FAN-OUT PACKAGING TECHNOLOGIES AND MARKET 2020

Market & Technology Report - June 2020

What will be the next killer applications for Fan-Out packaging after application processor engines?

WHAT'S NEW

Market shares of manufacturers

- Market shares of players within each market class, including UHD FO, HD FO and Core FO, between 2019 and 2025

Companies making big moves

- In February 2020, Deca became an independent technology development and licensing company, and exited the manufacturing business
- In 2019, SEMCO FOPLP was acquired back by Samsung Electronics
- In February 2020, Nepes built an independent management system by spinning off its FO packaging business as a subsidiary called Nepes Laweh

New commercialization products of Fan-Out packaging

- TSMC has more than 20 product tape-outs in production or in development as of August 2019
- TSMC inFO_oS for chiplets, 5G networking
- TSMC inFO_AiP is expected to go into production in 2020 for Apple's iPhone 5G
- HiSilicon has started to adopt ASE's FOCoS even more for its network server end-device
- JCET two-die eWLB is found in the Fitbit 3 smartwatch
- Apple's Series 4 smartwatch adopts TSMC inFO APE+Dummy Die Si
- Mediatek AiP Fan-Out mmWave Radar

KEY FEATURES

- Market valuations based on top-down and bottom-up model in package units, revenue, and wafer production volumes
- Market shares based on production projections
- Supply value chain analysis
- State-of-the-art technologies and trends
- End-user application adoptions

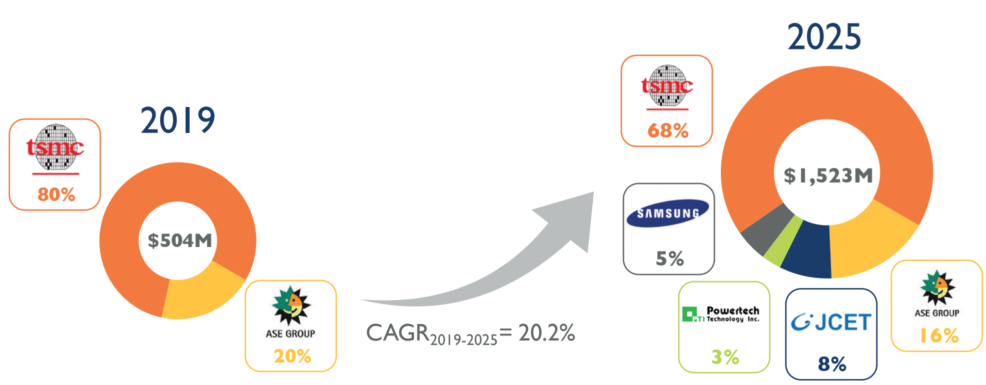
NEW MARKET CLASS DEFINED: UHD FO

Fan-Out (FO) packaging is penetrating into even higher-end input/output (I/O) densities, much greater than 18 per mm^2, and finer redistribution layers (RDL), with length to side (L/S) measurements far below 5µm/5µm. Along with the proliferation of new technologies and new commercialized products, industry players are having difficulty segmenting the market. Consequently, in the 2020 report, Yole Développement (Yole) has clearly defined FO packaging market classes into Ultra High Density (UHD) FO, High Density (HD) FO and Core FO. This will allow readers to understand and make informed decisions on strategies to gain a competitive advantage within individual market class. This helps industry players understand what capabilities each segment is looking for or offering. Depending on how industry players would like to position themselves in the marketplace, any technology strategy must embrace a combination of options and approaches targeted to demand needs.

In 2019, TSMC, the leading foundry with premium packaging capability, has been running production of its inFO_oS process with a N16 network System-on-Chip (SoC) processed at L/S below 2µm/2µm with a 1.5X reticle, speculated to be for MediaTek. Production for inFO_oS started its ramp in 2018. TSMC is diversifying its portfolio towards advanced packaging, a strategy that benefits from being one company with few business models. For example, TSMC is creating value with two distinctive businesses. It generates front-end (FE) dies and kills FE competitors by bundling the dies with advanced packaging. Within the packaging world, TSMC is a premium Outsourced Semiconductor Assembly and Test (OSAT) company. But its FE foundry is even more impressive for leading advanced node scaling against cutting-edge competitors like Samsung and Intel. Although TSMC's FE foundry previously did not operate like an OSAT it may have to do so partially for UHD FO because it no longer produces memory. Hence, TSMC is now beginning to operate simultaneously as an OSAT when required to maximize the benefits of its foundry FE business.

