Commercialization of 800V for EVs to play crucial role in growth strategy of OEMs

Substrates & epi comprise nearly 70% of the SiC value chain, says Research In China.

As new energy vehicles and battery technology boom, charging and battery swapping in the industry chain have become weak links for the development of new energy vehicles. Inconvenient charging and short cruising range have become sore points that plague every consumer buying electric vehicles.

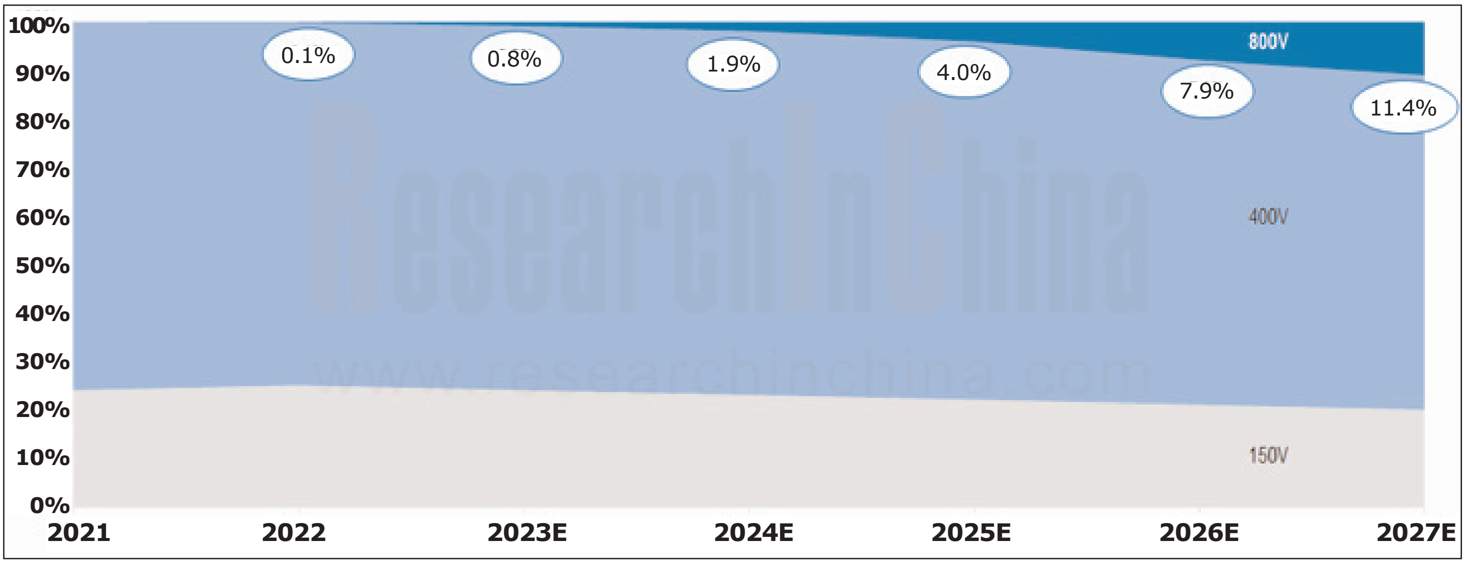
In this context, 800V high-voltage charging for new energy vehicles has been a spotlight, notes the '800V High Voltage Platform Research Report, 2023' by Research In China. 2022 was the first year for the development of 800V high-voltage platforms in China. In particular, a large number of 800V high-voltage platform models will go on sale during 2023–2024.

In the current stage, 800V platforms are still facing a situation of "loud thunder but small raindrops". Insurance data show that insured vehicles with 800V platforms in China were still fewer than 10,000 units in 2022. The low cost performance and poor ultrafast charging experience offered by 800V models are the major flaws criticized by consumers.

The industry boom still requires lower cost of upstream materials and systems, and the gradual deployment of downstream 480kW/500kW ultrafast-charging piles to cover key use scenarios, so that 800V models can be pulled into the market explosion node that is expected to come in about 2024, according to the plans of large auto makers.

