POWER MODULE PACKAGING 2018: MATERIAL MARKET AND TECHNOLOGY TRENDS

Market & Technology report - July 2018

Power packaging is continuously adapting to power application market trends.

KEY FEATURES

- Presentation of detailed analysis of thermal interface materials (TIMs), thermomechanical issues in power modules and case studies and technological innovations
- 2017-2023 market value for the power electronics field and especially for power modules
- Complete analysis of power module packaging design
- Deep insight into each part of a standard power module package: substrate, baseplate, die attach, substrate attach, encapsulation and interconnections
- Technology trends and roadmaps
- 2017-2023 market metrics and forecasts for each type of packaging component (substrate, baseplate, die attach, substrate attach, encapsulation, interconnections and TIMs)
- Evolution of different business models
- Supply chain analysis and evolution trends
- Complete presentation of Wide Band Gap device packaging
- Packaging trends for the coming years

WHAT'S NEW

- Focus on packaging for Wide Band Gap devices
- Analysis of the newest power module designs, including the Tesla Model 3 power module, Mitsubishi J1-series and Infineon's HybridPack Drive
- Insight into emerging business models within the supply chain
- 2017-2023 market metrics and forecasts for thermal interface materials (TIMs)

THE IGBT POWER MODULE MARKET GREW 18.1% IN 2017, DRIVING THE POWER MODULE PACKAGING MATERIALS BUSINESS

2017 was an impressive year for the IGBT power module market, as it grew 18.1% compared to 2016. And so far, the perspectives for 2018 are even better, with over 20% growth in the first half of the year. The main explanation of this drastic market explosion is the boost from the electrical and hybrid electric vehicle (EV/HEV) sector, especially in China. It has also been an exceptional year for industrial motor drives in Asia.

Other device modules, like those based on MOSFETs and bipolar transistors, show a slight decrease. Consequently the overall power module market value ended at $3.54B, growing 11.3% year-on-year. By 2023 the market is expected to be over $5.5B. This promising market is beneficial for the packaging material business that Yole Développement (Yole) covers in this report, "Power Module Packaging 2018".

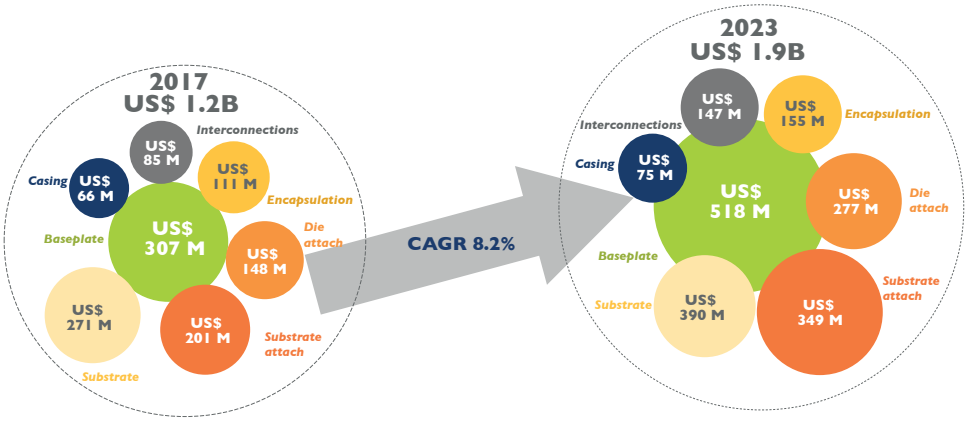
The power module packaging material business is worth $1.2B, a little more than a third of the total power module market. It is a very dynamic market, where continuous innovations and material enhancements and a lot of R&D investment are needed. This power module packaging material market's compound annual growth rate (CAGR) for 2017-2023 will be 8.2%, coming close to a $2B business opportunity by 2023.

In terms of technology, the report takes a deep look into substrates, baseplates, die-attach, substrate-attach, encapsulation, interconnections and thermal interface material (TIM) markets. Almost 50% of the current $1.2B market value is substrates and baseplates. Another 25% of that market is exclusively from die-attach and substrate attach materials. Major technological choice trends in these segments can therefore rapidly impact the power module packaging overall market.

