STATUS OF THE ADVANCED PACKAGING INDUSTRY 2020
Market & Technology Report - July 2020
OSATs, foundries, and IDMs all want to impact the growing advanced packaging market.

PLAYERS ACROSS THE SEMICONDUCTOR SUPPLY CHAIN ARE MAKING A STRONG PUSH INTO THE ADVANCED PACKAGING BUSINESS

Once the traditional, exclusive domain of OSATs and IDMs, today a paradigm shift is occurring in the assembly / packaging segment of the semiconductor manufacturing supply chain. Players from different business models (foundries, substrate/PCB suppliers, EMS/ODMs) are entering this market and cannibalizing OSATs’ share. Advanced packaging (AP) is moving from a package substrate platform to silicon, a shift that is providing opportunities for giants like TSMC, Intel, and Samsung to flex their muscles in the AP segment and emerge as key innovators of new AP technology. TSMC especially has emerged as the leader in terms of developing an innovative advanced packaging platform from fan-out (InFO) to 2.5D Si interposer (CoWoS), to 3D SoIC. Based on current packaging revenue rankings, TSMC is #4 among OSATs.

Meanwhile, other top OSATs such as ASE/SPIL, Amkor, and JCET are investing in various advanced SiPs and fan-out technology to gauge their competition and increase their advanced packaging market share. IC substrate & PCB manufacturers, EMS companies, and display industry players are also entering the AP arena via panel-level fan-out packages, SiPs, and embedded dies (and passives) in organic substrates. This trend will continue in 2020 and beyond. All these supply chain shifts and their related implications, as well as a production overview of >25 major packaging suppliers per advanced packaging platform, are summarized and analysed in this report.

Deeper insight into financial performance enables us to create a link between technology evolution, supply chain shifts, and the overall success of individual players in this changing landscape. Furthermore, this report offers a closer look at the 2013 - 2019 financial evolution of the top 25 OSATs. Yole Développement (Yole) experts also investigate the various facets of the U.S.-China trade war and its potential effect on the semiconductor supply chain (including assembly and packaging) and consider whether a clear-cut winner/loser scenario will emerge.

STRONG GROWTH CONTINUES IN THE ADVANCED PACKAGING MARKET

In 2019 the total IC packaging market was $68B. Advanced packaging (AP) accounted for $29B and is expected to grow at a CAGR of 6.6%, reaching $42B in value in 2025. At the same time, the traditional packaging market will grow at a CAGR of 1.9% and the total packaging market will grow at a CAGR of 4%, reaching $43B and $85B in value, respectively. With a CAGR of 6.1%, the advanced packaging market is expected to more than double its revenue – from $20B in 2014 to ~$42B in 2025. This is almost triple the expected growth for the traditional packaging market, estimated at a 2.2% CAGR.
Due to the impact of Covid-19, the AP market is expected to decrease by 6.8% YoY in 2020. However, Yole Développement (Yole) expects this market to rebound in 2021, with ~14% YoY growth. The highest CAGR revenue is expected from 2.5D / 3D TSV IC, ED (in laminate substrate), and fan-out (21.3%, 18%, and 16%, respectively), as high-volume products further penetrate the market: for example, FO in mobile, networking, and automotive; 3D stacking in AI/ML, HPC, data centres, CIS, and 3D NAND; and ED in automotive, mobile, and base stations. By revenue segment, the mobile & consumer market constituted 85% of total advanced package revenue in 2019, and it will grow at a 5.5% CAGR to constitute 80% of AP revenue by 2025. Telecom & infrastructure is by revenue the fastest-growing segment (~13%) in the AP market, and will increase its market share from 10% in 2019 to 14% by 2025. Meanwhile, in terms of revenue the automotive & transportation segment will grow at 10.6% CAGR from 2019 - 2025, reaching ~$1.9B in 2025. Yole’s report explores the field of advanced packaging and presents a comprehensive yearly prospectus of the latest market and technology developments. It 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 2019 - 2025 timeframe.

