



Semiconductor Industry Speaker Series

"Outlook for 2021: Are There Supply Limitations to
Growth?"

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TechSearch International, Inc.

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Outlook for 2021: Are There Supply Limitations to Growth?

- TRACK INNOVATION
- IDENTIFY TRENDS
- ANALYZE GROWTH
- INFLUENCE DECISIONS

RELEVANT, ACCURATE, TIMELY

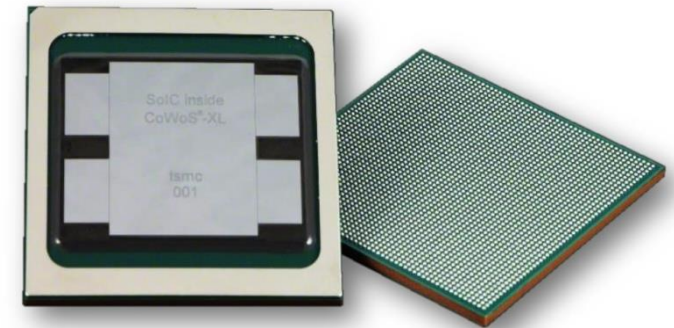
**E. Jan Vardaman,
President and Founder**

Growth Areas for 2021

- **Datacenter and cloud computing expansion continues**
 - Drives demand for servers and server CPUs
 - Drives demand for DIMMs
 - Drives demand for AI accelerators
 - Drives integrated photonics development
- **Demand for AI accelerators and networking**
 - Driving demand for HBM (49% CAGR in wafers 2020-24)
 - Silicon interposers
 - FO on substrate
 - Bridge solutions
- **Laptop and tablet sales growth driven by work from home and educational demand**
- **Gaming systems remain popular**
- **Growth in 5G infrastructure hardware and 5G smartphone**
- **Automotive industry returns to growth**



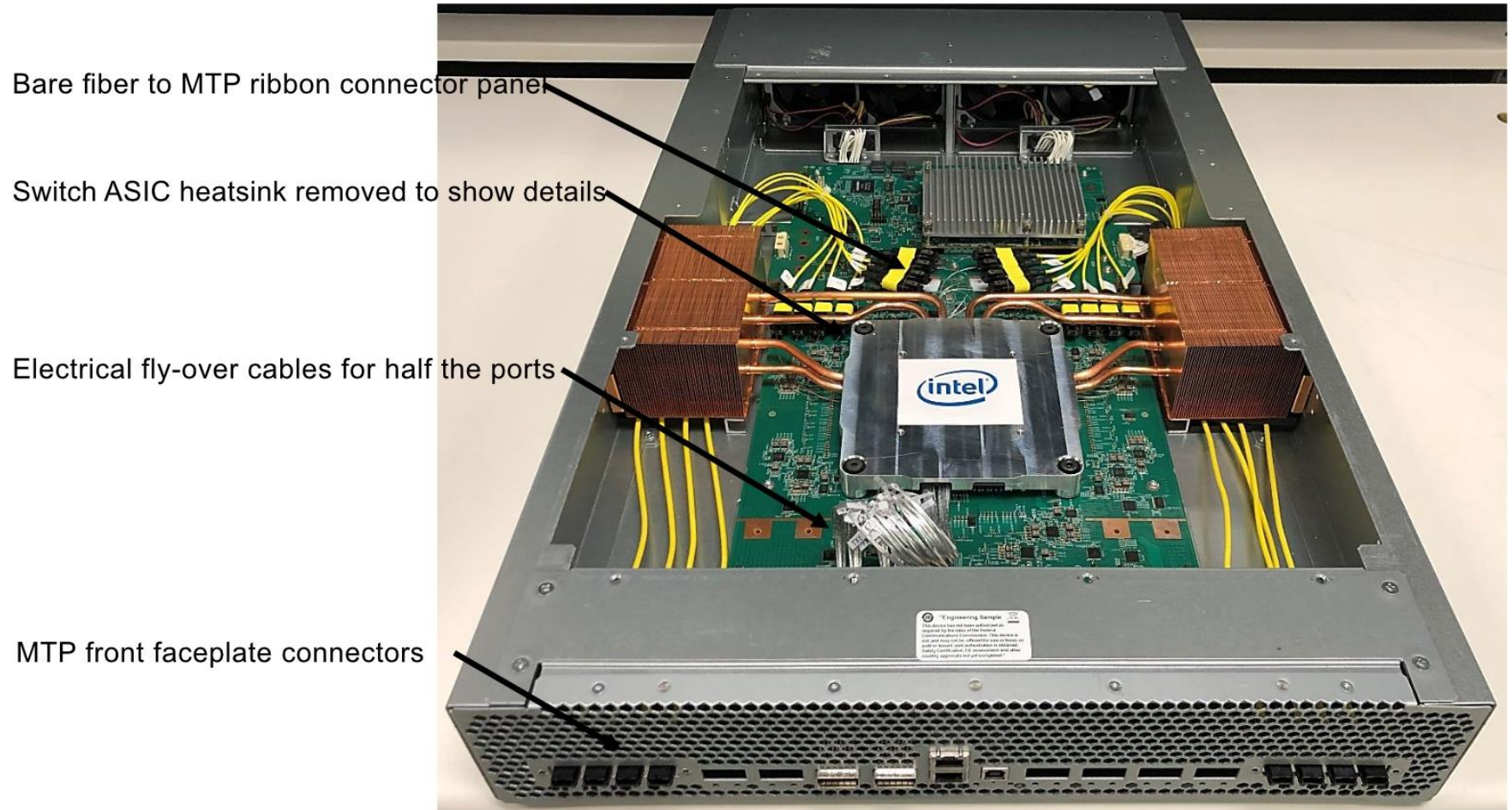
Source: Datacenterknowledge.com.



Source: TSMC.

Integrated Photonics Packaging

- Intel's co-packaged Ethernet switch with integrated photonic engines
- Designed for 25.6Tbps and 51.2Tbps switch generations



Source: Intel.

5G Infrastructure Rollout Continues

- **5G infrastructure rollout**

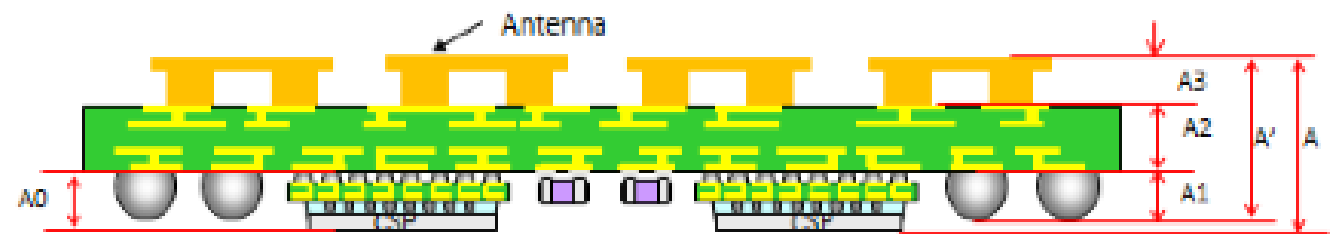
- China's Ministry of Industry and Information Technology says 710,000 5G base stations were installed in 2020 (sub-6 GHz)
- 600,000 base stations to be installed in 2021 (if sufficient components are available)
 - Drives demand for RF modules
 - System-in-Package
- Rollout continues in U.S. and Europe (mmWave)
- mmWave drives small cell

- **Drives demand for complex SiPs**

- Laminate substrates with AiP



Source: techhq.com.

