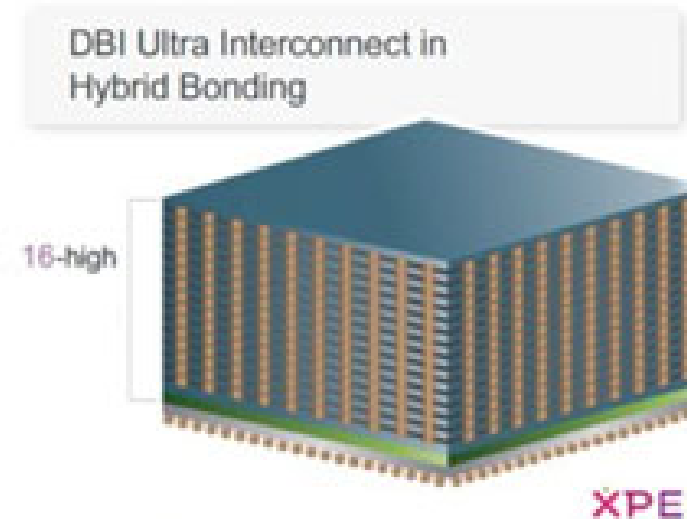
HBM process flow

Hybrid bond – bumpless technology



Transition to hybrid bonding → Test challenges!

- Cu pad contamination
- How to perform KGD test?
- Test of HBM stack only after assembly → yield issues



