

Fan-in WLP: Technology and Market Trends

A. Ivankovic, T. Buisson, S. Kumar, A. Pizzagalli, J. Azemar, R. Beica
Yole Developpement
75 cours Emile Zola
Villeurbanne, 69100 France
Ph: +33-472-830-196; Fax: +33-472-830-183
Email: ivankovic@yole.fr

Abstract

The semiconductor industry is facing a new era in which device scaling and cost reduction will not continue on the path they followed for the past few decades, with Moore's law in its foundation. Advanced nodes do not bring the desired cost benefit anymore and R&D expenses for new lithography solutions and devices in sub-10nm nodes are rising substantially. Subsequently, new market shifts are expected in due time, with "Internet of Things" (IoT) getting ready to take over pole market driver position from mobile.

In these circumstances, where front-end-of-line (FEOL) scaling options remain uncertain and IoT promises application diversification, in order to answer market demands, the industry seeks further performance and functionality boosts in package level integration. Emerging packages such as fan-out wafer level packages, 2.5D/3D IC and related System-in-Package (SiP) solutions together with more conventional but upgraded flip chip BGAs aim to bridge the gap and revive the cost/performance curve. In such an environment, what is the importance of fan-in wafer level packages (FI WLP), the current status of the fan-in WLP industry and how will fan-in WLP market and technology evolve? This work aims to answer these questions by performing an in-depth analysis on fan-in WLP market dynamics and technology trends.

Key words

fan-in, wafer level packaging, forecast, roadmap, cost and investment, Internet of Things

I. Introduction

The semiconductor industry is facing a new era in which device scaling and cost reduction will not continue on the path they followed for the past few decades, with Moore's law in its foundation. Advanced nodes do not bring the desired cost benefit anymore and R&D investments in new lithography solutions and devices in sub-10nm nodes are rising substantially. Furthermore, new market shifts are expected in due time, with "Internet of Things" (IoT) getting ready to take over pole market driver position from mobile. In these circumstances, with an emerging market driver promising future application diversification on one hand and scaling options remaining uncertain on the other, the spotlight is turned to packages for cost, performance and functionality improvement.

The industry seeks further performance and functionality boosts in integration and wafer level packages [1-6]. Emerging packages such as fan-out wafer level packages and 2.5D/3D IC solutions together with more conventional but upgraded flip chip BGAs aim to bridge the gap and revive the cost/performance curve. However, although

seemingly out of the spotlight, fan-in wafer level packages remain a constant presence with unmatched attractive features.

Fan-in wafer level packages are one of the more mature technologies in an industry full of disruptions, maintaining appeal and still on an evolutionary track. Their specific advantages – primarily size and cost remain to be engaging for more than a decade. This work focuses on the analysis of recent developments and future trends of the fan-in wafer level package market and technology.

Firstly, an overview of fan-in WLP market drivers is given, followed by a discussion comparing fan-in and fan-out WLP. Subsequently, information regarding the fan-in wafer level packaging market is presented including forecasts and application trends. The study takes into account analog, mixed signal and digital devices, microelectromechanical systems (MEMS) and CMOS image sensors (CIS).

Furthermore, an overview of the fan-in WLP supply chain is given, followed by trends in fan-in WLP technology and the future roadmap. Prior to the conclusion, a capacity

increase driven investment is discussed followed by a reflection on fan-in WLP and IoT.

II. Market drivers

Although seemingly out of the spotlight, fan-in wafer level packages remain a highly important and constant presence with unmatched advantages in cost and form factor. As pointed out in Fig. 1, fan-in WLP hold 16% of the total number of packages, while serving 4.4% of the wafer market at only 1.5% of the total semiconductor revenue (WLP services counted) [1].