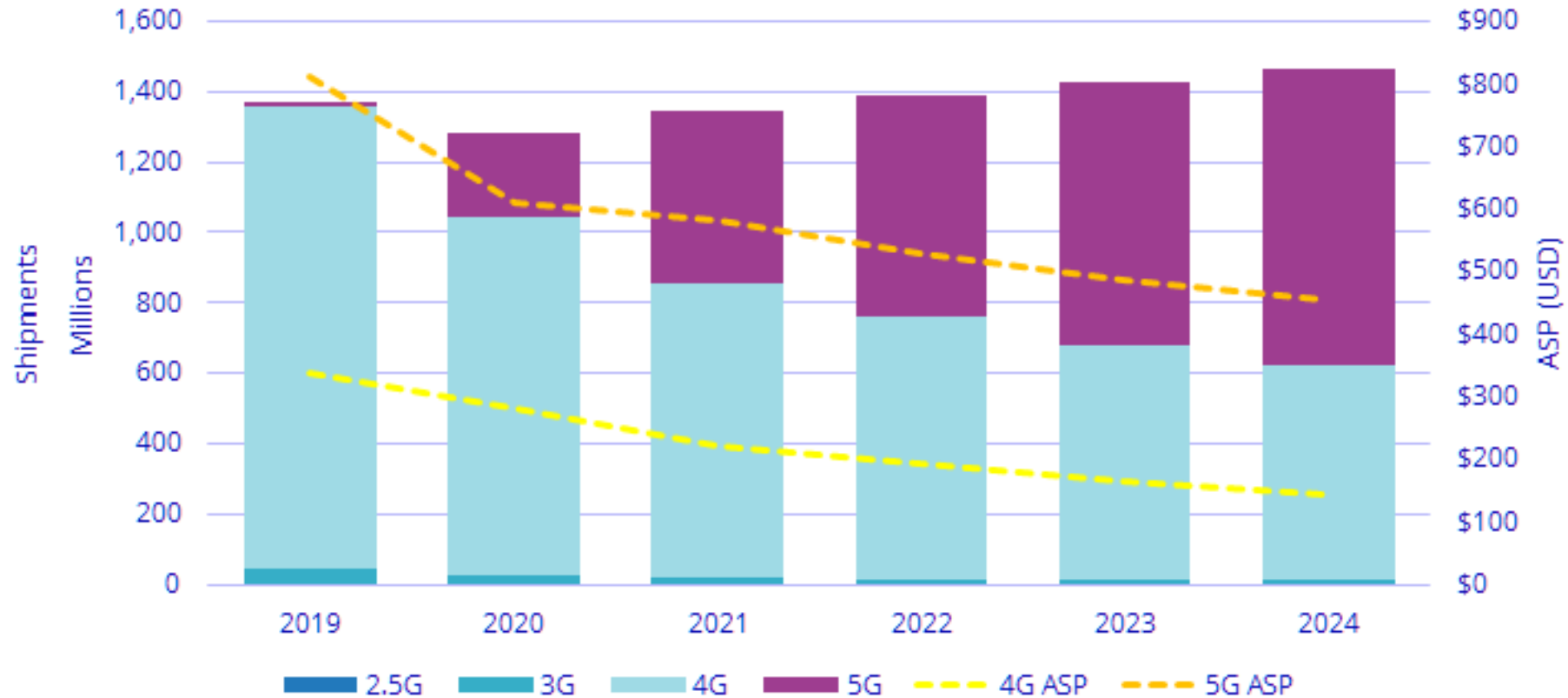


Source: JCET.

