FAN-OUT PANEL-LEVEL PACKAGING

FOPLP Production Solutions
Driving productivity growth
**Ever-evolving packaging technologies driven by end products**

The semiconductor market has its application foundation rooted not only in traditional PC and 3C applications and is now venturing into IoT, Big Data, 5G communications, AI, autonomous cars, and smart manufacturing. Semiconductor clients demand slimmer form-factors, lower power consumption, and lower chip costs. This makes packaging technology even more important.

Integrated circuit (IC) packaging is the final stage of semiconductor device fabrication. Packaging has acted as a space and electrical transformer providing protection for the contents of the package and access for power and signals to and from the outside world.

With the demands for smaller, more efficient, and highly durable ICs will only increase over time as consumer demand for thinner and lighter electronics grows. As such, package technology has gone from lead frame, flip chip package to fan-in wafer level packaging which helped to decrease chip size and thickness whilst effectively lowering fabrication cost.

However, fan-in wafer-level packaging still faced great challenges with the vast advances of end products. (1) Bumping is limited to the die size while continuing scaling down chip size. (2) The assembly cost gets higher while decreasing solder ball size. So, it is difficult and challenging for fan-in wafer-level packaging to increase more and more I/O counts due to the limit of the die size and the constraint on the cost of bump formation process while shrinking bump size. Therefore, the packaging market tends toward more advanced fan-out package. An overall of the features:

- **Smaller form factor**
  - Without package substrate, a thinner package can be achieved.
  - Fan-out package integrates different chips into a single 2D package, achieving volume thinning SiP (System in Package) technology.

- **Greater efficacy**
  - The RDLS are routed inward and outward, enabling thinner packages with more I/Os.
  - Using RDL to connect chips of different functions, the functionality will increase by integration into a single package.

- **Lower cost**
  - Fan-out package technology drastically simplifies the complex process steps and reduces material usage, whilst effectively lowering the overall production cost.

There are two fan-out packaging technologies: Fan-Out Wafer-Level Packaging (FOWLP) and Fan-Out Panel-Level Packaging (FOPLP). Though the technical uses and applications are different, both can achieve thinner appearance for the final product. However, the cost of FOPLP is lower than that of FOWLP making it the highest profile advanced package technology in recent years.

---

*Source (Excl. TSV): WSTS / Yole Développement*
Fan-out packaging is now an integral part of the portfolio

THE WAY TO MINIATURIZE THE PACKAGE FORM FACTOR BY FAN-OUT PACKAGING TECHNOLOGY IS TO CONNECT DIFFERENT FUNCTIONS OF THE CHIP TO THE PASSIVE COMPONENTS BY RDL, OR TO FABRICATE IC WITH 3D STRUCTURES. BOTH TECHNIQUES CHANGE THE CONNECTION AND FABRICATION METHOD IN ORDER TO INTEGRATE HOMOGENEOUS OR HETEROGENEOUS CHIPS INTO A SINGLE PACKAGE.

Multi-Chip module packaging is an important facet of modern electronic miniaturization and microelectronic systems. It was designed for multiple integrated ICs to facilitate their use as a single package. This is considered a way to extend the “Post-Moore’s Law” era.

Fan-out package is the prevailing technology in advanced package. Its process: (1) Dicing a wafer. (2) Mounting known good dies (KGD) on carrier for molding. (3) RDL and solder bump formation. (4) Separate molding and reusable carrier. (5) Package singulation. This technique not only creates more I/O contact on package by fan-out, it also reduces package volume and accomplishes homogeneous or heterogeneous chip integration.

Therefore, chips are able to have higher performance and chip makers are able to lower the overall fabrication cost, while also simplifying the process steps and lowering the error rate.

At the heart of innovation: FOPLP technology

The development of low density fan-out, platforms to encompass the requirements of potential new applications such as the 5G, AI & IoT.

Fan-out continuously moves towards more and more homogeneous or heterogeneous multi-chip module integration into a single package. Thus, the larger fan-out package size will be the trend to achieve a more complex form of multi-chip integration to have more powerful performance.

FOPLP is attracting most attention as it brings economies of scale due to the large size of the panel and higher carrier usage ratio of 95 %. The ratio is much higher than that of wafer size FOWLP (carrier usage ratio of 85 %), and enables higher-volume production of large packages. Currently, FOPLP is based on two major technologies: FPD and PCB production process and equipment.