Deployment of 800V ultra-fast charging:

- **Xpeng**: for the top ten cities by orders for G9, concentrate on building S4 ultrafast charging stations. In 2023, S4 stations will be used to provide energy replenishment in key cities and along key highways; it is estimated that in 2025, in addition to the current self-operated 1000 charging stations, Xpeng will build another 2000 ultrafast charging stations.
- **GAC**: in 2021, GAC introduced a fast-charging pile with maximum charging power up to 480kW. It is predicted that, in 2025, 2000 supercharging stations will be built in 300 cities across China.
- **NIO**: in December 2022, NIO officially released a 500kW ultrafast charging pile with maximum current of 660A supporting high-power charging. The fastest charging time for 400V models is only 20 minutes; for 800V models, the fastest charge from 10% to 80% takes 12 minutes.
- **Li Auto**: in 2023 Li Auto has started the construction of 800V high-voltage supercharging piles in Guangdong, and its goal is to build 3000 supercharging stations in 2025.
- **Huawei**: in March 2023, the 600kW supercharging



Penetration of 800V high-voltage platforms in new energy passenger cars in China, 2022–2027 (estimated).

pile exclusively for AITO came out in Huawei Base in Bantian Street, Shenzhen. This charging pile, named FusionCharge DC Supercharging Terminal, adopts single-pile single-gun design. The manufacturer is Huawei Digital Power Technologies Co Ltd. Its external dimensions are 295mm (L) x 340mm (W) x 1700mm (H) and the product model is DT600L1-CNA1. The charging pile has an output voltage range of 200–1000V, maximum output current of 600A, maximum output power of 600kW, and liquid cooling.

Due to the high construction cost of 480kW ultrafast-charging piles, generally speaking, an ultrafast-charging station is equipped with just one or two 480kW super-charging piles and several 240kW fast-charging piles, and supports dynamic power distribution. Overall, according to the plans of auto makers, it is conceivable that in late 2027 ownership of 800V high-voltage platform models will reach 3 million units; the number of 800V supercharging stations will be 15,000–20,000; the number of 480/500kW supercharging piles will exceed 30,000.

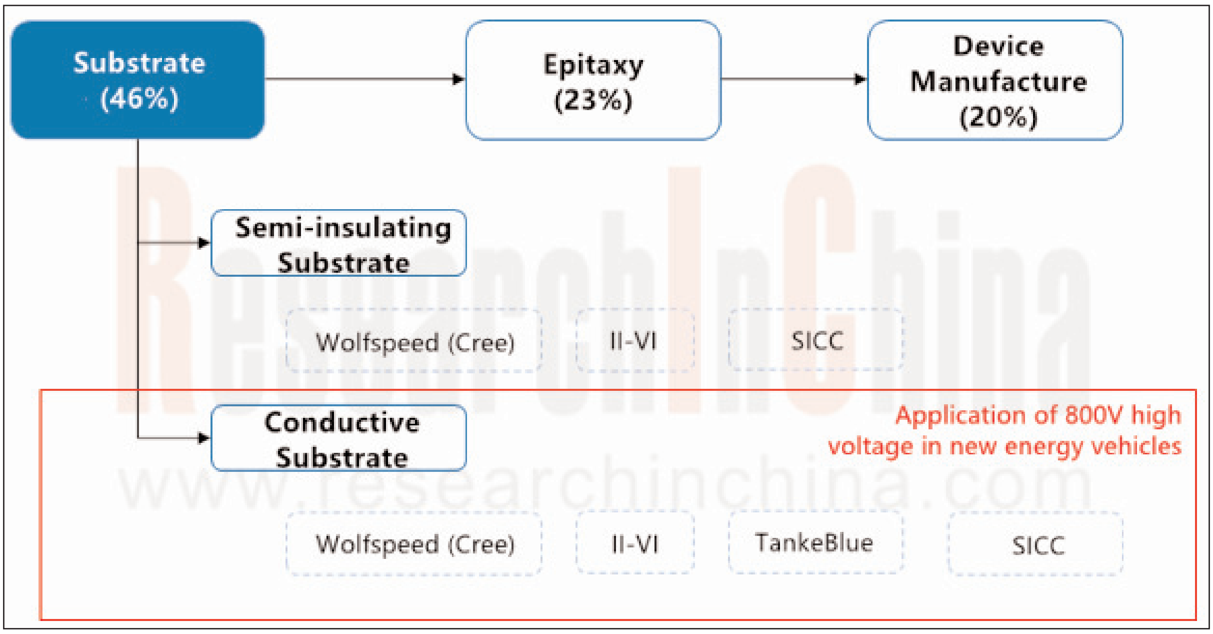
As well as charging piles, in the evolution of architecture from 400V to 800V, the implementation of vehicle engineering also remains very complicated. It requires simultaneous introduction of an entire system spanning semiconductor devices and battery modules to electric vehicles, charging piles, and charging networks, and poses higher demands on reliability, size and electrical performance of connectors. It also requires technology improvements in mechanical, electrical and environmental performance.