Source: Xperi-Adeia

*KGD = Known Good Die

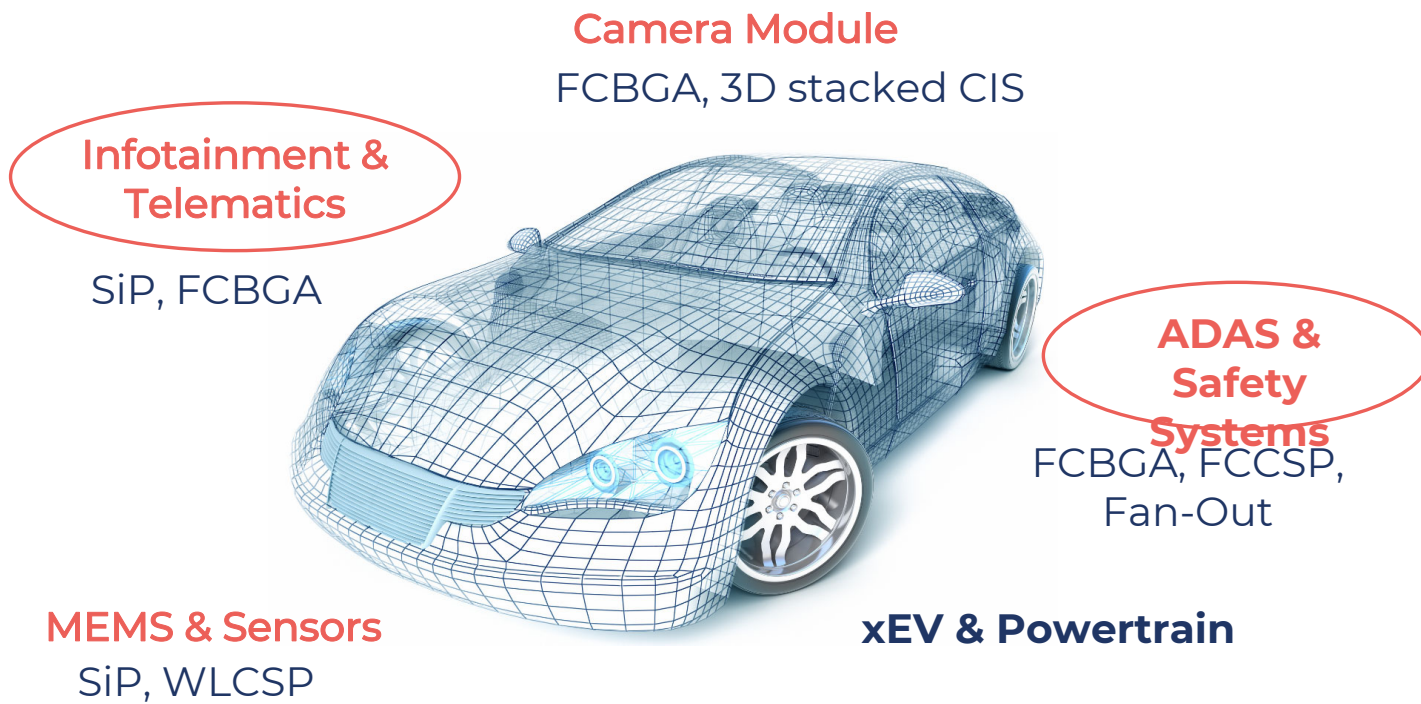
*KGSD = Known Good Stacked Die



HIGH-END PACKAGING GOING TO AUTOMOTIVE?

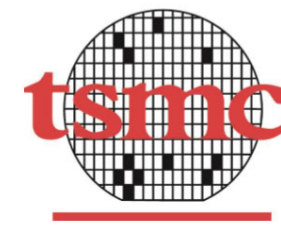
Reliability and test concerns

Where is advanced packaging needed?

