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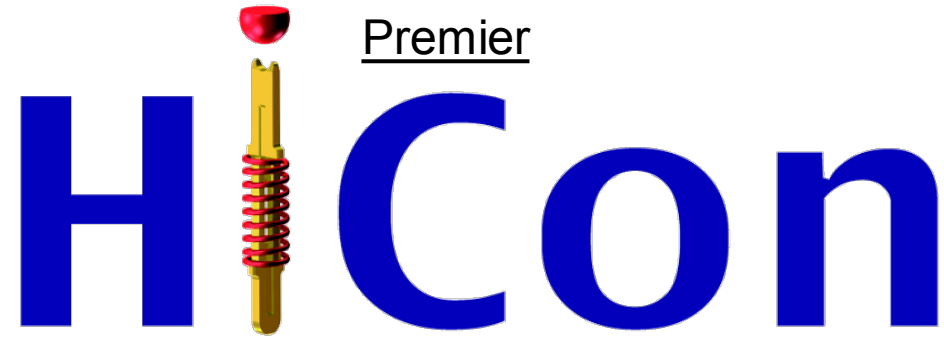
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Mesa, Arizona
March 5-8, 2023

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Evolution of Semiconductor Technologies with New Applications Are Bringing A Bigger Stage for Test Suppliers

John West and Lin Fu
Yole Group



Mesa, Arizona • March 5–8, 2023



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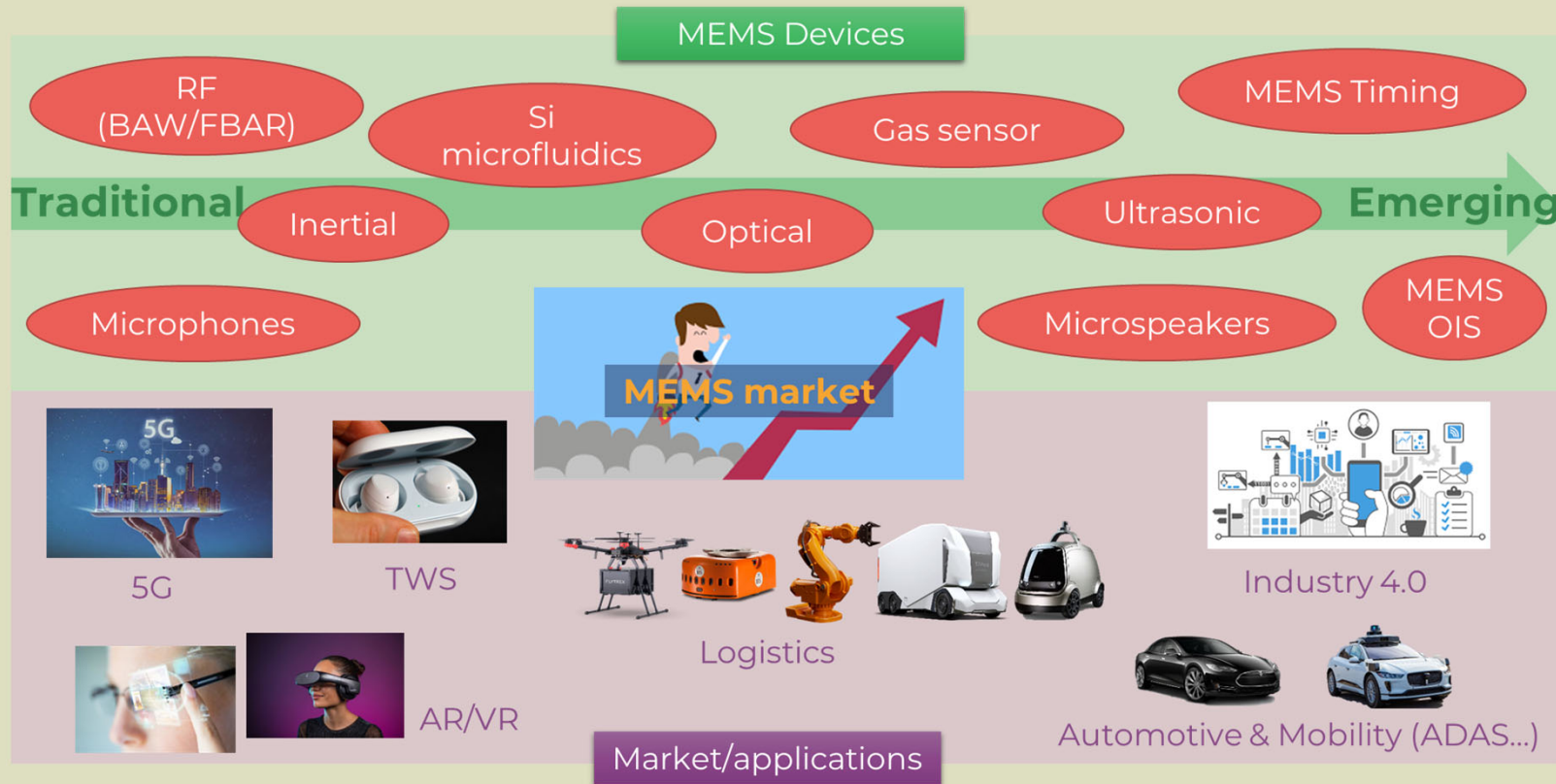


