Status of the Advanced Packaging Industry 2021

Market and Technology Report 2021
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Yole’s market forecast model is based on the matching of several sources:

- **Comparison with existing data**
- Monitoring of corporate communication
- Using other market research data
- Yole’s analysis (consensus or not)

- **Comparison with prior Yole reports**
- Recursive improvement of dataset
- Customer feedback

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**Top-down approach**
- Aggregate of market forecasts
  - @ System level

**Bottom-up approach**
- Ecosystem analysis
  - Aggregate of all players’ revenues
  - @ System level

**Market**
- Volume (in Munits)
- ASP (in $)
- Revenue (in $M)

**Top-down approach**
- Aggregate of market forecasts
  - @ Semiconductor device level

**Bottom-up approach**
- Ecosystem analysis
  - Aggregate of key players’ revenues
  - @ Semiconductor device level

**Semiconductor foundry activity**
- Capacity investments and equipment needs

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**Preexisting information**

**Primary data**
- Reverse costing
- Patent analysis
- Annual reports
- Direct interviews

**Secondary data**
- Press releases
- Industry organization reports
- Conferences

**Information Aggregation**
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COMPANIES CITED IN THIS REPORT


> 100 companies cited in the report
WHAT’S NEW IN THE STATUS OF ADVANCED PACKAGING 2020?

- Updated forecast of the semiconductor market including memory & non-memory components
- Includes key system-level demand forecast: mobile & consumer, automotive, telecom & infrastructure
- Updated Advanced Packaging market data (2019-2026):
  - By revenue, wafer, and unit forecasts
  - By Advanced Packaging platform: flip-chip, fan-out, fan-in, 3D stacked, embedded die
- Analysis of US-China effect on semiconductor business & supply chain
- Updated 2019 - 2025 revenue, wafer, and unit forecasts, by various application segments: consumer & mobile, automotive & transportation, telecom & infrastructure, medical, industrial, defense & aerospace
- Updated supply chain analysis with focus on impact of foundry entry into Advanced Packaging business
- Wafer starts share by manufacturers from different business models (IDM, OSAT, foundry) by different Advanced Packaging platform and its evolution
- Updated financial analysis of the top 25 OSATs (2013-2020) by various parameters: Revenue, YoY growth, R&D, CapEx, Gross profit, Gross Margin, Net Income etc.
- Updated M&A data, and provides different scenarios for OSATs for 2019-2026
In 2019, the Advanced Packaging team from the Semiconductor, Memory and Computing Division at Yole Développement started the “Advanced Packaging Monitor”, providing quarterly updates and deeper focus on these segments.

The main objectives of this monitor are the following:

- Near-term market dynamics on quarterly basis
- Long-term market dynamics for 2019-2025
- CapEx & capacity by major players
- Market share of major OSATs/foundries
- Package ASP per given market/platform
- Device/application adoption for Advanced Packaging technologies
SYSTEM INTEGRATION LEVELS

LEVEL 3: end device/equipment

LEVEL 2: device/equipment board

LEVEL 1: semiconductor packaging

LEVEL 0: semiconductor die/wafer

LEVEL 1+2: semiconductor package + board

iPhone 6

iPhone 6 PCB

Qorvo RF SiP in the iPhone 6s Plus

Power amplifier in Qorvo RF SiP

Semiconductor wafer

Si dies

Package substrate

Board (PCB)
ADVANCED PACKAGING PLATFORMS

No substrate
- Fan-Out
- WLCSP

Organic substrates
- Flip-Chip
  - BGA
    - FC BGA
    - FO on Substrate
    - 2.5/2.1D
    - 3D
  - CSP
  - LGA

Leadframe substrates
- Flip-Chip
- FC QFN (MIS)

Ceramic substrates
- Flip-Chip
- HTCC

Embedded Die
- Flip-Chip
- LTCC
### ADVANCED PACKAGING PLATFORMS – Classification at System Integration Level

**Wafer level**
- **Level 1 - Die**
  - FIWLP
  - FOWLP
  - 3D
- **Interconnection**
  - TSV/TGV
  - Bump/pillar
  - Silicon/glass bridge
- **Substrate/leadframe**
  - Level 2 - Packaging
  - Module
  - Level 3 - No SMT needed