Smartphone Growth Returns in 2021: Driven by 5G



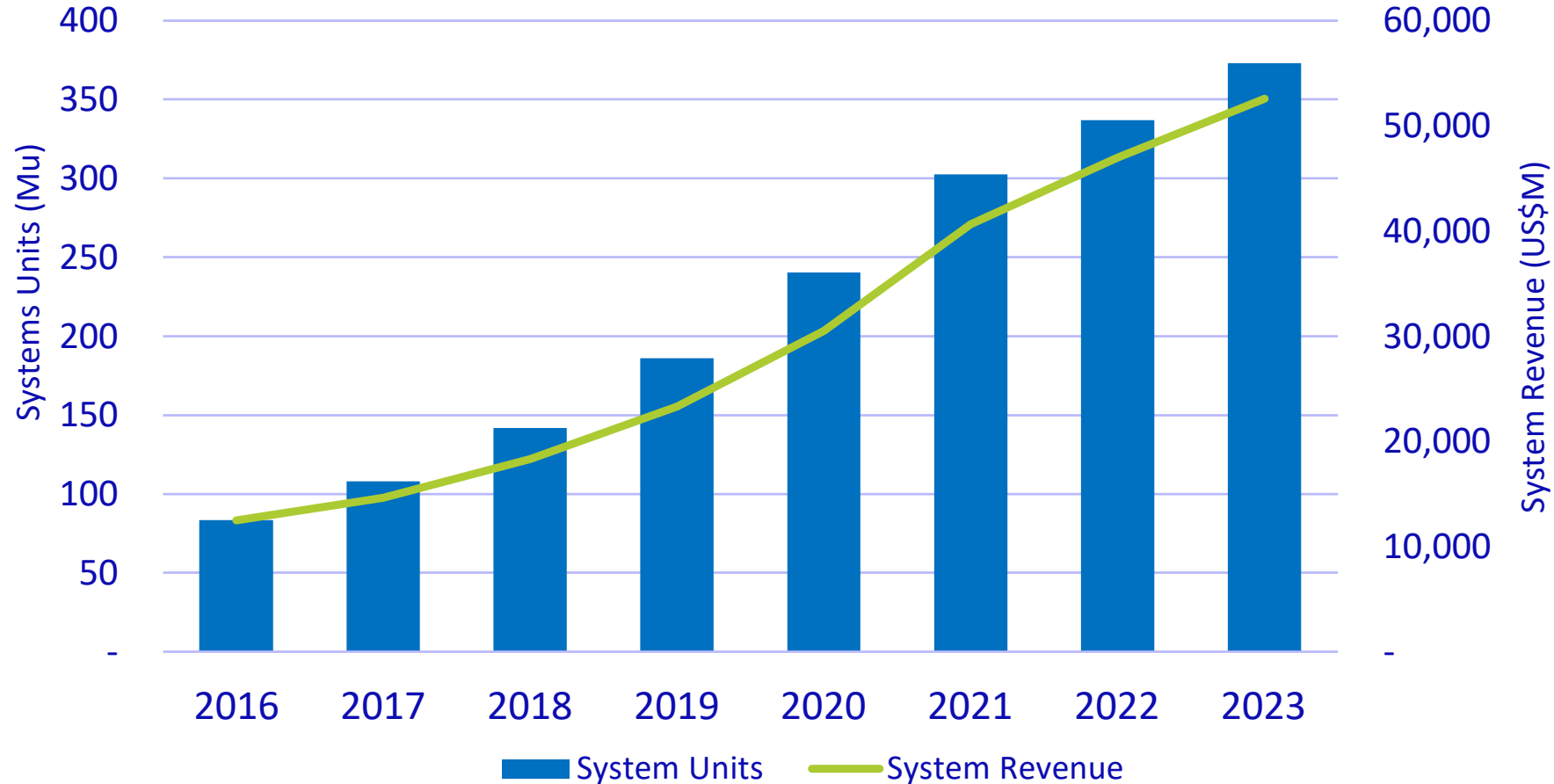
Worldwide Smartphone Forecast, 2020Q3



Source: IDC 2020

Automotive Market Returns to Growth

ADAS System Forecast



Source: IDC.

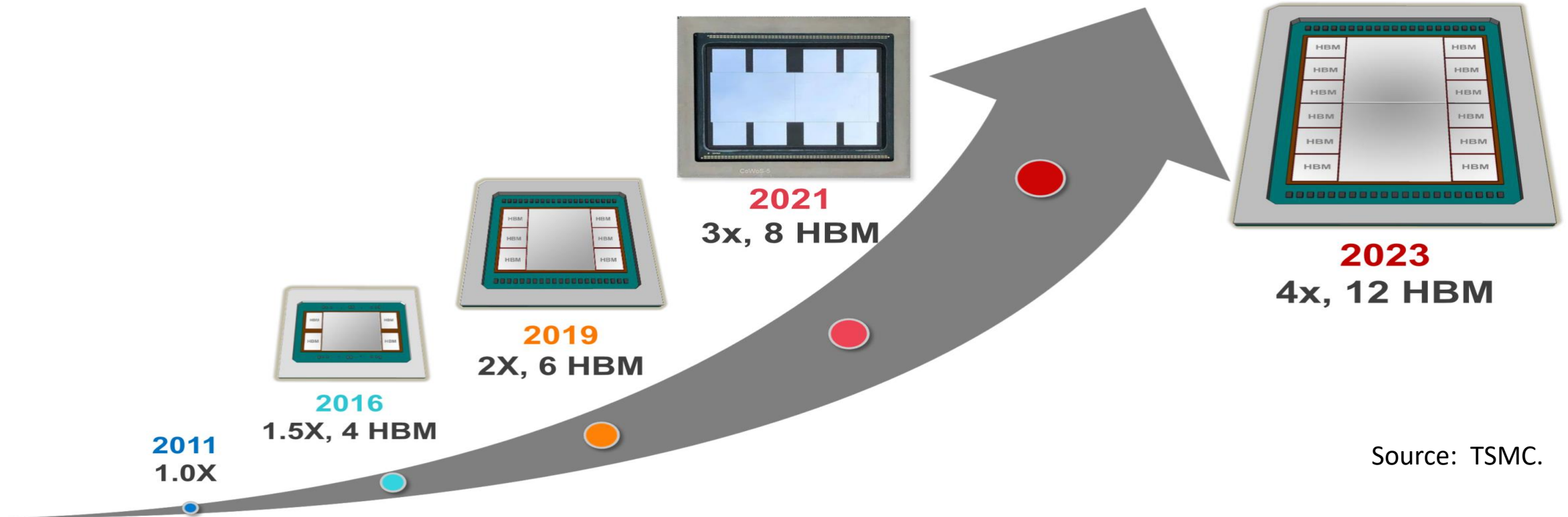
- **Automotive market worst slump in history in 2020 (-20% vehicle sales), but expected to return to growth in 2021 (as much as 11% increase in vehicle sales—EV growth projected)**
 - Despite decline, adoption of safety features continues
 - ADAS includes cameras, radar, ultrasonic, and LiDAR

Finally, The Industry Recognizes the Importance of Packaging

- **Economic advantage of silicon scaling is gone**
 - High cost of moving to next silicon node
 - High cost of fabrication includes design, mask, and fab process
 - Only a limited number of foundries can afford to participate for the limited number of companies at advanced nodes
- **Heterogeneous integration provides an opportunity to achieve economic advantages lost with end of pure silicon scaling**
 - Many options for the package including silicon interposers, FO on substrate, chiplets, and variations of 3D stacking
- **Heterogeneous integration (especially chiplets) offers improved SI, PI, lower inductance and thermal resistance, form factor advantages**
- **Co-design of silicon and package essential**



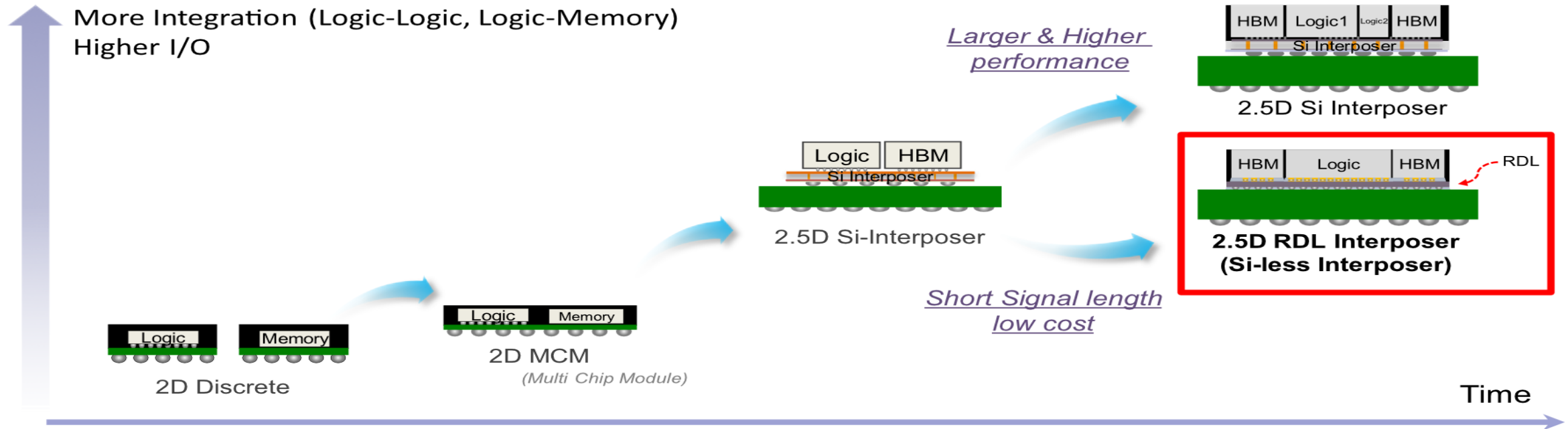
TSMC's CoWoS-S for High-Performance Computing



Source: TSMC.

