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Mitsubishi Electric Develops Trench-type SiC-MOSFET with Unique Electric-field-limiting Structure

Will contribute to smaller and more energy-efficient power electronic equipment

TOKYO, September 30, 2019 – Mitsubishi Electric Corporation (TOKYO: 6503) announced today that it has developed a trench-type[1] silicon-carbide (SiC) metal-oxide-semiconductor field-effect transistor (MOSFET) with a unique electric-field-limiting structure for a power semiconductor device that achieves a world-leading[2] specific on-resistance of 1.84 mΩ (milliohms) cm^2 and a breakdown voltage of over 1,500 V. Mounting the transistor in power semiconductor modules for power electronic equipment will lead to energy savings and equipment downsizing. After improving the performance and confirming the long-term reliability of its new power semiconductor devices, Mitsubishi Electric expects to put its new trench-type SiC-MOSFET into practical use sometime after the fiscal year beginning in 2021.

Mitsubishi Electric announced its new trench-type SiC-MOSFET today at the International Conference on Silicon Carbide and Related Materials (ICSCRM) 2019, which is being held at the Kyoto International Conference Center in Japan from September 29 to October 4.

[1] Gate electrode embedded in a trenched semiconductor substrate, used to control current by applying voltage
[2] According to Mitsubishi Electric research as of September 30, 2019, for devices with a breakdown voltage of over 1,500 V

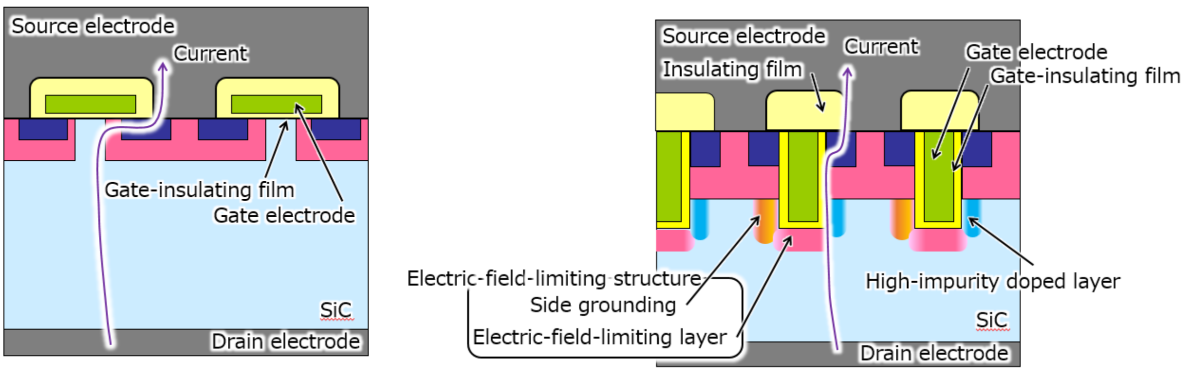

Fig. 1 Cross-sectional view of conventional planar SiC-MOSFET (left) and new trench SiC-MOSFET (right)

Key Features

1) Unique electric-field-limiting structure ensures device reliability

SiC-MOSFETs control current flowing through the semiconductor layer between the drain and source electrodes by applying a voltage to the gate electrode. To achieve control with a small voltage, a thin gate-insulating film is required. If high voltage is applied in a trench-type power semiconductor device, a strong electric field can concentrate in the gate and can easily break the insulating film.

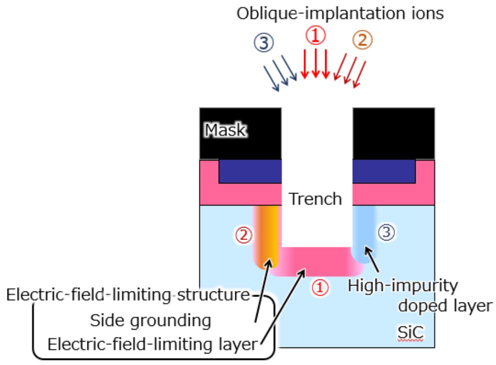

Fig. 2 Developed manufacturing method for trench type SiC-MOSFET

To correct this, Mitsubishi Electric developed a unique electric-field-limiting structure that protects the gate-insulating film by implanting aluminum and nitrogen to change the electrical properties of the semiconductor layer, taking advantage of the trench structure (Fig. 2).

First, aluminum is implanted vertically and an electric-field-limiting layer is formed on the bottom surface of the trench (Fig. 2-①). The electric field applied to the gate-insulating film is reduced to the level of a conventional planar power semiconductor device, thereby improving reliability while maintaining the breakdown voltage of over 1,500V.

