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硅 IGBT 引领功率电子产业[1]

内容概览：

- 市场预测：
  全球功率电子 2019 年的市场规模达 175 亿美元，2019 年至 2025 年间的 CAGR[2]为 4.3％。
  2019 年 IGBT[3]模块市场规模为 37 亿美元。
  功率 IGBT 模块的需求增加是由 EV/HEV[4]驱动的。Yole 称从 2019 年到 2025 年的预期增长为 18%。
- 技术趋势：
  EV/HEV 和工业电机领域的增长推动了 IGBT 模块市场的发展。
- 供应链：
  硅 IGBT 市场竞争企业为器件设计提供了不同的方式……
  领先的功率电子企业是营收在十亿美元级别的大公司。
  而中国公司比亚迪和中国中车都位居全球领先的功率电子企业之列。
  2019 年，英飞凌以 28%的市场份额引领 IGBT 功率模块市场。在中国，英飞凌仍然是最大的厂商之一。

“IGBT 等硅器件正从成熟的基础设施和工艺中受益。新一代器件即将上市。除了性能上的改进，由于向 12 英寸硅晶圆的过渡，使与 WBG[5]材料的竞争更加激烈，Si[6] IGBT 的成本也将进一步降低”， **System Plus Consulting 的技术与成本分析师 Amine Allouche** 称。

根据 System Plus Consulting 的合作伙伴 Yole Développement（Yole）在其《2020 年功率电子产业态势》报告中所述，硅器件在功率电子市场中占了大部分。

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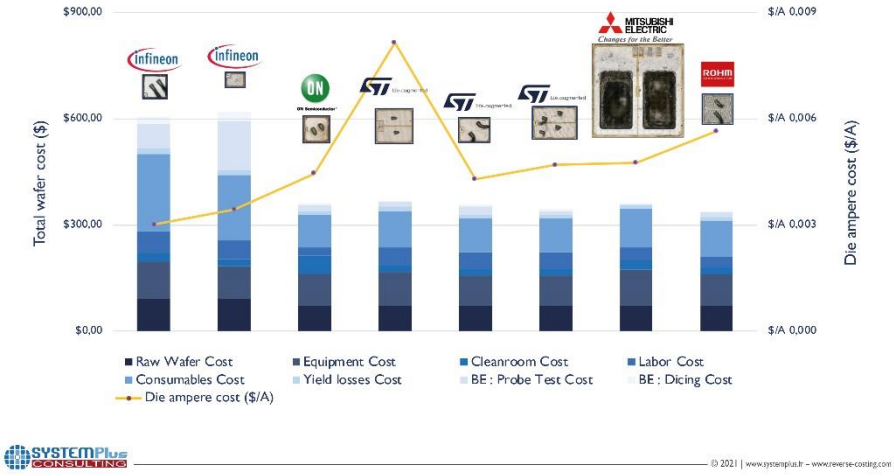
[1]摘自：
《2021 年硅 IGBT 比较》，System Plus Consulting，2021
《2020 年功率电子产业态势》报告，Yole Développement
《英飞凌 EasyPACK™ FS100R12W2T7》，System Plus Consulting，2020

[2]CAGR：年均复合增长率
[3]IGBT：绝缘栅双极晶体管
[4]EV/HEV：电动车/混合动力车
[5]WBG：宽禁带
[6]Si：硅

回顾 2019 年，整个功率半导体器件市场规模为 175 亿美元，而 2019 年-2025 年间的 CAGR 为 4.3%。IGBT 模块传统上用于工业或可再生能源转换器等应用，在 2019 年的市场中占 37 亿美元。目前能效法规或更高的清洁能源目标正在推动这些应用发展，它们占据了 IGBT 模块整体市场的 46%。尽管如此，功率 IGBT 模块的关键应用无疑还是 EV/HEV，其从 2019 年至 2025 年的预期增长为 18%。

IGBT total wafer cost & die ampere cost breakdown

(Source: Silicon IGBT Comparison report, System Plus Consulting, 2021)



在此背景下，同属 Yole 企业集团的 Yole 和 System Plus Consulting 两家公司对颠复性功率电子技术及相关市场进行了深入调研。这两家公司揭示了最新的创新技术，并着重点明商业机遇。

- System Plus Consulting 在其《2021 年硅 IGBT 比较》报告中，通过介绍来自 11 家领先 IGBT 竞争企业，覆盖 8 个电压等级的 31 款硅 IGBT 晶体管，展现了最先进的技术。

