Overview

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Power Devices for a Carbon-neutral Society

Satisfying the rapidly increasing global demand for energy while attaining a carbon-neutral society as proposed by the Conference of the Parties 21 (COP21) and Sustainable Development Goals (SDGs) is an urgent task. One main goal of the UN's SDGs is to solve the energy problem. With electricity accounting for an increasing share of energy demand, it is crucial to develop technologies for using electric power efficiently in order to achieve a carbon-neutral society. This growth in electric power and electronics is being driven by the accelerating trend toward e-mobility, renewable energy, Society 5.0 (Internet of Things (IoT), AI, and network-connected society), and so forth. Accordingly, the Japanese government designated electrification and the use of renewable energy for electric power generation as important technical developments under its "Green Growth Strategy Through Achieving Carbon Neutrality in 2050" issued in 2020. Power devices and power electronics, which control electric power, the flow of energy, and energy utilization, are key components of environmental measures and industrial competitiveness.

New power device technologies having enhanced performance have been introduced from time to time. Examples include: the planar type, trench type, and super junction (SJ) type for metal-oxide-semiconductor field-effect transistors (MOSFETs), depending on the withstanding voltage; and the carrier storage and field stop (FS) structure for insulated gate bipolar transistors (IGBTs). Ground-breaking technical development has pushed their performance for switching devices to the limit. Next-generation power devices are being developed that use new semiconductor materials such as silicon carbide (SiC) to overcome the physical limits of conventional silicon. In addition, next-generation power devices and power modules are under development by applying a new scaling law to silicon IGBTs while combining complementary MOS (CMOS) digital technologies. These next-generation higher-performance power devices and power modules offer new functions and values. Till now, the main role of power devices has been to control the output to ensure that the equipment in which they have been installed operates in an optimum way. Combining digital technologies with this output control enables self-examination and self-restoration of power devices, other modules, and equipment, and allows them to cooperate with the input side, for example, linkage with higher-order equipment and other units via networks. Thus, for new intelligent power devices, power devices and CMOS digital technologies are being combined in a cooperative way: they function as complex systems that have communication, digital, AI, and IoT functions, in addition to improved conventional single functions such as higher energy-saving performance of electric power converters. On the new energy grids where cyberspace converges with physical space, namely the flow of information and the flow of energy, power devices and power electronics equipment themselves function as virtual systems that cooperate and link with each other to optimize the efficiency of electric energy in society as a whole.

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Under such circumstances, a new index that indicates the energy-saving effect of power devices and power electronics and also their spread, the "negawatt cost," has been proposed. In terms of negawatt cost, the energy-saving effects brought about by power devices and power electronics are regarded as the same as renewable energy power generation effects, because the saved energy can be effectively used for other purposes, and the energy-saving cost is equal to the power generation cost. The index comprehensively evaluates technologies that support a carbon-neutral society in 2050 by bridging the divide between energy-saving and new energy.

In June 2021, the Japanese Ministry of Economy, Trade and Industry positioned the digital industry, digital infrastructure, and semiconductors as principal national items in its Strategy for Semiconductors and the Digital Industry, and stated that it would actively strengthen them. The government announced that it would promote advanced logic semiconductor design, for example, a post-5th Generation Mobile Communication System (5G), application system base semiconductors, and edge AI chips/next-generation computing. Meanwhile, as measures to promote green innovation of semiconductor technologies, the government is focusing on shifting to power semiconductors, optoelectronics devices (information electronics), and photoelectric fusion. These are key materials for saving energy and reducing electric power consumption to cope with the increasing use of electricity as society digitalizes. Power devices, which are crucial for this digital transformation, are themselves evolving into new intelligent power devices in combination with digital technologies and will control the carbon-neutral society.

Amid these drastic changes, I sincerely hope that Japan remains ahead of others through cooperation between industry and academia.