**Substrate/Strip level (Panel based)**
- **Level 1 - Die**
  - Conventional wire-bond based SiP is not covered in this report
- **Interconnection**
  - Flip-chip
  - Wire-bond
- **Substrate/leadframe**
  - Standard organic substrate
  - Advanced organic substrate
  - Organic interposer
  - Mold embedding
  - Ceramic/leadframe and others
- **Organic substrate**
  - CSP
  - BGA Standard
  - BGA Advanced
  - LGA
  - FC
- **SiP/PoP, etc.**
  - WB
- **Panel level**
  - FOPLP
  - RDL
  - Organic/glass substrate etc.
  - ED in laminate
  - ED in PCB/Flex

*Lv=level*
GLOBAL ECONOMIC OUTLOOK

According to World Bank, the global economy is set to expand 5.6 percent in 2021 (its strongest post-recession pace in 80 years) and 4.3% in 2022. This recovery is uneven and largely reflects sharp rebounds in some major economies. China economy is expected to grow at impressive 8.5% in 2021, while USA economy will grow at 6.8%.

In many emerging market and developing economies (EMDEs), obstacles to vaccination continue to weigh on activity. As the global economy rebounds from COVID-19 induced global recession, the accompanying strength in global trade offers an opportunity to jump-start the recovery in EMDEs. The global outlook remains subject to significant downside risks, including the possibility of additional COVID-19 waves and financial stress amid high EMDE debt levels. Policy makers will need to balance the need to support the recovery while safeguarding price stability and fiscal sustainability and to continue efforts toward promoting growth-enhancing reforms.

SEMICONDUCTOR INDUSTRY OUTLOOK

- Despite COVID-19, semiconductor market grew by 6.8% in 2020 to reach ~ $440B in 2020. Going forward, the market will grow by whooping 25% to reach $551B by 2022.
- On a regional basis, sales into the Americas market stood out, increasing annually by 19.8% in 2020. China remained the largest individual market for semiconductors, with sales there totaling $151.7 billion in 2020, an increase of 5.0%. Annual sales also increased in 2020 in Asia Pacific/All Other (5.3%) and Japan (1.0%), but decreased in Europe (-6.0%)
- Logic ($117.5 billion in 2020 sales) and memory ($117.3 billion) were the largest semiconductor categories by sales. Annual sales of logic products increased by 10.3% compared to 2019, while sales of memory products were up 10.2%. Within the memory category, annual sales of NAND flash products stood out, increasing 23.1% to $49.5 billion in 2020. Sales of micro-ICs — a category that includes microprocessors — increased 4.8% to $69.6 billion in 2020. Sales of all non-memory products combined increased by 5.2% in 2020 and that category reached an all-time high in total sales.

Despite COVID-19, semiconductor market grew by 6.8% in 2020 to reach ~ $440B in 2020. Going forward, the market will grow by whooping 25% to reach $551B by 2021.
SEMICONDUCTOR M&A

Driven by the mega acquisitions deal, 2020 was the record year for semiconductor M&A agreements. Compared with 2019, the M&As value increased by 272% in 2020 to reach ~$118B. Majority of the deals happened in latter half of the year.

Semiconductor acquisitions in 2020 were driven by large IC companies looking to sharpen their positions in emerging and high-growth market opportunities, such as embedded machine-learning and AI capabilities, self-driving cars, all-electric vehicles, expansion of data centers for cloud-computing services and proliferation of the sensors and systems connected to IoT.

Key consolidation drivers include desire to supplement organic growth, revenue & cost synergies to drive growth, importance of scale given cutting edge R&D costs, desire to add complementary and market exposure and fear of missing out.

Out of total semiconductor M&A, Semiconductor Packaging M&A was only ~ $4B in all 5 past years combined.
Moore’s law has guided the global semiconductor industry for past decades (since 1965), improving both performance and cost through node scaling. After 2002 (130nm), the industry has been consolidating extensively. Limitations in scaling have disrupted companies competing in this business. Presently, it is an oligopoly market, with a handful of key players remaining.

Moore’s law states that the number of transistors in an integrated circuit chip doubles every 2 years

Data referenced from Intel and WikiChip

* Patent applications, references, and technology development announcements have been taken into consideration. The chart shows the number of players with leading-edge manufacturing capabilities as of 2020.