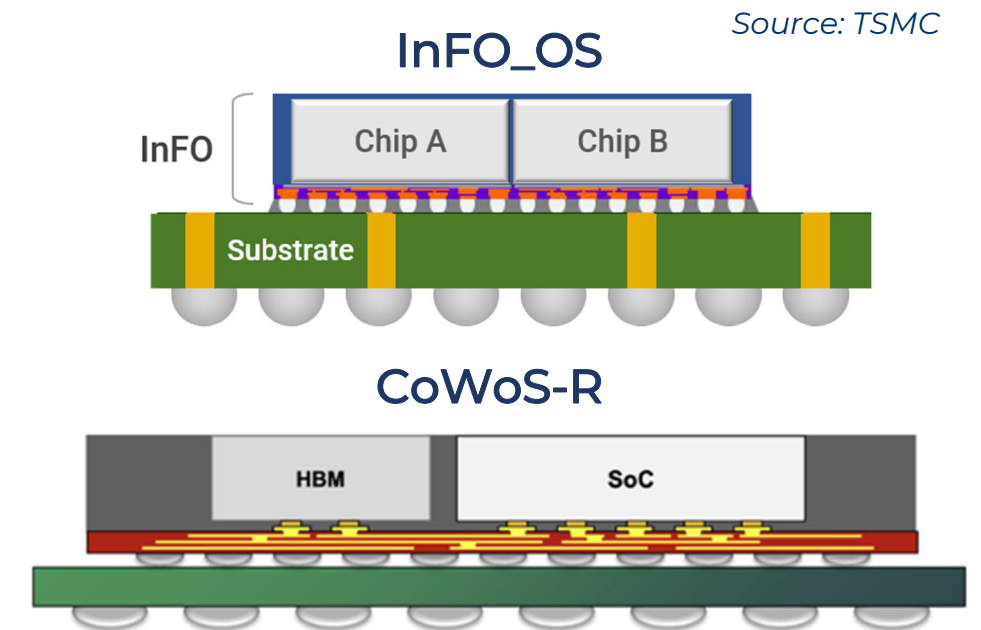


Adoption of 2.5D and 3D packaging

Computing power > 2000 TOPS needed for autonomy and generative AI



AEC Q100 Grade2 qualified by Q4'25



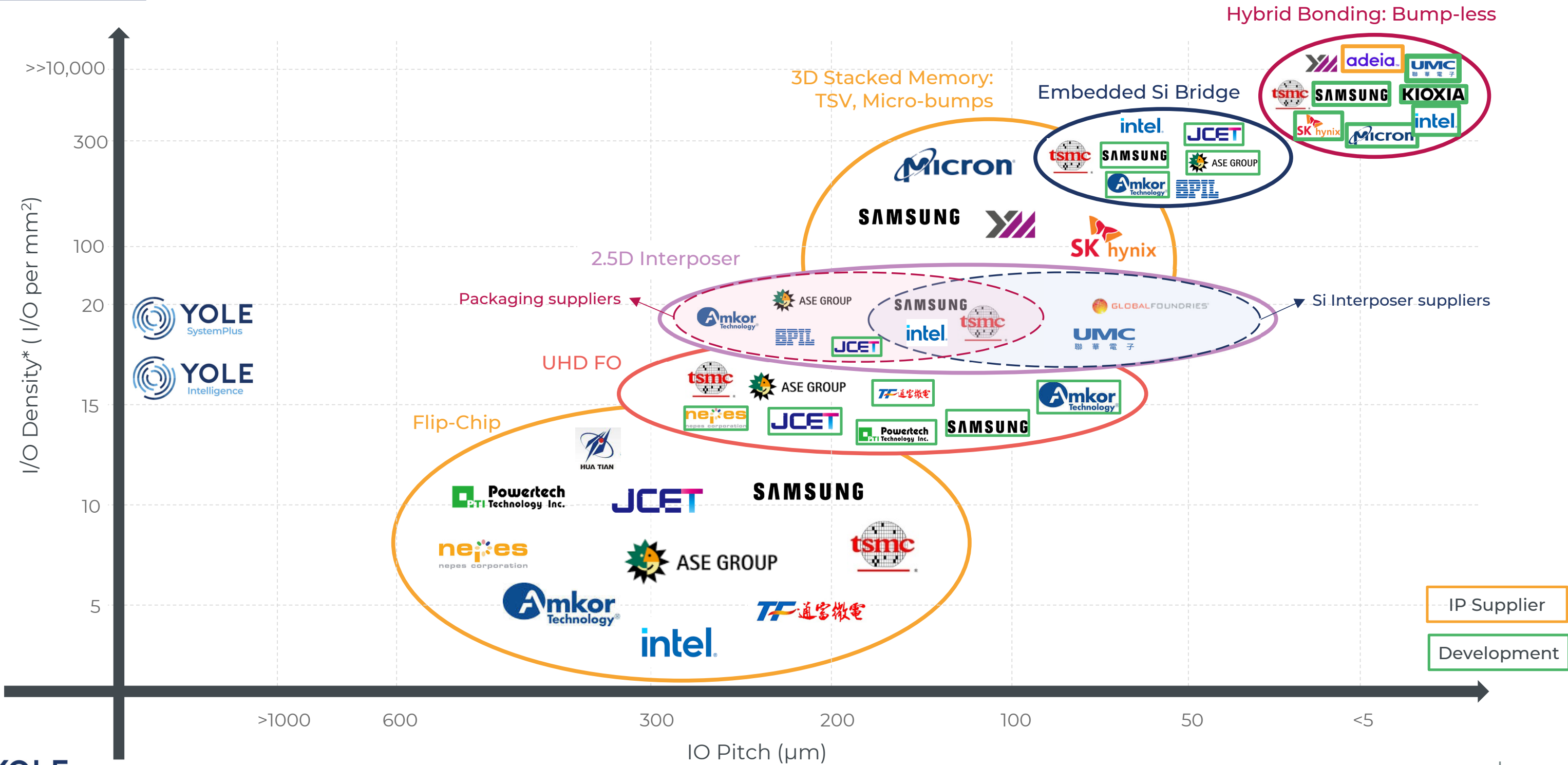
Challenges

- Very high demands on reliability → higher working temperature and longer lifetime is required
- No redundancy like at the datacenter level
- Testing process and specifications are challenging → higher test intensity and longer testing time
- Development timescales are much longer than in the consumer market

