7th-Genenation “X Series” RC-IGBT Module “Small-2B”

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Recently, as a solution to the energy resource depletion and global warming issues, expectations are rising for power electronics technology that contributes to the efficient use of energy. Above all, demand is increasing for insulated gate bipolar transistor (IGBT) modules, which are major components of power conversion equipment used in a wide range of fields including the industrial, consumer, automobile and renewable energy ones. A lowered power dissipation and improved reliability are strongly required of these IGBT modules. To make equipment smaller, there is also high demand for increasing the output current while maintaining the same package size as conventional products. However, increasing the output current of an IGBT module causes the operation temperature of IGBT and free wheeling diode (FWD) to rise, possibly leading to lower reliability. Accordingly, it is essential to have technological innovation for achieving both high output and high reliability.

Fuji Electric has developed the 7th-generation “X Series” semiconductor chips and packages to commercialize high-reliability IGBT modules. For this series, Fuji Electric has newly developed a reverse-conducting IGBT (RC-IGBT).

This RC-IGBT has the conventional IGBT and FWD functions integrated into one chip, as is shown in Fig. 1, making the chip area per rated current smaller. This has made it possible to mount more chips, which has resulted in a larger output as compared with conventional products that use the same package.

This paper describes the “Small-2B,” an RC-IGBT module integrating this RC-IGBT chip.

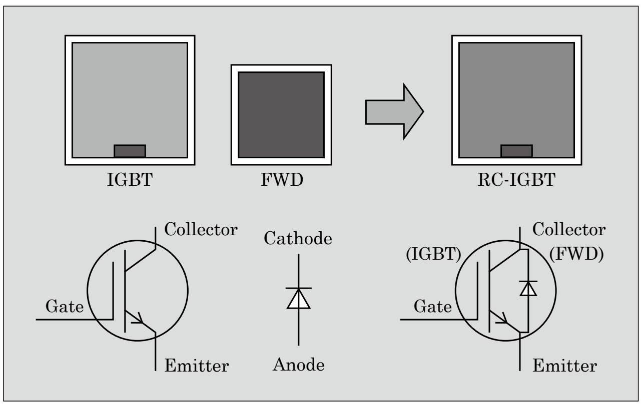

Fig. 1 Schematic drawings of RC-IGBT chips and equivalent circuits

1. Technologies Applied

1.1 Chip technology

The X Series IGBTs have the collector-emitter saturation voltage $V_{CE(sat)}$ significantly reduced because the surface gate structures have been miniaturized as compared with the “V Series” 6th-generation IGBTs. The products formed into a thin wafer have achieved an improved trade-off relationship between the turn-off loss and $V_{CE(sat)}$. On the other hand, a thin wafer causes a voltage oscillation at turn-off energy and reduces the breakdown voltage in case of without technical considerations. Therefore, we have solved this problem by optimizing the field stop layer, which

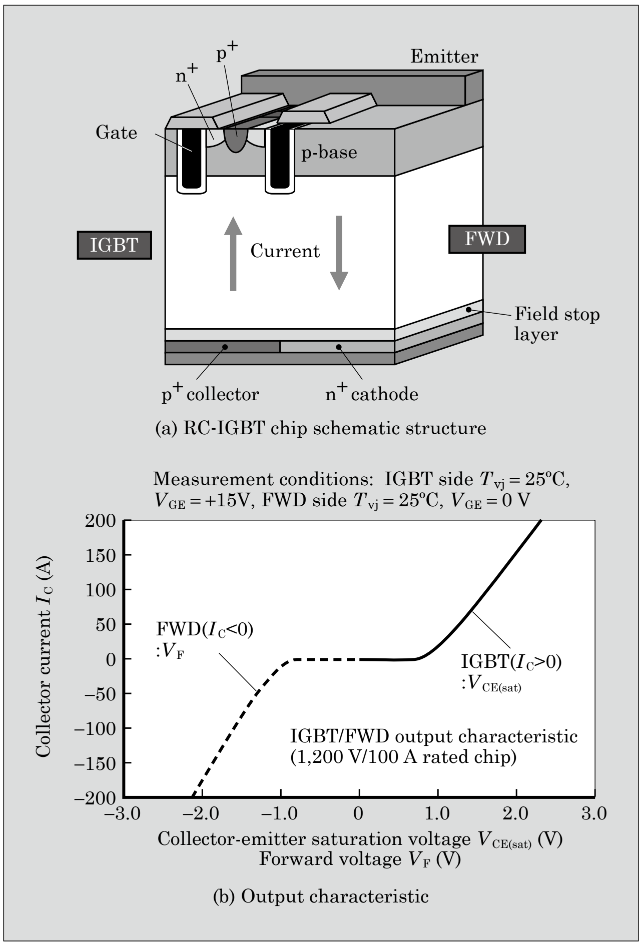

Fig. 2 Cross-sectional view and output characteristic of X Series RC-IGBT chip

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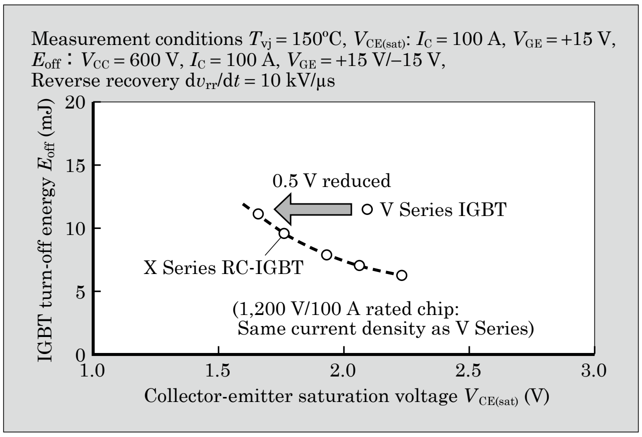


Fig. 3 Trade-off characteristic of X Series RC-IGBT chip

is the voltage withstanding structure on the back side of semiconductor chips.