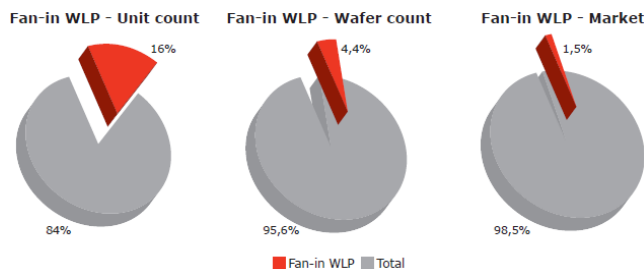


Fig. 1: Fan-in WLP shares in the total semiconductor market

As indicated in Fig. 2, wafer level packages represent a solution where high performance, small form factor and lower cost combine. The mobile market continues to be the main driver for WLP and is the one especially pushing for these advantages. More than 90% of all fan-in packages are found in handsets (especially smartphones) and tablets. As mobile driven fan-in WLP market growth and innovation continue, a bright future lies ahead with new IoT driven applications on the horizon.

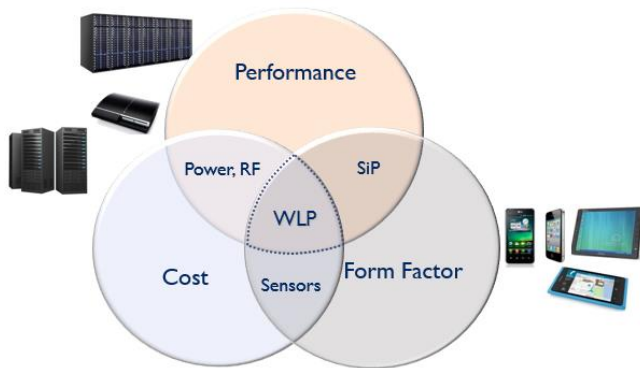


Fig. 2: WLP market drivers

III. Fan-in vs. Fan-out

When compared to flip chip packages, fan-in WLP have clear advantages in footprint and a thinner package profile, as indicated in Fig. 3. Fan-in WLP remove the need for wirebonds, an interposing substrate, flip chip bumps and in most cases also mold compound. Consequently, this results

in shorter interconnects, lower parasitics and enhanced electrical performance, both in terms of speed and frequency.

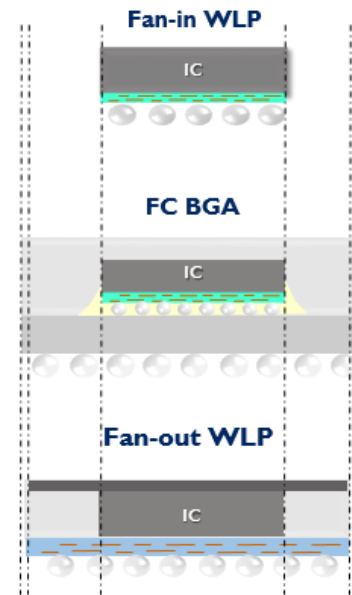


Fig. 3: Schematic comparison of fan-in WLP with a flip chip BGA and fan-out WLP

On the other hand, an inherent limitation of fan-in WLP is available die area for signal redistribution and board connectivity. When pin count exceeds the available Si area, fan-out WLP can provide a smooth transition. Fan-out WLP are designed to extend I/O count, not constrained by die size area. Alternatively, fan-out packages can offer relaxed pitch.

Fan-in WLP trends indicate that package size is increasing and further pitch reduction is investigated to accommodate more I/Os. Bump pitch of 0.4 mm and 0.35 mm is in high volume production, 0.3mm and 0.25mm are in consideration, although not likely to switch below 0.35 mm in the next 2 years. Larger than 20 mm x 20 mm fan-in dies have been produced and qualified for specific applications, however, in general warpage and board level reliability for large dies remain concerns.

With fan-in and fan-out WLP potentially overlapping, a question arises if they are complementary or competing technologies? Fan-in is unmatched in terms of form factor and cost. If technically feasible, fan-in is the first option. Fan-out WLP is still a niche market and panel level packaging is still challenged by yield/cost/infrastructure, although interest is growing. From one point of view, fan-out WLP can be considered as an extension to fan-in WLP, when fan-in pin count capabilities are exceeded. Therefore, these fan-in WLP and fan-out WLP are not direct competitors. In certain cases fan-out WLP can encounter competition in leadframe and single layer substrate

packages. On the other hand, fan-out WLP are very well positioned for multi die packages and SiP structures.