HIGH-END PACKAGING – SUPPLY CHAIN

Mapping of players based on technology

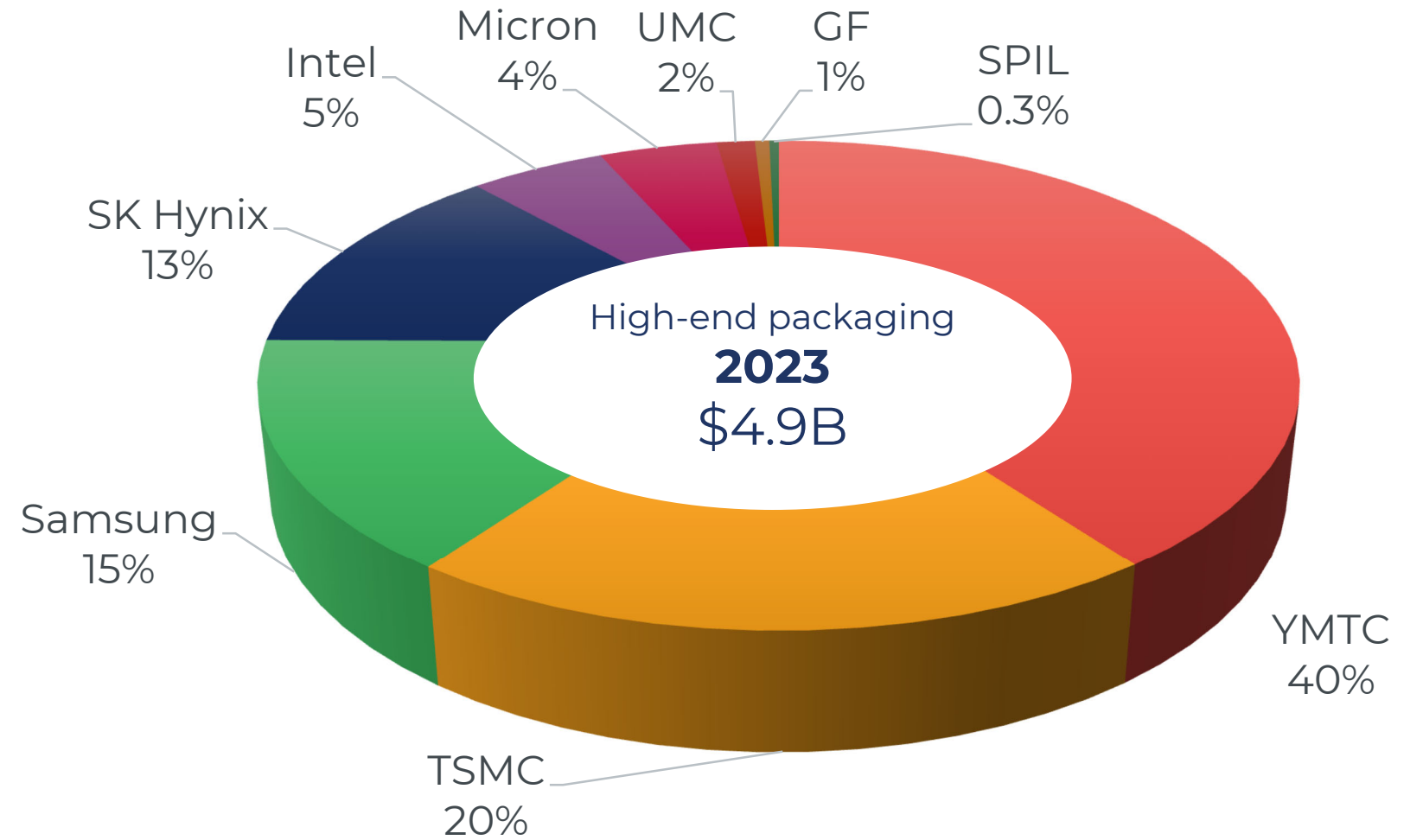
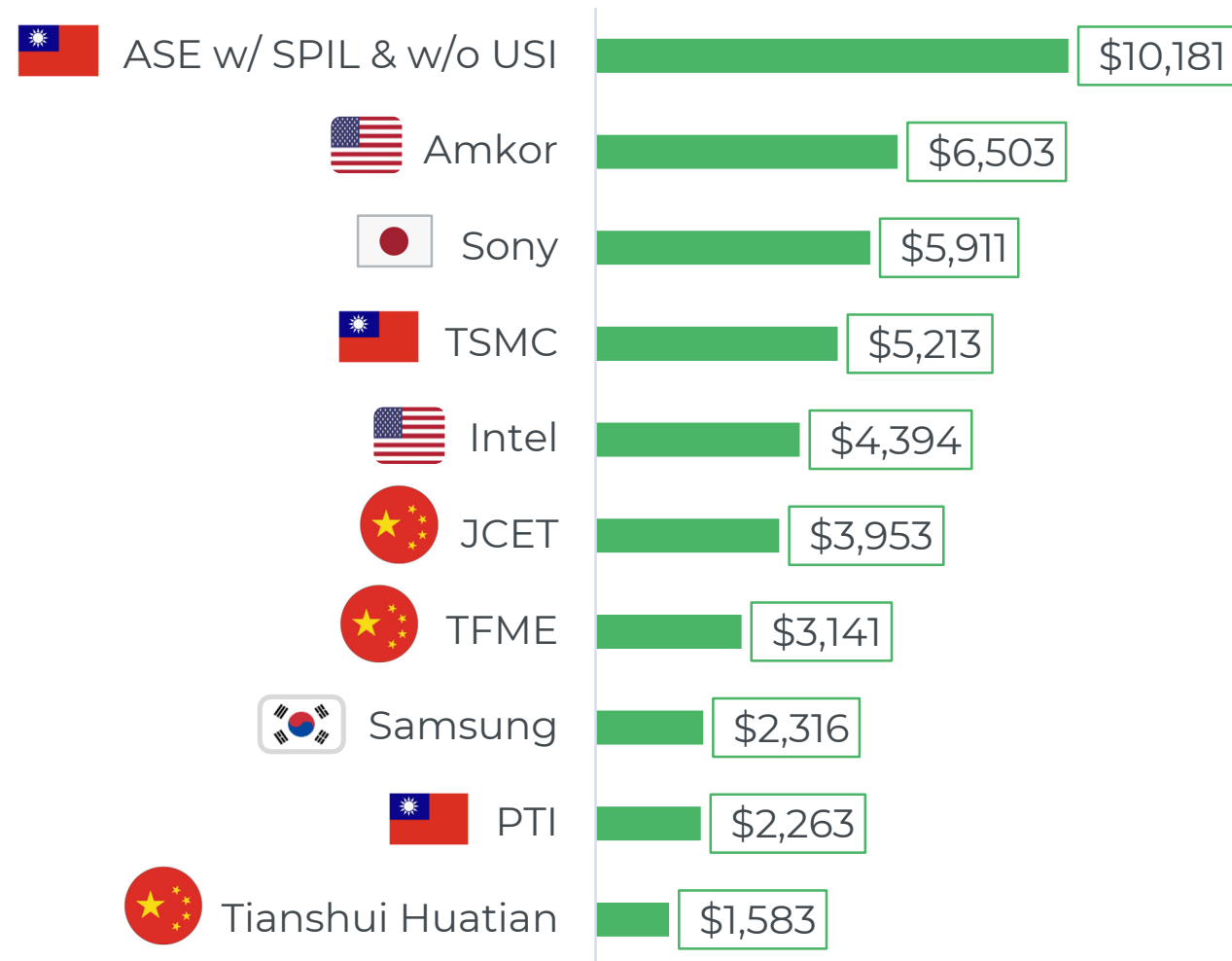
Non-exhaustive List of Players



TOP 10 PACKAGING SUPPLIERS' REVENUES – 2022-2023 RANKING



Top Packaging Supplier Ranking by 2023 Revenue (\$M)



What to expect next?

