OSAT Production Testing of 5G, Power Discrete & 3D Packaged ICs

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Agenda

1. Test Markets
2. 5G
3. Power Discrete
4. 3D IC
Test Markets

Mobility, Communications & RF

Automotive

Power SiC & GaN

Advanced Packages 3D IC

Test Technologies are Evolving in all Markets
Agenda

1. Test Markets
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4. 3D IC
RF Technology Application Use Cases

**Indoor**
(Low Power)

- Tx
- Rx
- Rx
- Tx

1. Wi-Fi, BT, NFC, IoT
2. Carrier frequency
3. Bandwidth
4. Power at FC: Operational range
5. Number of users
6. Interferences

**Outdoor**
(High Power)

- Tx
- Rx
- Rx
- Tx

1. Cellphone 3GPP, BS, satellite
2. Carrier frequency
3. Bandwidth
4. Power at FC: Operational range
5. Number of users
6. Interferences

All RF Technologies, All Package Types, Including AiP
5G Test Transition & Challenge

1G-4G

RF 600 MHz ~6 GHz
- Filters
- Switch
- PA
- FEM
- Attenuators

1G 1981
2G 1992
3G 2001
4G 2011
5G 2020

2.4 GHz & 5.8 GHz bands

Internet of Things

LoRa
Source: lora-alliance.org
~800 MHz band

WiFi™
Source: wi-fi.org
2.4 GHz & 5.8 GHz bands
802.11 A, B, G, N, AC

2.4 GHz band

zigbee
Source: ezzigbee.com
2.4 GHz band

Bluetooth™
Source: bluetooth.com
2.45 GHz band

GNSS, GPS
~1.5 GHz band

Latency & Speeds (BW)
5G Test Transition & Challenge

4G
FR1

NB Internet of Things

3GPP – FEM, SW/Trans. PA, LNA, Ant. 100 MHz – 800 MHz BW

Source: wikipedia.org

802.11ad/ay (57-66 GHz), ~2 GHz BW: Transceivers

Source: analog.com

FR2

4G

Wi-Fi 6,7
802.11ax/be
1024…4096 QAM
160-320 MHz BW

Source: broadcom.com

Skyworks
Sky5

5G NR ultra high band Tx, Rx, MIMO, BT, GPS, Wi-Fi, ant: Mux, ant tuning SW, PA

Large product volumes

Source: qualcomm.com

Ultra-low Latency, Multi-Gb Throughput, High Connection Count

5G

Automotive Radar

Automotive (76-81GHz), 0.6-4 GHz BW; transceiver
RF 5G & mmWave Band Segmentation

Amkor RF Products in All Bands!
Amkor’s DSMBGA RFFE

- Double sided component attach
- Double sided mold
- Conformal & shielding
- RFFE: LNA, PA, switch, filters & duplexers
- Production test
5G Broadband Products

- Switches
- Transceivers
- Attenuators
- Amplifiers
- FEMs
- Diplexers
- Base Station + User Equipment
- WLCSP, LGA, BGA
- Antenna Integration
Production Test Challenges

5G is Forcing All Aspects of Production Application Design to Evolve
Agenda

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2021-2027 Power SiC Devices by Market Segment

Source: Yole Intelligence March 2022
# Power Technology Target Specifications

**IGBT, MOSFET – Si, SiC, GaN Single & Modules**

## Pathfinding/Definition/Development vs. Deployment

<table>
<thead>
<tr>
<th>Perf Attribution</th>
<th>Si (1.1eV)</th>
<th>GaN (3.4eV)</th>
<th>SiC (3.2eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC $V_{CE}$, $V_{BE}$, $I_D$, Gain, $R_{DS-ON}$, Temp</td>
<td>~100V, nom power density, efficiency</td>
<td>~150V, med-power density, efficiency</td>
<td>~1800V, high power density; high efficiency</td>
</tr>
<tr>
<td>AC Frequency, $I_{Pulse}$, $C_g$, $T_{On}$, $T_{Off}$, UIS, $T_{rr}$</td>
<td>Nom SW frequency</td>
<td>Hi SW frequency</td>
<td>Med-high SW frequency</td>
</tr>
</tbody>
</table>

### Higher Power, Higher Thermal Considerations During Product Test
Power Technology Target Specifications

Test Flow

- **Wafer Probe**
  - Post probe – packaging or die sales or WLBI

- **Burn-in**
  - Package level burn-in process qualification

- **Final Test**
  - Package level final test & QA flow

- **System Level Test**
  - Application-level test

- **Post Test**
  - EOL package, dry, ship

- **In production (today)**
  - Final test & post test
  - Max envelope: 900V/10A-75V/160A