Tier-1 suppliers race to unveil 800V component products. Most new products to be available during 2023–2024

Leadrive Technology: in 2022, the first silicon carbide (SiC)-based `three-in-one` electric drive system jointly developed by Leadrive Technology and SAIC Volkswagen went into trial production and made a debut at the Volkswagen IVET Innovation Technology Forum. Tested by SAIC Volkswagen, this ‘three-in-one’ system equipped with Leadrive Technology’s silicon carbide ECU can increase the cruising range of the ID.4X model by at least 4.5%. Additionally, Leadrive and Schaeffler will co-develop electric drive assembly products including an 800V SiC electric axle.

SOP Plans of Major Global Silicon Carbide (SiC) Device Companies

Self-built Production Line		
Company	**Product Layout**	**Product Development Stage**
BYD	Started self-developing IGBT in 2005 and SiC in 2020	IGBT has iterated to 5.0, and SiC power modules are used in Han EV
BIO	A SiC power module process experiment line	Designed annual capacity of 5000 sets of modules
BorgWarner	IGBT module and SiC Mosfet module	3 Viper packaging and testing lines for the Phase II of Suzhou factory project
UAES	IGBT power module	Bosch produces SiC chips
Vitesco Technologies	IGBT and SiC modules	Packaging line in Tianjin factory
Denso	SiC power module	Applied to Toyota fuel cell vehicle Miral
Leadrive Technology	IGBT and SiC power modules	Plan to self-build production lines
Equity Cooperation		
Company	**Product Layout**	**Product Development Stage**
SAIC	IGBT module	Established joint venture SAIC Infineon Automotive Power Modules (Shanghai) Co, Ltd. together with Infineon
	Automotive chip	Initiated the establishment of the Shanghai Automotive Chip Engineering Center together with the Shanghai Industrial μTechnology Research Institute; to build an automotive chip pilot test line and a production line
Geely	SiC chip	Established joint venture AscenPower together with AccoPower among others
Dongfeng Motor	IGBT module	Established joint venture Zhixin Semiconductor together with CRRC Times
FAW	IGBT and SiC modules	FAW Fund as the leading investor established a joint venture together with eMotor Advance, and founded wholly-owned subsidiary eMotor Semiconductor in Suxiang Cooperation Zone
Li Auto	SiC chip, module	Established a joint venture with Sanan Semiconductor
GAC	IGBT module	Established joint venture Guangzhou Qinglan Semiconductor Co., Ltd. together with CRRC Times
Zhenghai Group	SiC module	Established joint venture HAIMOSIC together with ROHM Semiconductor



- **Vitesco Technologies**: the highly integrated electric drive system product EMR4 is projected to be mass produced in China and supplied to global customers in 2023. EMR4 will be spawned at Vitesco's factory in Tianjin Economic-Technological Development Area and delivered to auto-makers both inside and outside China.