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2023

MEMS Market Trends



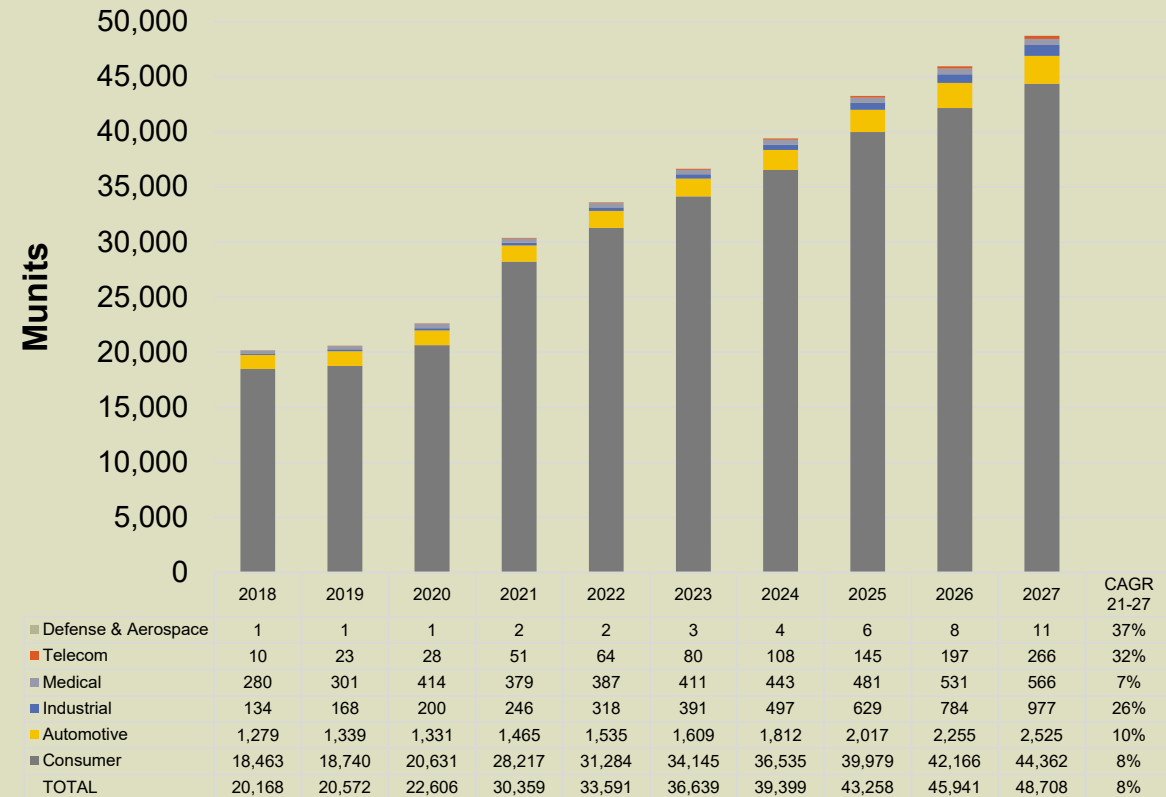
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MEMS Devices Shipments

- Between 2020 and 2021, growth was strong, mainly due to anticipated penetration of **5G smartphones and associated RF MEMS filters** (>50% YoY).
- In 2021, more than **30 billion** MEMS devices were shipped worldwide. We expect this to reach almost **49 billion** by 2027, with an overall 8% CAGR₂₁₋₂₇.
- We also expect a strong penetration of up-and-coming MEMS timing devices across all markets, driving up the growth rates in smaller markets, especially in the telecom and defense & aerospace markets (32% and 37% CAGR₂₁₋₂₇, respectively).