New high performance computing (HPC) products will emerge and more UHD FO will be needed for as a cost-effective high-end package as compared to 2.5D interposers. Samsung Electronics is the leading integrated device manufacturer (IDM). PTI is the leading Fan-Out Panel Level Packaging (FOPLP) OSAT, specializing in memory packaging. JCET China is the leading OSAT in China. All three are known to have started qualifying UHD FO with various customers, and it is within their roadmaps. Samsung Electronics has been developing FOWLP with LS of 2µm/2µm for this business. PTI is targeting large die packaging at finer LS with FOPLP. Also, JCET is the midst of qualifying for Huawei in 2020. Overall, these FO packaging players are all leading specialists in their own fields and/or regions.

2019-2025 Ultra High Density Fan-Out revenue forecast by manufacturers*



**Market share is based on revenue as estimated from each manufacturer's production forecast. Breakdown of High Density (HD) & Core Fan-Out market class by manufacturers is detailed in the report*

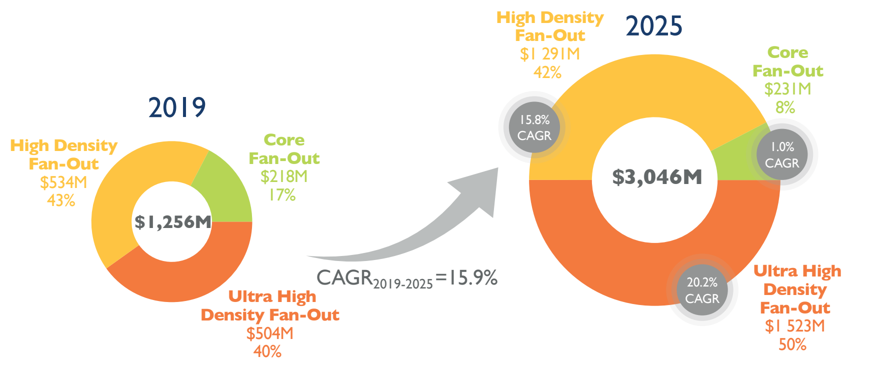
(Yole Développement, June 2020)

HD FO REMAINS A BATTLE BETWEEN TSMC AND SAMSUNG

In 2018, Samsung Electro Mechanics (SEMCO)'s FOPLP process has made a positive impact on FO packaging market. Samsung's adoption of HD FOPLP in its smartwatch was the key milestone. At the moment, HD FO is essentially driven by only Apple's application processor engine (APE), made using TSMC's inFO_PoP. On the other hand, we expect Samsung to commercialize HD FOPLP in its own luxury and high-end smartphones. Consequently, Samsung will create its own HD FO market share of 21% by 2025.

Samsung Electronics is stepping up to its game by strengthening the synergy between semiconductor manufacturing and packaging. A strong indication is the acquisition of SEMCO's FOPLP technologies. This is an attempt to improve the yield and gain more technical breakthroughs for FE plus packaging solutions. Equally important, Samsung Electronics has the same model as TSMC now. It is able to provide an APE, FE plus packaging bundle solution for Apple. The expiry of Apple's contract with TSMC is a very good chance to grab back market share. Although Samsung has adopted HD FO in its smartwatch with in-house FOPLP technology, it is understood that the cost is not as low as expected because of lower yields. Samsung has the resource and capability to achieve the desired cost in due time. The question is whether Samsung can achieve it in the shortest time possible and come up with an attractive solution by 2020, because qualification needs to start before 2021. Whether Samsung Electronics can elevate high volume manufacturing (HVM) capabilities to a cost effective scale like TSMC's over a short term remains an open question. The catch up by Samsung Electronics has been impressive.