  该报告重点介绍了这些器件设计和制造工艺之间的主要差异与共同点。System Plus Consulting 的分析师们指出了 IGBT 技术及其对器件尺寸和生产成本的影响。System Plus Consulting 提供了详尽的分析，包括物理上、技术上和制造成本的比较。功率电子分析师还带来了对电流密度相关的技术趋势的全面了解，并添加了一个专门的章节，着重与 SiC 晶体管的芯片安培成本进行比较。
- 同时，System Plus Consulting 全年都将对一系列经过选择的关键功率电子部件进行详细分析。《英飞凌 EasyPACK™ FS100R12W2T7》就是其中之一。《英飞凌 EasyPACK™ FS100R12W2T7》报告通过对该模块的全面拆解，揭示了这家领先功率电子公司在其全新 IGBT7 芯片中所做的技术选择。报告详细介绍了其二极管的设计，以及模块封装结构。它还对所有模块部件的技术数据、制造成本和

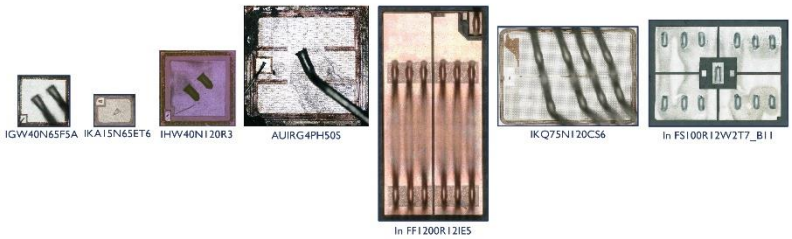
售价提供了专业意见，并准确比较了各项英飞凌 IGBT 技术的技术和成本：IGBT3、IGBT4、IGBT5 和 IGBT7。

System Plus Consulting 公司正与市场研究与战略咨询公司 Yole 密切合作，以获得对技术演变和市场趋势的深入理解。除了 System Plus Consulting 的逆向工程与成本分析，Yole 最近也发布了《2020 年功率电子产业态势》报告，带来功率电子行业的整体情况。因此，这项包含了供应链、市场趋势和预测、竞争企业排名和技术趋势的研究考察整个功率市场的现状，探究不同器件类型和材料的市场份额等诸多问题……

IGBT 技术及其应用的现状如何？有哪些主要细分市场？产业领导者们所做的技术选择是什么？System Plus Consulting 今天将带来其最新的 IGBT 技术反向工程与成本分析。

Silicon IGBT overview:
Infineon Technologies devices focus

(Source: Silicon IGBT Comparison report, System Plus Consulting, 2021)



Manufacturer	Device Code	Automotive	Technology	Packaging	Vce (V)	Ic (A)	Vce_sat (V), typ.	Qg (nC)
Infineon	IGW40N65F5A	x	TRENCHSTOP™ 5 High speed Fast	TO-247-3	650	46	1.60	95
Infineon	IKA15N65ET6		TRENCHSTOP™ IGBT6 + Diode	TO-220-3	650	21	1.50	37
Infineon	IHW40N120R3		TRENCHSTOP™ IGBT3 with monolithic diode	TO-247-3	1200	40	1.55	335
Infineon	AUIRG4PH50S	x	PT Planar IGBT4	TO-247AC-3	1200	81	1.47	151
Infineon	FF1200R12IE5		TRENCHSTOP™ IGBT5	*Module*	1200	150	*N/A*	*N/A*
Infineon	IKQ75N120CS6		TRENCHSTOP™ IGBT6 + Diode	TO-247-3	1200	75	1.85	530
Infineon	FS100R12W2T7_B11		TRENCHSTOP™ IGBT7	*Module*	1200	100	1.50	1800

Also included in this report: Termination, Pitch, Wafer thickness, Si epitaxy, Frontside doping number, Lithography mask number, Wafer Dicing type, current density, die size, figure of merit, technology introduction year.

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根据 System Plus Consulting 的团队在新发布的《2021 年硅 IGBT 比较》报告中所做的分析，硅 IGBT 厂商提供了各种不同的器件设计方法。因此，技术选择显然取决于目标电气性能和应用。System Plus Consulting 在其《2021 年硅 IGBT 比较》报告中强调，大多数厂商采用的是 FS[7]沟槽结构。

借此机会，英飞凌于 2019 年 3 月推出了新的 IGBT7 技术，用于其 Easy 封装平台。TRENCHSTOP™IGBT7 芯片基于新型微沟槽栅技术，与之前在 IGBT3 和 IGBT4 中使用的方形沟槽单元相比，具有新的单元结构。《英飞凌 EasyPACK™ FS100R12W2T7》的全面反向成本分析也是基于此，**Amine Allouche** 解释道：*“这一功率模块采用了英飞凌的最新 IGBT 技术与二极管技术：TRENCHSTOP™IGBT7 和 EC7 二极管。它能驱动 100A 的标称电流，额定电压为 1200V。”*