Global MEMS Volumes (Million units)



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Consumer MEMS Market

- MEMS devices are mainly shipped to the consumer market. In 2021, more than 28 billion units were shipped for consumer applications accounting for more than 90% of the shipments
- The consumer MEMS market will reach 44 billion units in 2027, **driven mainly** by **RF MEMS devices**, which accounts for 56% of the shipments (15.9Bu). The volume of RF MEMS is expected to grow to more than 23 billion units in 2027, with a 7% CAGR₂₁₋₂₇.
- With an increasing attachment rate of **MEMS microphones and inertial sensors** in consumer devices such as hearables/TWS (for better sound capture, beamforming, ANC, 3D Audio, etc.), we expect these devices also to be **significant drivers** for the consumer market.
- **MEMS microspeakers** will also **grow significantly** as they get adopted across various devices (all types of hearables first, then smartphones and eventually other electronic end-systems).
- **MEMS timing devices** will increase **by 5x five years** from now as they continue to replace older crystal-based timing technology.
- Other devices like **gas or environmental sensors** are **gaining traction** in the consumer market with the global awareness of indoor and outdoor air quality.



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2023

What Does It Mean for Socket Suppliers?

Challenges:

- MEMS devices and sensors transduce a physical input to an electrical output, which usually requires **a type of stimulus** (motion, sound, pressure, light etc.) during the test.
- Testing is usually more complex because we need make sure sensors **fully function in a system** after test.
- **Advanced packaging** adopted in MEMS devices like 2.5D/3D increase the testing complexity more.

Opportunities:

Assume the test socket life span ~ 200K

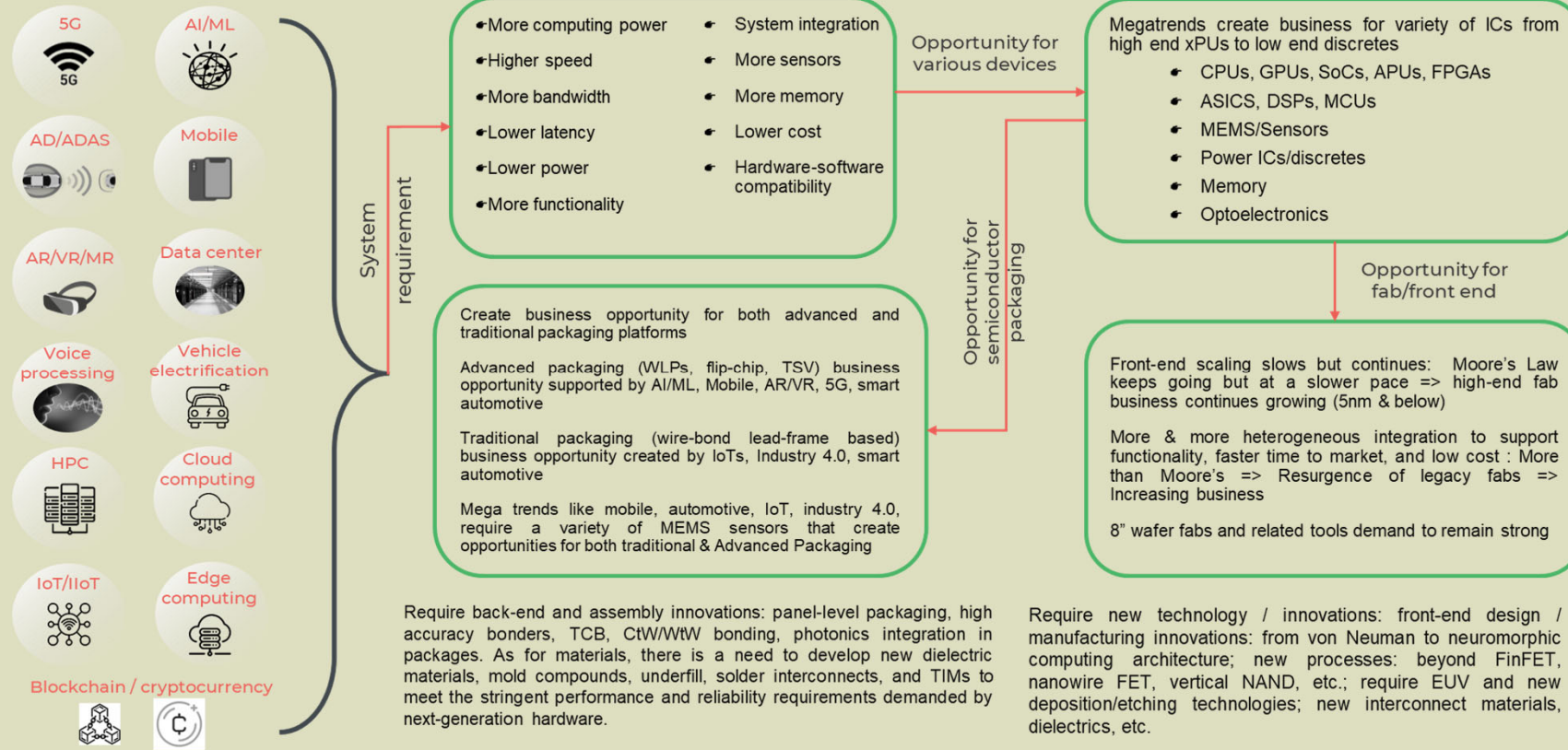
150K test sockets are required for MEMS devices in 2021, **245K** in 2027



