Preface

Power Semiconductor Devices — Driving Technology for Power Conversion Systems

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Power Electronics is the key technology to control the flow of electrical energy along the whole chain from generation, transmission and distribution up to various types of consumers, and to do so with great precision, extremely fast dynamic control, high efficiency, and high-power density on all power conversion stages. Furthermore, this technology is an enabler for the grid integration of renewable energy sources and E-Mobility and provide significant contributions to the key issues of improved energy efficiency, reduced consumption of materials as well as the sustainable energy supply based on renewables.

Sustainability and Global Warming

Power electronics is a cross-sectional and ubiquitous field as it covers many disciplines including material science, semiconductor physics, assembly and interconnection technologies, circuit topologies and control, in all applications dealing with electric energy. Today we know that changes in all energy sectors are needed, and that renewables-based electrification is the major step towards greenhouse gas reduction and climate change mitigation.

Mobility is key for global growth and societal wealth. As such, mobility is undergoing a transformation from fossil fuel mobility to sustainable and environmentally friendly electric mobility. In addition, electrification allows the rise of new mobility concepts such as drones and high-speed transportation like the hyperloop concept. In general power electronics for electric vehicles have progressed well with transitioning from Silicon based switching devices to SiC and GaN switching devices. Integration of the electric motor and the inverter is seen as a key development to achieve better integration and standardization. Challenges here are new active or hybrid EMC filter technologies to reduce size, weight, and costs.

Trucks and busses share the same roads as cars, but energy and power demands are higher, and the operation time is much longer. Power electronics is therefore designed to deal with higher lifetime requirements.

From all transportation systems, railway is the most experienced electrification so far. Trains and infrastructure are expected to last decades and as such power electronics must offer high reliability and long lifetime. The need for very high-speed trains is growing resulting in the development and implementation of MAGLEV trains and Hyperloop vehicles.

Emissions and noise from aircrafts must be reduced by 2040 and electrification will undoubtedly help in achieving these targets. In these application, semiconductors like SiC and GaN are needed and for the future even ultra-wide bandgap semiconductors (UWBG) will give an additional benefit.

Generally speaking, a lot of innovation towards smart converters using benefits from I 4.0 and AI will dominate power electronics in all fields of mobility and energy supply application. Sustainability is getting more in focus for all developments in the future.

Power semiconductor devices

The performance of active and passive power devices has always been a limiting but enabling factor for power electronics.

Silicon (Si) devices have been the workhorses of power electronics and will remain for the next decades. The low voltage MOSFET, the super junction MOSFET, the IGBT and thyristor-based devices have reached a level of maturity that ground-breaking innovations are not to be expected.

Two decades ago, the first silicon carbide (SiC) Schottky diode became commercially available, and one decade ago, the first SiC MOSFETs appeared on the market. In the meantime, SiC devices have reached a considerable market share and made the step out of the high-end niche into the mainstream, with the e-mobility and renewable energy technologies. Today the voltage range is covering from 650 V up to 6.5 kV and further development like the super junction MOSFET and the FinFET are attracting more and more attention.

Lateral gallium nitride (GaN) devices with voltage ratings up to 650 V are now established. There is currently a strong focus for consumer electronics but also for power supplies in ICT and data centres. All these applications take benefit from the low parasitic capacitances and the low gate charge. GaN-based converter

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circuits can operate at higher switching frequencies with still high efficiency and their volume and weight can be reduced significantly. Monolithic integration is an important advantage in lateral GaN technology. Vertical GaN transistors are recently considered for voltage ratings > 1,000 V and for higher current capabilities. The next step will be ultra-wide bandgap semiconductors (UWBG) made of Ga_2O_3, AlGaN, AlN or diamond crystals.

Power Electronics capability in Japan

Historically, Japan has a strong position in power electronics, on the technology side with power devices and on the application side with industry, renewable energy technologies and traction drives.

Japan industry is covering the whole value-added chain starting with materials, substrates, wafers, power devices, and converters covering a variety of applications.

From the very beginning of Power Electronics Fuji Electric is playing a key role, and in many cases, creates trend setting technologies. This issue provides an excellent example of the current technology available towards the future trends.

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