- Si interposers are the most mature technology and offer the highest density die-to-die connection in a side-by-side package configuration
- TSMC has 10 years of silicon interposer production and assembly
- Increasing size of interposer and multiple HBMs

Samsung's Packaging Trends

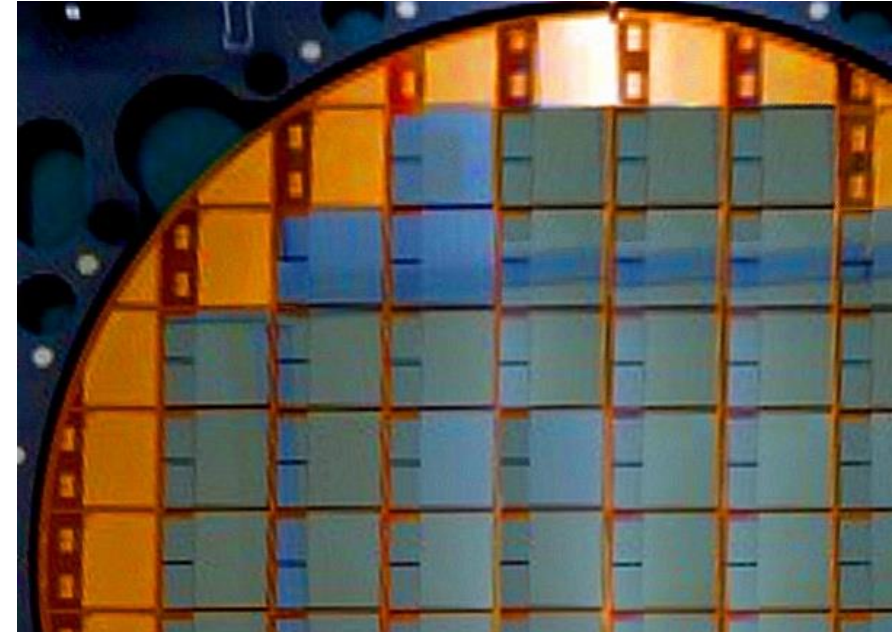


Source: Samsung.

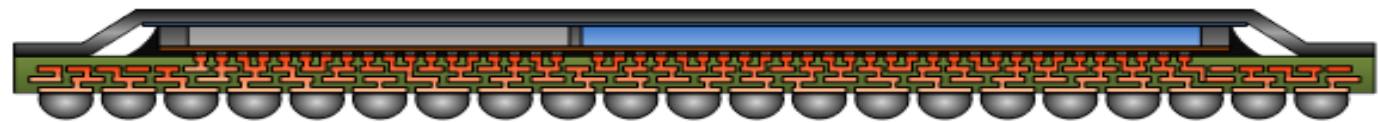
- Samsung seeing more applications for silicon interposer solutions

Fan-Out on Substrate

- **ASE's Fan-Out Chip on Substrate (FOCoS)**
 - RDL with $2\mu\text{m}$ L/S
 - Up to 3 RDLs plus UBM
 - High I/O (>1,000)
- **TSMC Integrated Fan-Out on Substrate called InFO-R (R=RDL)**
 - RDL with $2\mu\text{m}$ L/S
 - 3+ RDLs plus UBM
- **Amkor's Substrate Silicon Wafer Integrated Fan-out Technology (Substrate-SWIFT®)**
 - RDL with $2/2\mu\text{m}$ L/S
 - Up to 4 RDLs plus UBM



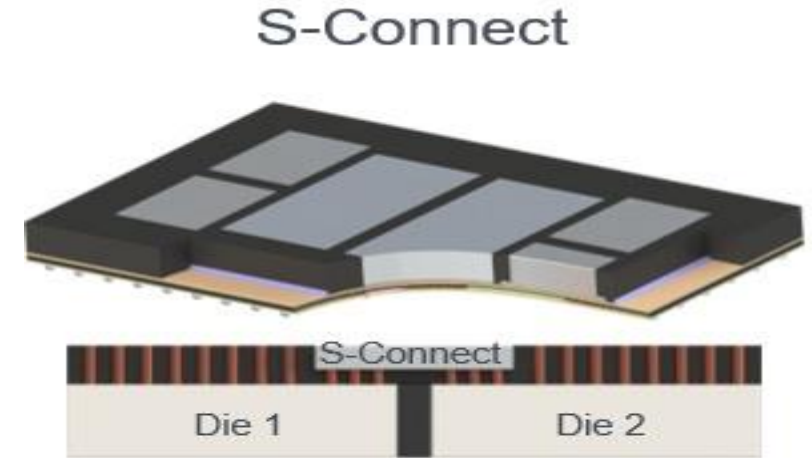
Source: ASE.



FOCoS – Fan Out Chip on Substrate (FO FCBGA)

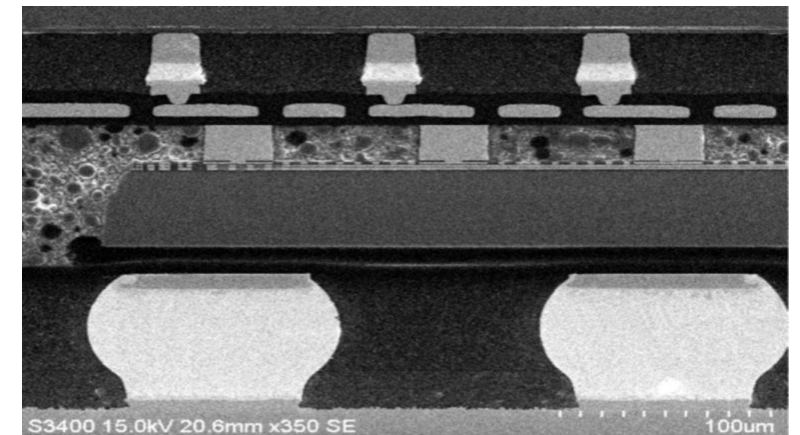
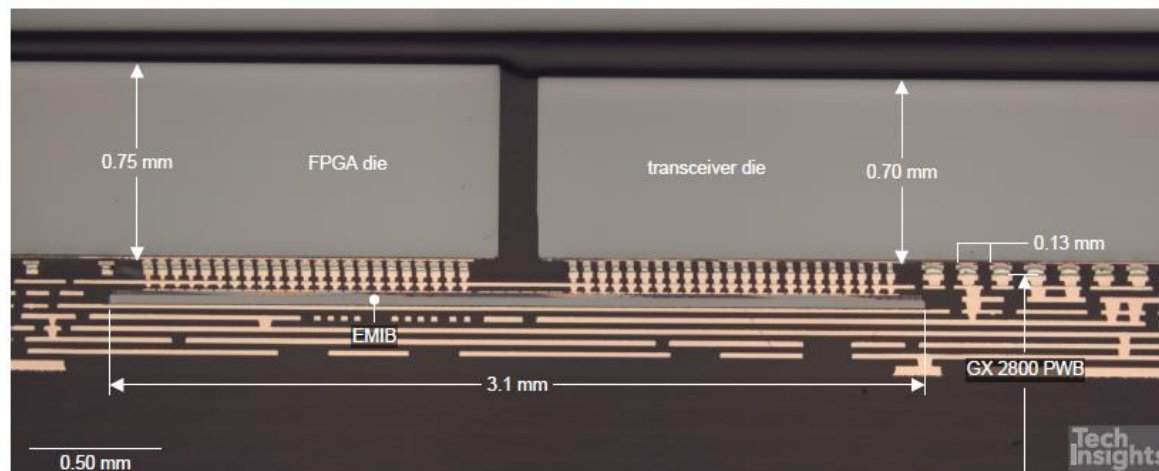
Embedded Bridge