Fan-In/fan-out I/O count turning point is not clearly defined and depends on several parameters and design requirements. Most fan-in dies are below 200 I/Os and below 7 mm x 7 mm. However, announcements have been made claiming extension of fan-in WLP I/O count to 800 I/Os in the months to come. Fig. 4 presents an illustration of an estimated turning point between fan-in and fan-out WLP.

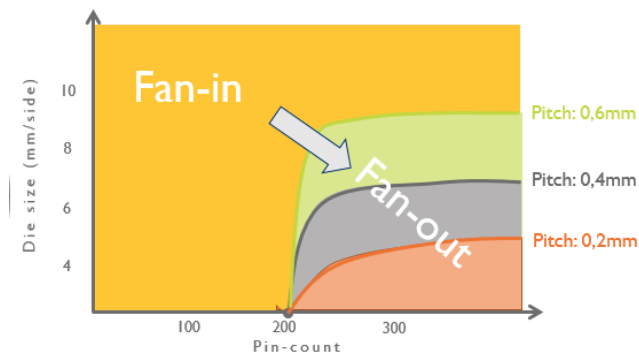


Fig. 4: Estimated turning point of fan-in and fan-out WLP

IV. Market forecasts

Fan-in WLP is forecasted to continue a stable growth, with a market just short of 3 billion \$ (WLP services) in 2014 and a CAGR between 2014-2020 of 8%. The total wafer count in 300mm equivalent wafers is reaching 4 million with a projected CAGR of 8% while the unit count (Fig. 5) is found at 35 billion with a projected CAGR of 9%. Throughout the past few years, MEMS and CMOS image sensors have been increasing their share compared to analog, mixed signal and digital ICs and are now accounting for 25% of the total fan-in WLP services revenue.

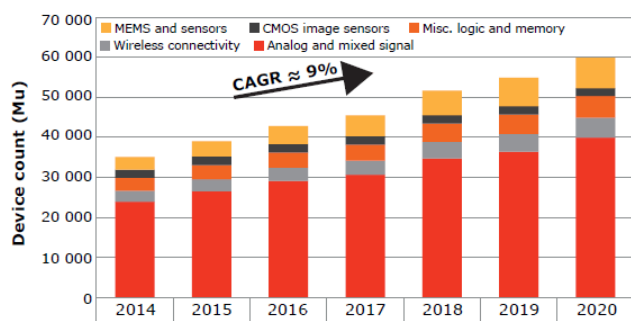


Fig. 5: Fan-in WLP unit forecast

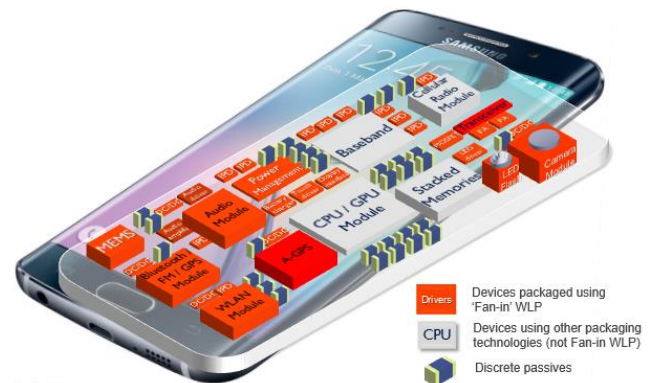


Fig. 6: Fan-in WLP penetration status in mobile platforms

The leading applications by wafer demand in the analog, mixed signal and digital domain are BT+WiFi+FM combos and RF transceivers followed by PMU, audio/video codecs, DC/DC converters, ESD/EMI IPD. MEMS devices are lead by digital compasses, RF filters, accelerometers and gyroscopes. CMOS image sensors are strongly positioned in 2nd place by overall fan-in application rankings, after BT+WiFi+FM combos. BT+WiFi+FM combos, CMOS image sensors and RF transceivers account for ~50% of all fan-in WLP applications. Fig. 6 illustrates the high penetration of fan-in WLP in mobile platforms. Devices found in fan-in WLP form are marked orange. Some of the new applications arising for fan-in WLP in the near future are MEMS gas sensors and automotive radar.

