Fan-out IC Packaging Trends Impact On Equipment Capital Structures

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Quality Solutions in Silicon Packaging & Assembly
Supply Chain Squeeze

PCB with Embedded Silicon

WLAN Combo

BB/Modem

ASE GROUP

AP

TSMC

Amkor Technology

Unimicron

IBIDEN

Kyocera

Samsung

TTM Technologies

Daeduck

Nanya

StatsChipPAC

JCET

SAMSUNG ELECTRO-MECHANICS

SHINKO
Fan Out Adoption

• What is fan out
  – Its structure
  – How it is unique

• What obstacles exist
  – Lost OSAT’s Revenue Streams
  – Depreciation is replacing Material Costs
    • Asset utilization becomes the most critical KPI

• How can the equipment supply chain enable greater user profitability
  – Lower cost processing
  – Faster Payback
  – Fungability
What is Fan-out

Laminate based BGA

Today

Tomorrow

Embedded Wafer Level BGA

Form Factor Interconnect Size, Cost

leadframe

BGA

Flip Chip

Fan Out

Source: Infineon
fcCSP with Substrate Structure

Substrate can be
(1) glass reinforced dielectric (MCG BT, Hitachi E679) or
(2) Build up film (Ajinomoto ABF)

Changing Dynamics
- Substrate suppliers are doing more packaging (embedding silicon)
- OSAT customers are consigning substrates

• Mat’l: 60-75%
  – Subs: 50-70%
• Labor: 10-15%
• Depr: 15-30%
Fan-out Build Up Structure

Changing Dynamics
- Companies with fab infrastructure enter packaging space
- Asset utilization becomes much more important

• Mat’l: 20-25%
• Labor: 15-20%
• Depr: 40-65%
Cost per Transistor is Rising

![Graph showing decreasing cost per million gates as technology node decreases, with a note indicating 28nm may become the optimal cost node.](image-url)
Fan-out Process Flow Fab Polymer & RDL Wafer-based

1. Wafer Tape to Carrier
2. Die (Active side down) to Wafer Tape
3. Compression Molding of Mold Compound over Die
4. Wafer Tape Separation and Removal
5. Rotate 180º
6. Apply Polymer 1
7. Photo Define Vias and Build Up RDL 1
8. Apply Polymer 2 and Photo Define UBM vias
9. Plate UBM Pads
10. Place Solder balls
11. Package Singulation
Smartphone Platform Package Adoption

- **Front End Modules**
  - NAND
  - SCSP
  - SIP
  - Mobile DDR
  - Multiband/mode Transceiver

- **Mobile Peripherals**
  - WLAN Combo (WiFi/NFC/BT)
  - PMIC
  - Audio Processor
  - GPS
  - Application Processor
  - Baseband Processor
  - Display Touch-Screen
  - Touch Screen Controller

- **Core Components**
  - Camera
  - MEMS Sensors
  - Multiband/mode Transceiver
  - FC PoP
  - FC CSP
  - QFN®
  - WLCSP
  - MLF®
  - fcCSP
  - fcBGA
  - WLCSP
  - MLF®
  - Audio Processor
  - PMIC
  - WLAN Combo (WiFi/NFC/BT)
  - Application Processor
  - Display Touch-Screen
  - Touch Screen Controller

2018
Package Trends & Positioning

![Package Trends & Positioning Diagram]

- **I/O**
  - 850
  - 750
  - 650
  - 550
  - 450
  - 350
  - 250
  - 150
  - 50

- **Body Size**
  - 3 mm
  - 5 mm
  - 7 mm
  - 9 mm
  - 11 mm
  - 13 mm
  - 15 mm

- **Components**
  - DC/DC PMIC
  - General PMIC
  - Audio Codec
  - WLAN Combo
  - Cellular PMIC
  - BB/Modem
  - Modem FCBGA-333 Qualcomm MDM9625M