- **Companies with embedded bridge developments**
 - Amkor (embedded in RDL, chip last)
 - ASE (embedded in RDL, chip first)
 - IBM (embedded in laminate substrate)
 - Intel (embedded in laminate substrate)
 - SPIL (embedded in RDL, chip last)
 - TSMC (embedded in RDL for FO, embedded with Si interposer-CoWoS)



Source: Amkor Technology

Intel's Embedded Multi-die Interconnect Bridge (EMIB)



Source: ASE.

Source: TechInsights.

Chiplets: Key Enabler for Next 10-20 Years

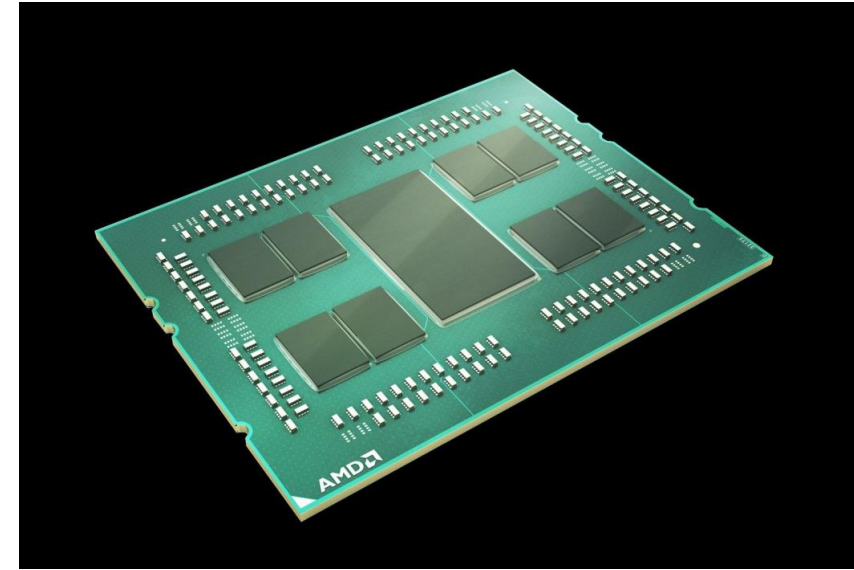
- **Chiplet demand driven by:**

- Need for a more cost-effective solution given the economic challenging of continued silicon scaling
- Desire to reuse IP
- Improved electrical performance
- Reduced power consumption
- Faster time-to-market
- Form factor advantages

- **Need a robust Ecosystem**

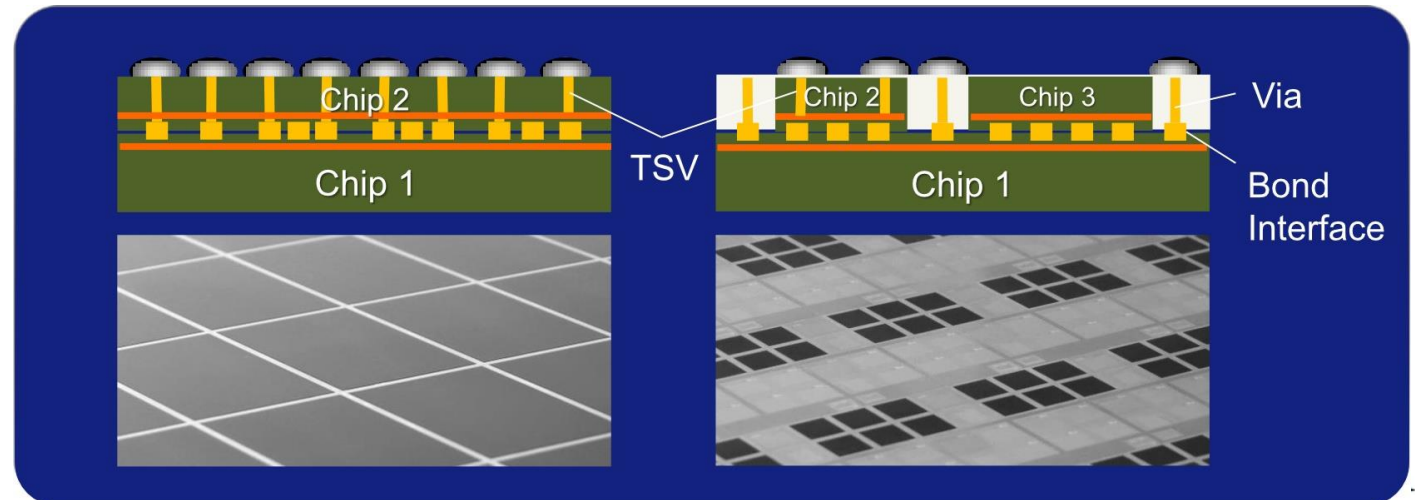
- EDA tools and modeling capability
- Adequate substrate capacity
- Thermal solutions
- Test strategies

AMD's chiplet design on organic substrate



Source: Wired.com.

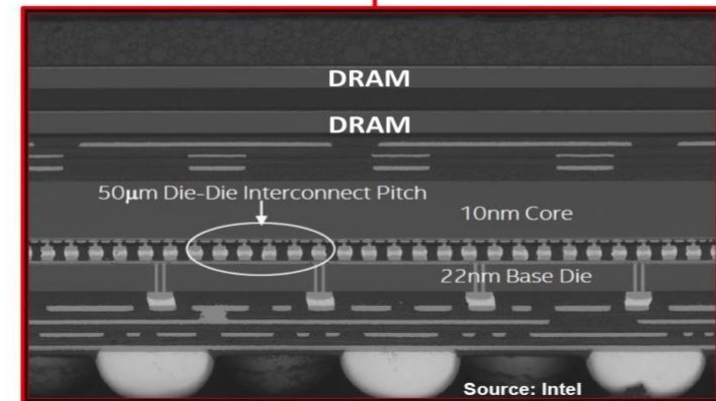
TSMC's SoIC



Source: TSMC.