Next, the side grounding connecting the electric-field-limiting layer and the source electrode is formed (Fig. 2-②) by using a newly developed technique to implant aluminum in an oblique direction to enable high-speed switching and reduced switching loss.

2) Locally formed high-impurity doped layers achieve world's lowest level of on-resistance

The trench SiC-MOSFET has transistor cells that are smaller than those of planar types, allowing more cells to be arrayed on a single chip. If transistor intervals between the gate electrodes are too narrow, however, current flow becomes difficult and device resistivity increases. Mitsubishi Electric developed a new method for implanting nitrogen in an oblique direction to locally form a layer of SiC with a high concentration of nitrogen, which allows electricity to be conducted easily in the current path (Fig. 2-③). As a result, even when cells are arrayed densely, resistivity can be reduced by approximately 25% compared to the case of no high-concentration layer.

The new manufacturing method also allows intervals of the side grounding to be optimized (Fig. 3). The result is a specific on-resistance of 1.84 mΩ (milliohms) cm^2 at room temperature, about half that of planar types, while maintaining a breakdown voltage of over 1,500 V.

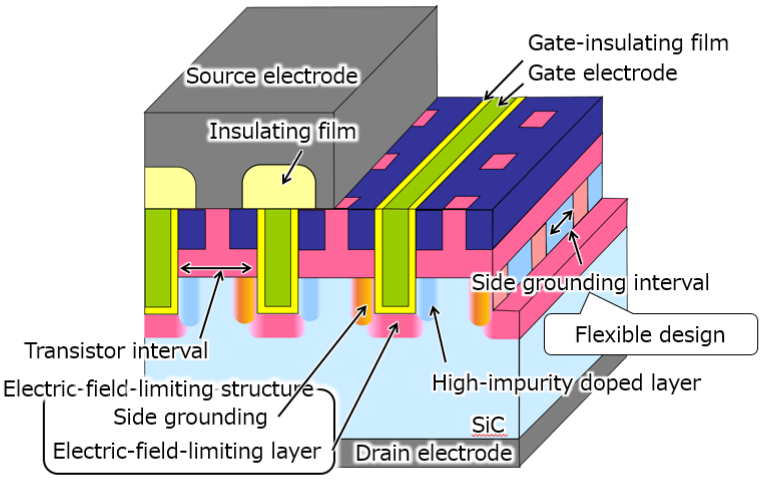

Fig. 3 Three-dimensional schematic of new trench-type SiC-MOSFET

Background

Power electronic devices used in a wide range of fields, such as electric appliances, industrial equipment, automobiles and railcars, are increasingly required to offer energy savings, miniaturization and high efficiency. In addition, conventional silicon-insulated gate bipolar transistors (Si-IGBTs) are being replaced with SiC-MOSFETs in power semiconductor modules used to control and convert electric power.

SiC-MOSFETs comprise numerous transistor cells arrayed side by side. To reduce overall device resistivity, the resistance of each cell must be reduced and cells must be arrayed more densely. For this reason, the trench type is being used increasingly in place of the conventional planar type because it allows cells to be arrayed densely in substrate trenches rather than mounting gate electrodes on the substrate.

The trench type, however, has had problems with its gate-insulating film breaking at high voltage. To correct this problem, Mitsubishi Electric developed a unique electric-field-limiting structure based on advanced simulations that were conducted during the structural-design stage. Reducing the electric field applied to the gate-insulating film to that of a conventional planar-type level enables the gate-insulating film to achieve greater reliability under high voltage. Also, specific on-resistance has been reduced by approximately 50%. In addition, the reduced specific on-resistance suppresses heat generation, allowing the use of a smaller cooling device for energy savings and miniaturization. Further, Mitsubishi Electric has developed a new manufacturing method to mass produce its new SiC-MOSFET.

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About Mitsubishi Electric Corporation

With nearly 100 years of experience in providing reliable, high-quality products, Mitsubishi Electric Corporation (TOKYO: 6503) is a recognized world leader in the manufacture, marketing and sales of electrical and electronic equipment used in information processing and communications, space development and satellite communications, consumer electronics, industrial technology, energy, transportation and building equipment. Embracing the spirit of its corporate statement, Changes for the Better, and its environmental statement, Eco Changes, Mitsubishi Electric endeavors to be a global, leading green company, enriching society with technology. The company recorded a revenue of 4,519.9 billion yen (US$ 40.7 billion*) in the fiscal year ended March 31, 2019. For more information visit:
www.MitsubishiElectric.com

*At an exchange rate of 111 yen to the US dollar, the rate given by the Tokyo Foreign Exchange Market on March 31, 2019