- **Brands**
  - A-CPU PoP-1155 Apple/TSMC

2018
Fan Out Adoption

• What is fan out
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  – Lost OSAT’s Revenue Streams in Material Value Add
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• How can the equipment supply chain enable greater user profitability
  – Lower cost
  – Faster Payback
  – Fungability
Asset Intensive Operations

• Wire bonders and chip attach machines generate $$ the moment they are plugged in
  – Like planes in the air

• Platform commonality makes operations, maintenance and planning easy

• What fuels their economic engine now?
  – Profit per X | Jim Collins, Good to Great
  – Profit per Seat or Profit per Asset
Cost Influencers by Major Process

- Substrate margins at risk as end customers begin consigning
- FanOut competitiveness also impacted

![Diagram showing process flow for Wire bond CSP, fcCSP, Fan-out WLP, and WLCSP with different stages like Final Test (FT), P&P+T&R, BG+L+S, and 3Msk RDL.]

**Acronyms**
- DP: Die Prep (back grind, saw)
- BG: Back grind
- LS: Laser saw
- DA: Die Attach
- WB: Wire bond
- M: Over mold
- P&P: Pick & Place
- T&R: T&P+Tape & Reel
Discounting Depreciation Can Give Positive Cash Flow

- fbGA positive at ~0.75
- Fan-out positive at ~0.45
Players by Trace/Space Design Needs

- DC/DC PMIC: 50-150
- Cellular PMIC: 20 to 40
- WLAN Combo: 5 to 40
- Audio Codec: <1
- General PMIC: <1
- BB/Modem: <1
- AP: 2-5 w/TSV
- HBM*: 2-5 w/HBM
- NAND: 5 to 40
- * Could drive need for 2.1D Substrates or alternative interposer packaging method

WLCSPs fcCSP or FOWLP Stacked NAND

*2018 SiPAQ Confidential – 15
Package Trends & Positioning

I/O

Body Size

5 mm 7 mm 9 mm 11 mm 13 mm 15 mm

3 mm 5 mm 7 mm 9 mm 11 mm 13 mm 15 mm

Bump DC/DC PMIC General PMIC Audio Codec WLAN Combo Cellular PMIC

fcCSP WLCSP WLAN Combo BB/Modem AP

2018
Package Trends & Positioning

- **Package Convergence**
  How to find the best balance of form factor and IO count to achieve low cost and low risk.

- Increasing I/O
- Reducing Costs
- Leveraging Assets

Body Size

I/O

- fcCSP
- Bump
- WLCSP

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• How can the equipment supply chain enable a shift
  – Lower cost processing (i.e., faster throughput, lower equipment costs, equipment longevity, panel and circle)
  – Faster Payback
  – Fungability
What Can Change to Drive Agents

• Equipment Providers
  – Faster equipment throughput
  – Lower cost clean room environmental requirements
  – Longer equipment life
  – Lower cost Equipment

• OSATs
  – Seasonal pricing strategies (for managing capital intensive businesses)

• IC Suppliers
  – Greater ownership over Laminate Substrate supply chain and elimination of GM stacking
## Risks – An OSAT Perspective

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Laminate Substrate Interposer</th>
<th>Typical IC Packaging</th>
<th>Fab-based Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation</td>
<td>Low</td>
<td>Mid</td>
<td>High?</td>
</tr>
<tr>
<td>Fungibility (i.e., Control Risk)</td>
<td>High</td>
<td>Mid</td>
<td>Low?</td>
</tr>
<tr>
<td>Payback Period</td>
<td>1-3 months</td>
<td>&lt; 2 Years</td>
<td>&lt; 3 Years</td>
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<tr>
<td>OSAT Cares</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GM Markup</td>
<td>0-15%</td>
<td>17-25%</td>
<td>25-35%</td>
</tr>
<tr>
<td>IC Supplier Cares</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead-times</td>
<td>Long</td>
<td>-</td>
<td>Short</td>
</tr>
<tr>
<td>Material obsolescence risk</td>
<td>High</td>
<td>-</td>
<td>Low</td>
</tr>
<tr>
<td>GM Markup on Substrate</td>
<td>0-15%</td>
<td>17-25%</td>
<td>25-35%</td>
</tr>
</tbody>
</table>
Intevac’s MATRIX® PVD – Advanced Packaging

