

STATUS OF THE POWER MODULE PACKAGING INDUSTRY 2021

Market & Technology Report - November 2021

EV/HEVs are transforming the power module packaging supply chain with the evolution of substrate, interconnection, and die-attach technologies. Lower cost is starting to win over higher performance.

WHAT'S NEW

- Update on key power module packaging trends
- Focus on SiC and GaN power device packaging
- Deep insight into power module substrates, technology trends, and supply chain
- Focus on power module packaging requirements for various applications
- Focus on China
- Focus on 800V battery - impact on power module packaging

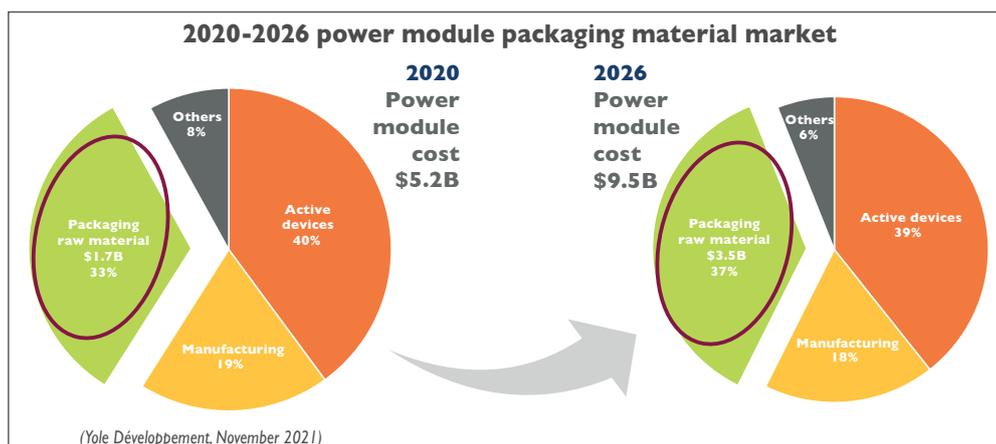
KEY FEATURES

- Overview of the main applications for power devices, along with their drivers and future trends
- Analysis of application trends' impact on package design and packaging material demand
- Detailed analysis of each packaging component, along with 2020-2026 market data
- Insight regarding crucial technology trends
- Analysis of the power module supply chain for devices and packaging components
- Analysis of power module packaging requirements for various applications including EV/HEV, rail, motors, wind, PV and UPS
- Analysis of impact of COVID-19 on the power electronic industry
- Focus on China

THE COST OF RAW MATERIALS FOR POWER MODULE PACKAGING WILL REPRESENT ABOUT 37% OF TOTAL POWER MODULE COST BY 2026

The power module is one of the key elements in power converters and inverters. The market for power modules will reach \$9.5B by 2026, with a 2020-2026 compound annual growth rate (CAGR) of 10.5%. In 2020, motor drives represented the most significant power module market with a value of \$1.6B. However, by 2026 electric and hybrid electric vehicles (EV/HEVs) will become the most significant power module market, representing a market value of almost \$3.6B. In case of raw materials for power modules, in 2020, the power module packaging