BorgWarner: the new 800V SiC inverter adopts Viper's patented power module technology. The application of SiC power modules to 800V platforms reduces the use of semiconductors and SiC materials. This product will be mass produced and installed on vehicles between 2023 and 2024.

800V still in ascendance, but battle for SiC production capacity has begun

In new 800V architectures, the key to electric drive technology is the use of 'third-generation' SiC/GaN semiconductor devices. While bringing technical benefits to new energy vehicles, technology iterations also pose many challenges to automotive semiconductors and the entire supply chain. In the future, 800V high-voltage systems with SiC/GaN as the core will usher in a period of large-scale development in automotive electric drive systems, electronic control systems, on-board chargers (OBCs), DC–DC, and off-board charging piles.

In particular, silicon carbide is at the core of the high-voltage platform strategy of OEMs. Although 800V is still growing at present, the war for SiC production capacity has already started. OEMs and tier-1 suppliers are competing to form strategic partnerships with suppliers of SiC chips and modules or to set up joint ventures with them for the production of SiC modules in order to lock in SiC chip capacity.

On the other hand, the campaign for SiC cost reduction has also been launched. At present, SiC power devices are extremely expensive. In Tesla's case, the value of SiC-based MOSFET per vehicle is about $1300; at its recent annual investor day, Tesla announced progress in the development of its second-generation power chip platform, mentioning a reduction of 75% in silicon carbide device usage, which attracted a lot of attention in the market.

Tesla's confidence lies in the fact that the auto-maker has independently developed a TPAK SiC MOSFET module and is deeply involved in the chip definition and design. Each bare die in the TPAK can be purchased from different chip vendors to establish a multi-supplier system (ST, ON Semiconductor, etc). TPAK also allows for the application of cross-material platforms, e.g. mixed use of IGBT/SiC MOSFETs/GaN HEMTs.

(1) China has built a SiC industry chain, but with a technology level slightly below the international level

Power devices based on SiC offer the benefits of high frequency, high efficiency and small volume (70% or 80% smaller than IGBT power devices), and have been seen in the Tesla Model 3.

From the perspective of the value chain, substrates comprise more than 45% of the cost of silicon carbide devices, and its quality also directly affects the performance of epitaxy and the final product. The substrate and epitaxy comprise almost 70% of the value, so cutting their cost will be the main development direction of the SiC industry. The silicon carbide required for high voltage (800V) for new energy vehicles is mainly conductive substrate SiC crystal. The existing major manufacturers include Wolfspeed (formerly Cree), II–VI, TankeBlue Semiconductor and SICC.

In terms of global SiC technology development, the SiC device market is monopolized by large vendors such as STMicroelectronics, Infineon, Wolfspeed and ROHM. Chinese vendors already have large-scale production capacity, and are on a par with international developments. Their capacity planning and production timescale are almost equal to their foreign peers.

Regarding the SiC substrate development level, 6-inch substrates currently prevail in the SiC market, and the 8-inch SiC substrate is a development priority globally. At present, only Wolfspeed has achieved the mass pro-

	1990-1995	1995-2000	2000-2005	2005-2010	2010-2015	2015-2020	2020-2025
Wolfspeed	1991: first substrate 1993: commercialization of 30mm substrate	1995: 50mm 1999: 4 inches		2009: 6-inch substrate		2015: 8-inch substrate	2022: fully spawned the 8-inch
II-VI			2004: produced the 3-inch		2012: displayed the 6-inch 2013: produced the 6-inch	2015: 8-inch conductive type 2019: 8-inch semi-insulating	2024: to spawned the 8-inch
ROHM SEMICONDUCTOR			2000-2002: fundamental research on devices	2009: acquired SiCrystal	2011: spawned the 4-inch 2014: spawned the 6-inch		2021: 8-inch substrate 2025: to spawn the 8-inch
ST life.augmented						2019: acquired Norstel AB for 6-inch substrate capacity	2021: delivered 8-inch wafers
安森美半导体 ON Semiconductor						2021: acquired GTAT	2021: launched the 8-inch 2025: to spawn the 8-inch
TANKEBLUE 天科合达				2006: 2 inches 2008: 3 inches	2012: successfully developed the 4-inch	2017: spawned the 4-inch 2018: developed the 6-inch semi-insulating	2020: spawned the 6-inch 2023: to spawn the 8-inch
SICC					2012: spawned the 2-inch 2013: spawned the 3-inch	2015: spawned the 4-inch semi-insulating 2017: spawned the 6-inch conductive type 2019: spawned the 6-inch semi-insulating	
SEMISiC 烁科晶体				2009: SiC research		2020: spawned the 4 to 6-inch 2020: displayed the 8-inch	2021: produced 8-inch crystals 2022: produced 8-inch wafers
JSG							2022: displayed the 8-inch 2023: to spawn the 8-inch