- Lowest Cost of Ownership
  - Highest Throughput
    - 240 300mm UPH
    - No robot or queue constraints
    - Capable of 90% UE
  - Smaller factory footprint
  - Lower material waste
  - Improved yield from reduced ESD on die-first products
  - Convert sputter material type or product form factor in under 2-hours
  - Proven 30-year time in the field
Intevac’s MATRIX® PVD

- Ability to sputter on anything provides greater fungibility and unique competitive solutions

- Challenges: Getting OSATs to understand the ‘squeeze’ and need for new mindset
  - Need an alternative infrastructure to compete against TSMC and more ‘substrate/pcb’ like
  - Find a way to qualify faster with no risk of downtime
  - Providing the end market with dual sourcing
Relative Cost – Flip Chip vs Fan-out

• The larger the influence of the interposer becomes in the package design, the more disparity between Fab-based and Laminate Substrate becomes.
• Equipment depreciation comes off the books

Die Size

Body = Die Size + 0mm (WLCSP)

Body Size

Higher $

Lower $

Die Size + 0.25mm

Die Size + 0.5mm

Die Size + 1.0mm

Die Size + 1.5mm

Die Size + 2.0mm

Die Size + 2.5mm

Die Size + 3.0mm

FanOut[1ML]

Source: Amkor Technology
Creator: Jon Woodyard
Change Agents – Throughput and Longevity

- Substrate costs also continue to drop
- Substrates may get eventually consigned

Source: Amkor Technology
Creator: Jon Woodyard

Die Size vs. Body Size

WLCSP

Body = Die Size + 0mm (WLCSP)

Die Size+ 0.25mm
Die Size+ 0.5mm
Die Size+ 1.0mm
Die Size+ 1.5mm
Die Size+ 2.0mm
Die Size+ 2.5mm
Die Size+ 3.0mm

Higher $  vs.  Lower $
Substrate Costs Continue to Drop

- Aggressive pricing
- Lower layer counts (1 ML)
- Less encumbered by change control restrictions
## Financials & Resulting Influencers

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Laminate Substrate Supplier</th>
<th>OSAT</th>
<th>Foundry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue</td>
<td>2-3 Billion</td>
<td>4-6 Billion</td>
<td>&gt;30 Billion</td>
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<tr>
<td>Capital Expenditures</td>
<td>13-17%</td>
<td>15-20%</td>
<td>&gt;30%</td>
</tr>
<tr>
<td>SG&amp;A % of Rev</td>
<td>4-7%</td>
<td>5-7%</td>
<td>3%</td>
</tr>
<tr>
<td>R&amp;D % of Rev</td>
<td>2.5-3.5%</td>
<td>4%</td>
<td>8-9% ($3B)</td>
</tr>
<tr>
<td>Gross Margin</td>
<td>9-16%</td>
<td>17-22%</td>
<td>50%</td>
</tr>
<tr>
<td>Op Margin</td>
<td>5-10%</td>
<td>5-10%</td>
<td>40%</td>
</tr>
</tbody>
</table>
What is Fan Out

- A Semiconductor package with a Fab-based substrate platform
- An Asset rather than Material-based substrate platform
- OSATs gain revenue streams but asset management risk

Obstacles, Risks and Concerns

- Laminate solutions take revenue streams and get more cost competitive
- Depreciation costs escalate
- Profit per Asset becomes most significant KPI

Enabling a Transformation

- Understand customers Business as well as Technical concerns
- New Infrastructure is great but obstacles must be overcome
- Understand change control restrictions
Thank you