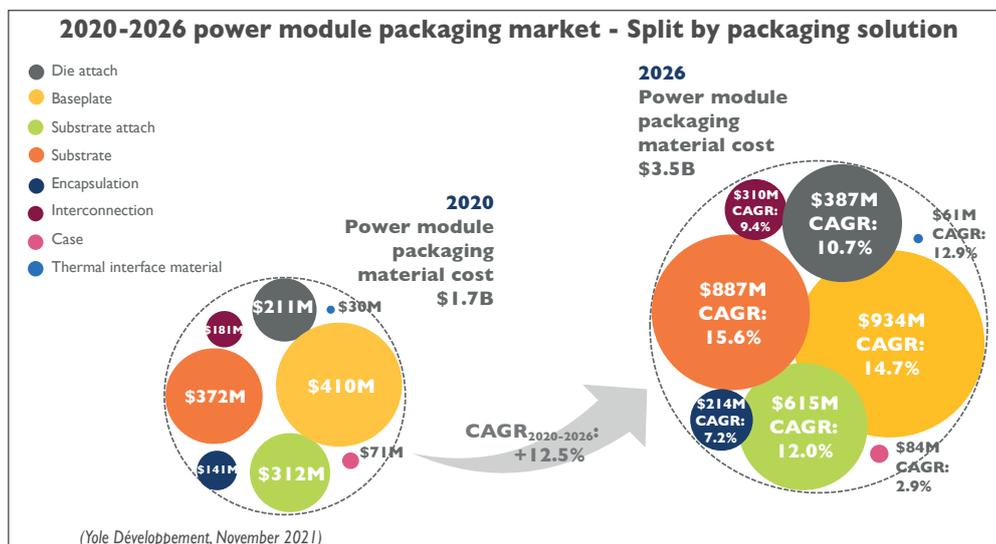
raw materials market was worth almost \$1.7B. The cost of raw materials for power module packaging represented about 33% of the total power module cost. By 2026, the power module packaging raw material market will represent around 37% of the total power module market. The market share of power module packaging raw materials is increasing as use of expensive power module packaging components such as silver sintering-based die-attach, silicon nitride active metal brazing (AMB) substrates are growing.



HOW WILL THE POWER MODULE PACKAGING MARKET REACH AN IMPRESSIVE \$3.5 BILLION MARKET VALUE BY 2026?

The power module packaging raw materials market is growing and will reach an impressive \$3.5B market value by 2026. This market's

promising outlook is beneficial for the power module packaging material business, which Yole Développement covers in this report.



This report looks closely at the substrate, baseplate, die-attach, substrate-attach, encapsulation, electrical interconnection, and thermal interface material (TIM) markets in terms of technology and market forecast. In 2020, the largest packaging material segment was for baseplates, followed by substrates. While other 28% of that market is represented by die-attach and substrate-attach materials. The major technological choices in

these segments can rapidly impact the overall power module packaging market. For example, the market share for silicon nitride as a substrate material (TIM) markets in terms of technology is increasing, driven primarily by EV/HEVs. This technology is pricier than more conventional aluminum oxide substrates. The 2020-2026 CAGR for the substrate market is 15.6%, higher than for other market segments.

EV/HEV APPLICATIONS INCREASINGLY DRIVE TECHNOLOGY TRENDS IN POWER MODULE PACKAGING

In the past, power packaging technology needs were driven by industrial applications. Today EV/HEV applications increasingly drive technology trends in power module packaging. The requirements for power, frequency, efficiency, robustness, reliability, weight, volume and cost of automotive power modules are often more severe than industrial products due to high vehicle safety standards and a harsh environment. Therefore, high power density and highly reliable power module packages are needed. Today, silicon-based modules are the standard power modules for EV/HEV systems. However, silicon carbide (SiC) semiconductors provide higher efficiency compared to silicon-based die. Therefore, SiC-based power modules are also gaining popularity in the automotive market. The introduction of SiC technology pushes the development of new power packaging solutions as SiC devices can work at higher junction temperatures and higher switching frequencies with smaller die sizes.

