Opportunities to Move Up the Value Chain... an OSAT Perspective

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ASE Group
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Overview

- Industry Dynamics and Opportunity
- ASE Overview
- Key Trends
- Growth Opportunities
- Enabling Factors
- Summary
Industry Dynamics

- Value chain consolidation – supply chain re-verticalization
  - Software / service providers developing hardware platforms
  - System OEMs & software /service providers establishing IC design capability
  - Creating differentiated platform solutions through system integration and optimization

- Moore’s Law slowing
  - Cost/transistor increasing for advanced process nodes
  - High development, design and tooling cost
  - Enabling alternative integration paths to SoC

- Convergence acceleration
  - Mobile, wearable and IoT system products driving functional integration and miniaturization
  - Functional modules optimized for performance, power and form factor
  - Focus on energy, efficiency, connectivity
  - Reduced time to market / revenue
  - System BOM simplification

- Growing need for differentiated packaging solutions to facilitate system integration, miniaturization, optimization and cost reduction
An emerging market – System in Package

A Differentiated Packaging Solution

- System in Package (SiP) will see exponential growth as systems integration, miniaturization & power density trends continue.

Source: ASE estimates

- Semiconductor: \(~\$330B\)
- Board Assembly: \(~\$700B\)
- OSAT: \(~\$26B\)
- Electronics: \(~\$1.8T\)
SiP/SiM is a package or module that contains a functional electronic system or sub-system that is integrated and miniaturized through IC assembly technologies.
SiP/SiM: Broad range of potential applications

Where Are The Key Growth Focus Areas?

- Touch
- Sensor
- Wireless
- Storage
- Power Management
- Camera Module
- RF Front End
- Lighting
ASE’s Role in the Manufacturing Value Chain

Vertical Integration Capabilities

- Material
- Assembly
- Wafer Bumping / Probing
- Foundry
- Integrated Circuit Design
- Engineering Test

Module Board Assembly & Test (DMS)
Final Test

Services Offered by ASE Group
Leverage Capability to Enable OEM Drivers

OEM
System Integration

Various functional devices optimized for SiP

Storage
SSD in computing

Processor
FPGA/CPU for data center

Display
Camera in smart devices

Power Management
PMU in electric vehicle

OSAT
SiP Manufacturing: OEM’s Enabler
Applications Driving Growth Through 2018

Source: Gartner, June 2014 “Semiconductor Forecast Database, Worldwide, 2Q14 Update”
Note: Y axis cut off at 0% for clarity, so some major markets like Desktop PCs do not appear in the chart as they have negative CAGR
Areas of Growth Potential for SiP – Power Markets

- **Motor drivers**
- **EV/HEV vehicles**
- **White goods**
- **hi fi audio**
- **Uninterruptible power supplies**
- **Power management for PCs**
- **Power management for Wireless items**
- **Blade servers**

**Power (Watt):**
- 1G
- 100M
- 10M
- 1M
- 100k
- 10k
- 1k
- 100
- 10

**Frequency (Hz):**
- 10
- 100
- 1k
- 10k
- 100k
- 1M
- 10M
- 100M

**Sectors:**
- **High Power**
- **Medium Power**
- **Low Power**
Power Market Trends

- Power applications span a huge space with differing requirements with respect to performance, cost, and size.
- The low power application space is driving form factor reduction, functional integration etc.... in high volumes.
- Higher power densities, faster switching speeds, and higher thermal requirements are pushing packaging technologies such as embedded die package (SiP) and Power Stack.
- These new packaging technology alternatives drive the need for new enabling technologies.

- Interconnects
  - Limit performance losses
- Package Construction
  - Better thermal management
- Materials
  - Smaller form factor
- Enable heterogeneous integration
Power Packaging Focus Areas for Growth

Leveraging the need for SiP/SiM type packaging.....

- 2013 worldwide power semiconductor ~ $15bn:
  - Discrete ~ $11.5bn, module ~ $4bn.

- Discrete market commoditized / limited growth, but module market is projected to grow at 11% CAGR (transportation, renewable energy, EV/HEV & industrial motor drivers)

- IGBT is the major power module device type with ~$3.3Bn. Highest volumes in the 400v – 1300V space.
  - IGBT market split by package type: ~20% Discrete, 8% IPM, and 72% Modules
## Power Packaging Focus Areas for Growth

Leveraging the need for SiP/SiM type packaging.....

<table>
<thead>
<tr>
<th>Focus</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Discrete</strong></td>
<td><em>Discrete</em> power devices, usually packaged as traditional TO-220, TO-247 pkg</td>
</tr>
<tr>
<td><strong>Modules</strong></td>
<td>Modules contain <em>single power circuity</em> type such as MOSFET, IGBT module</td>
</tr>
<tr>
<td><strong>Power Integrated Modules</strong></td>
<td>Power modules contain <em>multiple power circuitry</em> in single housing. Mostly <em>IGBT</em> Based</td>
</tr>
<tr>
<td><strong>Intelligent Power Modules</strong></td>
<td>Power modules that combine power transistor with <em>control and protection circuity</em> in single housing. Mostly <em>IGBT</em> Based</td>
</tr>
<tr>
<td><strong>Power Stacks</strong></td>
<td><em>Multiple power modules</em> mounted on heat sink with driver and protective sensors and external components such as capacitor banks and interface terminals</td>
</tr>
</tbody>
</table>
Enablers for SiP in the Power Market

- Many possible combinations based on diverse market space:
  - Business Model
    - Ownership and Support
    - Investment strategy – across all areas below
    - Turnkey Levels and Scale
  - Technology
    - Knowledge Base
    - IP
    - Design and Analysis Capabilities
  - Collaboration/Partnering
    - Customers
    - Supply Chain/Competitors
    - Industry Consortia / Universities
    - Standards Organizations
  - Services Integration
    - Vertical and Horizontal across Mfg, Bus, Tech, Support functions
**Business Models & Competitive Landscape**

- Vertical integration is prevalent for players in the power space.
- Discrete power semiconductor companies also expand their product portfolio to the module manufacturing.
- There are also specialized power module makers.

