

STATUS OF THE ADVANCED PACKAGING INDUSTRY 2021

Market & Technology Report - September 2021

Advanced Packaging is now of strategic importance for IDMs, foundries, and OSATs, leading to more than US\$10 billion in investment.

WHAT'S NEW

- Updated forecast of the semiconductor market, including memory and non-memory components
- Key system-level demand forecast: mobile & consumer; automotive, telecom & infrastructure
- Update of our advanced packaging market data (2020 - 2026):
 - > By revenue, wafer, and unit forecasts
 - > By advanced packaging platform: flip-chip, fan-out, fan-in, 3D stacked, embedded die
- Analysis of the "U.S. - China effect" on the semiconductor industry and supply chain
- Updated 2020 - 2026 revenue, wafer, and unit forecasts, by various application segments: consumer & mobile, automotive & transportation, telecom & infrastructure, medical, industrial, defense & aerospace
- Revised supply chain analysis, with a focus on the impact of foundries entering the advanced packaging business
- Wafer-starts market shares and evolution by manufacturers from different business models (IDM, OSAT, foundry) and by various advanced packaging platforms
- Amended financial analysis of the top 26 OSATs (2013 -2020) by various parameters: revenue, YoY growth, R&D, CapEx, gross profit, gross margin, net income, etc.
- M&A data update and different scenarios for OSATs, covering 2020 - 2026

KEY FEATURES

- Advanced packaging market overview
- Drivers and dynamics
- Future applications
- Disruptions and opportunities
- Technology trends and forecasts
- Revenue, wafer, and unit forecasts, per platform
- Revenue, wafer, and unit forecasts, per application segment
- Future development, per platform
- Impact of front-end scaling
- Supply chain analysis
- Production overview, per player (IDM, OSAT, foundry)
- Supply chain analysis and shifting business models
- Financial analysis of the top 26 OSATs
- M&A analysis and recent developments

ADVANCED PACKAGING MARKET TO REACH ~US\$48B BY 2026

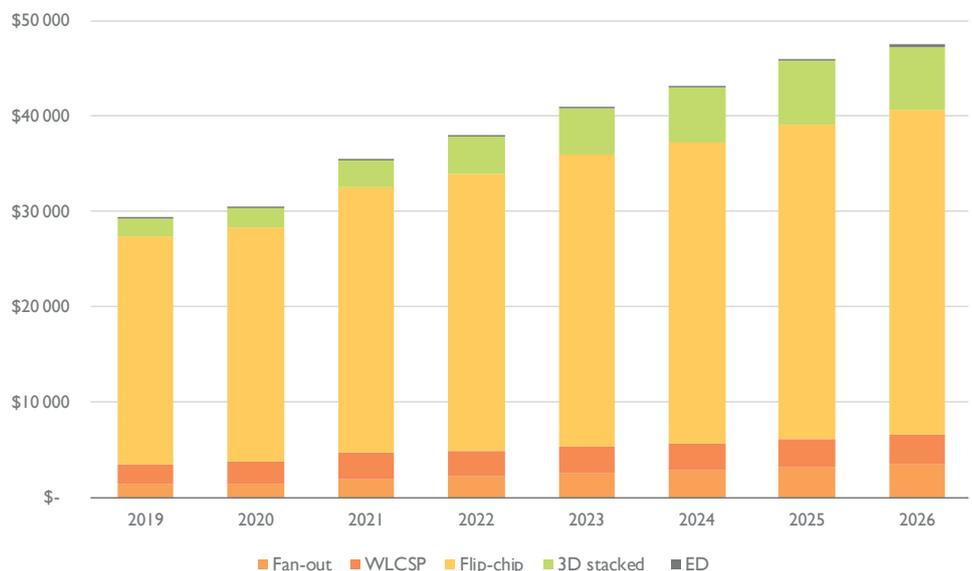
After a slowdown in 2020 due to COVID-19, the global economy is set to expand by 5.6% in 2021 (its strongest post-recession pace in 80 years) and 4.3% in 2022. Despite the COVID-19 induced global recession, the semiconductor market performed strongly in 2020. While demand by industry was uneven throughout the year due to global lockdowns, remote work and education, online entertainment, and shifts in consumer buying behavior, global semiconductor revenue grew by 6.8% YoY to reach \$440 billion in 2020. Going forward, the market will grow by more than 15% to exceed half a trillion dollars by 2022.