The following describes the RC-IGBT to which the X Series technology has been applied. Figure 2(a) shows a schematic structure of the X Series RC-IGBT chip and Fig. 2(b) the output characteristic. An RC-IGBT has the structure of both IGBT and FWD in one chip and allows a current to flow in both the forward (solid line) and reverse (dotted line) directions.

As shown in the IGBT turn-off energy and $V_{CE(sat)}$ trade-off characteristic of the X Series RC-IGBT in Fig. 3, $V_{CE(sat)}$ has been reduced by approximately 0.5 V from that of the conventional V Series.

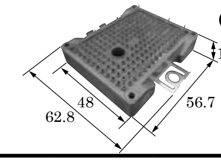
1.2 Package technology

In order to realize a high output current, the X Series IGBT module has increased the guaranteed continuous operating temperature from the conventional 150 °C to 175 °C. A higher output current increases the current variation arising from load fluctuation. This in turn causes a larger temperature fluctuation and thermal stress variation as well. Therefore, persisting in the conventional structure may cause the aluminum wire bonding on the semiconductor chips and solder under the chips to deteriorate, thus shortening the product life, and may cause lower reliability. The silicone gel filled inside the products for ensuring insulation performance is exposed to high temperature for a long time and the insulation performance may be deteriorated. With the X Series, we have optimized the aluminum wire layout, solder under the chips and silicone gel to solve these problems.

2. Product Line-Up

Table 1 compares the V Series, X Series and X Series RC-IGBT of the "Small-2B" line-up. Up to now, the maximum rated current was 35 A for the V Series and the X Series. The RC-IGBT technology has newly been applied to increase the maximum rated current to 50 A.

Table 1 "Small-2B" line-up comparison

		Rated current (A)			
		15	25	35	50
Small-2B	V Series	V-IGBT + V-FWD			
	X Series	X-IGBT + X-FWD			X-RC
Package appearance					

3. "Small-2B" Characteristics

Figure 4 shows the result of calculating power dissipation in an inverter using the X Series RC-IGBT module Small-2B 1,200 V/50 A. As compared with using the V Series IGBT module Small-2B 1,200 V/35 A, power loss of the X Series RC-IGBT module is approximately 15% lower.

Figure 5 shows the result of calculating the IGBT junction temperature against the inverter output cur-

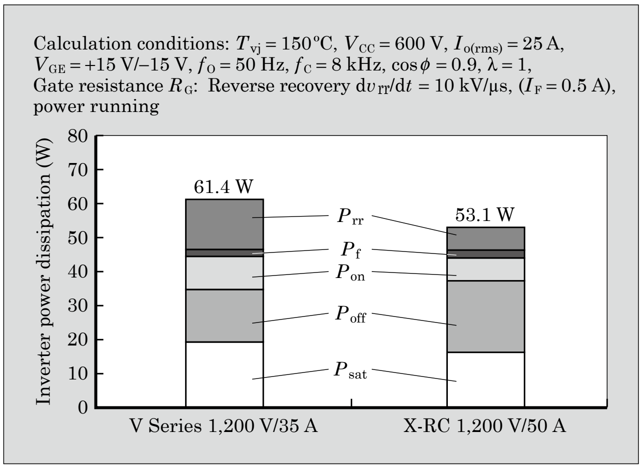


Fig. 4 Result of inverter power loss calculation

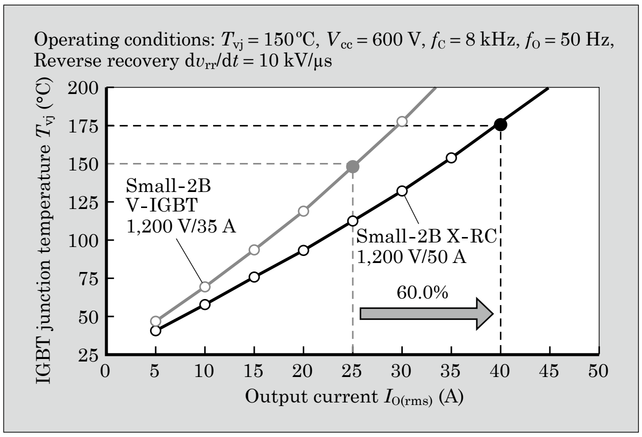


Fig. 5 Relationship between output current and IGBT junction temperature

rent. We have reduced the inverter power dissipation and raised the guaranteed continuous operating temperature from 150 °C of the V Series to 175 °C of the X Series to successfully achieve a 60% increase in the output current of products with the same package.

Launch time

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