7th-Generation "X Series" 1,200-V/2,400-A RC-IGBT Modules

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The energy demand is steadily increasing in the world because of population increase and economic growth. To prevent global warming by CO_2 emission control and create responsible and sustainable society, high expectations are growing for the power electronics technology that efficiently converts electrical energy. Among these, a demand for insulated gate bipolar transistor (IGBT) modules, which are power semiconductors, is increasing as a key device for a power conversion system used in a wide variety of fields such as industry, consumers, automobiles and renewable energy.

Recent power conversion systems are becoming small and low-cost and have high reliability; therefore, IGBT modules are required to have higher power output and reliability. Fuji Electric has commercialized the 7th-generation "X Series" IGBT modules having higher power output and reliability by the technological innovation of chips and packages.

We developed a reverse-conducting IGBT (RC-IGBT) having the functions of an IGBT and a free wheeling diode (FWD) on one chip, as shown in Fig. 1. By combining the RC-IGBT technology and the above X Series technology, the total area per rated current has been reduced of the semiconductor chip mounted in the IGBT module. As a result, the rated current of the new product having the same size as before has been increased, and we have developed a new product having higher power output, which had been difficult with the conventional technology.

This review describes the "PrimePACK™*1 3+" with 1,200 V/2,400 A of the 7th-generation "X Series" RC-IGBT module we developed.

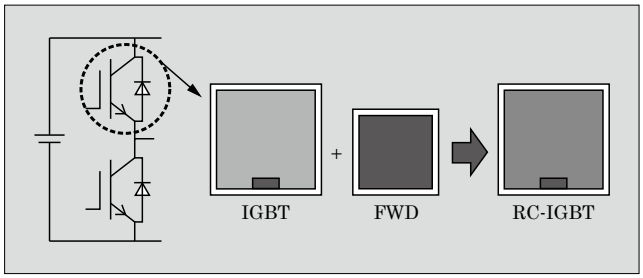


Fig.1 Schematic diagram of RC-IGB chip

1. Features

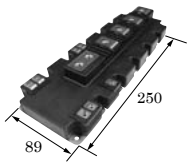
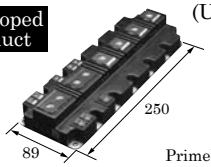
Table 1 shows the appearance and line-up of the conventional product and the developed product. With the technological innovation of RC-IGBTs and packages, the rated current of the product having a blocking voltage of 1,200 V has been increased from 1,800 A (maximum) to 2,400 A.

2. Applied Technology

2.1 Chip Technology

Figure 2 shows the cross-sectional structure and equivalent circuit of the X Series RC-IGBT. The conventional product required two chips: an IGBT and a FWD, which was connected in antiparallel. The RC-IGBT has the functions of an IGBT and a FWD on one

Table 1 Product appearance and line-up

		Rated current (A)		
		1,400	1,800	2,400
1,200 V	V Series	V-IGBT + V-FWD		
	X Series	X-IGBT + X-FWD		X-RC-IGBT
Product appearance		Conventional product  (Unit: mm) PrimePACK™*3		Developed product  (Unit: mm) PrimePACK™*3+

*PrimePACK™: Trademark or registered trademark of Infineon Technologies AG

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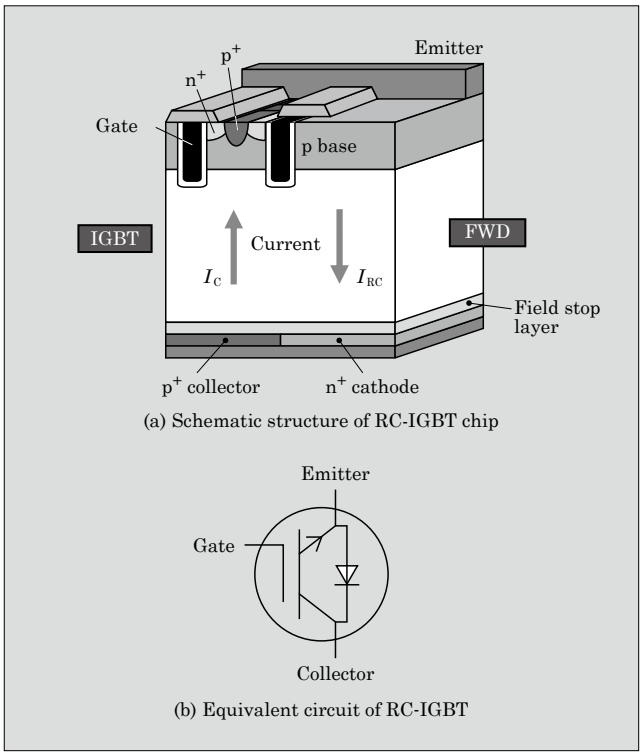