duction of 8-inch SiC. The Chinese company SEMISiC has produced 8-inch N-type SiC polished wafers on a small scale in January 2022. Most international companies plan the production of 8-inch SiC substrates during 2023.

(2) GaN is still at an early stage of application in automotive, and the layout pace of related manufacturers is quickening

Gallium nitride (GaN) is largely used in consumer electronics fields such as tablet PCs, TWS earbuds and notebook computer fast charging (PD). Yet, as new energy vehicles thrive, electric vehicles become a potential application market for GaN. In electric vehicles, GaN field-effect transistors (FETs) are very applicable to AC–DC OBCs, high-voltage (HV) to low-voltage (LV) DC–DC converters, and low-voltage DC–DC converters.

In the field of electric vehicles, GaN and SiC technologies complement each other and cover different voltage ranges. GaN devices are suitable for tens of volts to hundreds of volts, and in medium- and low-voltage applications (less than 1200V); their switching loss is three times less than SiC in 650V application. SiC is more applicable to high voltages (several thousand volts). Currently, the application of SiC devices in a 650V environment is mostly to enable 1200V or higher voltage in electric vehicles.

China still has a big gap with foreign counterparts in development of Ga_2O_3, and has yet to achieve mass production

By virtue of having a large energy bandgap, high breakdown field strength and strong radiation resistance, gallium oxide (Ga_2O_3) is expected to dominate in the field of power electronics in the future. Compared with common wide-bandgap SiC/GaN semiconductors, Ga_2O_3 boasts a higher Baliga figure-of-merit and lower expected growth cost, and has more potential in application to high-voltage, high-power, high-efficiency and small-size electronic devices.

In policy's term, China is also paying ever more attention to Ga_2O_3. As early as 2018, China began exploring and studying ultra-wide-bandgap semiconductor materials including Ga_2O_3, diamond and boron nitride. In 2022, China's Ministry of Science and Technology brought Ga_2O_3 into the National Key R&D Program during the '14th Five-Year Plan' period.

On 12 August 2022, the US Department of Commerce's Bureau of Industry and Security (BIS) issued an interim final rule that establishes new export controls on four technologies that meet the criteria for emerging and foundational technologies, including: gate-all-around (GAA) technology, electronic design automation (EDA) software, pressure gain combustion (PGC) technology, and the two ultra-wide-bandgap semiconductor substrates, gallium oxide and diamond. The two export controls came into effect on 15 August. Ga_2O_3 has drawn more attention from the global scientific research and industrial circles.

Although gallium oxide is still at the initial stage of R&D, China has made several breakthroughs within 15 months since the start of 2022. Its gallium oxide preparation technologies — from 2-inches to 6-inches in 2022, and then to 8-inches most recently — are maturing. Chinese Ga_2O_3 material research units include: China Electronics Technology Group Corporation No.46 Research Institute (CETC46), Evolusia Semiconductor, Shanghai Institute of Optics and Fine Mechanics (SIOM), Gallium Family Technology, Beijing MIG Semiconductor, and Fujia Gallium Industry; listed companies like Xinhu Zhongbao, Sinopack Electronic Technology, Jiangsu Nata Opto-Electronic Material and San'an Optoelectronics; plus dozens of colleges and universities. ■

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