For instance, the penetration of silver sintering as a die-attach technology is increasing among the industry, and even arriving in some EV/HEV power modules. As this technology is more expensive, the CAGR2017-2023 for the die-attach market is 11%, much higher than for the other market segments.

The second highest CAGR2017-2023 is for interconnections, at 9.5%. This is because new interconnection technologies, like flexible interconnection foils, are more costly compared to more cost-effective but less reliable aluminum wire-bonding. The other major technological change that will impact the global market will be an increasing use of silicon nitride (Si3N4) active metal brazing (AMB), which will capture 37% of the power module substrate market by 2023. As the demand for Si3N4 increases, its high cost is expected to decrease faster than the other ceramic materials.

Power module packaging: 2017 -2023 raw material market size per packaging part

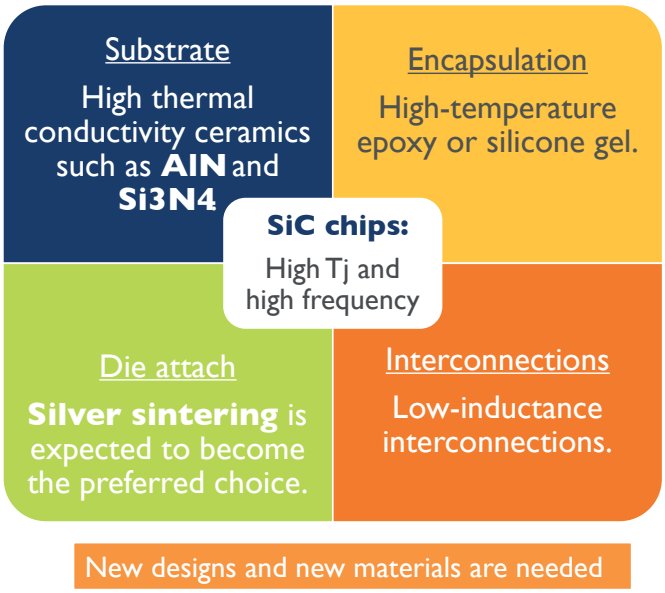


(Yole Développement, July 2018)

SILVER SINTERING, NEW SUBSTRATES AND INTERCONNECTION TECHNOLOGIES ARE THE LATEST INNOVATIONS DRIVEN BY EV/HEV AND THE ARRIVAL OF WBG

Technical trends in power module packaging are mainly driven by the entrance of the Wide Band Gap (WBG) materials and the challenging system requirements of the booming EV/HEV industry. Indeed, the introduction of the WBG semiconductors SiC and GaN is pushing the development of new power packaging solutions, as these devices can work at higher junction temperatures and higher switching frequencies with smaller die sizes.

SiC module packaging: Main technologies that will need to evolve



(Yole Développement, July 2018)

In order to take advantages of SiC's properties, reliable and robust die attach technologies that work at 200 °C are required. Silver sintering is today the big star for SiC power modules, due to its high melting temperature point, exceeding 900°C. In term of substrates, high thermal conductivity materials will be chosen such as AlN and Si3N4, as dies need to dissipate the losses from a smaller surface. In addition, the interconnection technology is a key factor for the good performance of SiC devices. Many companies are therefore developing their own low-stray inductance interconnections such as GE's Power Over Lay (POL) or Semikron's SKiN technology. In contrast, GaN devices are not yet packaged in power modules, and are using advanced packaging technologies. GaN Systems' printed circuit board-embedded GaN packages are the best example.

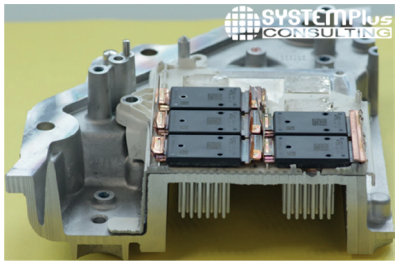
The EV/HEV industry's demanding requirements for high power density and mechatronics integration are driving many of the other power packaging innovations. Today, there are two clear trends: over-molded double-side cooled modules for hybrid cars and single-side cooled modules with pin-fin baseplates for battery-only electric cars.