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6 **2023**

Packaging Market Trends

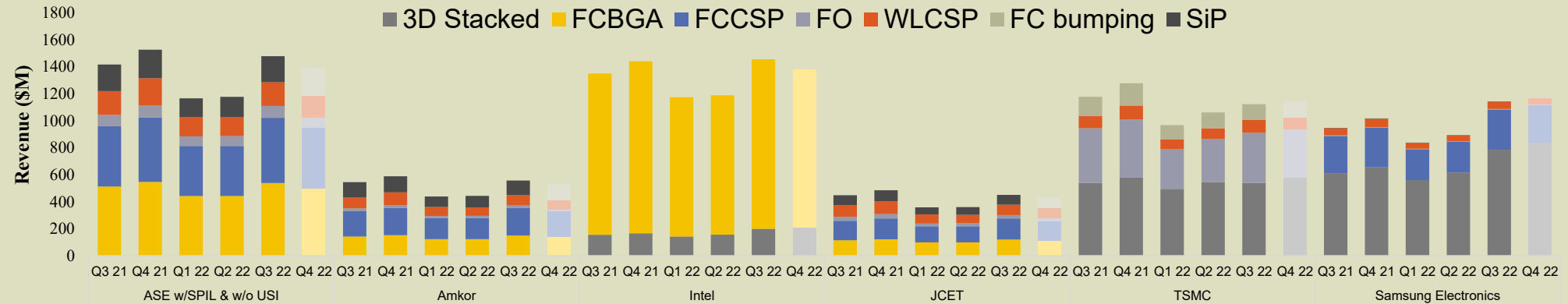


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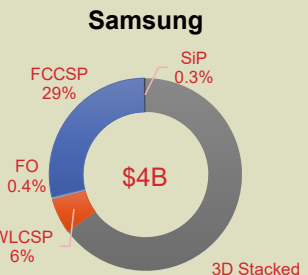
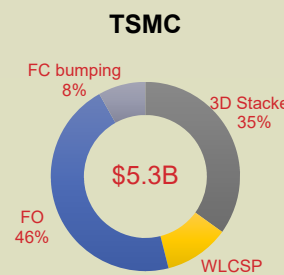
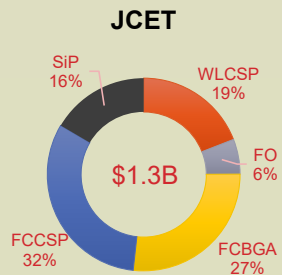
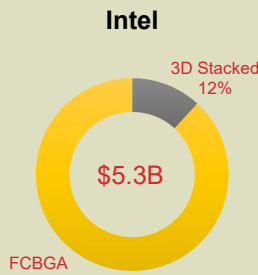
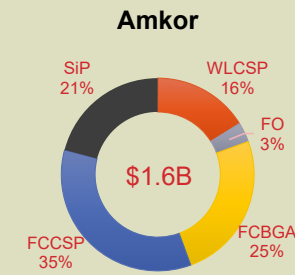
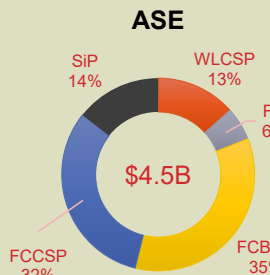
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More and More Advanced Packaging Involved

Quarterly Revenue by Player and Advanced Packaging Platform



2022 Estimation*



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Challenges for Test Suppliers

