SIGNIFICANT NEW DEVELOPMENTS IN A DYNAMIC FAN-OUT LANDSCAPE

TSMC has further extended its lead in the “High-Density Fan-Out” (HD FO) market, with gen-2 integrated Fan-Out (inFO) High-Volume Manufacturing (HVM) production and successful qualification of gen-3 inFO for Apple’s iPhone application processor engine (APE). TSMC understands that industry technologies and applications are undergoing unprecedented change in a new, digital mega-trend-driven era. Consequently, exciting technological developments exist to address these new demands.

TSMC has commenced risk-production of inFO-oS (on substrate) for HPC qualifications. Moreover, the company is developing inFO-AiP (antenna-in-package) for mmWave applications (5G, etc.), and inFO-MS (memory-on-substrate) for data-server applications (i.e. cloud). TSMC is also creating a new market segment called ultra-high-density Fan-Out (UDH FO), with a very aggressive sub-micron L/S roadmap and >1500 I/O.

In the “core” Fan-Out (Core FO) market, SEMCO and Powertech Technology Inc. (PTI) have stolen the limelight by rolling out Fan-Out panel-level-packaging (FOPLP) volume production for the first time in Fan-Out packaging history. SEMCO utilized embedded package-level-packaging (ePLP) technology in the Samsung Galaxy smartwatch for the consumer market, for a multi-die FO package consisting of APE + Power Management Integrated Circuit (PMIC) with ~500 I/O. PTI successfully commenced FOPLP PMIC in Low Volume Manufacturing (LVM) for MediaTek’s automotive radar application.

For packaging houses to remain attractive for key fabless players like Qualcomm and MediaTek, cost-reduction is necessary. To this end, SEMCO, PTI, ASE/Deca, and Nepes have invested in Fan-Out at panel-level by leveraging existing facilities and capabilities to achieve economy-of-scale production. Currently, only SEMCO and PTI have been able to kick-start production because the yield for panel-level processing requires optimization and new technology qualification for HVM.

FAN-OUT PACKAGING: BUSINESS MODEL EVOLUTION

Currently, all key OSAT/foundry/IDM players have Fan-Out packaging solutions in the market. The Fan-Out landscape remains dynamic, with more opportunities to maximize performance at a lower cost - hence the adoption of Fan-Out by various business models. In a mega-trends-driven era, Fan-Out platforms are increasingly viewed as one of the top options amongst leading package technologies.

In 2015, the Fan-Out market was small and consisted mostly of standard devices like Baseband (BB), RF, and Power Management Unit (PMU). But after TSMC’s 2016 game-changer with inFO for Apple’s iPhone APE, market value increased 3.5x by 2017. Thus the HD FO market segment was created, reducing the market-share ratio of OSATs.
Since then, SEMCO/Samsung (IDM) has joined the Fan-Out packaging market as a new entrant and expanded it into the consumer market. Moving forward, TSMC is betting on inFO to secure new high-end packaging projects in mobile, HPC, and networking. While SEMCO/Samsung continues to gain ground on TSMC in the HD FO market and generate value in core FO, OSATs will keep competing for business - but under price pressure from fabless. In this scenario, PTI may emerge as a Fan-Out packaging leader due to FOPLP’s cost-effectiveness and a possible HD FOPLP breakthrough for multi-die with logic + memory, etc.

Fan-Out packaging market value is expected to grow at a 19% CAGR from 2019 - 2024, reaching a market size of $3.8B. Meanwhile, the love-hate relationships and politics surrounding OSATs, IDMs, and foundries will continue to unfold. Any big change in Fan-Out strategy will have a ripple effect on the entire supply chain.

**STRONG GROWTH IN A MARKET THAT IS MORE FRAGMENTED THAN EVER**

The core FO market confirmed its stability in 2018, with significant new entrants joining via FOPLP. Although FOWLP players are the default choice due to a long history of established qualifications, mid-end devices may be too costly for FOWLP players. Hence, FOPLP players will emerge as a cost-effective option for the core market’s new demands. We foresee fabless being “spoiled” by FOPLP margins, and beginning to demand the same benefits for existing business. Moving forward, a price war between FOWLP and FOPLP is inevitable.