This report summarizes other tendencies such as the use of organic insulator foils in insulated metal substrates (IMS) and the "integrated substrates" that merge a ceramic substrate and a pin-fin baseplate. With all these new technologies, the EV/HEV power packaging landscape is fast-evolving and dynamic. That is why Yole follows the leading packaging material suppliers like DOWA, Denka, Rogers and Alpha, and the module manufacturers like Bosch, Mitsubishi Electric and Semikron, very closely to quickly understand their future technology innovations.

NEW CHAPTERS: A WBG PACKAGING - TESLA'S MODEL 3 POWER MODULES - MITSUBISHI ELECTRIC'S J1 SERIES INNOVATIVE INTEGRATED SUBSTRATES

The Power Module Packaging 2018 report has several new features, including an entire chapter which focuses on WBG module packaging challenges, innovations and future trends. Yole has also introduced the TIM market and its forecasts as part of the power module packaging market, building on the 2017 report, where just the different TIM technologies were described. Yole's analysts have also now analyzed the Transient Liquid Phase Soldering (TLPS) technology as a future alternative to die-attach.

Example of STMicroelectronics' SiC MOSFETs modules in Tesla's Model 3*



* Extracted from System Plus Consulting report : Tesla Model 3 Inverter with SiC Power Module from STMicroelectronics, June 2018

Example of STMicroelectronics' SiC MOSFETs modules in Tesla's Model 3 reverse engineered by System Plus Consulting

(Yole Développement, July 2018)

An exciting, fresh, case study explores Tesla's Model 3 power module, which has been manufactured by STMicroelectonics and reverse engineered by System Plus Consulting. Similarly, photos and an explanation of Mitsubishi Electric's J1-series power module, with its very innovative integrated ceramic and baseplate pin-fin substrate design secrets. The Power Module Packaging 2018 report will bring you all these latest innovations and much more.

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TABLE OF CONTENTS (complete content on i-Micronews.com)

OBJECTIVES OF THE REPORT

- Highlight power module packaging market analysis and forecasts
- Provide a deep insight into state-of-the-art package designs and materials
- Describe the current packaging challenges for SiC and GaN Wide Band Gap devices
- Identify the key technology trends that will shape the market in the future
- Understand the main challenges and proposed innovations
- Deliver supply chain analysis and trends

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AUTHORS

As analysts within the Power & Wireless division at Yole Développement (Yole) Alejandra Fuentes Suarez, Dr. Milan Rosina and Mattin Grao Txapartegi co-authored the Power module packaging 2018: Material market and technology trends report:

Mattin Grao Txapartegi investigates power packaging solutions to analyze the latest technical challenges, market growth and competitive landscape. Getting a deep understanding of the technology evolution, the market trends and the strategies of each player are part of his mission at Yole. Previously he acquired a comprehensive expertise in the design of power converters for EV at Renault (France). As an engineer, Mattin graduated from Grenoble INP (FR) with specialization in embedded systems for transportation. He has also an advanced master in aeronautics from the Arts & Métiers ParisTech (FR).

Dr. Milan Rosina has 20 years of scientific, industrial and managerial experience involving equipment and process development, due diligence, technology, and market surveys in the fields of renewable energies, EV/HEV, energy storage, batteries, power electronics, thermal management, and innovative materials. He previously worked for the Institute of Electrical Engineering in Slovakia, Centrotherm (Germany), Fraunhofer IWS (Germany), CEA LETI in France, and utility company ENGIE in France.
Dr. Rosina received his Ph.D. degree from National Polytechnical Institute (Grenoble, France).

Alejandra Fuentes Suarez daily researches the latest developments in power converter topologies, passive components, power modules packaging and EV/HEV. Previously Alejandra acquired extensive expertise in the design of power converters for solar, wind, hydro and motor drive applications at Semikron (France). Alejandra graduated from UJF (Grenoble, FR) and INP (Grenoble, FR) as an electrical engineer, specializing in design of power electronics system. She also holds an advanced master's in the field of Marketing and Management of Energy from the Grenoble Business School (Grenoble, FR).

ASSOCIATED REPORT

Automotive Power Module Packaging Comparison 2018 - Structural, Process and Cost Report by SystemPlus Consulting

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CONTACTS

For more information about :

- Consulting & Financial Services: Jean-Christophe Eloy (eloy@yole.fr)
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