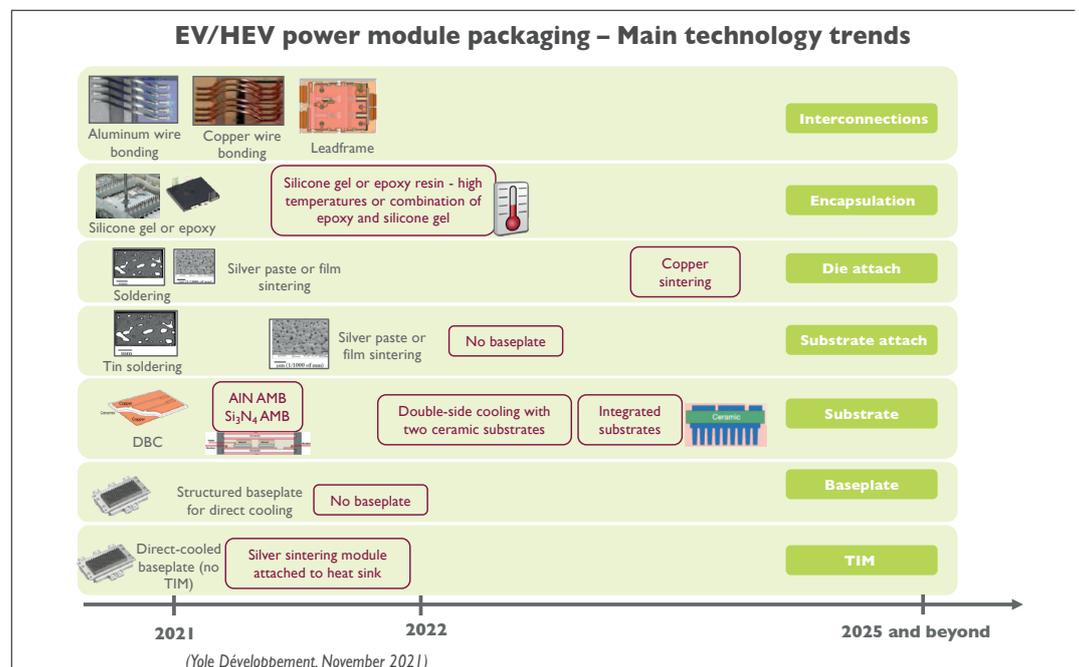
Power module packaging solutions are moving towards high-performance materials and reducing the number of layers, size, and interfaces while conserving electrical, thermal, and mechanical characteristics.

In terms of substrate, currently, the most common substrate for power module packaging is Al_2O_3

(DBC (direct bonding copper) metallized ceramic substrate. However, as shown in the report, the industry moves toward materials with better mechanical stability and higher thermal conductivity such as Si_3N_4 AMB (Active Metal Braze). The trend of double-side cooling with two substrates is also growing. To make the power module package thermally more stable and take advantage of SiC's properties, reliable and robust die-attach is required. Therefore, the use of silver sintering is growing. In addition, interconnection technology is a critical factor for the excellent performance of power modules. Even though aluminum wire bonding remains the mainstream, copper wire bonding will also be widespread. Wire-free modules using flexible interconnections or top lead frames will see considerable growth. Although the trend of double-side cooling with two substrates/lead frames is growing, single-side cooled power modules with pin-fins baseplate will also be preferred by many players

The vast business opportunity in the power module packaging market attracts interest from different players in the power electronics supply chains.

However, power module packaging technology is more than just wire bonding, soldering, and encapsulation. The packaging technologies, especially for applications with strong demand for



power density, performance and reliability are very complex and require specific know-how. Many newcomers in power module packaging have underestimated packaging complexity and are struggling to bring their packaging concepts to the commercial production. Initially they targeted performance and reliability. Nowadays, many players must refocus their development

efforts on manufacturing processes and material choices to achieve acceptable manufacturing yield and manufacturing throughput and reduce manufacturing costs. Therefore, external partners with the required know-how are more than welcome to speed up development and bring products to market earlier.

COMPANIES CITED IN THE REPORT (non exhaustive list)

Ametek, Avantor, Aismalibar, A.L.M.T. Corp., Alpha & Omega Semiconductor, Amkor, AOS Thermal Compounds, Almatiss, Aurel, Arlon, Amulaire, BYD, Boschman, Bosch, CRRC, CeramTec, CoorsTek, CPS Technology, Comelec Sa, Curtiss-Wright, CML Europe, CHT Group, Dupont, Denka, Dow, Dowa, Danfoss, Elkem, Electrolube, Ferrotec, Fuji Electric, Heraeus, HALA Contec, Hitachi Metals, Hitachi Chemicals, Henkel, Indium corporation, Infineon, Interplex, Japan Fine Ceramics Co. Ltd., KCC, Kyocera, KinWong Electronic, KISCO, Laird, La Chi Enterprise Co. Ltd, MacDermid Alpha Electronics Solutions, Momentive, Merck, Maruwa, Muller Ahlhorn, Mitsubishi Electric, MacMic, NGK Insulators, Namics, ON Semiconductors, Plansee, Powerex, Parker, Parylene Coating Services, Renesas, ROHM Semiconductor, Rogers Corporation, Shin-Etsu, Suzhou Kary Nanotech, Sumitomo Bakelite Co. Ltd, STMicroelectronics, Semikron, Specialty Coating System, Silga, Shengyi Technology, StarPower, Serigroup, Sensitron Semiconductor, Showa Denka, Silvermicro, Semiland, Texas Instruments, Tesla, Tanaka, Tatsuta, Toshiba, Wacker, Wieland, Würth Elektronik, Vincotech, Ventec, and more.

