FOWLP and Flip Chip Cost Comparison: Impact of the Supply Chain Crunch

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Agenda

➢ Introduction
➢ Process Flows
➢ Cost Comparisons
➢ Yield Comparison
➢ Summary
INTRODUCTION
The question of which packaging technology is the best choice will always exist

- Mature versus new technology can be particularly interesting

Some factors to consider when choosing a packaging technology

- Technical requirements
- Size requirements
- Supplier capabilities
- Cost

The right packaging choice is the one that meets design requirements at the lowest cost

- 5 years ago, a FOWLP versus flip chip cost comparison was already carried out – But pricing has changed since then
- Global pandemic → Supply chain issues → Mature technology price increases
Cost Components of each Activity

- The time required to complete the activity
- The amount of labor dedicated to the activity
- The cost of material required to perform that activity – both consumable and permanent material
- Any tooling cost
- The depreciation cost of the equipment required to perform the activity
- The yield loss associated with the activity
## Cost vs. Price

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
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<tbody>
<tr>
<td>Direct Cost</td>
<td>Measured Cost – May be done at the activity level or at the factory level</td>
</tr>
<tr>
<td>Indirect Cost</td>
<td>Factory cost that is not directly associated with an activity. Support, quality, manufacturing engineering, utilities, plant, etc.</td>
</tr>
<tr>
<td>Overhead</td>
<td>Company cost that needs to covered. Typically G&amp;A, marketing, engineering, etc.</td>
</tr>
<tr>
<td>Profit Margin</td>
<td>Usually a percentage on total cost</td>
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<tr>
<td>Risk Factor</td>
<td>A higher than usual margin allocated to new technologies</td>
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</tbody>
</table>

Cost models are used to estimate this directly.

While all 4 of these vary widely, their total is driven to a level of consistency by the market. They are usually applied on top of direct cost as a % and per manufacturing object.
Typical Flip Chip Process Flow

1. BUMP WAFER
2. WAFER MOUNT & DICE
3. SUBSTRATE CREATION
4. DIE BOND
5. UNDERFILL
6. ATTACH LID / HEAT SPREADER
7. BGA BALL ATTACH & REFLOW
8. SINGULATE (if Strips)
9. INSPECTION / TEST
10. TO BURN IN TEST

Typical Wire Bond Process Flow

1. WAFER MOUNT & DICE
2. WIRE BOND
3. ATTACH LID / HEAT SPREADER
4. SUBSTRATE CREATION
5. ENCAPSULATION
6. BGA BALL ATTACH & REFLOW
7. SINGULATE (if Strips)
8. INSPECTION / TEST
9. TO BURN IN TEST

A lot of steps can occur here, depending on substrate complexity.
Typical Chip-first Face-down FOWLP

- SEMICONDUCTOR PROCESSING
- WAFER PROBE
- WAFER MOUNT & DICE
- PLACE DIE ON TAPE ON CARRIER
- BUILD RECONSTITUTED WAFER WITH MOLD
- REMOVE FROM CARRIER
- REDISTRIBUTION LAYER
- UNDERBUMP METALLIZATION
- BACKGRIND
- BALL ATTACH & REFLOW
- SINGULATION
- INSPECTION / TEST
- TO BURN IN TEST

Chip-first face-up and chip-last FOWLP are other variations on the process, not shown.
➢ Flip chip and wire bond have two discrete processes: substrate and assembly

➢ FOWLP is a process that essentially combines substrate and assembly processing into one

➢ Major cost drivers
  • Wire bond
    ▪ Package size
    ▪ Substrate structure
    ▪ Wire count & wire material
  • Flip chip
    ▪ Package size
    ▪ Substrate structure
    ▪ Cost of bumping the incoming wafer
  • FOWLP (chip-first face-down)
    ▪ Package size
    ▪ Number of imaging steps (number of RDLs)
COST COMPARISON
➢ Design details that impact cost
   • Package and die size
   • Layer count/substrate structure
   • I/O count, wire count and other wire details
   • Does the incoming die need to be bumped or not
   • Many others

➢ Isolate one variable at a time to test its impact on cost

➢ Costs included in the following charts
   • Direct costs of packaging
   • Costs to prepare the incoming wafer (add bumps, dice, etc.)
   • Overhead/indirect costs
   • Profit margin
   • 1 RDL (FOWLP), 2L substrate (FC and WB)
- FC and WB data labelled “standard” is based on average prices prior to 2020

- FC and WB data labelled “2021” is based on pandemic pricing, specifically around the first half of 2021

- No pricing is truly standard
  - Different volumes and customers can command very different pricing from the same supplier for a similar product
  - Pre-pandemic and pandemic prices here are as comparable as possible, in terms of comparing a similar volume/end customer in all cases
Changing Package Size: FC vs FOWLP

Changing Package Size for a 4x4mm Die

Package Cost ($)

Package size (mmxmm)

- Fan-out
- FC - Standard
- FC - 2021
FOWLP was cost-effective until only about a 6x6mm package prior to the pandemic.
FOWLP appears cost-effective until about an 8x8mm package with recent flip chip price increases.
Changing Package Size: WB vs FOWLP

Changing Package Size for a 4x4mm Die
Assume same design requires extra 1mm in WB

FOWLP Package size (mmxmm)

- Fan Out
- WB - Std Au
- WB - Std Cu
- WB - 2021 Cu
- WB - 2021 Au
Changing Package Size: WB vs FOWLP

A standard WB package with copper wire always appeared cost-effective compared to FOWLP in the past, but at the smallest package tested here, they are similar based on recent pricing.
A standard WB package with gold wire appeared cost-effective compared to FOWLP around the smallest package tested here, but FOWLP appears more cost-effective up to a 7x7mm package with recent price increases.
Changing Die Size: FC vs FOWLP

7mmx7mm Package - Varying Die Size

Package Cost ($) vs Die size (mmxmm)

- Fan-out
- FC - Standard
- FC - 2021
FOWLP was competitive at this package size for only a large die in the past, but may be competitive up to a 3x3mm die with recent FC price increases.
- Yield is an important component of cost

- FOWLP cost model considers defect density, not a set yield number (like assuming all packages, regardless of size, have a 99% yield)
  - Upcoming charts are labelled low, medium, and high yield, since we can’t label them with a specific yield number

- Following charts assume a $1 die is being packaged in all cases
Changing FOWLP Yield: FC vs FOWLP

FOWLP Yield Sensitivity

Package Cost ($)

5x5 6x6 7x7 8x8 9x9 10x10

Package size (mmxmm) for a 4x4mm die

- FC Standard
- FC 2021
- Best Yield
- Medium Yield
- Low Yield
Changing FOWLP Yield: FC vs FOWLP

Here is the original crossover point with standard FC and FOWLP at high yields.

Lower yields shift this by almost a full package size.
Lower yields shift this by a full package size.

Here is the original crossover point with recent FC pricing and FOWLP at high yields.
 ➢ FOWLP, FC, and WB packages have different cost drivers

 ➢ Selecting the right package for a design is already complex
   • Supply chain issues further complicate this decision

 ➢ Pricing changes driven by the pandemic make FOWLP appear cost-effective versus mature technologies in more scenarios than before

 ➢ Yield considerations can also shift the cost-effectiveness of FOWLP, regardless of whether we’re considering old or recent pricing