Mitsubishi Electric Accelerates Automotive Electrification with SiC Power Semiconductor Modules

As environmental awareness rises and power electronics equipment becomes more energy efficient, silicon carbide (SiC) has been attracting attention as a next-generation power semiconductor material. Mainly, SiC has a wider band gap and higher breakdown field than silicon (Si), which has been conventionally used. When applied to semiconductor wafer materials for power semiconductor devices, SiC offers superior performance such as significantly reduced power dissipation, high temperature operation, and faster switching operation.

Mitsubishi Electric Corporation has been developing and mass-producing SiC-MOSFETs (metal-oxide semiconductor field-effect transistors) and SiC-SBDs (Schottky Barrier Diodes). We have so far commercialized products in a wide range of breakdown voltage classes - from 600V for home appliances to 3.3kV for electric railways.

For energy saving in power electronics equipment, it is important to reduce the power loss of the power semiconductor devices used in the devices, and the development and commercialization of trench-type SiC-MOSFETs, which enable even lower loss, is in progress.

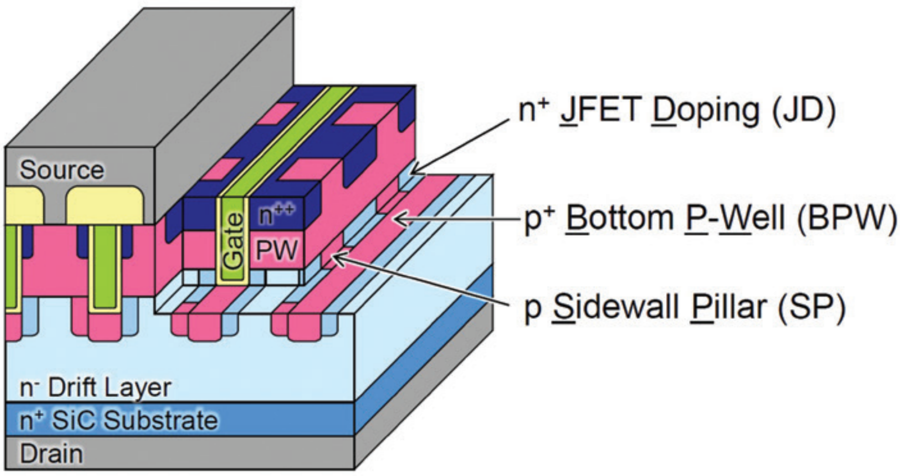

Figure 1: Structural schematic of the trench SiC-MOSFET developed by Mitsubishi Electric

Trench-type MOSFETs can achieve higher cell integration by reducing the cell pitch and lower device resistance by embedding the gate electrode in the trench. On the other hand, the key point is how to solve the problems of reduced device reliability due to the concentration of electric field stresses at the bottom of the trench and reduced short-circuit resistance due to low resistance and high current.

Features of Mitsubishi Electric’s Trench SiC-MOSFETs

Mitsubishi Electric's trench SiC-MOSFETs are composed of (1) a p-type protection layer (BPW: Bottom P-Well) that reduces the electric field stresses applied to the bottom of the trench, (2) a p-type sidewall pillar (SP: Sidewall Pillar) that grounds the BPW, (3) an n-type JFET (Junction Field Effect Transistor) doping layer (JD: JFET Doping) to prevent current path narrowing (Figure 1). In this structure, the bottom of the trench is covered with a P layer (BPW) to prevent direct application of electric field stress to the trench gate, thereby solving the problem of reduced device reliability. For short-circuit resistance, both a P layer (SP) and an N layer (JD) are intentionally placed on the side of the trench, and the P/N layer ratio is adjusted to solve the short-circuit resistance issue and achieve low resistance. Another feature of this structure is the use of gradient ion implantation in the trench to enable fabrication using a simple process.

Suit Power Semiconductor Modules for Automotives

Mitsubishi Electric's trench SiC-MOSFETs can meet the requirements of a wide variety of applications. Particularly, the company is vigorously promoting their use in power semiconductor modules for automotive applications. For automotive power semiconductor modules, there is a need to reduce the size, weight, and height of power semiconductor modules to secure

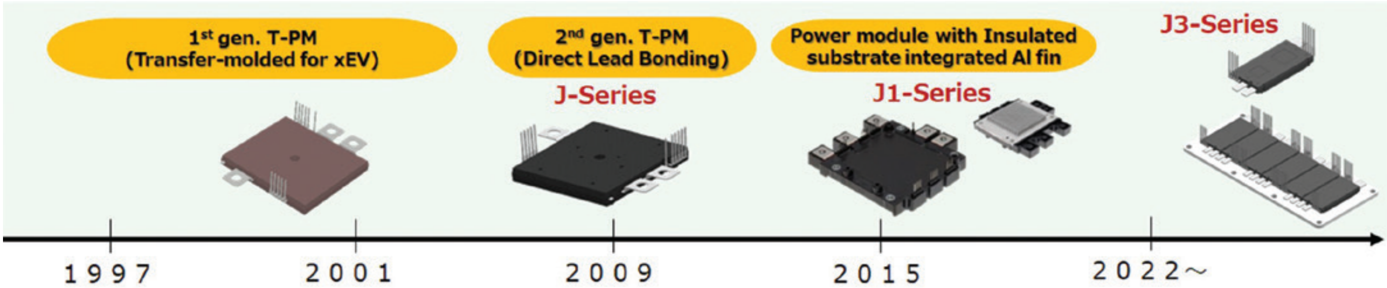

Figure 2: Transition of Mitsubishi Electric's automotive power semiconductor modules