**Note:** The chart illustrates the chronological order of players pursuing Moore’s Law.
### TECHNOLOGY ROADMAP: FROM NANO-SCALE TO MICRO-SCALE..

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2016</th>
<th>2018</th>
<th>2020</th>
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<td>Intel</td>
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<td>Samsung</td>
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<td>TSMC</td>
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<td>GF</td>
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<td>14nm</td>
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**Advanced packaging**

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<td>Stacked die µBump pitch (µm)</td>
<td>95 to 48 µm</td>
<td>44 to 20 µm</td>
<td>20 to 10 µm</td>
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<tr>
<td>Die to substrate FC Bump pitch (µm)</td>
<td>200 to 150 µm</td>
<td>80 to 40 µm</td>
<td>60 to 30 µm</td>
<td>50 to 30 µm</td>
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<tr>
<td>Substrate to board BGA Ball pitch (µm)</td>
<td>400/350 µm</td>
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**Industry is looking into the growing importance of functional roadmap**

**Advanced packaging is essential to bridge the scale-gap between die and PCB**

Average trends based on technology and industry expectation

*Minimum dimension
**SEMICONDUCTOR PACKAGING OPPORTUNITY**

Driven by demands of semiconductor hardware created by mega trends

<table>
<thead>
<tr>
<th>Sector</th>
<th>CPU /GPU</th>
<th>APU</th>
<th>MCUs</th>
<th>ASICs</th>
<th>FPGAs</th>
<th>Memory</th>
<th>Sensors /Actuators/CIS</th>
<th>Analog /Discretes</th>
<th>Opto-electronics</th>
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<tr>
<td>AI/ML</td>
<td>FC, 2.5D/3D, FO, SIP</td>
<td>FC, FO,ED</td>
<td>FC, WB, QFN, WLCSP</td>
<td>FC, FO</td>
<td>FC, 2.5D/3D, FO</td>
<td>FC, FO, WB, QFN, WLCSP</td>
<td>FC, FO, WB, QFN</td>
<td>FC, WB, FO, QFN, WLCSP</td>
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<tr>
<td>Smart automotive /Electrification/ADAS</td>
<td>FC, 2.5D/3D, FO, SIP</td>
<td>FC, FO,ED</td>
<td>FC, WB, QFN, WLCSP</td>
<td>FC, 2.5D/3D, FO</td>
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<td>FC, FO, WB, QFN, WLCSP</td>
<td>FC, WB, FO, QFN, WLCSP</td>
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<tr>
<td>AR/VR</td>
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<td>FC, 2.5D/3D, FO</td>
<td>FC, 2.5D/3D, FO</td>
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<td>FC, FO, WB, QFN, WLCSP</td>
<td>FC, WB, FO, QFN, WLCSP</td>
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<td>HPC</td>
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<td>FC, 2.5D/3D, FO</td>
<td>FC, 2.5D/3D, FO</td>
<td>FC, 3D</td>
<td>FC, FO, WB, QFN, WLCSP</td>
<td>FC, WB, FO, QFN, WLCSP</td>
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<td>SiP, 2.5D/3D, FC, WB</td>
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VOLUME PRODUCTION ROADMAP FOR FOWLP

Key parameters

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<th>2019</th>
<th>2020</th>
<th>2021</th>
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<tbody>
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<td>Max. inter-module interconnects</td>
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<td>Min. die-to-die distance</td>
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VOLUME PRODUCTION ROADMAP FOR IC SUBSTRATE (FC CSP)

Key parameters

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VOLUME PRODUCTION ROADMAP FOR FAN-IN WLP

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VOLUME PRODUCTION ROADMAP FOR IC SUBSTRATE (FC BGA)

Key parameters

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<th>≤ 2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
<th>2026</th>
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<tbody>
<tr>
<td>Max. flip chip</td>
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<tr>
<td>Max. inter-module interconnects</td>
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<tr>
<td>Max. no. of RDLs</td>
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<tr>
<td>Min. line/space</td>
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<tr>
<td>Package minimum thickness (without BGA)</td>
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<tr>
<td>Max. die size (XxY dimensions)</td>
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<tr>
<td>Min. die size (XxY dimensions)</td>
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<tr>
<td>Min. bump pitch</td>
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Roadmap described here is for volume production and is an expected average of the different technologies on the market.