HD FO growth has never been bigger, due to TSMC possibly doubling its capacity in order to acquire new business in the coming years. Also, SEMCO/Samsung has already confirmed FOPLP with APE, and it will not be long before this is rolled out in Samsung smartphones to challenge TSMC for Apple’s APE business.

Key fabless players like Qualcomm and MediaTek will continue to push packaging houses for Fan-Out solutions at lower cost, especially in higher-end devices. PTI is the only potential option for achieving this, and in the process could reach a new milestone with high-end memory Fan-Out packaging. This being said, it will be hard to achieve and hence may only materialize much later, in 2022.

Will Fan-Out packaging continue to cannibalize and put flip-chip, advanced substrate, and interposer
manufacturers out of business? Fan-Out packaging’s key benefit is the ability to integrate dies together flexibly, and at thinner dimensions. Fan-Out can displace 2.5D interposers with fine L/S Fan-Out packaging on substrate. It can also displace flip-chip and advanced substrate. Such is the potential of Fan-Out packaging technology, and it is already underway in the APE business via TSMC’s inFO-APE and SEMO’s FOPLP.

OBJECTIVES OF THE REPORT
• Identify and describe technologies classifiable as “Fan-Out”
• Update the business status of Fan-Out technology markets
• Analyze, by application, the key market drivers, benefits, and challenges for Fan-Out packages
• Describe the different existing technologies, including their trends and roadmaps
• Review the Fan-Out supply chain and landscape
• Provide a market forecast for the coming years, and a prediction of future trends

COMPANIES CITED IN THE REPORT (non exhaustive list)

TABLE OF CONTENTS (complete content on i-Micronews.com)
Introduction 5
  > Report scope and objectives
  > Companies cited in this report
  > Glossary
What’s new since our last report? 11
Executive summary 17
Advanced packaging trends 62
Overview of FO packaging 80
  > FO - introduction and package-level definition
  > Drivers - differentiation and benefits
Cost analysis 103
  > Different types of FO, comparison with other packages and yield-cost
Technologies and products 116
  > Segmentation
  > Fan-Out packaging technologies: available and expected
  > Technology roadmaps
  > Challenges and limitations
Fan-Out panel-level packaging 214
  > Panel trends and motivations
  > Reality of panel penetration
Supply chain status and analysis 232
  > Players and their positioning within the supply chain
  > Activity and progression: Business model evolution and positioning of key players
Commercialization status and analysis 256
  > Product types, and markets of interest
  > Which type of Fan-Out for which application?
  > Stories on manufacturing capabilities and opportunities and challenges
Market value and forecasts 313
  > Revenue (per end-market, per application)
  > Volume (in wafers and packages)
Conclusions 329
Appendix/Company presentation 334

RELATED REPORTS
Benefit from our Bundle & Annual Subscription offers and access our analyses at the best available price and with great advantages

> Status of Panel-Level Packaging 2018
> Status of Advanced Substrates 2018: Embedded Dies & Interconnects, Substrate Like PCB Trends
> Samsung Exynos 9110 with ePLP: First Generation of Samsung’s Fan-Out Panel Level Packaging
Find all our reports on www.i-micronews.com

Favier Shoo is a Technology and Market Analyst in the Semiconductor & Software division at Yole Développement, part of Yole Group of Companies. Favier is engaged in the development of technology & market reports as well as the production of custom consulting. After spending 7 years at Applied Materials as a Customer-Application-Technologist in advanced packaging marketplace, Favier had developed a deep understanding of the supply chain and core business values. Being knowledgeable in this field, Favier had given trainings and held numerous technical review sessions with industry players. In addition, he had obtained 2 patents. Prior to that, Favier had worked at REC Solar as a Manufacturing Engineer to maximize production capacity. Favier holds a Bachelor in Materials Engineering (Hons) and a Minor in Entrepreneurship from Nanyang Technological University (NTU) (Singapore). Favier was also the co-founder of a startup company where he formulated business goals, revenue models and marketing plans.
PRODUCT ORDER - Ref YD19001