- **Explore**
  - Probe, burn-in, system level test
  - Wider discrete, modules
  - Max envelope: >2000V/700A
## Test Equipment Suppliers

<table>
<thead>
<tr>
<th>Teradyne</th>
<th>UNITES</th>
<th>PowerTECH</th>
<th>SPEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tesec</td>
<td>AccoTEST</td>
<td>Microtest</td>
<td>Focused Test</td>
</tr>
<tr>
<td>ADVANTEST</td>
<td>LEMSYS</td>
<td>Shibasoku</td>
<td>CREA</td>
</tr>
</tbody>
</table>
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Amkor Multi-Die Package Technologies

Die Disaggregation to Allow Higher Levels of Integration!
Amkor Package Assembly Topologies

Amkor Technology, Inc.
Production Test Challenges

- No direct access
- Radiative access
- Digital system bus protocol

Die 2 interface physically
- A: Pinned out
- B: Not pinned out
Production Test Methodology – DFT

- Functional & structural test content
  - BIST, SBFT, scan – IEEE 1149.x, 1500, 1687, 1838

- Digital test instrumentation features

- Concurrent testing
3D IC Test View

CPU (logic), GPU, DDR/HBM die

Test challenge: Interconnects – substrate, interposer, die-to-die

Source: IEEE1838-2019
3D IC Test Challenge

► Power
  ▶ Cu pillar & µbump – contact resistance

► Signal
  ▶ Capacitive loading for signal & ground
  ▶ Crosstalk & increased noise in Si substrate
  ▶ Insertion loss & return loss – via/bump interface

► Thermal
  ▶ Interconnect/underfill layers
  ▶ End-of-the-line layers
  ▶ Bulk silicon
  ▶ µbump
  ▶ Heat sink

Call for Action
  ▶ Production test simplification
  ▶ Standardization
  ▶ Enable re-use
Production Test – Impact to Test Flow

Single chip production test flow

Wafer Probe → Packaging → Final Test → Burn-in (Reliability) → Final Test/QA → SLT → Post Test

Alter Test Flow
Test Content Re-distribution
Platform Level Test Quality
Summary

- Multi-die packages allow for denser integration
- Business continues to have economic and performance challenges
- Call to action – advanced test methods
- Amkor is the industry leader in advanced packaging and production test solutions
Amkor Test Services

24/7
Operation of fully networked test floors

Accurate and Thorough Test Services
Wafer probe, final test, strip test, film frame test, system level test, opens/shorts test, burn-in and complete end-of-line

Full End-of-Line Processing
Bake, scan, pack, ship and finished good services

Test Development
Software & hardware for probe, strip, final and system level test

Testing for Commercial, Industrial & Automotive Devices
Discrete, power, mixed-signal, memory, RF, MEMS and SiP devices

>3,600 Testers in 7 Locations
3,000 + Amkor, 600 + consigned

Tested Annually
10 Billion units
7-9 Million wafers

Test is an integral part of the overall Amkor business
Over 40 years of Automotive test experience

amkor.com/test-services
Thank You

Vineet Pancholi, Vineet.Pancholi@amkor.com
Learn more ▶ amkor.com/test-services/
Abstract: OSAT Production Testing of 5G, Power Discretes & 3D Packaged ICs

- The presentation will be segmented into three. OSAT production testing challenges of three vital product families that are important to our semiconductor industry will be showcased in each segment. The first segment will describe the products and impacts to RF production testing of both Sub-8GHz carrier frequency range and the mmWave frequency range of operation. The second segment will explore emerging MOSFET technologies that enable faster switching rates and higher voltage and current topologies. The third segment will describe the challenges of production test content for 3D-stacked advanced packages.

- 5G RF has enabled mmWave carrier frequencies, small cell deployment, massive MIMO (Multiple In, Multiple Out), beam forming, and full duplex wireless transmission and reception operations. These features require new production test methodologies.

- There is an astronomical rise in battery powered applications like toys, consumer goods, automotive and trains. Power path turn on/off with MOSFETs is in the critical path. The technology has advanced from the traditional Si to GaN and SiC based products that have a smaller size and allow for higher application efficiencies. Test specifications and limits are improving and production testing methods are evolving to account for these changes.

- Advanced packaging has enabled the path to integrate chiplets within a single package. Heterogeneous Integration (HI) is a powerful design innovation that allows tighter integration and, in some cases, improved signal and power performance at the system level. Production test methodologies are being streamlined to make test a competitive advantage for our customers.