“HPnC” High-Current Power Module for Railcars

MITOMO, Satoshi*   ICHIKAWA, Hiroaki*   HARADA, Takahito*

In recent years, it has become necessary to improve energy efficiency and reduce CO_2 emissions as measures against global warming. As a result, power conversion equipment that utilizes power semiconductors is being increasingly used in a wide range of fields. In particular, this kind of equipment has been undergoing capacity improvements and size reductions in the fields of railcars and renewable energy, including wind power generation and photovoltaic power generation. Therefore, the large-capacity insulated gate bipolar transistor (IGBT) modules in the equipment need to be installed easily for large-capacities with parallel connection and downsized through further increased current density.

To meet these market demands, we have developed the HPnC (High Power next Core), which is high-current power module with a 7th-generation “X Series” chip in a new package (M292).

1. Features

Table 1 shows the product line-up and features of the HPnC. The HPnC has a 2-in-1 circuit configuration with 7th-generation X Series IGBTs and FWD chips. Furthermore, it also incorporates a thermistor to detect temperature rise inside the module. In order to ensure high heat dissipation and reliability, an aluminum nitride (AlN) ceramic has been utilized for the insulating substrate, while also using high thermal-conductivity magnesium and silicon carbide composite materials (MgSiC) for the base material characterized by the equivalent coefficient thermal expansion (CTE) as conventional aluminum and silicon carbide composite materials (AlSiC). As a result, the module with the high reliability demanded by railcars applications has been realized. Figure 1 shows the external appearance of the module. This package ensures mounting compatibility with the modules of other companies.

Fig.1 “HPnC”

2. Features of the New HPnC Package

Table 2 provides a comparison of package characteristics with the conventional HPM (high-power module) for railcars.

2.1 Low inductance package

A laminated structure[1] between the collector terminal and the emitter terminal was adopted in order to reduce inductance of HPnC, as shown in Fig. 2. As a result, the module inductance is reduced by 76% from 42 nH for the HPM to 10 nH for the HPnC.

2.2 Enhanced current density

The current density is increased by approximately 12% from 5.76 A/cm^2 for the HPM to 6.43 A/cm for conventional HPM. This enhancement is achieved by lowering loss through the use of a 3.3-kV 7th-generation X Series IGBT chip and reducing thermal resistance of the junction-case temperature through the use of a MgSiC base characterized by a thermal conductivity 1.5 times that of the conventional AlSiC base.

Table 1 Product line-up

Product type	Rated voltage (V)	Rated current (A)	IGBT	FWD	Package type	Circuit configuration	Thermistor	Insulating substrate	Base
2MBI1000XVF170-50	1,700	1,000	X Series	X Series	M292	2 in 1	Built-in	AlN	MgSiC
2MBI1200XVF170-50		1,200							
2MBI450XVF330-50	3,300	450							

* Electronic Devices Business Group, Fuji Electric Co., Ltd.

New Products

Table 2 Comparison of package characteristics

Item	HPnC	HPM (conventional product)	Improvement rate (%)
External appearance			—
Dimensions W×D×H (mm)	100 × 140 × 38	130 × 140 × 38	—
Circuit configuration	2 in 1	1 in 1	—
Rating (typical)	3,300 V / 450 A + 450 A	3,300 V / 1,000 A	—
Module inductance	10 nH	42 nH (2-in-1 configuration)	76.2
Inductance during 2-unit parallel connection	2.5 nH	21 nH	88.1
Setting area (cm^2)	140.0	173.7	19.4
Current density (A/cm^2)	6.43	5.76	11.6
RoHS	Compliant	Not compliant	—
Ease of parallel connection	Compliant	Not compliant	—

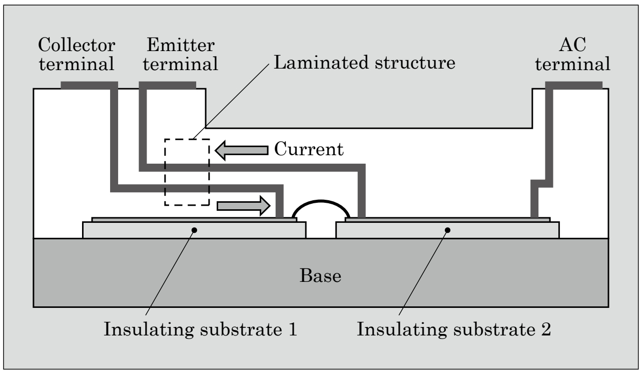

Fig.2 Cross-sectional view of "HPnC" laminated structure

2.3 Easy assembly in parallel connection and the reduction of total inductance

In recent years, it has become important that IGBT modules installed in high-capacity inverter systems are easily connected in parallel.