### 2019-2025 technology roadmap in wafer: From nano-scale to micro-scale

| Fan-out | CAGR 2019-2025 ~12.1% |
| Flip-Chip | CAGR 2019-2025 ~5.9% |
| Fan-in WLP | CAGR 2019-2025 ~1.3% |
| 3D Stacking* | CAGR 2019-2025 ~25% |
| Embedded Die | CAGR 2019-2025 ~17% |

*3D stacking includes portion of wafers not included in Flip-Chip or Fan-in
**Values represent packaging services (assembly and test) and do not include FEOL Si die processing

#### 3D/2.5D STACKING AND FAN-OUT HAVE EMERGED AS THE FASTEST-GROWING ADVANCED PACKAGING PLATFORMS

Advanced packaging has become crucial for semiconductor innovation and is essential for bridging the scaling gap between die and PCB. The semiconductor industry is developing products for scaling roadmaps and functional roadmaps, with the scaling roadmap expected to continue (7nm & below) even though only three players remain, and the pace has slowed. The functional roadmap, which uses heterogenous integration and is supported by AP, has become more prominent. Indeed, advanced semiconductor packaging is observed to increase a semiconductor product’s value by adding functionality and maintaining/increasing performance while simultaneously lowering cost. A variety of multi-die packaging (system-in-packages) are being developed in both the high- and low-ends for consumer, performance, and specialized applications that will address needs related to heterogeneous integration for functional performance and faster time-to-market.

Among the various AP technologies, flip-chip constituted ~83% of the market’s revenue in 2019. However, its share will decrease to ~77% by 2025, whereas the share for 3D stacking and fan-out will increase from ~5% each in 2019, to 10% and 7% respectively by 2025. 3D stacking and fan-out will continue growing at an impressive rate of ~21% and 16% respectively, and their adoption will

#### 2019-2025 advanced packaging wafer forecast by packaging platforms (12” eq wafer starts per year)

<table>
<thead>
<tr>
<th>2015</th>
<th>2017</th>
<th>2019</th>
<th>2021</th>
<th>2023</th>
<th>2025</th>
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<tbody>
<tr>
<td>22nm</td>
<td>1.6nm</td>
<td>1.0nm</td>
<td>0.7nm</td>
<td>0.5nm</td>
<td>0.3nm</td>
</tr>
<tr>
<td>28nm</td>
<td>1.4nm</td>
<td>1.0nm</td>
<td>0.7nm</td>
<td>0.5nm</td>
<td>0.3nm</td>
</tr>
<tr>
<td>20nm</td>
<td>1.6nm</td>
<td>1.0nm</td>
<td>0.7nm</td>
<td>0.5nm</td>
<td>0.3nm</td>
</tr>
<tr>
<td>20nm</td>
<td>1.4nm (licensed)</td>
<td>Stopped</td>
<td>0.7nm</td>
<td>0.5nm</td>
<td>0.3nm</td>
</tr>
<tr>
<td>16/14nm</td>
<td>1.0nm</td>
<td>0.7nm</td>
<td>0.5nm</td>
<td>0.3nm</td>
<td>0.2nm</td>
</tr>
</tbody>
</table>

Advanced Packaging is essential to bridge the scale-gap between Die and PCB

(Yole Développement, July 2020)
Further increase across various applications. The 3D stacking market's growth is led by 3D memory (HBM and 3D DDR DRAM), 2.5D flip-chip, fan-out, fan-in WLP, and stacked CIS. The fan-out packaging market is also expected to show strong growth, with players from different business models entering the market. Led mostly by mobile, fan-in WLP will grow at a 3.2% CAGR during 2019 - 2025. Embedded die, though small in market size, is expected to grow at an 18% CAGR over the next five years, with demand driven by markets like telecom & infrastructure, automotive, and mobile.

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 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.