- **Thermal control system** connected to chillers to maintain devices temperature
- **Test partially assembled devices** at final test and system level test when yield is not that high. Risks added by testing such as cracked dies / packages, shorting of exposed pads



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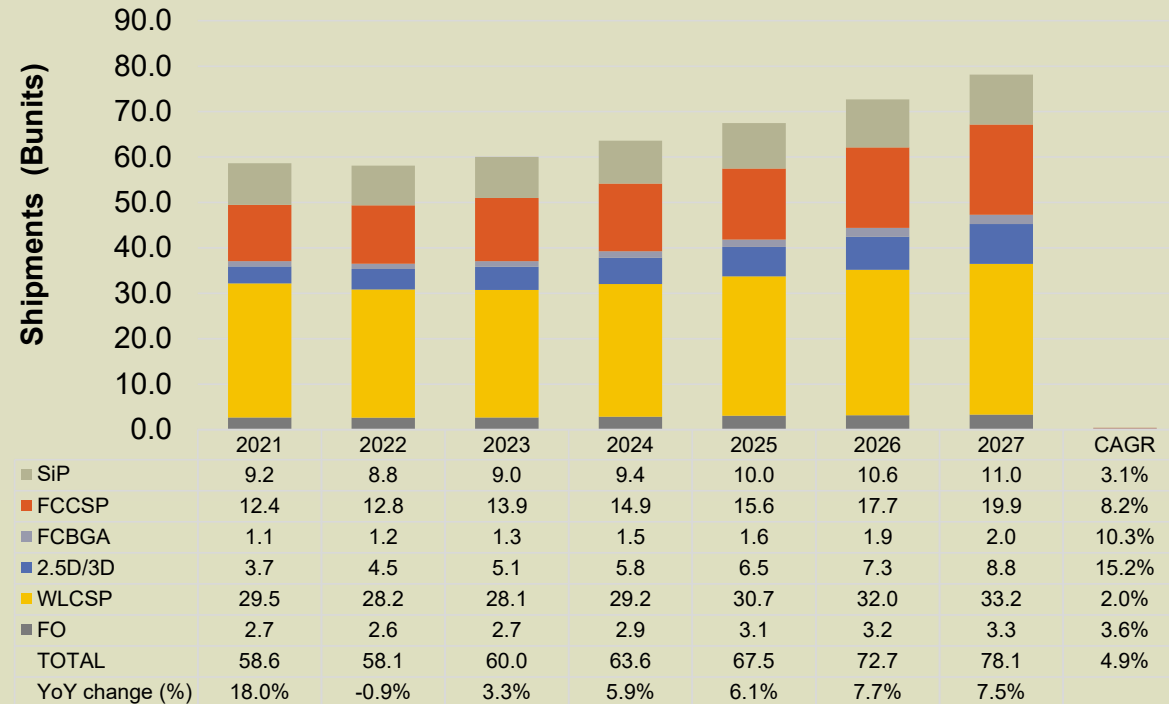
Advanced Packaging Shipments

Advanced packaging are expected to show a 4.9% CAGR₂₀₂₁₋₂₀₂₇, with **WLCSP** leading in terms of the total number of units, and **2.5D/3D** leading in terms of growth rates.

WLCSP accounting for more than 50% of total shipments.

For HPC and high-end gaming processors etc., typically include 2.5D and 3D packages, this market with CAGR of 15.2%.

Advanced Packaging Shipments (Billion units)



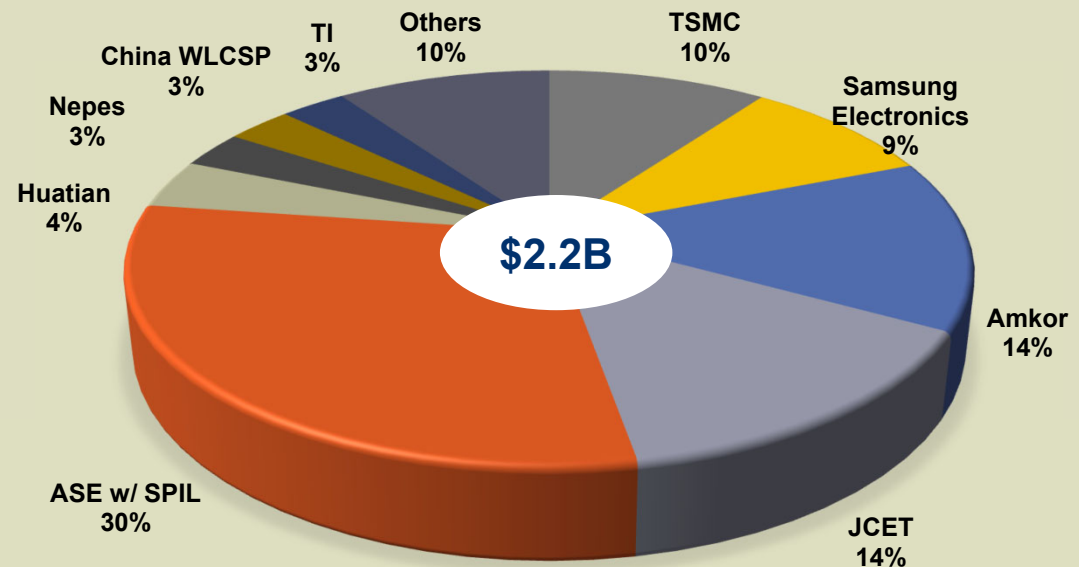
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2021 Market Shares of WLCSP Suppliers

