IGBT market and technology trends

2015 report

From Technologies to Market
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CHANGES FOR THE 2015 REPORT

New content in respect to previous edition

- 2nd IGBT Technologies and market report from Yole Développement
- New forecasts, extended from 2014 to 2020
- Market metrics and forecasts in Units (considering bare dies, discrete components or modules depending on the application)
- Segmentation modifications, stronger focus on evolution depending on the voltage
- Update on business models for IGBT manufacturing
- Focus on Chinese players and their business model and technologies
- Focus on IGBT technologies and architectures by player, with evolution from 1st generation to current generation
- Roadmap and future evolutions for IGBT architectures
- Focus on future evolutions for IGBT packaging
# MARKET SEGMENTATION

<table>
<thead>
<tr>
<th>Segment</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>EV/HEV powertrains and chargers</td>
</tr>
<tr>
<td>UPS</td>
<td>Data centers, hospitals, industries</td>
</tr>
<tr>
<td>Rail</td>
<td>Trains, metros and subways powertrains</td>
</tr>
<tr>
<td>Photovoltaics</td>
<td>Photovoltaics inverter and micro-inverters</td>
</tr>
<tr>
<td>Wind</td>
<td>Wind turbines inverters (on-shore and off-shore)</td>
</tr>
<tr>
<td>Motor drives</td>
<td>Industrial applications (lifts, HVAC, pumps, fans…), commercial motor drives</td>
</tr>
<tr>
<td>Industrial</td>
<td>Welding, Induction heating, Medical, Avionics and marine propulsion, Heavy duty vehicles…</td>
</tr>
<tr>
<td>Commercial</td>
<td>Consumer; White goods, Lighting, Cameras…</td>
</tr>
</tbody>
</table>

We focus on 6 key applications for power electronics and other ones with large volume market.

"IGBTs are used in…"

6 key applications for power electronics
YOLE METHODOLOGY

• Yole Développement uses mainly three different sources to best carry on this report:
  • **Internal knowledge**: Yole has been working in the power electronics industry for years now and we have acquired a deep understanding of the market and its trends and evolutions. We have created a rich internal data-base of figures and key contacts in the industry.
  • **Interviews**: We carry on an important number of interviews during the report production with key players of the industry all along the supply chain (dies and modules manufacturers, tiers 1 and 2, end users…).
  • **WSTS**: World Semiconductor Trade Statistics => access to raw data
Yole’s 2015 expectations for 2020 power electronics market are similar to 2014 expectations.
IGBT MARKET METRICS & FORECASTS

Evolution of the split by application between 2014 and 2020, in volume, for IGBT dies packaged as power modules

IGBT power module market growth will be driven mainly by EV/HEV

Those charts represent the split of bare dies packaged as power modules by application, thus depend on the amount of devices used by module. Split of IGBT power module by application is different.
IGBT MARKET METRICS & FORECASTS

IGBT market forecasts till 2020, in value and split by application

IGBT dies are used in a wide range of applications

IGBT market forecasts split by application, in value

- PV
- EV/HEV
- Wind
- Rail
- UPS
- Motors
- Grid
- White goods
- Consumer
- Welding
- Transportation (others)
- Others
- TOTAL
Split of IGBT dies per voltage in 2014, in volume and in value
IGBT MARKET METRICS & FORECASTS

Geographical point of view

- IGBT market is leaded by Asia, which represented more than 70% of the whole market in revenue in 2014
- Japan is still the leader, but followed closely by China
- Americas (including US) represented only 8% of whole IGBT market, despite their strong position in power electronics
- For high voltage IGBT (2.5kV and more), main markets are Europe and Japan

Whole IGBT market in 2014, geographical sales split, in value

Yole Développement – July 2015
ASP AND ASSOCIATED MARKET ANALYSIS

Evolution of market sizes and ASP with the time, depending on the voltage

1,200V and 650V IGBTs are expected to be the biggest markets by 2020, while 400V remains a niche market.
Different options to develop electrified vehicles