The opportunity is to complement existing customers and non-vertically integrated players with technology and services that address power packaging trends while also enabling flex capacity to larger players.

<table>
<thead>
<tr>
<th>Vertical Integration</th>
<th>Module</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Die</td>
<td>Die + Module</td>
<td>Die + Module</td>
</tr>
<tr>
<td>Module</td>
<td>Modules + System</td>
<td>Modules + System</td>
</tr>
<tr>
<td>Module Maker</td>
<td>System Maker</td>
<td>System Maker</td>
</tr>
</tbody>
</table>

- Die: Mitsubishi, Fuji, ABB, Hitachi, Toshiba
- Module: Fairchild, IR, IFX, STM, Vishay
- System: Danfoss, Electoviprymitel, Semikron, Powerex, IXYS, Vincotech, Schneider, Yaskawa, Siemens, Alstom

Source: Yole, 2013
Enabling Technologies for SiP/SiM

**Shielding**
- Board or package level
- Compartmental

**Thermal Management**
- Board or package level
- Compartmental

**Passives / IPD**
- Integrated Passive Devices

**Interconnection**
- Flip chip (MR & TCB)
- Wire Bond

**Antenna**
- Package integration for 2.4G/5G/60GHz

**Molding**
- MUF
- Exposed die

**SMT**
- Passives
- Components
- Connectors

**Wafer Bumping / WLP**
- Leadfree / Cu Pillar
- Bare die package

**Embedded Technology**
- Passive component
- Active device

**IEEE 802.11ac**
- Die thinning
- Die interconnect
- Die attach

**Mechanical Assy**
- Laser welding
- Flex bending
Collaboration

- Customer Road Map & Requirements Early Involvement
  - Identify Needs, Timing, and Potential Areas of Partnering
    - Business Requirements
    - Development activities
    - Infrastructure Requirements
    - Process/Equipment/Material Capabilities
    - Qualification Requirements

- Supply Chain
  - Materials
  - Equipment
  - Piece Parts/BOM materials
  - Assurance of Supply (Sourcing, Disaster Recovery, other risk mitigation strategies)
Collaboration

- **Others**
  - Leverage involvement in Standards organizations, Consortia, University and 3rd Party driven efforts

<table>
<thead>
<tr>
<th>Packaging Challenges</th>
<th>Key Factors</th>
<th>Current Solution</th>
<th>Emerging</th>
<th>Potential Breakthru</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Die Interconnect</strong></td>
<td>Resistivity</td>
<td>Al wire bonding</td>
<td>Al ribbon/ Cu wire bonding</td>
<td>Sintering Joint</td>
</tr>
<tr>
<td></td>
<td>Thermal Conductivity</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Lifetime</td>
<td></td>
<td></td>
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<tr>
<td><strong>Die attach</strong></td>
<td>Thermal cycling capability</td>
<td>Eutectic/Lead free Solder</td>
<td>Ag u-powder sintering</td>
<td>Nano powder sintering</td>
</tr>
<tr>
<td></td>
<td>Temperature of operation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manufacturability</td>
<td></td>
<td></td>
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<tr>
<td><strong>Substrate attach</strong></td>
<td>Thermal performance</td>
<td>DBC + Substrate</td>
<td>DBC to heat sink only</td>
<td>Micro-channel cooling</td>
</tr>
<tr>
<td></td>
<td>Size / Volume reduction</td>
<td></td>
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source: Yole 2013
Collaboration: SiP/SiM Design Flow

Fine tune for performance improvement & BOM reduction

Circuit Design

Performance Tuning & FA

Component BOM Selection

Assembly BOM Selection

Substrate Layout

High Density SMT
Collaboration: SiP/SiM Test Services

Test Strategy Consultation
• What tester to use?
• What/when/how to test?
• Test limits determination

Test Fixture Design & Turnkey
• Socket, PCB
• Shielding
• Automation tooling

Test Program Development
• Wireless connectivity
• KGD wafer sort, final test
• Handler test controller

Ramp up / Continuous Improvement
Data analysis
Yield Learning
Test time reduction
Failure mode analysis

Test Strategy Consultation
Test Fixture Design & Turnkey
Test Program Development
Ramp up / Continuous Improvement
Leverage Enablers and Value Chain

Enable electronic systems developers to achieve higher levels of functional integration and miniaturization

- Test
- Assembly
- Customer & Partners
- Supply Chain
- Substrate
- EMS/DMS
- Consortia

Financial strength & investment
Manufacturing capability & scale
Extensive packaging & systems knowledge base
End to end engineering services
Technology Development
Turnkey management & logistics services
Rapid time to market
Linkages to standards & technology drivers
Changing Industry Landscape

- Value Chain Consolidation is changing the industry:
  - Innovation, investment approaches as well as supply chain models.
- Specialized solutions for varying market spaces are driving complexity in terms of the number of approaches and choices needed to get an appropriate solution that satisfies both business and technical drivers.
- Need for Collaboration in the form of standards, IP, and strategic partnerships (investment and sourcing) that are necessary for transitions to new markets.
- Opportunities in the space between traditional OSATs and EMS providers will allow for further growth through leveraging capabilities and knowledge from both ends. Having the right capabilities, scale, flexibility and financial wherewithal to make it happen will be key.
Thank You

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