COMPANIES CITED IN THE REPORT (non exhaustive list)

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RELATED REPORTS, MONITORS & TRACKS
- Advanced Packaging Quarterly Market Monitor
- Fan-Out Packaging Technologies and Market 2020
- System-in-Package Technology and Market Trends 2020
- RF Front-End Module Comparison 2020 - by System Plus Consulting
- Qualcomm QET5100M Envelope Tracker Module with SEMCO’s Embedded Die Packaging Technology - by System Plus Consulting

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AUTHORS
Santosh Kumar is working as Principal Analyst and Director Packaging, Assembly & Substrates, Yole Korea, part of Yole Développement (Yole). Based in Seoul, Santosh is strongly involved in the market, technology and strategic analysis of the microelectronic assembly & packaging technologies and present his vision of the industry in numerous conferences as well as through papers and patents publication. Santosh Kumar received the bachelor and master degree in engineering from the Indian Institute of Technology (IIT), Roorkee and University of Seoul respectively.

Favier Shoo is a Technology and Market Analyst in the Semiconductor & Software division at Yole Développement (Yole), part of Yole Group of Companies. Based in Singapore, he is engaged in the development of reports as well as the production of custom consulting projects. With prior experiences at Applied Materials and REC Solar, Favier had developed a deep understanding of the supply chain and core business values. As an acknowledged expert in this field, Favier has provided training and held numerous technical review sessions with industry players. In addition, he has obtained 2 patents. Favier holds a Bachelor in Materials Engineering (Hons) and a Minor in Entrepreneurship from Nanyang Technological University (NTU) (Singapore).

Vaibhav Trivedi is a Senior Technology & Market analyst at Yole Développement (Yole) working with the Semiconductor & Software division. Based in the US, he is a member of Yole’s advanced packaging team and contributes to analysis of ever-changing advanced packaging technologies. Vaibhav has 17+ years of field experience in semiconductor processing and semiconductor supply chain, specifically on memory and thermal component sourcing and advanced packaging such as SiP and WLP. Vaibhav has held multiple technical and commercial lead roles at various semiconductor corporations prior to joining Yole. Vaibhav holds a Bachelor of Science in Chemical Engineering, and Master of Science of Material Science from University of Florida in addition to an MBA from Arizona State University.
CONTACT

Western US & Canada
Steve Laferriere - steve.laferriere@yole.fr
+1 310 600-8267

Eastern US & Canada
Chris Youman – chris.youman@yole.fr
+1 919 607 9839

Europe and RoW
Lizzie Levenez – lizzie.levenez@yole.fr
+49 15 123 544 182

Benelux, UK & Spain
Marine Wybranietz - marine.wybranietz@yole.fr
+49 69 96 21 76 78

India and RoA
Takashi Onozawa – takashi.onozawa@yole.fr
+81-80-4371-4887

Korea
Peter Ok - peter.ok@yole.fr
+82 1040890233

Japan
Miho Ohtake – miho.ohtake@yole.fr
+81 34405-9204
Toru Hosaka – toru.hosaka@yole.fr
+81 90 1775 3866

Japan and Singapore
Itsuyo Oshiba – itsuyo.oshiba@yole.fr
+81-80-3577-3042

Greater China
Mavis Wang – mavis.wang@yole.fr
+886 979336809 +86 136 61566824

Sales Coordination
& Customers Service
David Jourdan – david.jourdan@yole.fr
+33 472 83 01 90
Fayçal El Khamassi – faycal.khamassi@yole.fr
+33 472 83 01 95

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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CONTACTS
For more information about:
• Consulting & Financial Services: Jean-Christophe Eloy (eloy@yole.fr)
• Reports & Monitors: David Jourdan (david.jourdan@yole.fr) & Fayçal Khamassi (faycal.khamassi@yole.fr)
• Marketing & Communication: Camille Veyrier (camille.veyrier@yole.fr)
• Public Relations: Sandrine Leroy (sandrine.leroy@yole.fr)

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1.2 These General Terms and Conditions of Sale shall be deemed valid and enforceable between the Contracting Parties after acceptance of a purchase order by the Buyer under Article 1.3 below. For such purposes, the Buyer, when signing the purchase order which mentions “I hereby accept Yole Développement’s Terms and Conditions” is deemed to have unequivocally accepted these Terms and Conditions of Sale.