Intel Foveros Technology

- Intel's Foveros technology die are stacked on an active interposer using μ bumps
 - Active interposers can include power management features, voltage regulators, DC/DC converters
- Benefits include
 - Reduced voltage drop
 - Power efficiency
 - More immediate power delivery to the CPU cores
 - Elimination of passives on substrate
 - System-wide communication across multiple chiplets/dice vs. the limited die-to-die communication capability enabled by passive Si interposers
- Used in the Samsung Galaxy Note S (Mobile PC)
 - Longer lasting battery
 - No fan
 - Very thin package, allows thin product

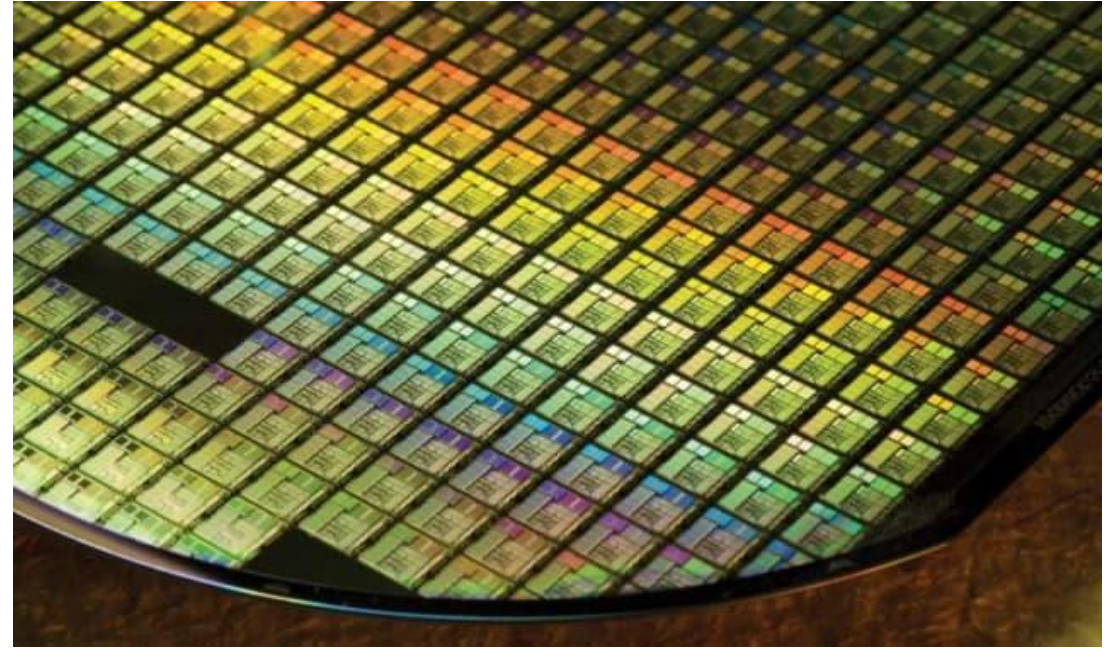


Intel's Lakefield CPU

- 10nm CPU
- 22nm Active Si Interposer

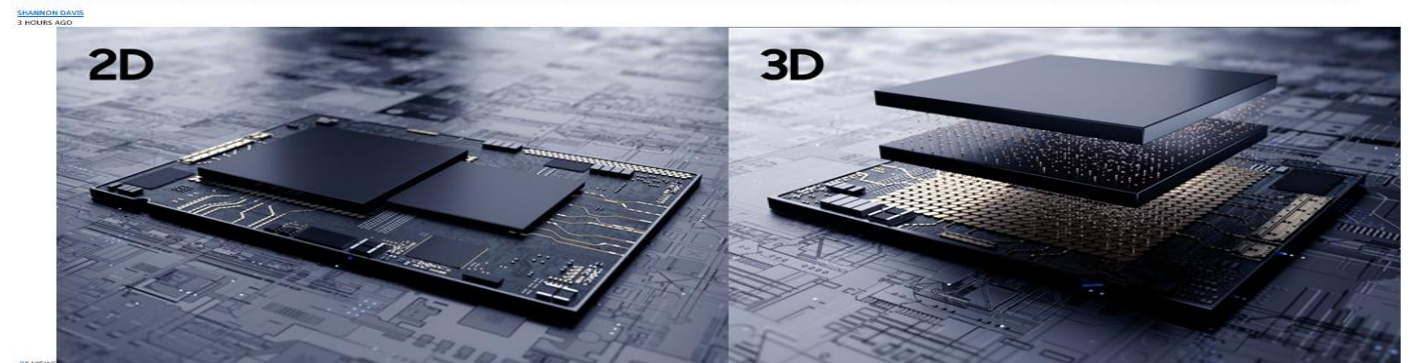
3D Integration Moves Forward

- **Intel's Foveros**
 - Die with μ bump bonded to active interposer
 - Future use of hybrid bonding
- **TSMC's SoIC and WoW**
 - System on Integrated Chip (SoIC) 3D stack using CoW process to handle $<10\mu\text{m}$ bond pitch between chips
 - Use of hybrid bonding
- **New forms of 3D IC**
 - Samsung SRAM + logic
 - Logic + logic



Source: TSMC.

Samsung Announces Availability of its Silicon-Proven 3D IC Technology for High-Performance Applications



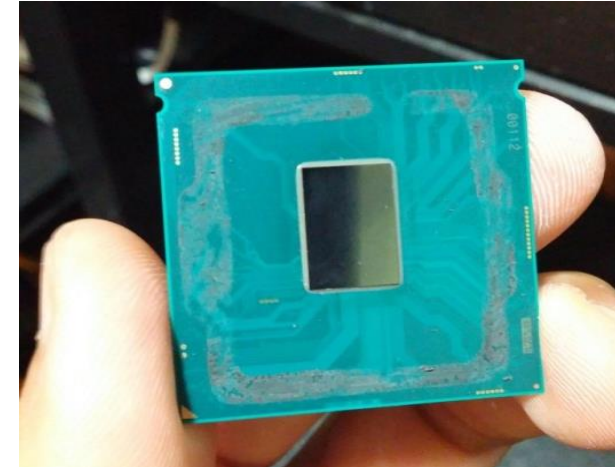
Source: Samsung.

What Could Go Wrong?