Within fan-in WLP, analog/digital/mixed signal and MEMS markets are on the rise, the CIS market is expected to stagnate. Due to rising pixel count, smartphone sub and feature phone main cameras are exceeding fan-in capabilities and subsequent decline for fan-in WLP in that area are expected to be the main cause of future stagnation of the CIS fan-in WLP market. As shown in Fig. 7, in 2014, 49% of all CIS were found in fan-in WLP. This percentage is expected to decline to 31% by 2020. CIS fan-in WLP services and market growth will depend on the penetration of automotive, surveillance and wearables sectors in comparison with the decline of the mobile phones sector.

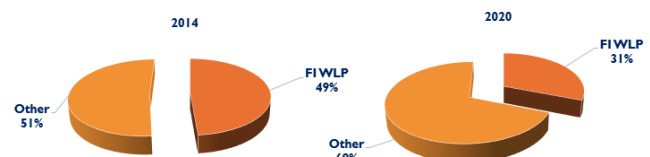


Fig. 7: Fan-in WLP share in CMOS image sensors

V. Supply Chain



Fig. 8: Non-exhaustive map of fan-in WLP manufacturing companies

Although present for more than a decade, fan-in WLP are still on an evolutionary track increasing production and attracting new applications. Current market data indicate fan-in WLP manufacturing capacities are full and more volume is required in both 200 mm and 300 mm wafer sizes. Currently, majority of production is still done on 200 mm wafers with 300 mm wafer production taking a substantial portion of the market and projected to increase further.

As illustrated in the non-exhaustive map of fan-in WLP manufacturers in Fig. 8, there are many players currently active on the market. The supply chain continues to develop with new companies entering this market and new business models being established. The competitive landscape is expected to increase as well as collaboration and partnership. The specialized wafer level packaging model, focused on fan-in and fan-out packages is emerging strong and competing with traditional OSAT leaders. Some new players are rising quickly, foundry involvement is no longer a small dent and new players from China are increasing activity on the market, bringing in a new type of competition with a strong support in capital and acquisition capabilities.

In total, over 70 high volume fabless and IDM companies implementing their design in fan-in WLP can be identified, along with over 20 high volume fan-in WLP manufacturing companies. Currently, fan-in WLP services are fragmented and lead by several OSATs, with inclusion of one WLP house, and IDM and foundry. Within the MEMS fan-in WLP services market, one company alone holds 1/3 of the market, while in the CIS fan-in WLP services market, one company holds more than 50% of the market.

VI. Fan-in technology

From a technology viewpoint, innovation continues in order to extend the capability of fan-in WLP. Current bump pitch in high volume is mostly at 0.4 mm with 0.35 mm present as well. Fan-in interconnect scaling continues, with L/S heading towards 10/10 um and below. Particular effort

is being made to increase the die size and I/O count. Max I/O count in high volume is heading above 200 and announcements have been made for high volume production up to 800 I/Os. The die size sweet spot ranges up to 7 mm x 7 mm with 8 mm x 8 mm and 9 mm x 9 mm qualified and ready. Fan-in dies above 20 mm x 20 mm have been recorded for niche applications. New bumping and RDL approaches are being developed in order to support the roadmap.

VII. Capacity investment

As current market data indicate full or near full fan-in WLP 200 mm and 300 mm capacity, new investments in the near future will be crucial. Furthermore, IoT is looming on the horizon creating an additional capacity parameter to consider.

Packaging fab utilization rate is above 85% on average worldwide, with more frequent peaks of demand exceeding capacity. As indicated in Fig. 9, current leftover capacity in 2014 is projected to be exceeded already by 2016. OSATs and WLP houses are expected to increase capacity first, followed by new players from China and other high budget foundry and IDM players.