- Total revenues of WLCSP suppliers were **\$2.2B** in 2021.
- In 2021, \$54M probe cards were used for WLCSP, and \$67M test sockets were used for WLCSP
- In total, market size was **~\$121M**.

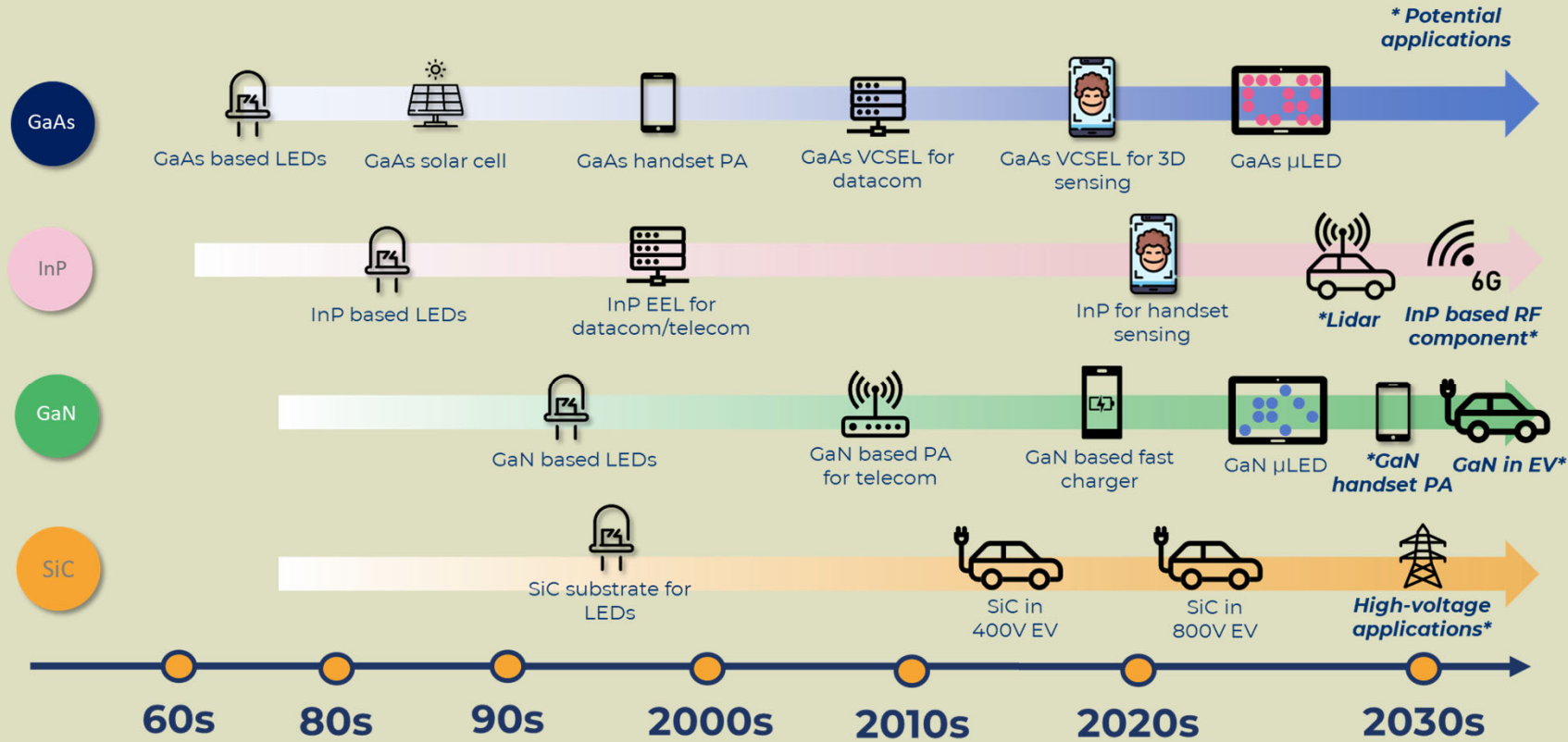
2021 Market Shares of WLCSP Suppliers



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Compound Semiconductor Market Trends