Please enter my order for above named report:
☐ One user license*: Euro 5,990
☐ Multi user license: Euro 6,490
- The report will be ready for delivery from January 10, 2019
- For price in dollars, please use the day’s exchange rate. All reports are delivered electronically at payment reception. For French customers, add 20% for VAT

I hereby accept Yole Développement’s Terms and Conditions of Sale

Signature:

*One user license means only one person at the company can use the report.

BILL TO

Name (Mr/Ms/Dr/Pr): ____________________________
Job Title: ____________________________
Company: ____________________________
Address: ____________________________
City: ____________________________
State: ____________________________
Postal code/Zip: ____________________________
Country*: ____________________________
Tel: ____________________________
Email: ____________________________
Date: ____________________________

PAYMENT

BY CREDIT CARD
☐ Visa ☐ Mastercard ☐ Amex
Name of the Card Holder: ____________________________
Credit Card Number: ___________ ___________ ___________ ___________
Card Verification Value: ___________ ___________ ___________ ___________
Expiration date: ___________ ___________

BY BANK TRANSFER
BANK INFO: HSBC, 1 place de la Bourse, F-69002 Lyon, France,
Bank code: 30056, Branch code: 00170
Account No: 0170 200 1565  87,
SWIFT or BIC code: CCFRFRPP,
IBAN: FR76 3005 6001 7001 7020 0156 587

RETURN ORDER BY
• MAIL: YOLE DÉVELOPPEMENT, Le Quartz,
  75 Cours Emile Zola, 69100 Villeurbanne/Lyon - France

SALES CONTACTS
• Western US & Canada - Steve Laferriere:
  +1 310 600-8267 – laferriere@yole.fr
• Eastern US & Canada - Troy Blanchette:
  +1 704 859 0453 – troy.blanchette@yole.fr
• Europe & RoW - Lizzie Levenez:
  +49 15 123 544 182 – levenez@yole.fr
• Japan & Rest of Asia - Takashi Onozawa:
  +81-80-4371-4887 – onozawa@yole.fr
• Greater China - Mavis Wang:
  +886 979 336 809 – wang@yole.fr
• Specific inquiries: +33 472 830 180 – info@yole.fr

(1) Our Terms and Conditions of Sale are available at www.yole.fr/Terms_and_Conditions_of_Sale.aspx
The present document is valid 24 months after its publishing date: January 10, 2019

ABOUT YOLE DÉVELOPPEMENT

Founded in 1998, Yole Développement 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 and well as IP and patent analysis. With a strong focus on emerging applications using silicon and/or micro manufacturing, the Yole group of companies has expanded to include more than 80 collaborators worldwide covering MEMS and Image Sensors, Compound Semiconductors, RF Electronics, Solid-state lighting, Displays, Software, Optoelectronics, Microfluidics & Medical, Advanced Packaging, Manufacturing, Nanomaterials, Power Electronics and Batteries & Energy Management.

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

CONSULTING AND ANALYSIS
• Market data & research, marketing analysis
• Technology analysis
• Strategy consulting
• Reverse engineering & costing
• Patent analysis
• Design and characterization of innovative optical systems
• Financial services (due diligence, M&A with our partner)
More information on www.yole.fr

REPORTS
• Market & technology reports
• Patent investigation and patent infringement risk analysis
• Structure, process and cost analysis
• Cost simulation tool
More information on www.i-micronews.com/reports

CONTACTS
For more information about :
• Consulting & Financial Services: Jean-Christophe Eloy (eloy@yole.fr)
• Reports: David Jourdan (jourdan@yole.fr) Yole Group of Companies
• Press Relations & Corporate Communication: Sandrine Leroy (leroy@yole.fr)

More information on www.i-micronews.com
Definitions: “Acceptance”: Action by which the Buyer accepts the terms and conditions of sale in its entirety. It is done by signing the purchase order which mentions “I hereby accept Yole Development’s Terms and Conditions”. “Buyer”: Any business user (i.e. any person acting in the course of its business activities, for its business needs) entering into the following general conditions to the exclusion of consumers acting in their personal, domestic or household affairs.

