SiC Lecture Series

11. Industrial SiC Chip Technology

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1200V-class MOSFETs are challenging to achieve with silicon due to their very high resistance. Therefore, 1200V-class SiC MOSFETs are devices that can fully demonstrate the advantages of SiC and are widely used in industrial and automotive applications. Currently, many device manufacturers position 1200V-class SiC MOSFETs as their flagship products, leading to intense development competition. This time, we will explain the overview of the technological development of 1200V-class SiC MOSFETs at Mitsubishi Electric.

As of 2024, Mitsubishi Electric is producing second-generation planar-type SiC MOSFETs and incorporating them into various modules for commercialization. Figure 1 shows the cross-sectional structure of the MOS cell part of the second-generation planar-type SiC MOSFET along with its features. First, optimization of the structure is carried out using n-type ion implantation technology (JFET doping) for the JFET region of the MOS cell, achieving a reduction in the resistance of the JFET region. Additionally, compared to conventional designs, the size of the MOS cell has been reduced, leading to a decrease in resistance through increased MOS channel density and the thinning of the SiC substrate. As shown in Figure 2, these improvements have enabled Mitsubishi Electric's second-generation SiC MOSFETs to reduce on-resistance by more than 30% compared to the first generation. Furthermore, the termination structure to maintain the breakdown voltage of the second-generation SiC MOSFETs employs a FLR (Field Limiting Ring) and forms an appropriate surface protection film.

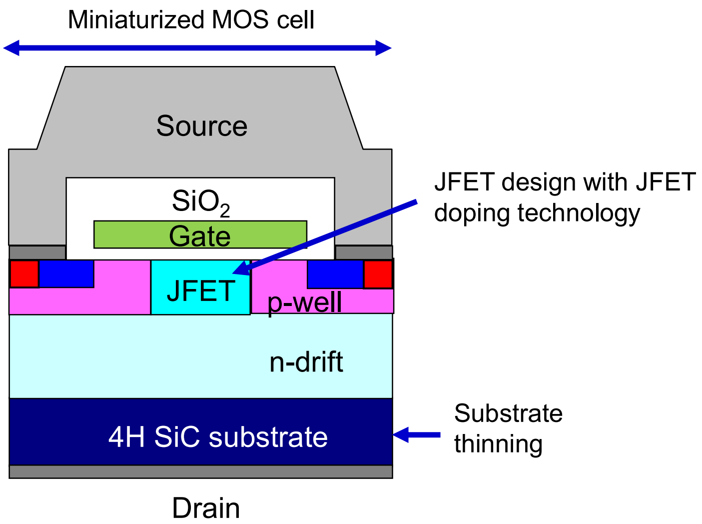

Figure 1 Cross-sectional structure of MOS cell part of the second-generation planar-type SiC MOSFET

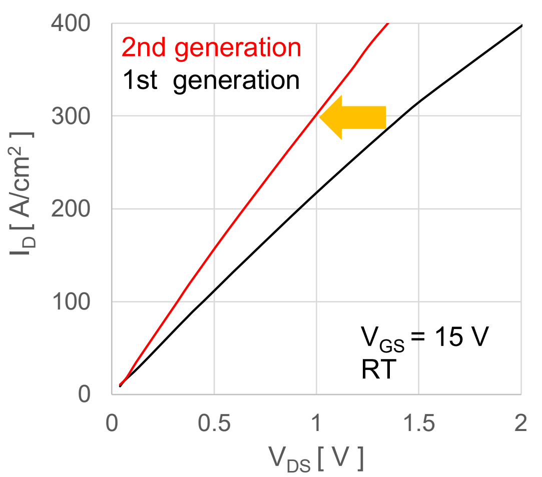

Figure 2 On-characteristics of SiC MOSFET - Comparison between the first and the second generation -

Mitsubishi Electric's second-generation SiC MOSFETs have been used in many systems in the market so far, and it has been sufficiently demonstrated that they have few failures and stable characteristics. Currently, further improvements are being made based on the structure of the second-generation SiC MOSFETs, and development is ongoing to realize more user-friendly SiC MOSFETs. Efforts are being made to commercialize modules with excellent performance and reliability.

As the next generation of 1200V-class SiC MOSFETs, Mitsubishi Electric is developing fourth-generation trench-type SiC MOSFETs. The third-generation SiC MOSFETs from Mitsubishi Electric are MOSFETs with an integrated SBD structure, which will be introduced in the next section. Figure 3 shows the structure of the trench-type SiC MOSFET.

Mitsubishi Electric's trench-type SiC MOSFETs feature a unique MOS cell structure formed using advanced ion implantation technology. Key characteristics include the reduction of electric field intensity by performing p-type ion implantation at the trench bottom (BPW: Bottom p-Well), where high electric fields tend to concentrate. Additionally, p-type and n-type ion implantation is performed on the trench sidewalls to maintain a constant potential in the BPW, ensuring stable operation during switching and reducing the resistance of the current path. These features enable Mitsubishi Electric's trench-type SiC MOSFETs to achieve high reliability, stable operation, and low on-resistance.

