INDUSTRY TRENDS: ADVANCED PACKAGING

Fan-Out, the new boost for panel-level-packaging

The semiconductor industry is breaking records and expectations are high for the market future. In this context, advanced packaging is transforming from follower of front-end industry to enabler of future semiconductor applications and products. This is because scaling and cost reduction is not possible just by continuing on the path the industry followed for the past few decades with Moore's law. Advanced nodes do not bring the desired cost benefit anymore and R&D investments in new lithography solutions and devices below 10nm nodes are rising substantially. In order to answer market demands, the industry seeks further performance and functionality boosts in integration. Packages are now requested to bridge the gap and revive the cost/performance curve while at the same time adding more functionality through integration. They become enablers for new designs, new performances and new applications.

In contrast with classical packages, advanced types of packaging illustrate the important emerging role for better packaging technologies and are already widespread in key markets requiring high-end performance. They are gaining more and more market share thanks to the needs of various applications to get better integration. They will continue to dominantly address high-end logic and memory in computing and telecom, with further penetration in analog and RF in high end consumer/ mobile segments, while eyeing opportunities in growing automotive and industrial segments.

Advanced packaging already represents roughly US$25 billion in 2018 and is experiencing a total revenue CAGR[1] 2017-2023 of 8%. This is higher than the semiconductor industry (4-5%), PCB[2] industry (2-3%) and more generally the global electronics industry (3-4%)[3].

The advanced packaging market is dominated by large IDMs[4] such as Intel and Samsung, 4 large global OSATs[5] and foundry and packaging house TSMC, accounting for 60% of the advanced packaging market. These leaders are working on numerous advanced packaging platforms such as Flip-Chip BGA[6], Fan-Out Packaging, 3D TSV[7], etc... Each platform gaining a lot of momentum but having different potentials and different characteristics. At the moment, the fastest growing platform is Fan-Out with 36% growth and experiencing a diversification of its targeted applications.

Since 2009, Fan-Out packaging has been wide spread in low-density applications, most of the time with single die, such as Baseband, Power management, RF[8] transceivers, etc... essentially in mobile phones and to a lower extent in automotive. This addressed the high demand from telecom industry for a thin and cheap package, capable of embedding ICs[9] while not being limited by chips' surfaces.

Comfort zone of the platform used to be low IO counts applications but its potential for larger IO counts applications and other markets has been demonstrated since then, thanks to the use of FO by Apple for their application processors.

The Fan-Out market is already large (US$1.2 billion in 2018) and amongst that, the high-density fan-out applications market is more than US$500 million. This could reach more than US$1 billion in the coming years if telecom players other than Apple are willing to switch to fan-out packaging, which is to be expected.

With such potential, the market is asking for more innovation and development and, as often in manufacturing, the main parameter of interest is the cost. The main trend in fan-out packaging being investigated at the moment to drive down cost is carrier size evolution and many manufacturers are considering that option or recently started production on panel. This will take time but will impact the market positively since cost reduction will enable further acceptance of the platform.

FOPLP[10] is currently attracting huge interest in the industry because of its low-cost potential and is attracting players with many different business models, including OSAT, IDMs, foundries, substrate manufacturers and FPD[11] players. Lots of players have been developing FOPLP technology, but after years of development/ qualification/sampling, three players are finally entering in production in 2018: Powertech Technologies (PTI), NEPES, and SEMCO. NEPES has been in low-volume production since 2017 and PTI has its first product released in the second quarter of 2018. ASE, in partnership with Deca Technologies, is in the advanced development stage and will commence volume production in 2019/2020. The FOPLP market is expected to reach roughly US$280 million in 2023 at a CAGR

2018-2023 of 79%[12]. First applications targeted by panel FO are low-density packages with limited L/S (10-15µm) and high potential volume devices (Baseband, RF, PMIC, etc...). SEMCO is also targeting denser and more complex products such as application processors for Samsung. SEMCO invested more than US$400 million during the last two years and has finally begun production with integrated APE for Samsung's new consumer product, the Galaxy Watch.

Equipment availability for PLP[13] is not a bottleneck today. Tools are available in the market to support various process steps in panel processing. However, certain tools that support high-density panel packaging are special and expensive. So, tool cost, not availability, is the bottleneck.