“Contracting Parties” or “Parties”: The Seller on one hand and the Buyer on the other hand.

“Intellectual Property Rights” (“IPR”) means any rights held by the Seller in its Products, including any patents, trademarks, registered designs, copyrights, technical information, commercial secrets and know-how, technical information, company or trading names and any other intellectual property rights or similar in any part of the world, notwithstanding the fact that they shall NOT be the subject of any pending registration of any of the above mentioned rights.

“Products”: Depending on the purchase order, reports or monitors on MEMS, Imaging, SSL, Advanced Packaging, MedTech, Power Electronics and more, can be bought either on a unit basis or as a bundled offer. (i.e. subscription for a period of 12 calendar months).

“Report”: The product sold, delivered or supplied by the Seller to the Buyer.

“Terms and Conditions of Sales” are expressed to be inclusive of all taxes. The prices may be reevaluated from time to time. The effective price is deemed to be the one applicable at the time of the order.

3. PRICE, INVOICING AND PAYMENT
3.1 Prices are given in the orders corresponding to each Product sold on a unit basis or corresponding to bundled offers. They are expressed to be inclusive of all taxes. The prices may be reevaluated from time to time. The effective price is deemed to be the one applicable at the time of the order.
3.2 Payments due by the Buyer shall be sent by cheque payable to Yole Development SA or by electronic transfer to the following account: HSBC, 1 place de la Bourse 69002 Lyon France Bank code: 30001 Branch code: 00170

Account n°: 0170 200 1565 87
IBAN: FR76 3005 6001 7001 7020 0165 587
To ensure the payments, the Seller reserves the right to request down payments from the Buyer. In this case, the need of down payments will be specified in the corresponding contract.
3.3 Payment is due by the Buyer to the Seller within 30 days from invoice date, except in the case of a particular written agreement. If the Buyer fails to pay within this time and fails to contact the Seller, 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 (except for companies using databases, tool…) are delivered only after receipt of the payment.
3.4 In the event of termination of the contract, or of misconduct, due to the Buyer’s fault, the Buyer will be liable for the loss of time at the stage in progress, and to take legal action for damages.

4. LIABILITIES
4.1 The Buyer or any other individual or legal person acting on its behalf, being a business user buying the Products for its business activities, shall be solely responsible for choosing the Products that suit his needs. The Buyer is responsible for making the payment for the Products it purchases, of the results he obtains, and of the advice and acts it deduces thereof.
4.2 The Seller shall not be liable for (i) direct and (ii) foreseeable pecuniary loss, caused by the Products or arising from a material breach of this agreement.
4.3 In no event shall the Seller be liable for: a) damages caused by an event without limitation, incidental or consequential damages (including, but not limited to, damages for loss of profits, business interruption and loss of programs or data or records in the data processing or in the data base) or inability to use the Seller’s website or the Products, or any information provided on the website, or in the Products; b) any claim attributable to errors, omissions or inaccuracies in the Product or interpretations thereof.
4.4 All the information contained in the Products has been obtained from sources believed to be reliable. The Seller does not warrant the accuracy or completeness of the data or the truthfulness of the information. The replacement is guaranteed for a maximum of two months starting from the delivery date. Any replacement is excluded for any event as set out in article 5 below.
4.5 The responsibility of the Seller is limited to the repair of the Products for which the Buyer is the end user and for which the Seller is the end user and for which the Seller’s part is similar to the Product initially ordered.
4.6 In the case where, after inspection, it is acknowledged that the Products do not conform to the contract, the Seller will be responsible for the repair or replacement of the defective products as far as the seller allows and without indemnities or compensation of any kind for labor costs, delays, or any other costs. The replacement is guaranteed for a maximum of two months starting from the delivery date. Any replacement is excluded for any event as set out in article 5 below.
4.7 The deadlines to which the Seller is asked to state for the mailing of the Products are given for information only and are not guaranteed. If such deadlines are not met, it shall not lead to any damage to the Buyer or to the Seller. The Seller will have the right to accept delays exceeding 4 months from the stated deadline, without information from the Seller. In such case only, the Buyer will be entitled to ask for a reimbursement of its first down payment to the exclusion of any further damages.
4.8 The Seller does not make any warranties, express or implied, including, without limitation, those of sale ability and fitness for a particular purpose, with respect to the Products. Although the Seller will take reasonable steps to screen Products for infection of viruses, the Buyer is aware that the Products may contain deactivating or destructive properties before making the Products available, the Seller cannot guarantee the Products are virus free from infection.