On the downsizing circuit board, chip package size decreases, but all chips are still able to be integrated and thereby decreasing the area taken up by the circuit board, which also decreases the size of the end product. On the other hand, the reduced area on circuit board can be used for other electronic components. FOPLP technology not only supplies end products with higher efficacy, it also provides higher cost-efficiency.

From 2019 to 2024, the CAGR of FOPLP is expected to reach more than 40.3 %. The estimated overall market size in 2024 will reach 460 million USD. This attracts players with many different business models, including outsourced semiconductor assembly and test (OSAT), integrated device manufacturers (IDMs), foundries, substrate manufacturers and FPD players. They perceive an opportunity to enter the advanced packaging business via fan-out technology.

Semiconductor manufacturers

Take the IDM and foundry for example: by integrating with the packaging, it is a beneficial commercial model to provide an entire chip package. In terms of packaging manufacturers, they can apply their existing experience to quickly incorporate FOPLP technology. The aim of investment is to find its potential cost benefit and to enhance product competitiveness.

PCB and FPD manufacturers

Simultaneous design and development of chip, packaging, and PCB are becoming more important. The lithography processes tools that have been developed for the production of printed circuit boards and flat panel displays can be applied to the FOPLP RDL process on large rectangular substrates as well. PCB and FPD manufacturers are able to reduce manufacturing costs by utilizing tools and process know-how.

* Data source: Research institute Yole Développement

### FOPLP PRODUCTION SOLUTIONS

<table>
<thead>
<tr>
<th>Substrate-less package</th>
<th>Homogeneous or heterogeneous multi-chip module integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>By using RDL process as foundation, drawing the needed RDL from the die does not require a substrate, nor does it need a wire-bond, and the package thickness can be decreased, if forming multiple dies simultaneously, the package can have multiple or even several dozen times more functions, this reduces the package thickness when multiple chips are stacked! Furthermore, simplifying the fabrication process also lowers material costs.</td>
<td></td>
</tr>
<tr>
<td>IC 1</td>
<td>IC 2</td>
</tr>
</tbody>
</table>

### Fan-out package

**Transparent glass**

* Carrier shape could be round or square, and its material could be glass, transparent glass, or other semiconductor materials

* Data source: Research institute Yole Développement

<table>
<thead>
<tr>
<th>Productivity increase that can be expected:</th>
</tr>
</thead>
<tbody>
<tr>
<td>In panel processing, the number of dies populated on a panel is much greater than the number of dies populated on a wafer</td>
</tr>
<tr>
<td>Production increase that can be expected:</td>
</tr>
<tr>
<td>The 300 mm square carrier corresponds to 1.4 times the 12” wafer carrier</td>
</tr>
<tr>
<td>The 600 mm square carrier corresponds to 5.7 times the 12” wafer carrier</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Higher carrier usage ratio, higher manufacturing efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>In panel processing, the number of dies populated on a panel is much greater than the number of dies populated on a wafer</td>
</tr>
</tbody>
</table>

Fan-out package can be attained. 

All mounted dies are KGD

KGDs are attached to the carrier and then encapsulated in an epoxy molding compound. By completing the following processes, e.g. Cu RDL, bump formation, carrier debonding, and package singulation, etc., the fan-out package can be attained.
Advanced packaging technology has shifted from wafer to rectangular carriers, such as glass panels or PCB, etc., resulting in a productivity advantage. Manz has extensive experience in PCB and FPD lithography process equipment (panel format) as well as fully integrated manufacturing solutions. This enables us to support fine L/S patterning on the panel, thick-resist lithography, panel handling capabilities, etc. and efficiently adapt to the FOPLP business.

Integration of diverse technologies
Manz has both process and equipment manufacturing expertise and unparalleled material and semiconductor knowledge. This combination of in-depth knowledge and capability is harnessed by Manz FOPLP Solutions to provide all the right tools for the panel business.

Integration of cross-field equipment
Manz’s R&D expertise not only involves the development of customer-specific/standardized tools, but also sees itself as a development partner. This efficient and state-of-the-art production solutions, which integrates all the required technologies, supports its customers in defining their own process parameters, shortening development times and ensuring their success.

