Power Modules Packaging Technologies & Market

May 28th – ECTC 2012
Power is everywhere!

Power Range of the targeted applications

1kW - 100kW

0 - 1GW+

- Wind Turbine
- PV inverter
- Rail traction
- Ships & Vessels
- Grid energy T&D
- Motor drive
- UPS
- EV/HEV
- Power supply / PFC

Compatible with GaN/Si technology

Compatible with GaN/bulk-GaN and SiC technology
Power Electronics Market

Breakdown by device type (M$)

2006-2015 power device market size

Source: Yole Développement

- **Power discretes** = MOSFET, rectifier, IGBT, Bipolar....
- **Power modules** = IGBT, diode or MOSFET modules, IPM
- **Power IC** = power management IC: mainly voltage regulators (POL) and drivers
Power Electronics Value Chain

2009

Electronics Systems
$118 B

Semiconductor power devices
$16.4 B

Silicon wafers
$1.02 B

2015

Electronics Systems
$132 B

Semiconductor power devices
$24 B

Silicon wafers
$1.80 B

CAGR: +1.9%

CAGR: +8%

CAGR: +10%

Source: SIA + SEMI + Yole
Introduction to power module packaging

- Common failure in a power module is caused by thermal cycling
- Mismatching CTE make layers to detach one from the other
- Some gel filling also cannot handle high temperature

**In red: Common failure locations**
Improvements in packaging can be made in 3 different aspects:

- **Die interconnection**, which is searching for innovative wire bonding or no-wires connection for better lifetime and reliability
- **Die attach**, which uses new materials for better lifetime
- **DBC+baseplate**, which uses new materials and suppress layers for improved cooling and smaller size

All applicable to Si and SiC
### Analysis of innovation trends in packaging for power modules

<table>
<thead>
<tr>
<th>Current solutions</th>
<th>Emerging technos</th>
<th>Potential breakthrough</th>
</tr>
</thead>
<tbody>
<tr>
<td>Widely used by all players</td>
<td>At mass production and growing in market shares</td>
<td>At R&amp;D stage. Still too expensive</td>
</tr>
<tr>
<td><strong>Interconnection</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al wire bonding</td>
<td>Al ribbon bonding</td>
<td>Foil sintering Foil ultrasonic wedge bonding</td>
</tr>
<tr>
<td><strong>Die attach</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb/Sn alloy Or SAC alloy</td>
<td>Copper wire bonding</td>
<td>Nano powder sintering (no heating and pressure for attach process)</td>
</tr>
<tr>
<td><strong>Baseplate Cooling</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseplate + heatsink AlSiC for long lifetime Al2O3 for cost</td>
<td>Thermal exchange improvements:</td>
<td>Micro-channel cooling</td>
</tr>
<tr>
<td></td>
<td>• Shower power • DBC to heatsink (no baseplate)</td>
<td></td>
</tr>
</tbody>
</table>
EV/HEV is one of the biggest market for power electronics in 2020, according to all forecast.

The main challenges will include manufacturability, reliability and lifetime, but also integration and weight.

Module packaging is already a great challenge in EV/HEV:
- The market is potentially large enough to involved huge developments founds.
- The level of integration will lead to custom solutions and all integrated inverter.
- Footprint, size, weight and cost and are all strong technical drivers.
Power module packaging trend in EV/HEV

Industrial standard

Denso 2004/Honda 2006
- Standard packaging
- Wirebonding
- Baseplate – one side cooling

Honda 2010
- Epoxy packaging
- Cu lead bonding
- Direct substrate cooling

Toyota 2010
- Standard packaging
- Ribbon bonding
- Direct substrate cooling
- Today’s standard (2012)

Delphi 2010
- Single IGBT/diode packaging
- Flip-chip soldering
- Double side cooling
- Too expensive

Denso 2008
- Single IGBT/diode packaging
- Flip-chip soldering
- Double side cooling
- Too expensive

• Improved cooling
• Higher integration
Analysis of innovation trends in packaging for power modules

The main improvements aspects are each leading to different technologies, but breakthrough technologies are solving all these issues at the same time:

- Using double side DBC, with integrated cooling solves all the potential issues at the same time. But no production process is cost effective, and no standard is being studied yet.

Several technologies are closer in time or already used in high-end packaging:

- Direct cooling is becoming a standard and widely used. The most showing example is EV/HEV. There is no clear trend in wirebonding:
  - Copper wires seems on its way to become a standard, being developed by several players including Infineon and Danfoss
  - Semikron pushes for Ag sintering applied to interconnection, but we have to wait and see for the results
  - Denso is putting ribbon Al bonding in Toyota Prius modules
- Die attach solutions are on the same trends, between copper and Ag sintering.

The innovation is going to be pushed forward by EV/HEV players. They need better power electronics conversion systems to gain in added value. Smaller and easier to cool are the two drivers.
Your contact at Yole Développement

- **Lionel Cadix, PhD**
  - Technology & Market Analyst – Advanced Packaging Technologies
  - cadix@yole.fr
  - +33 4 72 83 01 92

- **Yole Développement is currently launching a brand new offer dedicated to power packaging including**
  - Technological analysis
  - Market metrics and supply chain analysis
  - IP and patent analysis