Fig.2 Cross-sectional structure and equivalent circuit of the 7th-generation "X Series" RC-IGBT

chip, and thus it can turn on electricity in both the forward and reverse directions with one chip in the same way as the conventional product.

In addition, by applying the chip technology that makes the surface structure smaller and the wafter thinning technology, the X Series IGBT module has collector-emitter saturation voltage $V_{CE(sat)}$ that is smaller than that of the conventional "V Series" by approximately 0.6 V in the same switching energy E_{off}. Applying the wafer thinning technology generally involves the risk of blocking voltage drop and current and voltage oscillation at the time of turn-off. To solve these problems, we suppressed the blocking voltage drop and oscillation by optimizing the field stop (FS) layer provided on the back surface, which is the chip technology of the X Series.

2.2 Package Technology

To further increase the power output of the X Series IGBT modules, the chip bonding temperature T_{vjop} at the time of operation is increased from 150 °C of the conventional V Series to 175 °C. However, the increase in the operation guarantee temperature leads to deterioration in the strength of the material and increase in thermal stress. Therefore, there is a concern that the aluminum wire bonding parts and the solder bonding parts on the chip may deteriorate rapidly, shortening the product lifespan. In addition, silicone gel generally involves a concern that the gel gets torn and the insulation performance deteriorates under in a high temperature environment. In the X Series, we optimized the wire bonding and developed solder materials and silicone gel materials to solve the above problems.

Further, by adopting an AIN insulating substrate with high heat dissipation, the heat resistance between the chip bonding parts and the case has been reduced, improving the heat dissipation.

These technological innovations for the X Series achieve both of power output increase and high reliability.

3. Power Output Increase by Terminal Temperature Decrease

To achieve high power output, it is necessary to increase the current capability of packages in addition to improving the characteristics of semiconductor chips. This is because the terminal temperature can excessively rise when large output current flows.

As shown in the white box of the product appearance in Table 1, the developed product has two terminals, whereas the conventional product has one terminal, to suppress the terminal temperature increase.

Figure 3 shows the results of evaluating the terminal temperatures of the conventional product and the developed product. The developed product has an increased number of terminals and can distribute the current when electricity is turned on. This decreased the terminal temperature by 50 °C compared with the conventional product.

Thus, the heat generation caused by the current flowing through the terminals has been greatly re-