[7]FS：场截止型

媒体联络人

Sandrine Leroy，公共关系主管，leroy@yole.fr
Marion Barrier，公共关系助理，marion.barrier@yole.fr
Le Quartz, 75 Cours Emile Zola – 69100 Villeurbanne – Lyon – France – +33472830189
www.yole.fr - www.i-micronews.com– LinkedIn – Twitter

About our analysts

Amine Allouche serves as a Technology & Cost Analyst, Power Electronics, at System Plus Consulting, part of Yole Développement. With strong expertise in the field of power electronics, Amine produces reverse engineering & costing analyses while also working on custom projects. He collaborates closely with the laboratory team, and together they define the objectives of the analyses and determine the methodologies necessary to reveal the structure of a device and all materials required for its development and production. Amine's aim is to determine the technology choices made by the leading companies. In addition, Amine runs a daily technology watch to identify innovative power electronics components and related manufacturing processes. His objective is to gain a comprehensive understanding of the evolution of power electronics technologies and to identify the technological strategies of the leading players in this field. Amine attends numerous international trade shows & conferences where he meets the power electronics companies and discovers the latest innovations. He also presents key results of his studies during webcasts. Amine holds a master's degree in Micro & Nanotechnologies with a focus on integrated systems from Grenoble's Polytechnic Institute (France). He also graduated from the Ecole Polytechnique Fédérale de Lausanne (EPFL) (Lausanne, Switzerland) and the Politecnico di Torino (Italy).

Véronique Le Troadec is Senior laboratory analyst at System Plus Consulting. Veronique has extensive knowledge in reverse engineering of advanced technologies. She previously worked at Atmel Nantes where she was in charge of failure analysis of devices.

Peggy Gallois joined System Plus Consulting's laboratory of microelectronics team in July 2019. She previously worked in the laboratory of metallographic expertise for Dassault Aviation near Paris.

Ana Villamor, PhD Technology & Market Analyst, Power Electronics & Compound Semiconductors, is involved in many custom studies and reports focused on emerging power electronics technologies including device technology and reliability analysis. Previously Ana was involved in a high-added value collaboration related to SJ Power MOSFETs, within the CNM research center for the leading power electronic company ON Semiconductor. She holds an Electronics Engineering degree completed by a Master and PhD in micro and nano electronics from Universitat Autonoma de Barcelona (SP).

Milan Rosina, PhD, is Principal Analyst, is engaged in the development of the market, technology and strategic analyses dedicated to innovative materials, devices and systems. His main areas of interest are EV/HEV, renewable energy, power electronic packaging and batteries. He received his PhD degree from Grenoble Institute of Technology (Grenoble INP) in France. Milan Rosina previously worked for the Institute of Electrical Engineering in Slovakia, Centrotherm in Germany, Fraunhofer IWS in Germany, CEA LETI in France, and utility company ENGIE in France.

Abdoulaye Ly is Technology & Market Analyst specializing in Electronic Power Systems at Yole. His expertise is focused on power electronics system design. Abdoulaye graduated with a technical degree in 2014 from Bethune University Institute of Technology and in 2017 received an electrical engineering degree from Grenoble Institute of Technology. Abdoulaye LY previously worked for Centum Adetel Transportation as a system engineer and junior product manager for railway application.

About the reports

Silicon IGBT Comparison 2021

Exhaustive technology and cost comparisons of 31 Silicon IGBTs from Infineon, ON Semiconductor, STMicroelectronics, Mitsubishi, Rohm, Toshiba, Fuji Electric, Littelfuse, ABB, Microsemi, and the IGBT in StarPower's module. – Performed by System Plus Consulting

Status of the Power Electronics Industry 2020

China is reshaping the power electronic industry – Performed by Yole Développement

Infineon EasyPACK™ FS100R12W2T7

Discover the newest IGBT technology from Infineon: TRENCHSTOP™ IGBT7 with EC7 diode in EasyPACK™ module. – Performed by System Plus Consulting

About Yole Développement

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 and well as IP and patent analysis. With a strong focus on emerging applications using silicon and/or micro manufacturing, the Yole group of companies has expanded to include more than 80 collaborators worldwide… More

About System Plus Consulting

System Plus Consulting specializes in the cost analysis of electronics, from semiconductor devices to electronic systems. Created more than 20 years ago, System Plus Consulting has developed a complete range of services, costing tools and reports to deliver in-depth production cost studies and estimate the objective selling price of a product… More

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