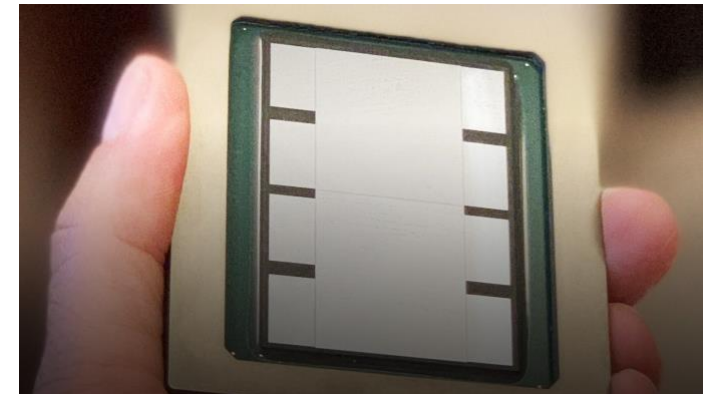


Laminate Substrate: Increased Demand

- **Datacenter and cloud computing expansion to meet demand**
- **Server volumes increasing**
 - Driving FC-BGA substrate capacity expansion
 - Increased layer counts (18-20 build-up layers)
 - Larger body sizes
- **AI accelerator demand increasing**
 - TSMC CoWoS
 - Future designs with FO on substrate such as ASE's FOCoS, Amkor's Substrate-SWIFT®, and TSMC InFO versions
 - All use laminate substrates
- **Networking switch products**
 - Increasing from 55mm x 55mm to 75mm x 75mm, 85mm x 85 mm, up to 100mm x 100mm body size
 - Increased layer counts



Source: Anandtech.com



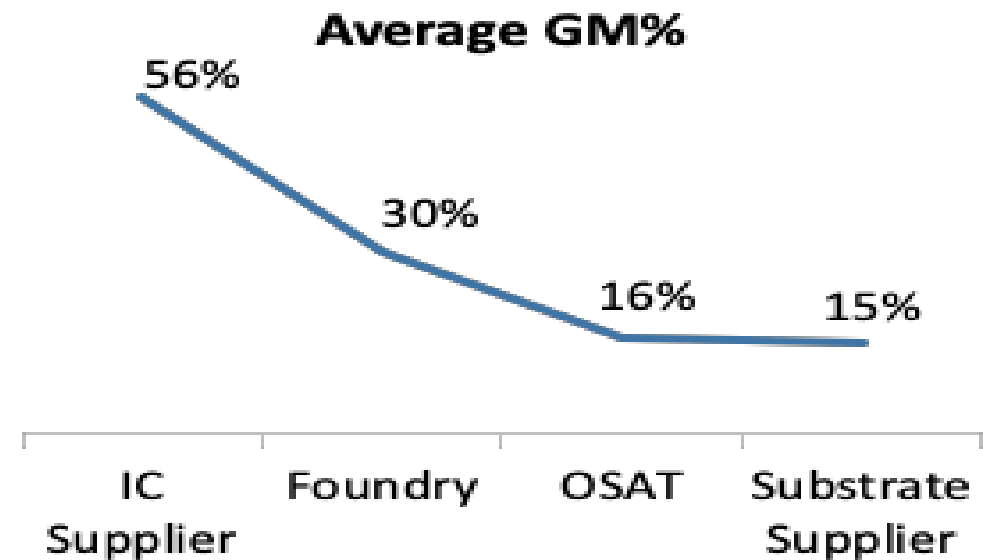
Source: TSMC.

Substrate Capacity Constraint

- **Fire damage to a Unimicron substrate facility in Taiwan is making a tight substrate capacity problem worse**
 - The plant supplied FC-CSPs including antenna-in-package (AiP) substrates
 - Unimicron transferred production to other factories, but some companies are unable to find capacity
 - The facility damaged by the fire was also used for non-Intel FC-BGA build-up substrate production (lamination process)
- **Very little FC-BGA and FC-CSP capacity is available**
 - In many cases, available capacity uses different material sets from the commonly used Ajinomoto build-up materials (or Sekisui material) and BT-resin
 - Qualification process for new suppliers and materials is long and expensive ([can we make this shorter?](#))
 - Some laminate substrate equipment has long lead times of up to a year
 - Capacity is expected to be tight through end of the year
- **Prices for IC package substrates are increasing, lead times stretched out**

Substrate Landscape: Does It Pay to Invest?

- The level of investment required for next generation substrates is difficult for substrate manufacturers to meet with the current revenue stream
- Advanced substrates require investment in front-end manufacturing capability up to \$300M for advanced substrate line (~5 μ m L/S)
- Substrate companies have relatively low margins



- AMD 44%
- Intel 53.3%
- Nvidia 58.5%
- Xilinx 67%

- TSMC 45.5%
- UMC 14.4%

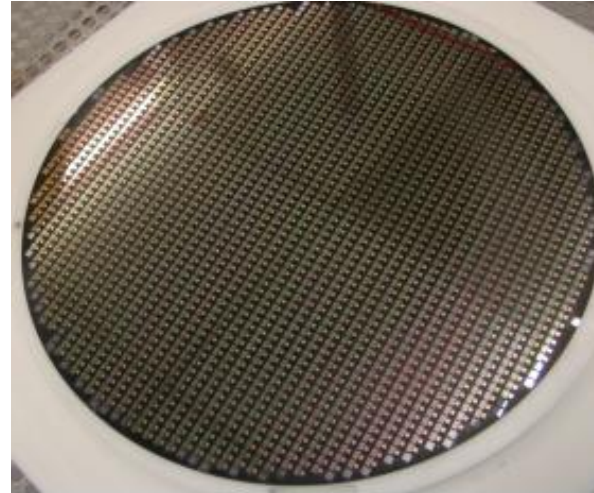
- ASE 20%
- Amkor 16%
- JCET 11.2%
- PTI 19.1%
- TFME 13.7%

- Shinko Electric 10.49%
- Kinsus 12.4%
- Ibiden 22%
- Unimicron 13.6%

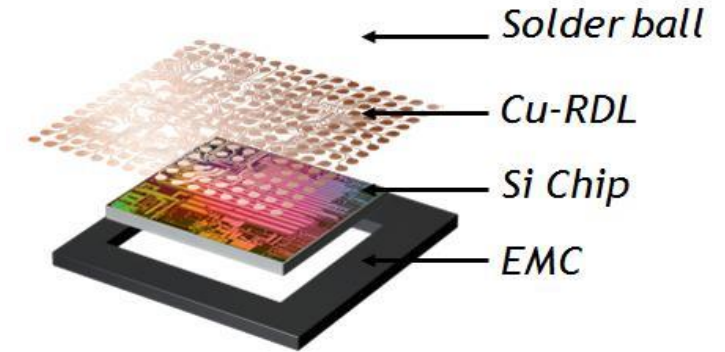
*OSATs *may* operate on Consigned Substrates business model resulting in lower ASP/GM%.

Could Substitute FO-WLP: Drives Higher Growth?

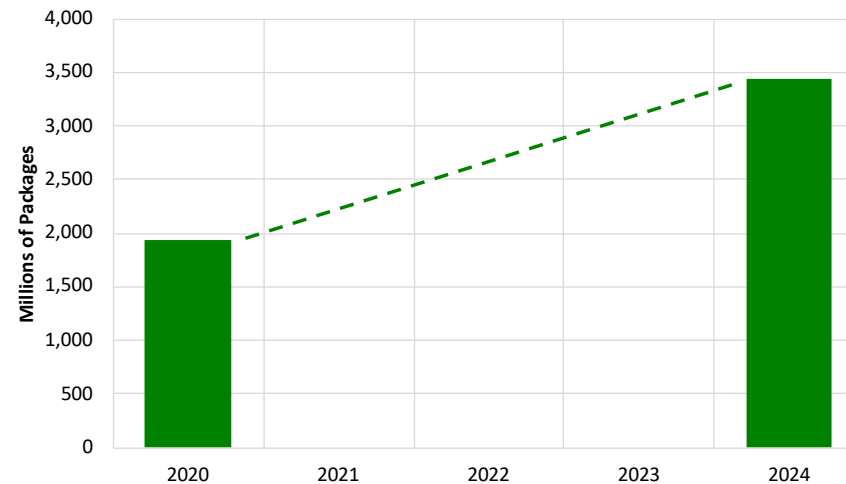
- **FO-WLP = no substrate**
(Companies considering this option to deal with substrate shortage)
- **Market shows a 15.5% CAGR in units through 2024**
 - Applications for FO-WLP include mobile devices, automotive radar, and high-performance computing and telecommunications



Source: Amkor Technology.