<table>
<thead>
<tr>
<th>Functions</th>
<th>SSV</th>
<th>Mild HEV</th>
<th>Full HEV</th>
<th>PHEV (with EREV)</th>
<th>EV (BEV or FCV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start/stop: Stop engine idles when a vehicle slows down and comes to a stop</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Regenerate braking</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Additional power for a few seconds (electric motor)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Additional power for mid distance (city traffic)</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Power for long distance (10 to 40 miles)</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Recharge of battery on the grid or with a generator</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Energy savings</td>
<td>5-10% (up to 25% in city traffic)</td>
<td>10-25%</td>
<td>25-50%</td>
<td>50-100%</td>
<td>100%</td>
</tr>
<tr>
<td>Electric power</td>
<td>3-8 kW</td>
<td>4-20 kW</td>
<td>30-75 kW</td>
<td>70-100 kW</td>
<td>70-100 kW</td>
</tr>
<tr>
<td>Car example</td>
<td>PSA C2</td>
<td>Honda civic</td>
<td>Toyota Prius</td>
<td>GM Volt</td>
<td>Nissan leaf</td>
</tr>
</tbody>
</table>
IGBT market for EV/HEV will be multiplied by 3 between 2014 and 2020.
IGBT FOR WIND TURBINES

Supply chain for wind turbines is already well established.
With a very strong local market, Chinese companies are entering the die manufacturing market. Nowadays, 1/3 of overall IGBTs are sold in China, which represents a $1B market. However, near 97% of IGBTs and related products are imported from abroad. Local manufacturers are trying to catch up with the technology gap between the leaders in the market and to make up with the increasing demand. For now their products are mainly used in low power applications such as air-conditioning or inductive heating.
IGBTs are now covering a wide range of voltage.

IGBT devices progressively entered all the voltage ranges and are now available from 400V to 6.5kV. At high voltage limit, IGBTs are facing wide band-gap devices competition. With strong developments of those technologies and their benefits, it seems that WBG have more advantages than IGBTs. Moreover, to achieve higher voltages, many IGBTs can be used in series. That's why we don't expect maximum IGBT voltage to increase in the future. Small voltage IGBTs have been developed in order to compete with SJMOSFET. Below 400V, IGBTs are starting to lose their advantages, and mainly MOSFETs are used.
TECHNOLOGY ANALYSIS

IGBT technology evolution and players involved

- 1985: PT (planar)
- 1988: NPT (planar)
- 1995: Thin wafer technologies
- 1997: Trench gate
- 1995: Trench FS
- 2002: CSTBT
- 2008: Trench FS (thin wafer)
- 2007: SPT+
- 2011: LPT-CSTBT (thin wafer)
- 2014: Advanced trench FS

The NPT IGBTs have a similar structure as power MOSFETs, except the fact that they have an injection P+ layer instead of a N substrate. On conduction state, this layer returns a reverse injection of minor carriers (holes move from the injection layer to drift region and emitter).

According to the neutrality principal of the electricity, this allows more electrons in the base, which means a better conductivity.

The name NPT is because the base (drift region) are profound enough to prevent depletion region from reaching in a cut-off state.
TECHNOLOGY ANALYSIS

----- technology evolution

PT
NPT
Trench gate
Field stop
Trench gate
Field stop
Trench gate
Field stop
Trench with
split gate

TrenchStop™
High Speed ?
High Speed 3 ?
TrenchStop™ 5

In the future, power modules will have been entirely reshaped, with the changes depending on the power targeted.

**Bosch example**
- Molded package
- Double side soldering
- Low inductance

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

**High-power modules**
- Encapsulation with parylene
- Ribbon bonding
- Silver (Ag) sintering for die attach
- Pin-fin baseplate

**Mid-power modules**
- Wide use of leadframe
- Over-molded package
- Top interconnections
- Ag sintering for die attach

---

**2014**

**2018**

**2020**

**2025**
PACKAGING FOR IGBT

Technology roadmap for embedded die, for power electronics

There are two main focuses seen in embedded technologies at the moment:

- Wireless/mobile market that created the first volume and is always looking for the best cost/form factor/performance trade-off is seeing tough competition from other packages. That is the market targeted by many companies, such as Unimicron, hoping to reach its very high volumes. This market is using low-power applications.

- Mid- and high-power applications (starting from 100W with Mosfets and going beyond several kW for IGBTs) market which has less volumes but has high needs for better heat management and less parasitics. These needs follow the trend of higher power density and better performance (frequency, power) of power devices, such as Mosfets, IGBTs and wide band gap devices.

- In the mid-/high-power applications, small dies packaging can have the same technology strategies as low-power applications (embedding at substrate level like Infineon DrBlade) but large dies see different strategies, such as Schweizer approach of embedding large dies directly at board level. The latter are very promising and already see some volume in the automotive market in Europe and USA.
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Credit Card Number: ____________________________
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Expiration date: ____________________________

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