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Application of Major Compound Semiconductors

Applications		GaN Sapphire	GaN SiC	GaN Si	X active layers Bulk GaN	SiC SiC	X active layers GaAs	X active layers InP
Photonics 	EEL				✓		✓	✓
	VCSEL				✓		✓	✓
	LED Lighting & Display	✓	✓	✓	✓		✓	✓
	RF		✓	✓		✓	✓	✓
	Power	✓		✓	✓	✓	✓	

EEL: Edge emitting laser
 VCSEL: Vertical cavity surface emitting laser

 Main application for this material amongst other established Compound Semiconductors

 In production

 In development/evaluation



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Challenges for Test Suppliers

- Test with **extreme accuracy** required for high-brightness LEDs
- **High frequency** test for RF applications
- **Higher rated voltages and peak currents** required for power applications

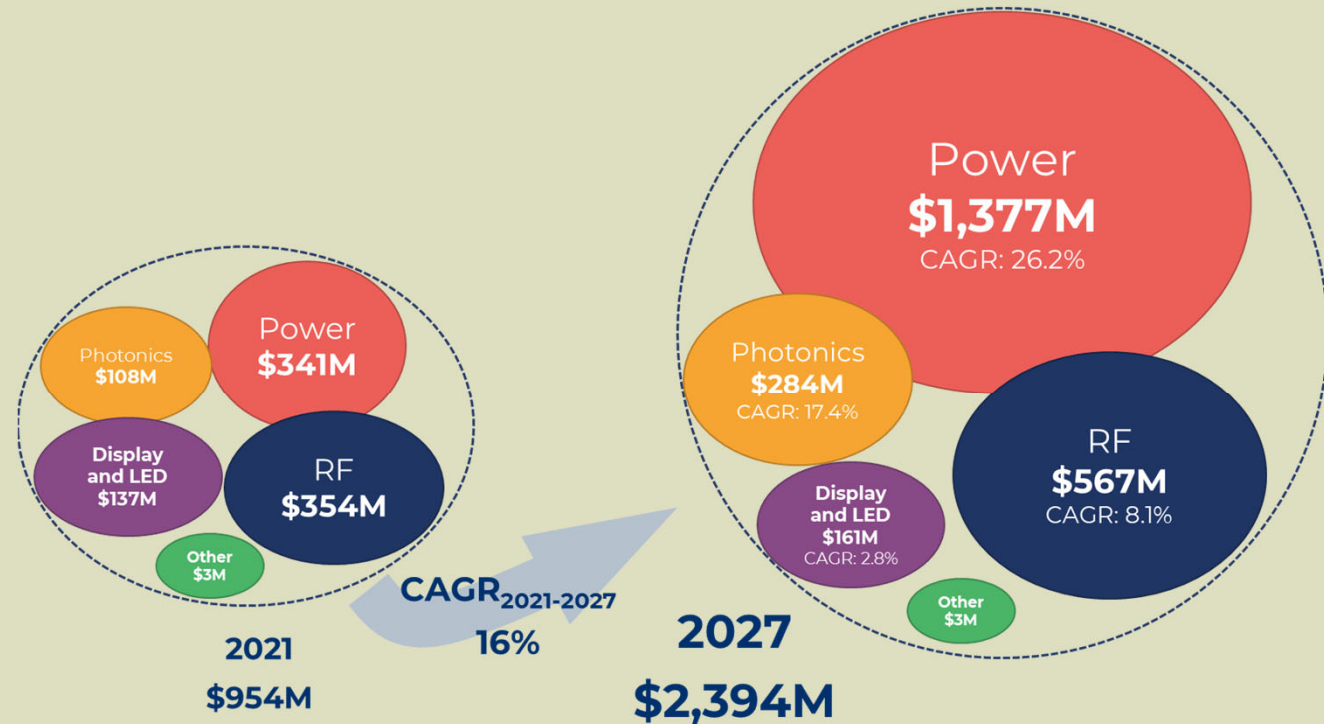


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Compound Semiconductor Substrate Market (\$M)


- Substrates in power applications will reach \$1.3B, strongly driven by Power SiC and Power GaN.
- Photonics will also grow with double-digit growth rate in the coming 5 years.
- The momentum in RF applications will align with the recovery of telecom infrastructure.



