Advancement in System in Package

Nozad Karim  l  VP, SiP Product Line
Welcome to the 2nd SiP Conference China 2018

▶ 2018: Focused on Smartphone, Wearables, IoT and Automotive
  ▶ SiP Business and Technology Trends
  ▶ SiP Enabling Technology
  ▶ Advancement in SiP Test Solution
  ▶ Advancement in SiP Materials
  ▶ Advancement in Automotive SiP

▶ 2019 and beyond, it will depend on you – we need your thoughts, opinions, suggestions and help
Conference Technical Sessions

SiP Business & Technology Trends
Consumer & Automotive System Solution

SiP Technology Trends
SiP Test solution
Advanced material & Assembly for Automotive

SiP Solutions
SiP Assembly Test Solution for Automotive

Panel Discussion
Exhibit Hall Reception
Entertainment by local cultural dance/music teams

Shanghai at Night

Closing Statement and glimpse of SiP Conference China 2019
Agenda

- Transformation to SiP
- Advanced SiP Market Segments
- SiP Solutions
- Mobile SiP
- Conclusion
Known Good System or Sub-System

- System on Chip
- Known Good Die
- Probably Known Good Die
- Known Good Sub-System
- Known Good System
Enabling the Future Transformation to SiP

- System integration & miniaturization
- Performance enhancement
- Effective compartmental and conformal shielding
- System level testing
SiP Miniaturization: System Size Reduction

Area (X,Y) Reduction
- Bare die and WLCSP
- Passive components; 01005 & 08004
- Advance design rules
- Doubled sided mold and assembly

Height (Z) Reduction
- Thin substrate
- Mold strip level back grinding
- Thin die and thin die spacer
- Thin mold cap
Concurrent SiP Design

- Design for cost
- Design for signal and power integrity
- Design for power reduction
- Design for electromagnetic compliances
- Design for thermal performance
- Design for mechanical constrains
- Design for manufacturability
- Design for test
- Design for reusability
- Strong collaboration with design teams
  ▶ Customer, suppliers, EDA tools, library,…
Advanced SiP Market Segments
Digital Data – Follow the Data

Data Centers → EDGE IT → Internet Gateways → Connected Devices

BY 2020

- AVG. INTERNET USER
  - 1.5 GB OF TRAFFIC/DAY
- AUTONOMOUS VEHICLES
  - 4 TB OF DATA/DAY
- AIRPLANE
  - 8 TB OF DATA/DAY
- SMART FACTORY
  - 1 PB OF DATA/DAY
- CLOUD VIDEO PROVIDERS
  - 750 PB OF VIDEO/DAY

Annual IP Traffic ~20 ZB

Driving Massive Data → 50 Billion Devices

Video ~75% of mobile data traffic by 2023
Major Package Trends

Mobility
- Ultra thin, small
- Integration, SiP
- 5G
- Envelope tracker
- AR/Streaming

IoT
- Miniaturization, SiP
- Integration, MEMS
- Security
- Power – Connected
- Home/Factory/Auto

Automotive
- Reliability G0/G1
- Integration, SiP
- 5G
- ADAS – Connected
- Infotainment, ECU

HPC/Networking
- Performance
- Integration, SiP
- Thermal, Power
- AI/AR
- Data center/Cloud
2017 Amkor End Markets

**43% COMMUNICATIONS**
- Smartphone
- Tablet
- Handheld Device

**26% AUTOMOTIVE & INDUSTRIAL**
- Driver Assist
- Infotainment
- Safety
- Performance

**18% COMPUTING**
- Data Center
- PC/Laptop
- Infrastructure
- Storage

**13% CONSUMER**
- Television
- Set-Top Box
- Personal Electronics
“The Big 5” Packaging Platforms

- **Chip Scale to Fan-Out**
  - Wafer

- **MEMS**
  - Laminate, LF & Now Wafer

- **Flip Chip (CSP or BGA)**
  - Laminate

- **Heterogeneous Integration**
  - Laminate or Wafer

- **System in Package**
  - Laminate
Expansive Wafer Level Packaging Toolkit
WLFO System Integration
High integration density, small size

Chip Scale to Fan-Out

Wearable

WLSiP – 8 x 8 mm²
Fan-Out Evolution to HDFO

**Fan-Out**

- **Wafer Level Fan-Out**
  - Single or multi-die (SiP)
  - Single layer lithography
  - Mobile & automotive centric

**High-Density Fan-Out**

- **Advanced SiP**
  - Enhanced electrical performance
  - Improved thermal performance
  - Advanced die to die connectivity

**“Advanced Fan-Out”**
MEMS

- IoE, wearables & industrial
  - Sensor fusion
  - Low power, form factor & cost
  - System & functional integration
    » Many die, broad packaging toolkit required

MEMS

Laminate, LF & Now Wafer
Flip Chip Technologies

▶ Enables all advanced packaging
▶ A mature technology
  ▶ Cost reduction & profile focus
  ▶ Density/Integration increasing
  ▶ Amkor’s enabling LAB technology proliferating
FCBGA/Adv SiP Process Flow