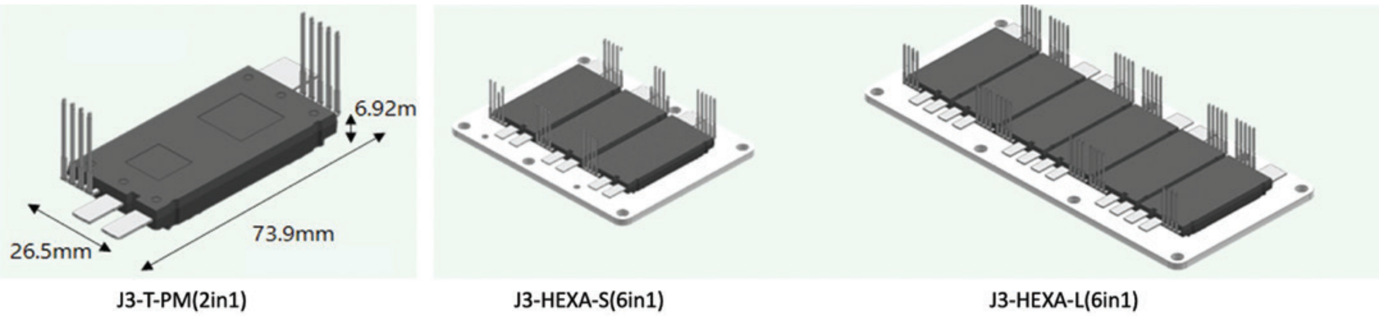

Figure 3: J3-Series

vehicle occupant and luggage space and to ensure collision safety.

Mitsubishi Electric has contributed to the development of electrification of automobiles by developing and commercializing power semiconductor modules for automotive use for more than 20 years (Figure 2). Especially in recent years, with the rapid spread of electric vehicles, automotive manufacturers have an urgent need to develop inverters for motor drives with various outputs in order to electrify multiple models of vehicles. However, because power semiconductor modules used in motor drive inverters come in a variety of shapes and characteristics, inverter design must be performed for each product, resulting in a high development load.

Transfer-Molded Technology

To solve this problem, Mitsubishi Electric is developing the J3-Series using the transfer-molded technology it has cultivated to date (Figure 3). Basically, the J3-Series is based on the J3-T-PM (J3 transfer molded power module), a compact, low height, lightweight 2-in-1 module, and can be increased in power output by increasing the number of J3-T-PMs in parallel according to demand. The product lineup with RC-IGBTs (reverse conducting IGBTs) or SiC-MOSFETs can be used for a wide range of outputs from 50 to 300kW maximum motor ratings (Figure 4). Meanwhile, inverter design can be easily realized by selecting the number of J3-T-PMs in parallel and SiC or Si power semiconductor chips to meet the requirements of each product, thereby reducing the development load.

Future Development Direction

To contribute to the further acceleration of electrification in the future, Mitsubishi Electric will continue to develop and commercialize further elemental technologies for Si and SiC power semiconductor chip technologies and packaging technologies. Accordingly, it aims to contribute to the realization of a carbon-neutral society.

About This Article:

Mitsubishi Electric Corporation provided the contents of the article (https://www.MitsubishiElectric.com/semiconductors/powerdevices/index.html)

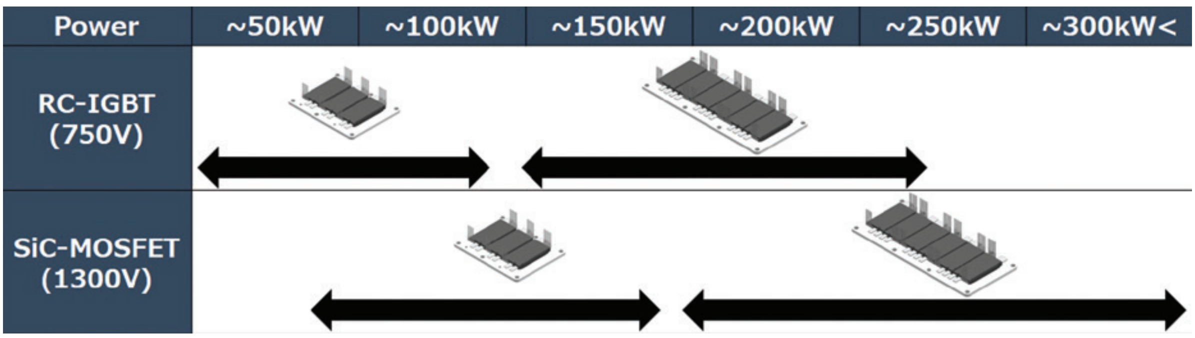

Figure 4: Motor output application range realized by the J3-Series