The Advanced Packaging (AP) market was worth \$30B in 2020 and is expected to grow at a CAGR₂₀₂₀₋₂₀₂₆ of ~8% to reach \$47.5B in 2026. At the same time, the traditional packaging market will grow at a CAGR₂₀₂₀₋₂₀₂₆ of 4.3%, and the total packaging market will grow at a CAGR₂₀₂₀₋₂₀₂₆ of 6%, to reach \$50B and \$95.4B, respectively. Growing at a CAGR₂₀₁₄₋₂₀₂₆ of 7.4%, the Advanced Packaging market is expected to more than double its revenue from \$20B in 2014 to ~\$47.5B in 2026. Due to ongoing momentum in the AP market, the share of AP in the total semiconductor market is increasing continuously and will reach almost 50% of the market by 2026. In terms of 300mm eq. wafer starts, traditional packaging still dominates with nearly 72% of the total market. However, AP is continuously increasing its share of wafers

which will increase to 35% in 2026 to reach more than 50M wafers. The value of AP wafer is almost double that of traditional packaging, resulting in a high profit margin for the manufacturers. Flip-chip constitutes ~80% of the AP market in 2020 and will continue to command a significant portion (~72%) of the market by 2026. Of the different advanced packaging platforms, 3D/2.5D stacking and fan-out will grow at ~ 22% & 16%, respectively, and adoption will continue to increase across various applications. Mainly led by mobile, Fan-in WLP (WLCSP) will grow at a CAGR of 5% during 2020-2026. Though small (~\$51M in 2020), the embedded die market is expected to grow at a 22% CAGR in the next 5 years, with demand driven by the telecom & infrastructure, automotive & mobile markets.

Yole Développement's Status of Advanced Packaging Industry 2021 report explores the field of advanced packaging and presents a comprehensive yearly prospectus of the latest market and technology developments. SAP2021 also offers a deep analysis of the supply chain, including player positioning, market share, and strategy/production per player (revenue, wafers). Moreover, the report includes revenue, wafer, and unit forecasts per packaging platform across various applications, along with a review of future production and possible developments during the 2020 - 2026 timeframe.

2019-2026 advanced packaging revenue forecast by packaging platform (\$M)



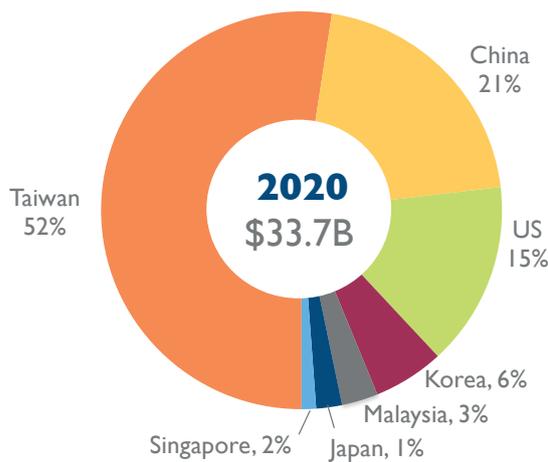
(Yole Développement, September 2021)

OSATS DOMINATE THE OVERALL AP MARKET, BUT BIG FOUNDRIES & IDMS ARE GROWING RAPIDLY IN THE HIGH-END SEGMENT

Currently, OSATs dominate the AP market, accounting for ~70% of the market by wafer starts. However, in the high end of the packaging segment (2.5D/3D stacking, high-density fan-out), the big foundries, like TSMC, and IDMs, like Intel and Samsung, dominate the market. These players are investing heavily in AP technology and are instrumental in moving packaging from substrate to wafer /silicon platforms. TSMC earned ~\$3.6B in advanced packaging revenue in 2020 and

announced an estimated \$2.8B CapEx in 2021 for its advanced packaging business specifically geared towards SoIC, SoW, and InFO variants, and CoWoS product lines. Intel's investment in various AP portfolios, such as Foveros, EMIB, Co-EMIB, is key to implement its IDM 2.0 strategy as unveiled by new leadership. They plan to capitalize on external and internal manufacturing resources to focus on design wins and increased market share, growing Intel's leadership in the client and data center domains. Samsung is aggressively investing in AP technology to boost its foundry business and emerge as a strong alternative to TSMC. On the other hand, OSATs are also investing heavily in AP technologies to compete in the lucrative market. OSATs' CapEx spending increased 27% YoY in 2020 (~US\$6B), which contributed to the very good financial year despite the COVID-19 impact. Overall, there is a paradigm shift in the packaging / assembly business, traditionally the domain of OSATs & IDMs. Players from different business models viz. Foundries, Substrate/PCB suppliers, EMS/DM, are entering the assembly/packaging business. The supply chain shifts and implications thereof as well as the production of >26 major packaging suppliers per advanced packaging platform are summarized and analyzed in the report.