5. FORCE MAJEURE
The Seller shall not be liable for any delay in performance directly or indirectly caused by or resulting from acts of nature, fire, flood, accident, riot, war, government intervention, embargoes, strikes, power failures, equipment failures, acts or supplies by suppliers or other difficulties which are beyond the control and not the fault of the Seller.

6. PROTECTION OF THE SELLER’S IPR
6.1 All the IPR attached to the Products are and remain the property of the Seller and are protected under French and international copyright law and conventions.
6.2 The Buyer agreed not to disclose, copy, reproduce, redistribute, resell or assign any part of it to any other party other than employees of its company. The Buyer shall have the right to use the Products solely for its own internal information and business purposes. In particular, the Buyer shall not use the Product for purposes such as: Information storage and retrieval systems; Recordings and co-transmitters over any network (including any local area network); Use in any timesharing, service bureau, bulletin board or similar arrangement or public display; Posting any Products to any other online service (including bulletin boards or the Internet); Licensing, leasing, selling, offering for sale or assigning the Product.
6.3 The Buyer shall be solely responsible towards the Seller of all infringements of this obligation, whether this infringement comes from its employees or any person to whom the Buyer has entrusted the Products. The Buyer is responsible for any related proceedings, and the Buyer shall bear related financial consequences in their entirety.
6.4 The Buyer will define within its company points of contact for the management of the contracts and the licensing of the Products. The Buyer shall keep a written record of each new report in PDF format. This person shall also be responsible for respect of the copyrights and will guaranty that the Products are not disseminated out of the company.
6.5 In the context of annual subscriptions, the person of contact shall decide who within the Buyer, shall be entitled to receive the protected link that will allow the Buyer to access the Products. In case of situation 5 above.
6.6 As a matter of fact the investor of a company, the joint venture done with a third party etc..cannot access the report and should pay a full license price.

7. TERMINATION
7.1 If the Buyer cancels the order in whole or in part or postpones the mailing, the Seller shall have the right to charge the entire costs that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may apply for any other direct or indirect consequential loss that may be borne by the Seller, following this decision.
7.2 In the event of breach by one Party under these conditions or the order, the non-breaching Party may send a notification to the other by recorded delivery letter upon which, after a period of thirty (30) days without solving the problem, the non-breaching Party shall be entitled to terminate all the pending orders, without being liable for any compensation.

8. MISCELLANEOUS
8.1 No modification of the Terms and Conditions are for the benefit of the Seller itself, but also for its licensors, employees and agents. Each of them is entitled to assert and enforce those provisions against the Buyer.
8.2 Any notice under these Terms and Conditions shall be given in writing. They shall be effective upon receipt by the other Party. The Seller may, from time to time, update these Terms and Conditions. The Seller and the Buyer agree that the latest version of these terms and conditions, provided they have been communicated to him in due time.

9. GOVERNING LAW AND JURISDICTION
9.1 Any dispute arising out or linked to these Terms and Conditions or to any contract (orders) entered into in application of these terms and conditions by the French Commercial Courts of Lyon, which shall have exclusive jurisdiction upon such issues.
9.2 Any negotiation between the Buyer and the Seller, in accordance with these Terms and Conditions.