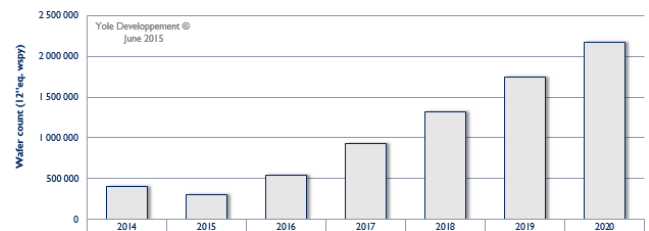


Fig. 9: 2014 leftover capacity and projected cumulative additional demand 2015 - 2020

VIII. IoT

IoT is expected to compete with mobile as the main market driver, eventually taking lead position. Main applications are expected to be linked to MEMS/sensors and wireless connectivity. In certain domains, such as wearables, market penetration has already started with smartwatches. The current business landscape is under reconstruction as big players are trying to position themselves in order to offer a complete platform for IoT through acquisitions and investing in start-ups. Up to 50% of involved companies on the IoT market are expected to be start-ups.

There is no clear roadmap for IoT packaging yet. A large number of applications implies that a variety of package types might find a role, rather than a few specific. Selection of package types will be driven by cost, form and need for functional integration.

A wide range of new applications are expected to be compatible with fan-in WLP, which presents an interesting

opportunity to increase the fan-in WLP demand further. Fan-in WLP and QFNs are expected to have a leading role when it comes to cost and form. Fan-out WLP can cover higher I/O counts when necessary. SiP type packages will have a significant role in functional integration. Fan-out WLP based SiPs and other advanced SiP approaches will be competing for applications. SiP packages are aimed at increasing functionality and are estimated not to compete directly with fan-in WLP.

No new equipment type is needed, but investments to increase capacity will be crucial. Fan-in WLP capacity is saturated and capacity increase by latest 2016 is imminent. OSATs are expected to lead capacity increase, followed by WLP houses and IDMs. China based manufacturers are willing to grow and establish their presence on the market. China based manufacturers have strong investment funds backing them up, comprise the ability to react fast if an opportunity arises to increase competitiveness and are evaluating options for direct investment or favorable acquisitions.

IX. Conclusion

Fan-in WLP are experiencing continuous growth and attracting new applications. With the spotlight turning from advanced nodes to advanced packaging for continuation of the cost/performance curve and with further functionality enhancement leading to package integration (2.5D/3D, fan-out, SiP), fan-in WLP remain unmatched in cost and form. Fan-out WLP is considered a complimentary, not competitive technology to fan-in WLP.

The mobile market continues to be the main driver for fan-in WLP with more than 90% of all fan-in packages found in handsets (especially smartphones) and tablets. As mobile driven fan-in WLP market growth and innovation continue, a bright future lies ahead with new IoT driven applications on the horizon, ready to take pole market driver positions. Fan-in WLP are considered to be well positioned for IoT along with QFNs, fan-out WLP and several competing SiP architectures.

Fan-in WLP are forecasted to continue a stable growth, with a market just short of 3 billion \$ (WLP services) in 2014 and a CAGR between 2014-2020 of 8%. The total wafer count in 300mm equivalent wafers is reaching 4 million with a projected CAGR of 8% while the unit count is found at 35 billion with a projected CAGR of 9%.

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RF transceivers account for ~50% of all fan-in WLP applications. Some of the new applications arising for fan-in WLP in the near future are MEMS gas sensors and automotive radar.

Within fan-in WLP, analog/digital/mixed signal and MEMS markets are on the rise while the CIS market overall is expected to stagnate due to rising pixel count of smartphone sub and feature phone main cameras exceeding fan-in capabilities.

Currently, majority of production is still done on 200 mm wafers with 300 mm wafer production taking a substantial portion of the market and projected to increase further. Currently, fan-in WLP services are fragmented and lead by OSATs, with inclusion of one WLP house, an IDM and foundry. Within the MEMS fan-in WLP services market, one company alone holds 1/3 of the market, while in the CIS fan-in WLP services market, one company holds more than 50% of the market.

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Current market data indicate full or near full fan-in WLP 200 mm and 300 mm capacity, new investments are needed in the near future. Current leftover capacity in 2014 is projected to be exceeded already by 2016.

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