REPORT OBJECTIVES

- Provide an overview of the main applications for power devices, along with their drivers and future trends
- Discuss the impact of application trends on package design and packaging materials
- Furnish an analysis of each packaging component, along with forecasts
- Identify the key technology trends that will shape the future power packaging market
- Deliver an overview of the power module supply chain for devices and packaging components
- Analyze the shifting of business models, synergies with other industries, and power device opportunities for newcomers

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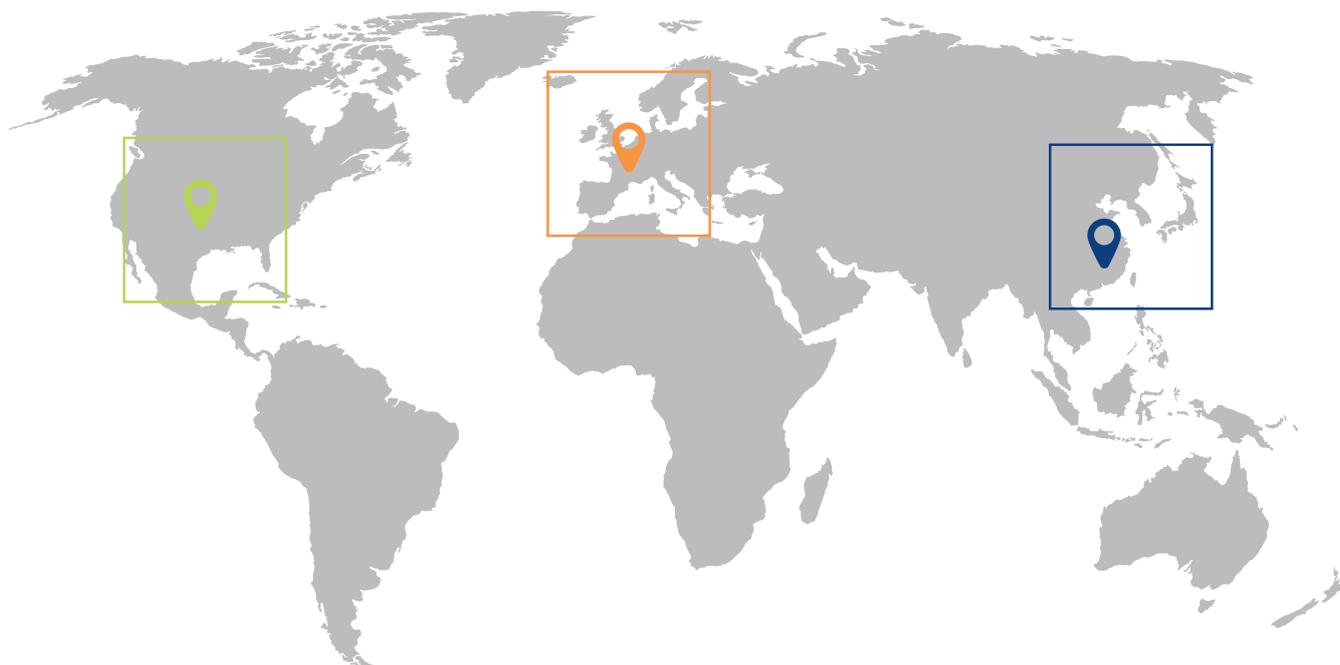
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Founded in 1998, Yole Développement (Yole) has grown to become a group of companies providing marketing, technology and strategy consulting, media and corporate finance services, reverse engineering and reverse costing services. With a strong focus on emerging applications using silicon and/or micro manufacturing, the Yole group of companies has expanded to include more than 120 collaborators worldwide covering MEMS and Image Sensors, Compound Semiconductors, RF Electronics, Solid-state Lighting, Displays, Software, Optoelectronics, Microfluidics & Medical, Advanced Packaging, Manufacturing, Power Electronics, Batteries & Energy Management and Memory.