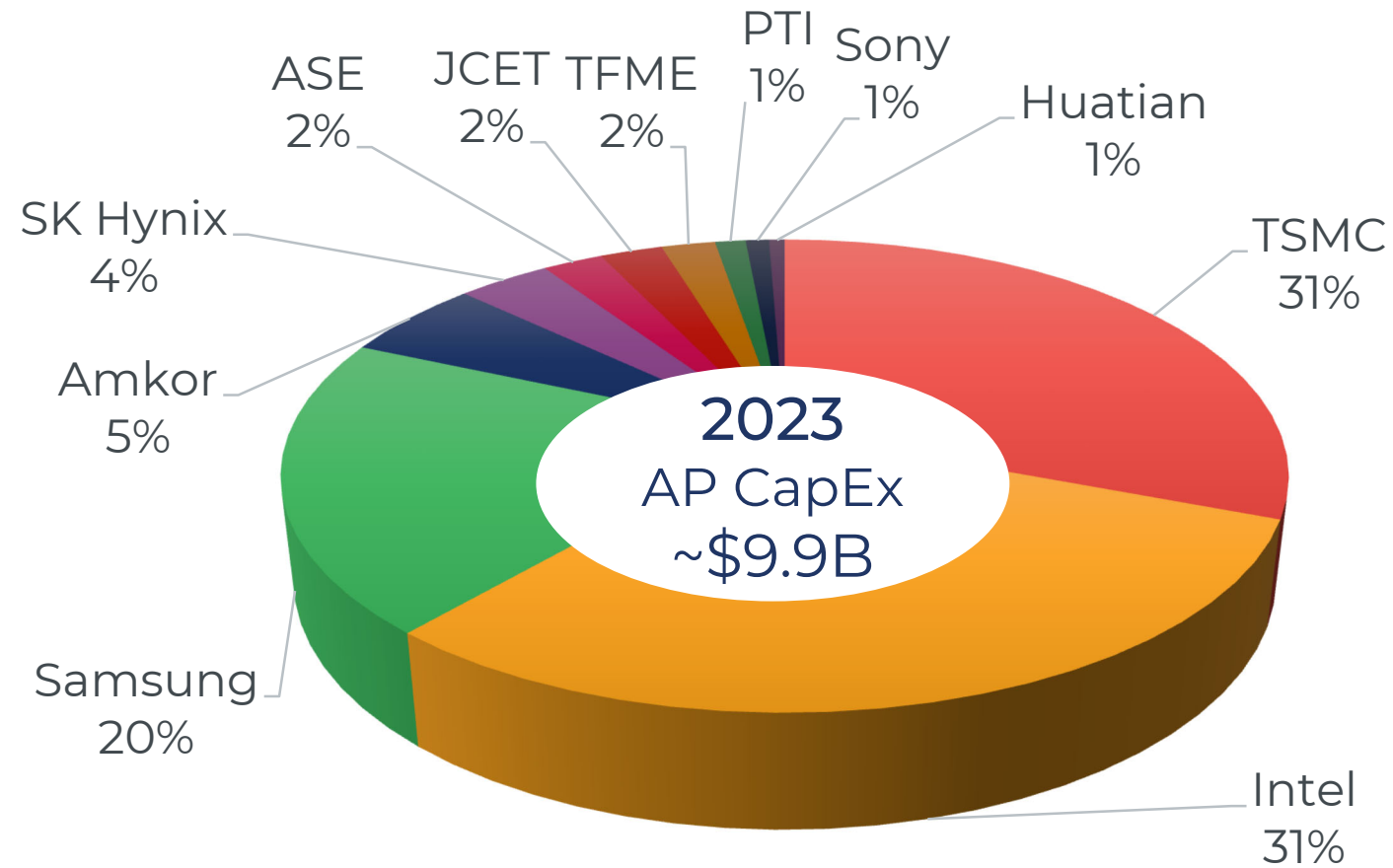
IDM/ Foundry market leaders

+

OSATs entering 2.5D

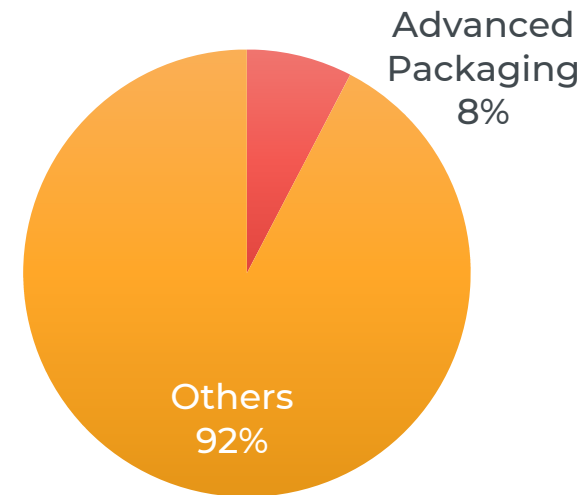
Source: Advanced Packaging Market Monitor Q1 2024, Yole Group

ADVANCED PACKAGING (AP) CAPEX FOR TOP PLAYERS

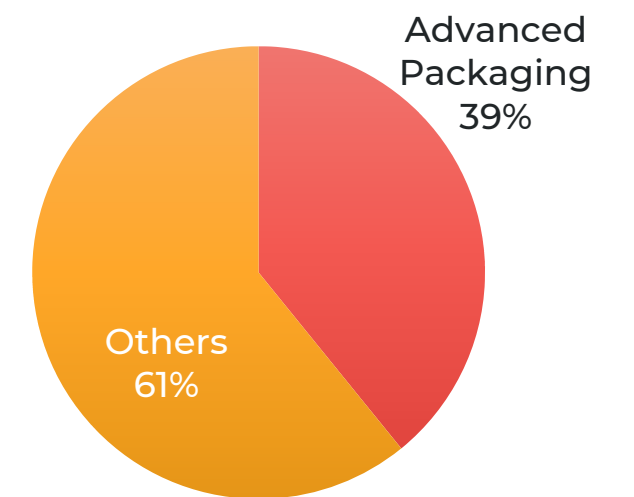


Advanced packaging CapEx generated by IDM, foundry and OSAT business models is expected to grow by about 16% in 2024

IDM/Foundry Total CapEx 2023 ~\$112B



Top 6 OSAT Total CapEx 2023e ~\$3.5B



Major HBM investors



Major 2.5D investors



Source: Advanced Packaging Market Monitor Q1 2024, Yole Group

CONCLUSIONS



- 2024 is set to be a year for recovery for the advanced packaging market as well as the semiconductor test and probe card markets.
- High-end advanced packaging is needed to answer generative AI demands with more die/chiplet integration, more HBM, high bandwidth and high-density interconnections.
- Technology trends of 2.5D interposer, 3D stacking, hybrid bonding and CPO suppose increased I/O counts, decreased I/O pitch and I/O density increase at the package level.
- Test intensity, test complexity and probe card demand increases as advanced packaging becomes widespread, making advanced packaging one of the main drivers for the probe card market.
- The industry needs to find optimal test solutions for 3D stacked dies using novel technologies like hybrid bonding.
- The adoption of high-end advanced packaging solution in automotive brings new test challenges as reliability concerns.
- IDMs and foundries lead the high-end packaging market but OSATs will be slowly penetrating the supply chain.

THANK YOU!