Power packaging 2015
For the coming years, expected trends are:

- Significant increase of automotive sector, following EV and HEV ramp-up
- Renewable energies and smart-grid implementation will drive industry sector ramp-up
- Steady erosion of consumer segment due to pressure on price (however volume will keep on increasing)
Two different technologies are used to assemble devices for power electronics:
- Discrete components
- Power module

One or the other technology is chosen thanks to system needs in terms of:
- Power
- Voltage
- Current
- Geometry
Roadmap of Power module technology toward higher integration and power density

Main targets are:
- a better cooling,
- a higher integration,
- and a higher frequency.

**Toyota 2010**
- Standard packaging
- Ribbon bonding
- Direct substrate cooling

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

**Delphi 2010**
- Single IGBT/diode packaging
- Flip-chip soldering
- Direct substrate cooling

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

**Mitsubishi 2014**
- Six Pack IGBT/Diode Package
- Cooling fin
- Thick Copper layer for thermal spreading
- Direct substrate cooling

**Bosch 2013**
- Molded package
- Die on Leadframe
- Thick Copper layer for thermal spreading
- Direct substrate cooling
Power module market revenue, split by application

Power module market will double between 2014 and 2020.
BRIEF PRESENTATION OF DIFFERENT EXISTING SOLUTIONS

--- power module for electrified cars

- --- has developed its own power module and supplies inverter makers
- --- has special cooperation with ---: the company can modify IGBT to fit the power module
  - For example, --- uses a unique double-side soldering for IGBT in the power module
  - 650V/600A capability
  - On chip current sensor

- --- power module is specially designed for automotive applications
  - Molded Package
  - Chips soldered on massive substrate (copper) for enhanced thermal spreading and Tj
  - Thin Film Insulator
  - Temperature sensor inside the package
  - Inductance: 10nH
Soldering remains the main die attach technology but there are numerous suppliers of solder due to its easiness of production.

Sintering is a rather new market of strong interest thanks to properties of that solution.

<table>
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<tr>
<th>Company Name</th>
<th>Area</th>
<th>Main products</th>
<th>Comments</th>
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<td>USA</td>
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<td>The Netherlands</td>
<td>Equipment</td>
<td>Partnerships with --- and --</td>
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DIE ATTACH FOR POWER MODULE

Die attach material market share in 2014

- Eutectic die attach (also called diffusion soldering) and sintering are new processes of die attach enhancing reliability but they are far from having spread all over the market yet.

- In the future we expect Ag Sintering to grow to follow needs in reliability.
Die attach market size evolution in M$ between 2010 and 2020, split by application

Die attach market was almost flat between 2010 and 2012, but we expect it to grow strongly until 2020.
Power module packaging represented a ---M$ market in 2014

• In a power module, the materials costs for the packaging represents around 30 % of the power module bill of material in 2014. This share tends to decrease due to material cost and number of interfaces reduction.

• This share represents materials costs only and does not include:
  • Manufacturing costs (Materials processing)
  • Chassis materials (plastic molded, lead frames, busbar, various chassis sealants…)

ROADMAP FOR POWER MODULE PACKAGING

Die attach

- The main technology used nowadays for die attach is tin soldering
- For future applications, target is to increase temperature, and tin soldering maximum temperature is around 200°C
- Solutions that are developed aim to achieve higher temperature, but also increasing reliability and lifetime

- In the future we expect sintering to take an increasing market share, with materials evolving with time

**Key challenges for die attach are thermal handling, reliability and manufacturability**

**Usual technologies used by...**

- Tin soldering
- Eutectic soldering
- Ag sintering
- Film sintering
- Alloys soldering

**Ag sintering is already used by some players: we expect its market share to grow up by 2020**

**Eutectic soldering has been used since 2010 by big players such as Infineon; this innovative technology could grow in the future**

**Film sintering is the logical evolution after powder sintering: it allows module size reduction and easier handling with equivalent performances**

**Alloys soldering can be a good alternative for those who don’t want to switch to sintering, but developments are still to be done to use it at a large scale**

What evolution for discrete devices packaging?

- Discrete components packaging evolution is motivated by the same reasons as power modules:
  - Miniaturization
  - Power density increase
  - Yield/Efficiency increase

Key words for discretes are the same as for power modules: efficiency and power density increase.
DISCRETE DEVICES PACKAGING

Evolution in discrete bonding: copper-clip

- In power semiconductor packages, wirebond technology is the traditional way to make electrical connections between the silicon die and the leadframe.

- To reduce conduction losses, wirebonds have been eliminated: a copper strap or clip is soldered directly to the surface of the die and the leadframe. Copper clip large cross section reduces electrical resistance.

- Copper clip technology particularly fits with "dual-side cooling" packaging => stray inductance and electrical resistance are reduced, and thermal dissipation capacity increases.

Source: —
There are two main types of Wafer Level Packaging: Fan-In WLP (also known as Wafer Level Chip Scale Packaging) and Fan-Out WLP.

FIWLP is quasi-equivalent to Flip-Chip Ball Grid Array (FC BGA), except that there is an intermediate layer for FC BGA.

With Fan-In solution, ball grid array is implemented below the chip (nothing out of die surface).

Fan-Out solution is more flexible as the balls can be “larger” than the chip thanks to connections.

Source: Yole's report “Embedded dies and Fan-Out Technologies and Market Trends”
DISCRETE DEVICES PACKAGING

WBG semiconductors packaging, case study: ---

• During PCIM 2014 conference, --- companies presented their new device packaged: ---
  • 100V/60A in 5x5mm

• This device (considered as an embedded die) is one of the first ones to take into account WBG specificities in an efficient package

• GaN devices focus is a good strategy:
  • Planarity (integration)
  • Needs for good heat management
  • Promising future market

• Yole expects --- device to show the way for future WBG semiconductors packaging
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(1) Our Terms and Conditions of Sale are available at www.yole.fr/Terms_and_Conditions_of_Sale.aspx
The present document is valid 24 months after its publishing date: March 10th, 2015

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Branch code: 001
Account n°: 0170 200 1565 87
BIC or SWIFT code: CCFRRPRP
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