The “More than Moore” market research, technology and strategy consulting company Yole Développement, along with its partners System Plus Consulting, PISEO and Blumorpho, supports industrial companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to grow their business.

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“Seller”: Headquartered in Villeurbanne (France), Yole Développement provides marketing, technology and strategy consulting, media and corporate finance services, reverse engineering/costing services as well as IP and patent analysis. With dedicated teams of technology & market analysts, Yole Développement operates worldwide with the key industrial companies, R&D institutes and investors to help them understand the market and technology trends.

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Reports are established in PowerPoint and delivered in a PDF format with an additional Excel file. 30 min of Q&A session with an analyst/author can be included for all purchased reports (except the ones bought as a one user license). More time can be allocated on a fee basis.

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1.3 Orders are deemed to be accepted only upon written acceptance and confirmation by the Seller, within [7 days] from the date of order, to be sent either by email. In the absence of any confirmation in writing, no order shall be deemed to have been accepted.

2. MAILING OF THE PRODUCTS

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2.2 The Seller shall by no means be responsible for any delay pursuant to Article 2.1 above, in particular in cases where a new event or access to new contradictory information would require the Seller analyst to dedicate extra time to compute or compare the data in order to enable the Seller to deliver a high quality Product.

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2.6 No return of Products shall be accepted without prior written notification from the Buyer to the Seller, even in case of delayed delivery. Any Product returned to the Seller without the Buyer providing prior notification to the Seller as required under Article 2.5 above shall remain at the Buyer’s risk. In no event shall the Seller incur any liability for Products erroneously ordered by the Buyer, or for any request from the Buyer to replace a Product previously ordered by a different Product.

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HSBC, 1 place de la Bourse 69002 Lyon France
Bank code: 30056
Branch code: 00170
Account n°: 0170 200 1565 87
BIC or SWIFT code: CCFRFRPP
IBAN: FR76 3005 6001 7001 7020 0156 587

To secure the payments due to the Seller, the Seller reserves the right to request down payments from the Buyer. In such case, the need for a down payment will be mentioned on the corresponding order.

3.3 Payment is due by the Buyer to the Seller within 30 days from invoice date, except as otherwise specifically agreed in writing by the Buyer and the Seller. If the Buyer fails to pay at the due date and fails to request and obtain from the Seller a payment extension, the latter shall be entitled to invoice interest in arrears based on the annual rate Refi of the “BCE” + 7 points, in accordance with article L.441-6 of the French Commercial Code.

3.4 The Seller publications (reports, monitors, tracks...) are due for delivery only after receipt by the Seller of any payment due by the Buyer prior to delivery.

3.5 In the event of termination of the contract by the Seller attributable to Buyer misconduct during the contract, the Seller will have the right to invoice all work performed at the time of termination, and to take legal action for damages.

4. LIABILITIES

4.1 The Buyer or any other individual or legal person acting on its behalf, being a business user buying the Products for its business activities, shall be solely responsible for the choice of the Products purchased as well as for the use and interpretations the Buyer makes of the documents it purchases, of the results the Buyer obtains, and of the advice and acts the Buyer bases thereon .

4.2 In no event shall the Seller be liable for:

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- Posting any Product to any other online service (including bulletin boards or the Internet);
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8.1 All the provisions of these General Terms and Conditions of Sale are for the benefit of the Seller, but also for that of its licensors, resellers and agents. Each of them is entitled to assert and enforce these provisions against the Buyer.

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