1. Laser Groove/Wafer Saw
2. Chip/Component Placement + Reflow + Deflux
3. Underfill
4. Lid Attach
5. BGA + BGA Side Caps + Reflow + Deflux

Flip Chip (CSP or BGA)
Laminate
FC Migration to Wafer Based Modules

- **Flip Chip Package**
  - CSP or BGA
  - Laminate

- **2.5D TSV Package**

- **PoP with fan-out architecture**

- **High-Density Fan-Out (HDO)**
  - HDFO on Substrate

- **Flip Chip**
  - CSP or BGA

- **Laminate**
HPC Needs in Data Center

- Higher performance
  - Higher bandwidth memory (e.g. HBM-2)
  - Move memory “close” — lower latency
  - Higher memory capacity (weights, look-up tables)
- Lower power
- IC fab yield improvement by die-splits
- IP reuse and higher I/O counts
Laminate Based SiP

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2016</th>
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<td># Components</td>
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<td># SiP Packages</td>
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Mobile SiP

Amkor Technology

PROPRIETARY/CONFIDENTIAL
Mobile Communications Market

- Maturing handset market
- Growth in select areas
  - Connectivity, RF, Sensors
- System complexity driving SiP
- 5G rollout is potential disrupter

(Unit sold in millions)

Source: IDC, McClean, GFK, Amkor
SiP Volume in High-End Smartphones

- **Galaxy S5 LTE-A**
  - 2% SiP

- **Galaxy S6**
  - 11% SiP

- **Galaxy S7**
  - 18% SiP (9/62)

- **Galaxy S6**
  - 11% SiP

- **iPhone 6S**
  - 20% SiP

- **iPhone 7**
  - 22% SiP (15/69)

- **iPhone 8**
  - 15% SiP (12/81)

- **iPhone X**
  - 22% SiP (12/54)

* Excluding: Camera modules, fingerprint sensors, microphone & MEMS
Mobile SiP

- Mix-Mode Controller
- Touch Screen Controller
- Application Processor
- Baseband Processor
- FEM: Antenna Switch, Filter, Duplexer, LNA & PA
- Mobile NAND & DDR
- WiFi/BT/GPS
- Sensors & MEMS
- Battery
- PMIC/Battery Charger
iPhone X Main Board

- SiP: 47%
- WLCSP: 38%
- Others: 16%
- None Shielded: 8%
- Shielded: 92%
System in Package (SiP)

Drivers of adoption
- Package level integration
- Faster time to market
- Miniaturization & cost

Amkor capabilities
- High volume manufacturing
- Innovative electronic shielding
- Advanced technology & design rules

Amkor: Increasing the Value

<table>
<thead>
<tr>
<th>RF-Front End Module</th>
<th>Connectivity Module</th>
<th>Controller Module</th>
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MEMS
WLCSP
Flip Chip
Compartmental Shielding
Passives Components
Pre-packaged
Wire bond
Stacked Die
System Integration & Miniaturization

Top side assembly

Bottom side assembly

Conformal shielding

Compartmental shielding
Technology Discriminators

- Double sided assembly DSBGA
- Double sided mold DSMBGA
- Embedded passive & active components
- Conformal & compartmental shielding
- Thin substrate
- Passive components (01005, 008004)
Amkor SiP Module Portfolio

- Compartment shield
  (Vertical & cage wire)
- Dual side mold
- Embedded active device
- Conformal shielding
DSMBGA Key Development Items

- **Gap between die and ball**
  - Much lower gap than DSBGA

- **Mold technology**
  - Thin die and mold cap

- **Pkg edge gap**
  - Narrower gap than non-molded

- **Strip grinding**

- **I/O reveal**
  - Ball exposed mold with TMV®
EMI Shielding – Compartment Shielding

- HVM with Cu wire bonding method compartment shielding
- Ongoing development for various type of compartment shielding
  - Cage by wire
  - Wire fence & vertical wire with strip grinding method
Reliability Test Result for (008004) Components

Reliability test result (# RR386394)
  Pass all items

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5G SiP

5G NR
- Antenna array integration
- Conformal shielding
- Partial molding
- System test

Computing and Networking
- 100 Gb/s + switching
- Low capacitive interconnects
- Design methodology
- Processor and 3D memory integration
Technology Toolbox – Antenna Platforms

- Antenna on substrate
- Antenna in package
- Passive component assembly
- SIP mmWave antenna module
- Partial molding
- Passive/filter integration
- Wafer level
- Antenna in package
- Antenna on mold
Advanced SiP – Best-in-Class Manufacturing

Automation

Material Management

Inspection

Process
Amkor has a full suite of technologies to enable future product needs.

**Mobility**
- Flip Chip
- WLCSP/Fan-out
- MEMS & Sensors
- Substrate SiP
- Wafer SiP

**IoT**
- Flip Chip
- WLCSP/Fan-out
- MEMS & Sensors
- Substrate SiP

**Automotive**
- FCBGA
- MEMS & Sensors
- Substrate SiP

**HPC/Networking**
- FCBGA
- Substrate SiP
- Wafer SiP

Conclusion
Thank You