Figure 3 shows an assembly comparison between HPM and HPnC modules with parallel connection. A three-layer structure consisting of an overlapped collector busbar, AC busbar and emitter busbar is utilized for the HPM. Therefore, this configuration is complicated to assemble when mounting to the main circuit. On the other hand, for the HPnC, a two-layer structure consisting of an emitter busbar and collector busbar is utilized. This enables the AC busbar to be flexibly configured in the opposite direction. This leads to simplification of power supply line and improvement of assemblability.

Furthermore, in the HPnC, the collector terminal and emitter terminal can be mounted close to the capacitor. This arrangement allows the busbar to be shorten and reduce the inductance of the main circuit. Therefore, total inductance that is the sum of the main circuit inductance and the internal inductance of the module can be reduced by reducing both the main circuit inductance and the internal inductance of the module for the HPnC. As a result, further high speed switching become possible.

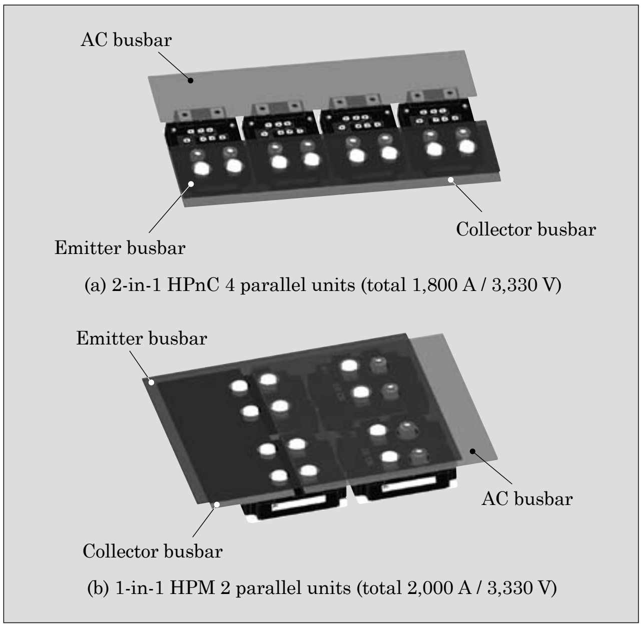

Fig.3 Comparison of assembly ease of modules with parallel connection

2.4 RoHS-compliance

It was difficult for the conventional HPM to conform to RoHS because the terminals and the direct copper bond (DCB) insulating substrate are bonded with solder. For the HPnC, adoption of ultrasonic bonding and bonded materials with equivalent CTE enables the achievement of RoHS-compliance and higher reliability than conventional products.

3. Improvement of IGBT Chip Characteristics

Figure 4 shows the improvement of characteristics

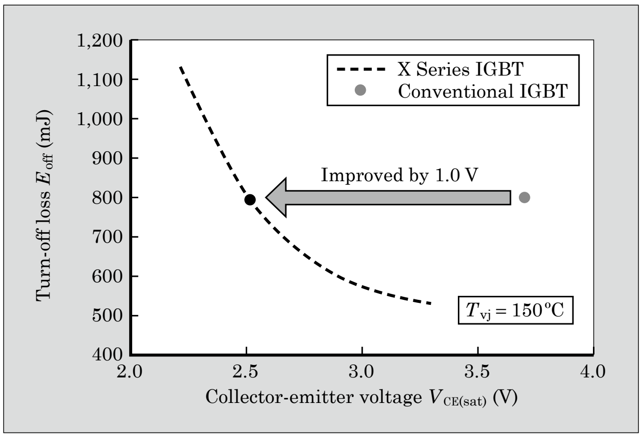

Fig.4 Characteristics improvement of the 3.3-kV "X-Series" IGBT chip

of the 3.3-kV X Series IGBT chips compared with conventional ones at junction temperature $T_{vj} = 150\,°C$. Turn-off loss E_{off} remained the same as before, but collector-emitter voltage $V_{CE(sat)}$ is improved by 1.0 V from 3.7 V for the conventional IGBT chips to 2.7 V for the X Series IGBT chip. The trade-off between $V_{CE(sat)}$ and E_{off} for X Series IGBT has been improved by expanding the active area through edge structure optimization and by thinning the drift layer.

References

(1) Sekino, Y. et al. "HPnC" High-Current SiC Hybrid Module. FUJI ELECTRIC REVIEW. 2017, vol.63, no.4, p.218-222.

Launch time

June 2020

Product inquiries

Sales Department I, Sales Division, Electronic Devices Business Group, Fuji Electric Co., Ltd.
Tel: +81-3-5435-7152

Fuji Electric
Innovating Energy Technology