Strong independent R&D strength
Manz has rich process and equipment manufacture experience, and with continuous research and development, its application in new markets of different disciplines is based on diverse core technological expertise. We are dedicated to extend our knowhow in the FOPLP area and help manufacturers to efficiently integrate the production chain and optimize their processes.

Coater
Wet chemistry tools:
- Electroplating tool
- Developer
- Stripper (horizontal or vertical)

Coater
RDL process equipment
- Coater
- Photomask
- Carrier removal
- Electroplating tool
- Developer
- Stripper (horizontal or vertical)

TOTAL PRODUCTION SOLUTIONS WITH DIVERSE TECHNOLOGICAL EXPERTISE

Wet chemistry
- Lithography process tools for high-density RDL process
- Cleaning / developing / etching / stripping / electroplating
- Vertical or horizontal types
- Write as batch types

Automation
- Modular solutions to automate production
- Total integrated solutions including wet chemistry, laser, and testing tools.

Coating
- Photoresist coating
- Photoresist stripping

Automation
- Vertical or horizontal types
- In-line or batch types

Laser processing
- Laser cutting / drilling
- Laser scribing / slit
- Laser lift-off of Pl film

Automation
- Laser direct imaging (LDI)
- Laser ablation

Integration of diverse technologies
Manz FoPLP Solutions

Wet chemistry tools:
- Electroplating tool
- Developer
- Stripper (horizontal or vertical)

Coater
RDL process equipment
- Coater
- Photomask
- Carrier removal
- Electroplating tool
- Developer
- Stripper (horizontal or vertical)
Manz FOPLP production solutions

WITH 8,000 TOOLS INSTALLED OVER THE PAST 30 YEARS FOR THE FPD AND PCB INDUSTRY, MANZ HAS MASTERED LITHOGRAPHY PROCESSES AND ELECTROPLATING SYSTEMS TO ACHIEVE A HIGH DENSITY OF RDL IN THE ADVANCED PACKAGE. OUR RELENTLESS R&D ACTIVITIES EXTEND NOT ONLY TO WET CHEMISTRY, BUT ALSO TO LASER, COATING AND AUTOMATION TECHNOLOGIES. THIS ENABLES MANZ TO OFFER INTEGRATED SOLUTIONS THAT CAN BE USED IN PRODUCTION FOR DIFFERENT SIZES, MATERIALS AND PROCESSES OF FOPLP TECHNOLOGY.

Wet chemistry
- Highly customizable tools in vertical, horizontal, in-line, and batch types.
- Highly integrable with Manz automation handling systems to enhance process capability and automatic production.
- Real-time monitoring of chemical components for processing quality control.
- Outstanding etching rate and uniformity realized by precision configurations of multiple nozzle and efficient chemistry transfer system.
- Plating uniformity >90%, via filling performance <20um.

Laser processing
- Laser drilling and ablation applicable for various substrates and materials, such as PI, epoxy, ABF, etc.
- Applicable for Through-Mold-Via (TMV) and Through-Glass-Via (TGV) laser drilling process.
- Offers a range of modular features and fully automated system assists which enable to shorten the actual commissioning time and ramp up production.
- Excellent optic designs and enable to collocate different laser sources to develop corresponding solutions for different applications.

Automation
- High flexibility and customization ability to satisfy client demands.
- A powerful multi-scale feature integration ability that captures customer requirements accurately.
- Low breakage rate and high yield.
- Allows PC/PLC control and propriety SCADA system.

Coating
- Excellent uniformity ≤2.5 %.
- Unique syringe pump design for excellent spray reproducibility >99.9 %.
- Coating pressure stability of under 0.15KPa.
- Two platforms of inline stage type/ gantry type.
- Supply air suspension system to effectively avoid the process variation.
- Slit coater is able to combine cleaner, developer, exposure tool and automatic handling systems which make up Manz Track Line lithography solution. It effectively reduces production variability as well as improves the process yield.

Founded in 1987, Manz AG is a global high-tech equipment manufacturing company. In addition to the CIGS stub turnkey production line in the Solar segment, the company focuses specifically on the automotive industry in the Electronics and Energy Storage segments.

The company, listed on the stock exchange in Germany since 2006, currently employs 1,600 people in eight countries.