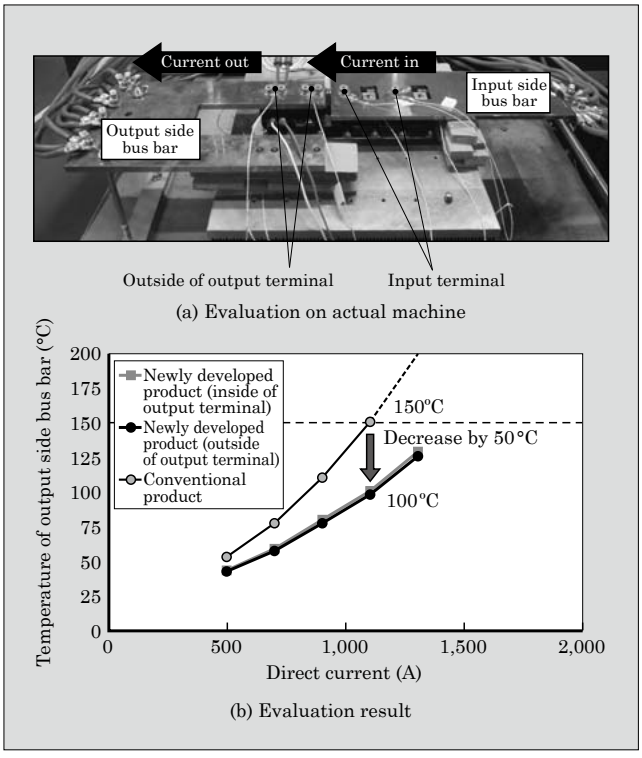

Fig.3 Results of heat-run evaluation and terminal temperature evaluation

duced compared with the conventional product, and the X Series can exhibit higher output with this higher current capability.

4. Features of "1,200-V/2,400-A" IGBT Modules

As described above, the RC-IGBT has a smaller total area of the semiconductor chip compared with the conventional combination of an IGBT and a FWD. However, when compared to the IGBT chip and FWD chip in the conventional product individually, the RC-IGBT has a larger chip area. Therefore, the RC-IGBT has lower heat resistance between the chip bonding parts and the case compared with IGBTs and FWDs, and therefore, it has excellent heat dissipation capability.

Figure 4 shows the calculation results of power consumption during inverter operation.

The developed product shows almost the same inverter power consumption as the conventional product. This equivalent power consumption and high heat dissipation capability, which is the feature of the RC-IGBT, reduces T_{vjmax} of the developed product by 31 °C compared with the conventional product.

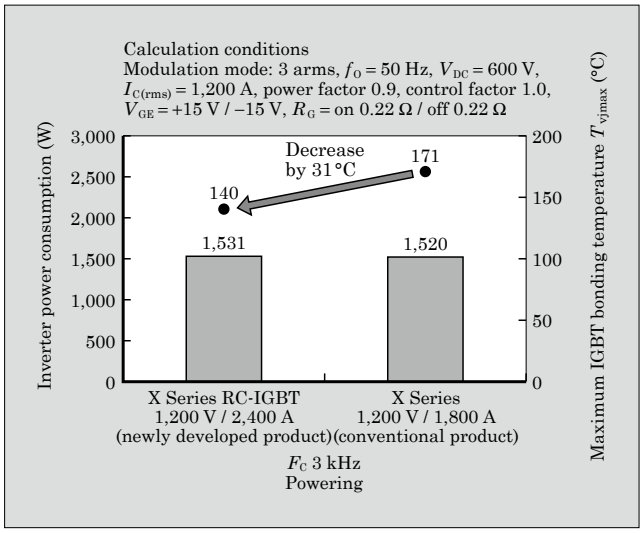

Fig.4 Calculation results of power consumption during inverter operation

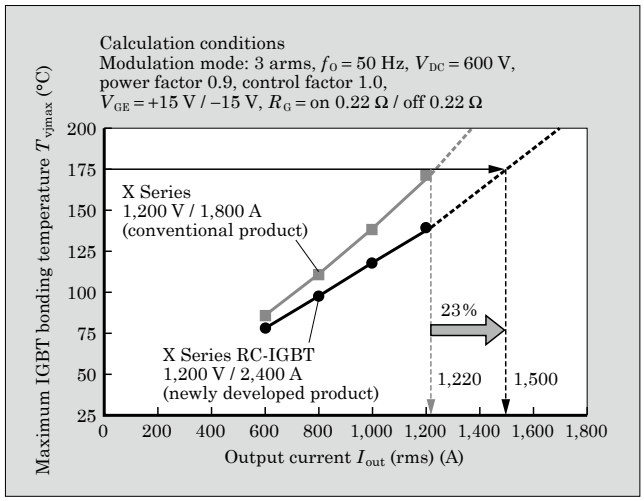

Fig.5 Relationship between output current and maximum IGBT bonding temperature

Next, Fig. 5 shows the calculation results of the inverter output current and the maximum IGBT bonding temperature T_{vjmax}. When the developed product is adopted, the output current of the power conversion system can increase by 23% compared with the conventional product.

Launch time

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Product Inquiries

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