2019-2025 Fan-Out packaging revenue forecast per market class



(Yole Développement, June 2020)

MORE TECHNOLOGIES IN CORE FO

Presently, embedded wafer level ball grid array (eWLB) still dominates Core FO, but M-series Fan-Out Wafer Level Packaging (FOWLP) is up and coming. In February 2020, Deca became an independent technology development and licensing company. Deca is now focused on enabling industry leaders with M-Series fan-out and Adaptive Patterning.

It is understood that ASE gained business from Qualcomm due to its licensing technology of M-series from Deca. Also, ASE has started to run production by in-house technology Fan-Out Chip on Substrate (FOCoS) for data center applications, which simply brings more limelight to FO packaging in the Core FO market.

In 2019, Nepes also acquired Deca's FO manufacturing operations in the Philippines. And at the same time, it spun off an FO packaging subsidiary called Nepes Laweh.

Also, ESWIN has been actively building its FOPLP fab and engaged customers within China low volume manufacturing, which is expected to start by 2021.

JCET China is very HiSilicon-oriented. In fact, it is noted that a HD FO line was built in China supporting HiSilicon's HD FO request. HiSilicon is trying to enable domestic OSATs whenever possible due to the trade war with the US. This benefitted JCET.

JCET Singapore used to enjoy large volumes from Qualcomm. Although the volume is not as significant as before, JCET Singapore has started to attract many new customers for 5G-driven applications. JCET is enjoying good business from existing Core power management integrated circuits (PMICs) and qualifying for new application due to 5G boom starting from 2019.

AIP ADOPTION IN FAN-OUT PACKAGING

Fan-Out Packaging: AiP commercialization roadmap

(Yole Développement, June 2020)

In 5G, the challenge is higher frequency operation. All of the packages have to be re-designed to optimize signal gains for higher frequencies. It is understood that one millimeter wavelength (mmWave) 5G iPhone will require three to four antenna-in-package (AiP) modules. Since FO packaging minimizes antenna signal loss in a thinner form factor. TSMC will provide at least one inFO_AiP product regardless of the format. Hence, FO packaging is desirable for AiP in higher-end phones pursuing sleeker design. Presently, it is understood that Apple's 5G iPhone will use a "phased array" antenna with two parts that work together to form a beam of radio signal. The beam can be electronically steered in different directions without the antenna moving. The modem chip and the antenna module work closely together to make this function properly. We do note that mmWave itself isn't new. For example, cars make use of mmWave radar chips operating at 77GHz. These radar chips are used for lane detection and other safety features, which is essentially packaged by FO, typically for luxury cars. It is known that TSMC has been very active in this aspect and we are expecting inFO AiP to take off in Apple 5G iPhones in 2020 and in Apple 5G iPads in 2021.

REPORT OBJECTIVES

- Identify and describe which technologies can be classified as 'Fan-Out packaging'
- Define clearly the different market classes of Fan-Out packaging
- Analyze key market drivers, benefits and challenges of Fan-Out packages by application
- Describe the different existing technologies, their trends and roadmaps
- Analyze the supply chain and Fan-Out landscape
- Update the business status of Fan-Out technology markets
- Provide a market forecast for the coming years, and estimate future trends

COMPANIES CITED IN THE REPORT (non exhaustive list)

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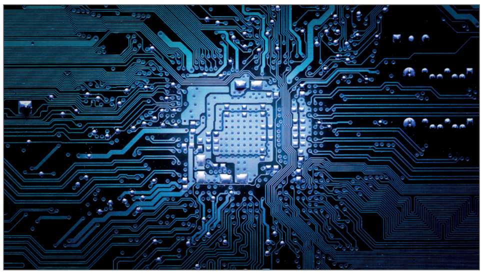
Favier Shoo is a Technology and Market Analyst in the Semiconductor & Software division at Yole Développement (Yole), part of Yole Group of Companies. Based in Singapore, he is engaged in the development of reports as well as the production of custom consulting projects. With prior experiences at Applied 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).