Source: JCET Group.

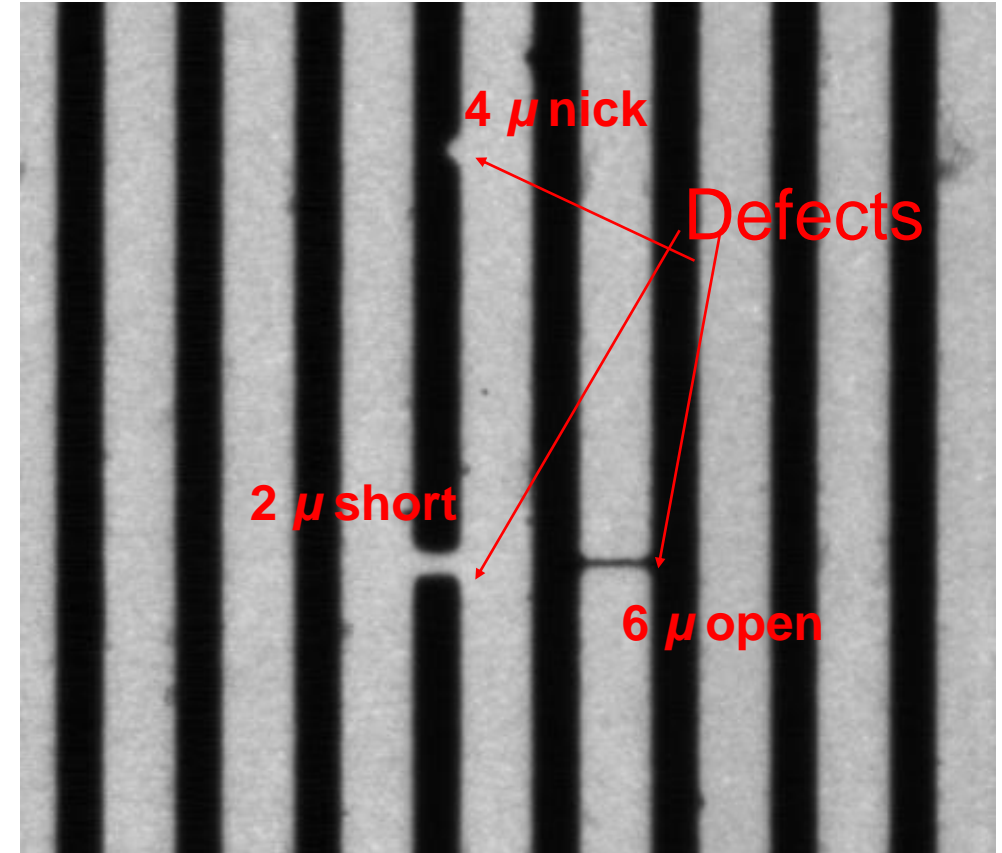


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Yield Improvement for Substrate Production?

- More parts per panel = greater available capacity?
- Improvement in substrate design to allow for higher yields?
 - Layer counts?
 - Fine traces?
- Process improvement to allow more good parts per panel?
- Metrology developments?



Source: Beltronics.

Conclusions

- **Industry needs to improve health of supply chain**
 - Leadframe companies exited market because no profit
 - Chip capacitors did not add capacity because no margin
 - 200mm wafer capacity remains a concern
- **Business model for IC package substrate business is broken**
 - Need new approach to business relationships to guarantee supply
 - Substrate suppliers must be able to make sufficient revenue in order to invest in next generation production



Thank you!

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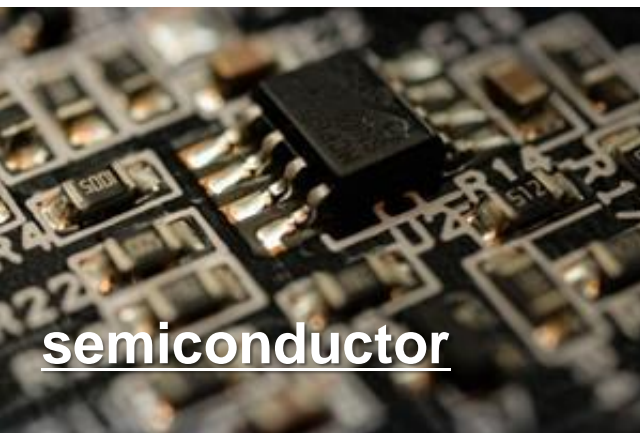
01 Analytical Services

Using latest analytic equipment by experienced skillful technicians

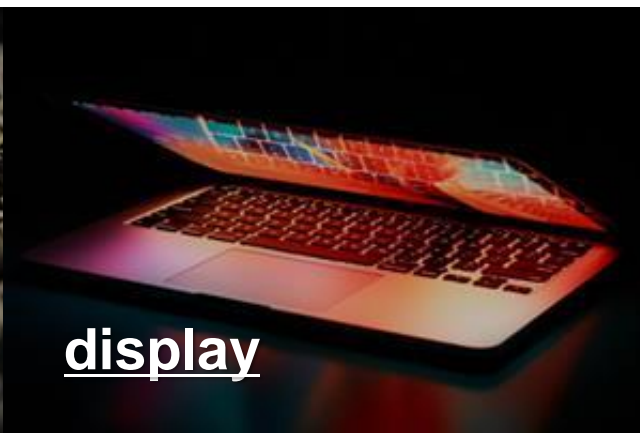
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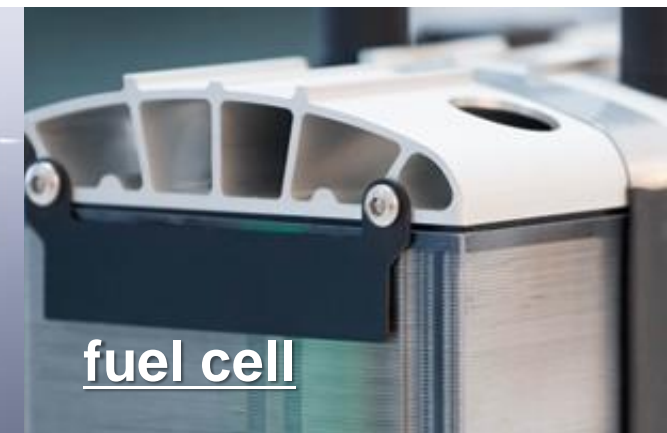
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battery



fuel cell

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