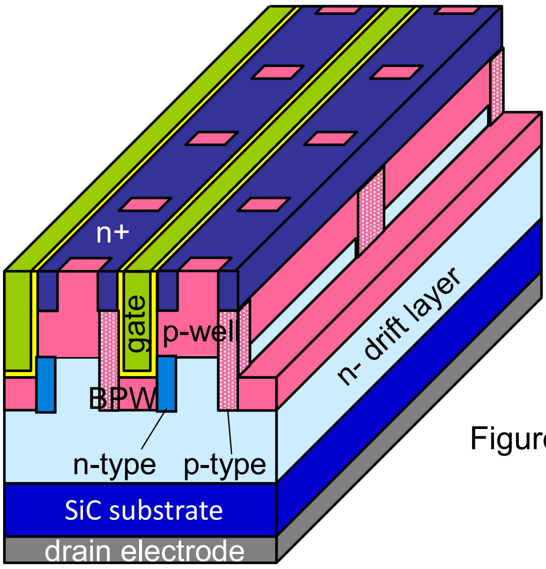

Figure 3: Cross-sectional perspective view of MOS cell part of the fourth-generation trench-type SiC MOSFET

Figure 4 compares the on-resistance of Mitsubishi Electric's trench-type SiC MOSFET and planar-type SiC MOSFET. It can be seen that the on-resistance is significantly reduced in the trench-type MOSFET. The specific on-resistance at room temperature is approximately 2mΩcm², achieving a top-level value. When the threshold voltage is high, the reduction in on-resistance is more pronounced in the trench-type compared to the planar-type. This is due to the formation of the MOS channel on a plane orthogonal to the (0001) plane, resulting in a relatively high effective mobility of the MOS channel, which is an advantage of the trench-type SiC MOSFET. Additionally, Mitsubishi Electric's trench-type MOSFETs have a high degree of design freedom in terms of ion implantation concentration and regions, allowing for the adjustment of various characteristics.

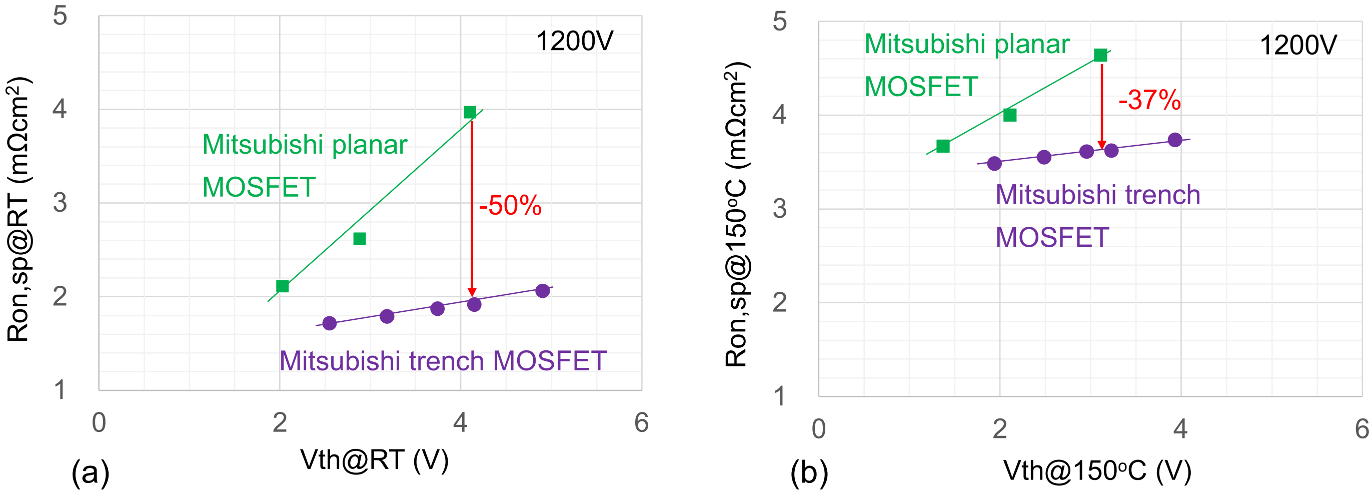

Figure 4 Comparison of on-resistance between Mitsubishi Electric's trench-type SiC MOSFET and planar-type SiC MOSFET: (a) at room temperature and (b) at high temperature(150°C)

Mitsubishi Electric's fourth-generation trench-type SiC MOSFET is ideal for xEVs, which strongly demand high threshold voltage and low on-resistance. As the initial application product, a module for xEVs is planned. In the future, the application of trench-type SiC MOSFETs will be expanded to various uses.

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Power Device Works