For some panel-producing process steps (plating, PVD[14], molding, die attach, and dicing), tools are readily available and can be adapted from the PCB[15], flat-panel display, or LCD[16] industries. However, for other key process steps inherent to advanced packaging (i.e. lithography), the development of new, upgraded tool capabilities is necessary to support such steps as fine L/S patterning on panel, thick-resist lithography, panel-handling capabilities, exposure field size, and depth of focus. Over the last few years, these tools have been in development at equipment suppliers.

Equipment suppliers are adopting different strategies for entering the PLP business: acquisition (for example, Rudolph Technologies has developed PLP-focused tools based on knowledge received through its acquisition of AZORES Flat Panel Display Panel Printer); by leveraging tool experience from other businesses and upgrading it (i.e. Evatec, Atotech, SCREEN); and by organically developing PLP tools from scratch (ASM). Also, some tool suppliers have a strong position in the FOWLP market but are skeptical of the PLP business and thus are taking a wait-and-see approach. Ultratech, Applied Materials, Lam Research are part of this group.

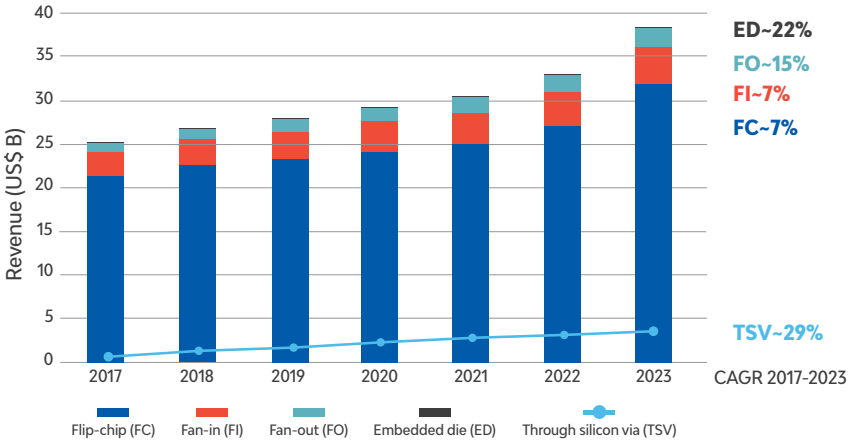
However, the issue of the standardisation of the panel size and assembly process is the biggest hurdle for equipment suppliers. Each player is developing its own process using different panel sizes and infrastructure (PCB/LCD/WLP/PV/Mix) catering to specific applications and customers. In this scenario it's not profitable for equipment suppliers to design and manufacture equipment according to different customers' requirements.

Advanced packaging has entered its most successful era boosted by needs for better integration and end of Moore's law. Among the different platforms, Fan-Out packaging appears to be one of the most dynamic at the moment and needs a new wave of cost reduction for even more widespread adoption. This shall be achieved thanks to the move towards panel scale once the challenges have been addressed by the industry.

1. *CAGR: Compound Annual Growth Rate*
2. *PCB: Printed Circuit Board*
3. *Source : Status of the Advanced Packaging Industry report, Yole Développement, 2018*
4. *IDM : Integrated Devices Manufacturer*
5. *OSAT : Outsourced Semiconductor Assembly and Test*
6. *BGA : Ball Grid Array*
7. *TSV : Through Silicon Via*
8. *RF : Radio Frequency*
9. *IC : Integrated Circuits*
10. *FOPLP : Fan-out Panel Level Packaging*
11. *FPD : Flat Panel Display*
12. *Source : Status of Panel Level Packaging report, Yole Développement, 2018*
13. *PLP : Panel Level Packaging*
14. *PVD : Physical Vapor Deposition*
15. *PCB : Printed Circuit Board*
16. *LCD : Liquid Crystal Display*

2017 - 2023 advanced packaging revenue forecast by packaging platforms in US$ B

Source: Status of the Advanced Packaging Industry report, by Yole Développement, 2018



As Technical Project Development Director at Yole Développement (Yole), **Jérôme Azémar** is supporting the development of strategic projects, following leading customers of the company within the semiconductor industry, from manufacturing to packaging. His mission is to develop Yole's business and technical knowledge in the industry, maintain long term relationships with its accounts and meet their expectations.

Santosh Kumar is currently working as Principal Analyst and Director Packaging, Assembly & Substrates, Yole Korea. He is involved in the market, technology and strategic analysis of the microelectronic assembly and packaging technologies. His main interest areas are advanced IC packaging technology including equipment & materials. He is the author of several reports on fan-out / fan-in WLP, flip chip, and 3D/2.5D packaging.

YOLE Développement