RELATED REPORTS, MONITORS & TRACKS



- Advanced Packaging Quarterly Market Monitor
- Equipment and Materials for Fan-Out Packaging 2019
- Status of the Advanced Packaging Industry 2019
- Mediatek Autus R10 (MT2706) 77/79 GHz eWLB/AiP Radar Chipset - *by System Plus Consulting*
- Fan-Out Packaging Processes Comparison 2020 - *by System Plus Consulting*

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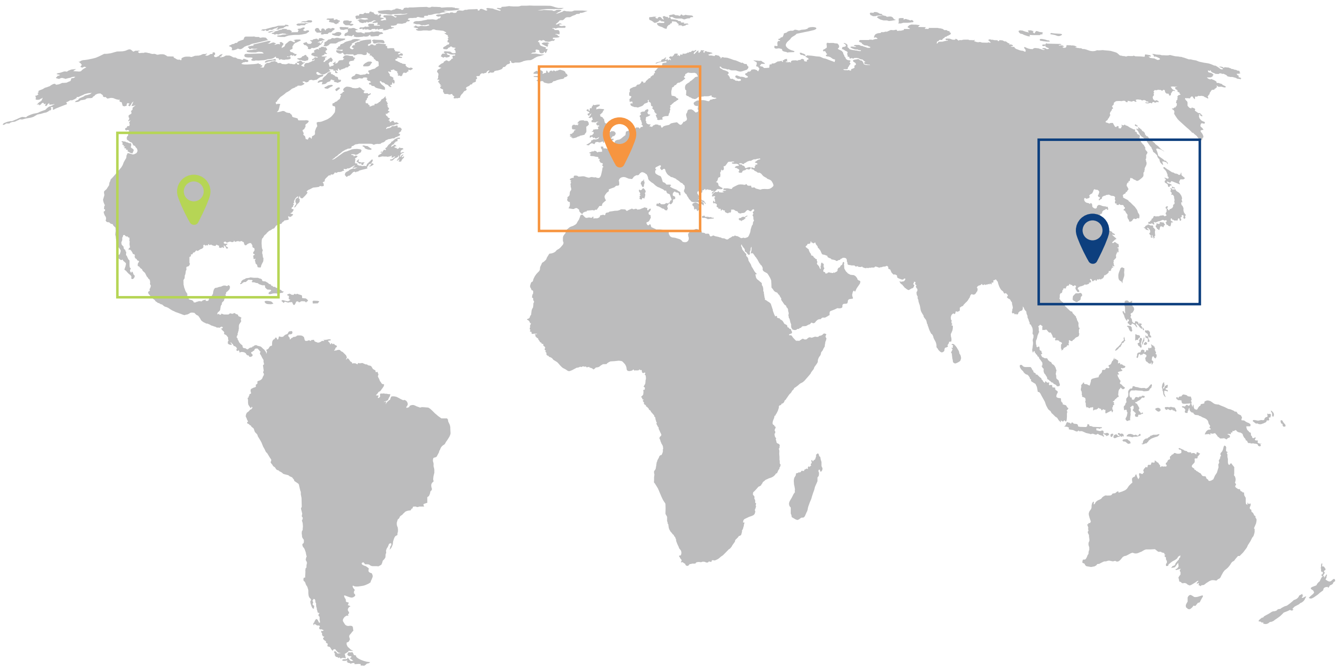

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Bank code: 30056
Branch code: 00170
Account n°: 0170 200 1565 87
BIC or SWIFT code: CCFRFRPP
IBAN: FR76 3005 6001 7001 7020 0156 587
To secure the payments due to the Seller, the Seller reserves the right to request down payments from the Buyer. In such case, the need for a down payment will be mentioned on the corresponding order.

3.3 Payment is due by the Buyer to the Seller within 30 days from invoice date, except as otherwise specifically agreed in writing by the Buyer and the Seller. If the Buyer fails to pay at the due date and fails to request and obtain from the Seller a payment extension, the latter shall be entitled to invoice interest in arrears based on the annual rate Refi of the "BCE" + 7 points, in accordance with article L.441-6 of the French Commercial Code.

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