Roadmap is based on volume production of the expected average of different technologies in the market, refined by interviews.
Advanced Packaging revenue is swiftly catching up to the traditional packaging market. In 2014, Advanced Packaging accounted for 38% of total packaging market. However, its market share will increase to ~50% in 2026 to reach ~$45.9B. In an 11-year period, Advanced Packaging revenue almost caught up with that of traditional packaging.
The Advanced Packaging market was worth ~$30.4B in 2020. It is expected to grow at ~8% CAGR 2020-2026 to reach ~$47.5B in 2026.

COVID-19 has no adverse impact on the AP market. The market increased by 4% in 2020 and is expected to grow strongly (16%) to reach $35B in 2021.

Highest revenue CAGR expected from 3D stacking, fan-out and ED (in laminate substrate), 22%, 15% and 25%, respectively, as high-volume products further penetrate the market -
- FO in mobile, networking, automotive;
- 3D stacking in AI/ML, HPC, datacenters, CIS, 3D NAND;
- ED in automotive and mobile.
ADVANCED PACKAGING FORECAST 2019-2026
TEN players, which includes 2 IDMs (Intel, Samsung), a foundry (TSMC), the top 5 global OSATs (ASE, SPIL, Amkor, PTI, JCET) together with Nepes and Chipbond, process approximately 75% of Advanced Packaging wafers.
**Note: SPIL included in ASE figures from 2019 onwards**

**FINANCIAL OVERVIEW FOR TOP 26 OSATS**

Revenue in 2020

**TOP 26 OSAT ranking by 2020 revenue [M$]**

- ASE (rev w/SPIL & w/o USI)
- Amkor
- JCET Group
- Powertech Technology
- Tongfu Microelectronics
- Tianshui Huatian Microelectronics
- King Yuan Electronics
- ChipMOS Technologies
- Chipbond Technology
- UTAC
- Hana Micron (Rev w/o Hana…)
- SFA semicon
- Greatek Elec
- Orient Semiconductor Electronics
- Sigurd Microelectronics
- Carsem
- LB Semicon Inc
- AOI Electronics
- Tong Hsing
- Formosa Advanced Technologies
- Ardentec
- Unisem Berhad
- Nepes Corporation
- Inari Amertron Berhad
- Walton Advanced Engineering
- Lingsen Precision Industries

**TSMC ranks between 3rd & 4th**

Top OSATs with heavy investments were creating a disparity with the rest of the pack.

Top 8 OSATs include 3 manufacturer HQ-ed in China, 4 manufacturer HQ-ed in Taiwan and 1 manufacturer HQ-ed in US. UTAC lost its 8th position from last year. ChipMOS Technologies has the 8th spot now.

Companies in the tail are at a higher risk if there is no differentiated technology or IP for merger and acquisition as an exit strategy.

Large OSATs were separated from the rest.

Top 8 OSATs continued with heavy investment in CapEx and R&D.

Players not within the Top 8 rankings need to catch up. Otherwise, they risk being acquired or incurring losses in business.
2020 REVENUE DISTRIBUTION BY TOP 26 OSATS

Based on company HQ location (Top 26 OSATs)

Out of Top 25 OSATs, Taiwan-based OSATs contributed more than half of the revenue in 2020 followed by China. US came third, and Korean OSATs were higher than Malaysian.
YOLE GROUP OF COMPANIES RELATED REPORTS

Yole Développement

Advanced Packaging Quarterly Market Monitor

Fan-Out WLP and PLP Applications and Technologies 2021

System-in-Package Technology and Market Trends 2021
HiSilicon Hi1382 Coherent Processor with ASE's FOCoS

Advanced System-in-Package Technology in Apple's AirPods Pro
HOW TO USE OUR DATA?

Yole Group of Companies, including Yole Développement, System Plus Consulting and PISEO, are pleased to provide you a glimpse of our accumulated knowledge.

We invite you to share our data with your own network, within your presentations, press releases, dedicated articles and more, but you first need approval from Yole Public Relations department.

If you are interested, feel free to contact us right now!

We will also be more than happy to give you updated data and appropriate formats.

Your contact: Sandrine Leroy, Dir. Public Relations
Email: leroy@yole.fr