2020 OSATs* revenue – Split by geographic area



* Based on the 26 OSATs ranking – 2020 revenue

(Yole Développement, September 2021)

ADVANCED PACKAGING TECHNOLOGIES TAKE CENTER STAGE

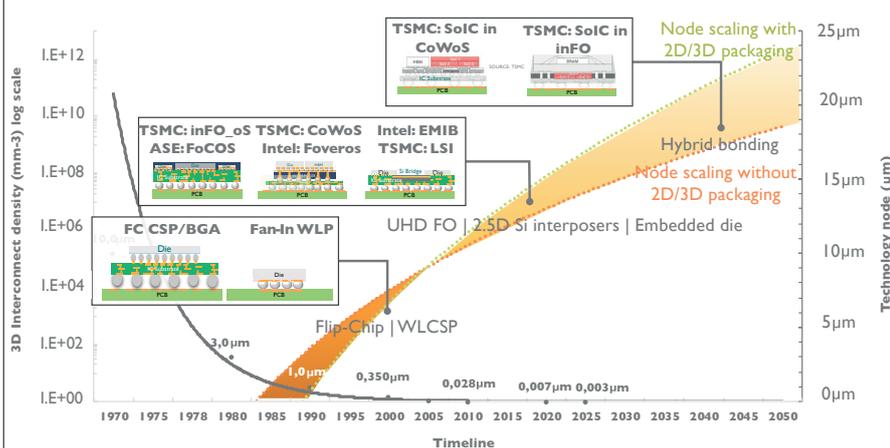
The semiconductor industry has entered a new age where mobile / consumer and other drivers, such as big data, artificial intelligence, 5G, high-performance computing (HPC), AR/VR/MR, cloud/edge computing, IoTs (including industrial IoT), smart automotive, industry 4.0, and hyperscale data centers are creating demand for system or subsystems which require high computing power, high speed, more bandwidth, low latency, low power consumption, more functionality, more memory, system-level integration, and a variety of sensors

while keeping the cost down. Heterogeneous integration using AP technologies is key to fulfilling these system performance requirements and increasing the value of semiconductor products, adding functionality, and maintaining/increasing performance while lowering cost. This places immense pressure on package suppliers, with an increasing degree of customization required for each individual customer.

Key technological trends in AP are: chiplet based approach to attain heterogeneous integration; opportunity for WoW in 3D NAND, HBM with I2 or I6 die stacked with pitch scaling to 35um; 3D SoC using hybrid bonding, with logic-logic or memory-logic stacked 3D IC for computing in data centers and HPC; large body size packages (~100x100mm2) to support AI, HPC, and networking; various innovations in packaging to support 5G mmWave in mobile double side molded BGA, low dielectric loss materials, Antenna in Package (AiP), etc.; high-density fan-out development and adoption will accelerate for mobile, HPC & networking; chip last fan-out using RDL interposer development; large package all-side molded WLCSP packaging adoption to increase.

This report focuses on the drivers for advanced packaging and the latest market dynamics and then examines packaging technology evolution with the help of short- and long-term roadmaps. Also featured

1970-2050 semiconductor packaging roadmap



(Yole Développement, September 2021)

is an analysis of the trends and challenges related to advanced packaging technology, supported by detailed roadmaps for the specific packaging platforms across various applications.

REPORT OBJECTIVES

The "Status of the Advanced Packaging Industry" is a yearly overview report. The objectives of the report are as follows:

Advanced packaging market overview

Drivers and dynamics - Future applications - Disruptions and opportunities

Technology trends and forecasts

Revenue, wafer, and unit forecasts by platform - Future developments by platform

Impact of front-end scaling - Scaling and functional roadmap

Supply chain analysis

Overview of production by player (IDM, OSAT, foundry) - Shifting business models

Financial analysis of TOP 26 OSATs

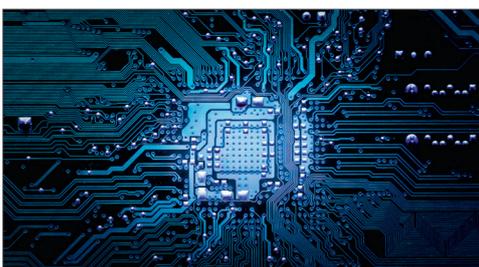
COMPANIES CITED IN THE REPORT (non exhaustive list)

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RELATED REPORTS, MONITORS & TRACKS



- Advanced Packaging Quarterly Market Monitor
- Fan-Out WLP and PLP Applications and Technologies 2021
- System-in-Package Technology and Market Trends 2021
- Intel Foveros 3D Packaging Technology
- NVIDIA A100 Ampere GPU

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ABOUT YOLE DEVELOPPEMENT

Founded in 1998, Yole Développement (Yole) has grown to become a group of companies providing marketing, technology and strategy consulting, media and corporate finance services, reverse engineering and reverse costing services. With a strong focus on emerging applications using silicon and/or micro manufacturing, the Yole group of companies has expanded to include more than 120 collaborators worldwide covering MEMS and Image Sensors, Compound Semiconductors, RF Electronics, Solid-state Lighting, Displays, Software, Optoelectronics, Microfluidics & Medical, Advanced Packaging, Manufacturing, Power Electronics, Batteries & Energy Management and Memory.

The “More than Moore” market research, technology and strategy consulting company Yole Développement, along with its partners System Plus Consulting, PISEO and Blumorpho, supports industrial companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to grow their business.

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