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Revenue growth of test essentials
higher than growth of Semiconductors

Cost of test up 



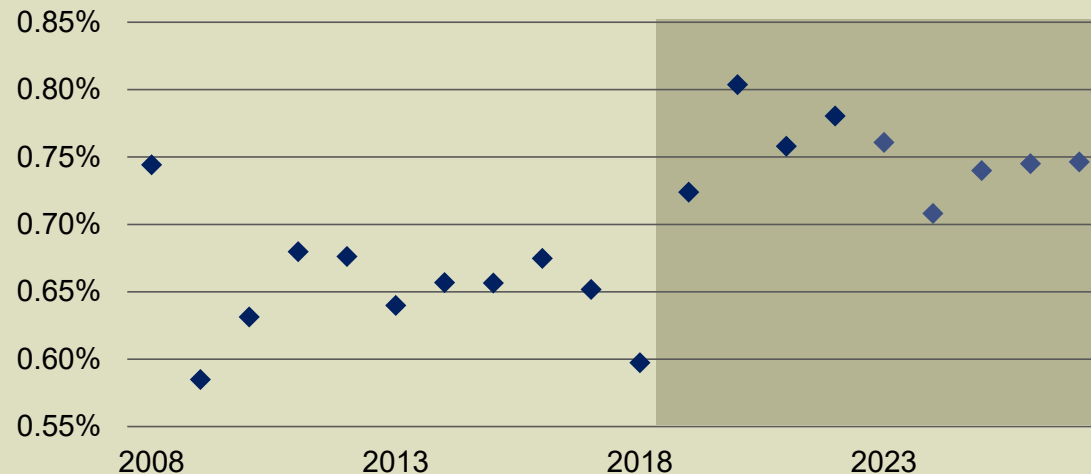
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TestConX 2023

Cost of Test Up

Probe Card & Socket Spending as a % of Semiconductor Revenues



Step change from 2019

Test challenges for semiconductors with different technologies / in different application fields are on the increase

~ Is this now a trend?

We believe the answer is **YES**

Difficult to make test cheap for high-end applications, but possible to make it less expensive based on the effort of test suppliers.



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17 **2023**

Revenue growth of test socket much **higher**
than growth of probe card in 2022

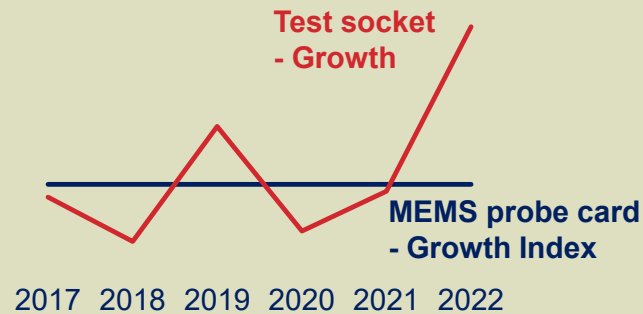
Will this trend continue ?



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2022 Test Socket Growth Tripled



Over the past 6 years demand for probe cards has been growing strongly. However, most of the growth has been for **MEMS probe cards** while demand for cantilever and vertical probe cards has been flat to slightly up. MEMS probe cards dominate the probe card market and now account for **68%** of all revenues. Demand for MEMS probe cards typically outgrows the demand for test sockets, but in 2022 demand for test sockets has surged ahead of MEMS probe cards.

Comparison of the sales performance between the top MEMS probe card suppliers and test socket suppliers in 2022 shows a dramatic difference in growth rates: **18% for test sockets, while demand for MEMS probe cards is trailing with 6% growth**. The difference is caused by several factors below:

- Increase in singulated die testing
- Socket suppliers gaining a greater share of the WLCSP market
- 100% System level test being used to test a greater number of advanced devices
- Prober manufacturing delay due to China lockdown in 2022
- Anything else?



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Summary

- Evolution of semiconductor technologies are bringing more and more test challenges.
- Testing is playing a more important role than ever.
- Chip designers is expecting to see more innovation from the test side including both test essentials and test equipment



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