1.3 Orders are deemed to be accepted only upon written acceptance and are effective from the date of order, unless the periods set forth in Article 1.2 are exceeded by email. In the absence of any confirmation of delivery, the order will be considered as having been accepted.

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2.1 Products are sent by email to the Buyer after Seller’s confirmation:

• A written price quotation, which the Buyer or its authorized representative signs and returns to the Seller, which the Buyer agrees to purchase the corresponding order.

• Electronic delivery format is defective, the Seller undertakes to email the Buyer, or to any organization acting for the Buyer’s interest, that the Buyer cancels the order in whole or in part or postpones the delivery of the Product, or that the Product is defective, the Seller undertakes to replace it at no charge to the Buyer provided that the Seller is informed of the defective formatting within 90 days of the date of delivery.

2.2 The person receiving the Products on behalf of the Buyer shall immediately verify the quality of the Products and the conformity of the contents. In the case of non-conformity shall be sent in writing to the Seller within 8 days of receipt of the Products. The Buyer agrees to produce sufficient evidence of such defects.

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3.1 Prices are given in the orders corresponding to each Product and are established in Excel. Additional costs can be added. Q&A with an Analyst is possible for each monitor (except where previously notified). Frequency of the reports varies according to the monitor or service (quarterly and monthly). Additional PDF and/or Excel files can also be added. The price is calculated from the time of receipt by the Seller.

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Account: n° 0710 220 1565 87
BIC or SWIFT code: CLEAFRPP
IBAN: FR76 3505 6001 7001 0215 0567
To secure the payments due to the Seller, the Seller reserves the right to request down payments from the Buyer. In such a case, the down payment will be managed according to the corresponding order.

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6.6 This acknowledgment and accepted by the Buyer that, whether purchased in the form of Bundles or Annual Subscriptions, all unsecured reports without payment of the full purchase price within the period of 12 month following acceptance of the corresponding order by the Seller in accordance with provisions of Article 1.3 above.

6.7 The Buyer can not guarantee that any investor that the Buyer to have the same contact person for the license purchased by the Buyer. This person will be the recipient of each new report.

7. TERMINATION

If the Buyer cancels the order in whole or in part or postpones the delivery of the Product, the Buyer shall indemnify the Seller for the entire cost that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may also apply for any other direct or indirect costs that may be incurred by the Seller pursuant to such cancellation or postponement.

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8.1 All the provisions of these General Terms and Conditions of Sale and all other documents issued by the Seller at any time at any time are hereby Object to any other Party. Seller, are DEEMED INAPPLICABLE TO ANY SALES MADE HEREUNDER, AND SHALL NOT BE BINDING IN ANY OTHER BUSINESS ACTIVITY FOR ITS BUSINESS NEEDS) PLACING AN ORDER PURSUANT TO THESE TERMS AND CONDITIONS OF SALE, WITH THE EXCLUSION OF ANY INDIVIDUAL CONSUMER ACTING FOR HIS/HER SEPARATE PERSONAL INTEREST.

8.2 Any notices under these Terms and Conditions shall be given in writing and shall be effective upon receipt by the other Party.

8.3 The Seller may, from time to time, update these General Terms and Conditions of Sale and all other documents issued by the Seller at any time at any time, without prior notice to the Buyer. The Buyer will be deemed to have received the latest version of such General Terms and Conditions of Sale, once they have been duly communicated to the Buyer by the Seller.

9. GOVERNING LAW AND JURISDICTION

9.1 These General Terms and Conditions of Sale or of any Licenses or Products purchased in application thereof shall be submitted to the French Commercial Court of Lyon, which shall have exclusive jurisdiction in any case. The Buyer agrees that any dispute shall be subject to the jurisdiction of the French Court of Lyon.

9.2 French law (with reference to any applicable conflict of law provisions) shall apply to these General Terms and Conditions of Sale and to the Agreement between the Buyer and the Seller made pursuant thereto.