IGBT Modules with Pre-Applied TIM

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ABSTRACT

When an IGBT module is mounted, thermal grease is applied between the cooling fin and the IGBT module to promptly transfer the heat generated from the IGBT module. An increasing number of customers are requiring IGBT suppliers to perform this thermal grease application. To meet this requirement, Fuji Electric has developed a family of IGBT modules with pre-applied thermal interface material (TIM) of phase change type. The adopted TIM features a high heat dissipation performance that is three times or better than that of the conventional products, and is liquefied at around 45 °C and solidified below that temperature, thus offering ease of transportation. This has realized IGBT modules with improved heat dissipation properties and reliability (thermal management).

1. Introduction

Insulated gate bipolar transistor (IGBT) modules are a vital component in various fields such as renewable energy (photovoltaic and wind power generation), automobiles, industrial equipment and social infrastructure. It is particularly important to improve aspects such as generated loss, heat dissipation properties and reliability for the improvement of the IGBT module features.

This paper describes an IGBT module with pre-applied thermal interface material (TIM) that improved heat dissipation properties and reliability (thermal management).

2. Background

Energy losses in power conversion in IGBT modules occur in the form of heat dissipation. Heat dissipation properties significantly affect the product lifetime and performance in power conversion. It is a common practice to apply thermal grease for conducting heat between the IGBT module and air/water cooling fin(1). The thermal grease that is referred to as 1 W has a thermal conductivity of around 1 W/(m•K), and it is often used for this purpose. Application patterns and applied quantity are very important(2). In recent years, an increasing number of customers have been requesting IGBT suppliers to perform thermal grease application in order to avoid incurring costs for application tools and grease printers, which would be necessary for assuring accurate application processing. In order to meet such demand, Fuji Electric has developed an IGBT module with pre-applied TIM. For this module, a 3 W-class TIM has been adopted, which has a heat dissipation performance that is three times or more effective than the conventional type. It is a phase-change type, with the property of liquefying around 45 °C but solidifying under this temperature for ease of transportation.

Although it is difficult to control the wet-spread of phase-change type TIMs, Fuji Electric has realized it by using the stencil mask designed by ourselves.

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3. Characteristics of Phase-Change Type TIM

The most significant feature of the newly developed IGBT module with pre-applied TIM is the use of the phase-change type TIM. This TIM has the following characteristics:

(a) It comes initially in a grease form.
(b) It transforms into rubber-like form by heat-treating to remove volatile solvent.
(c) It reverts to greasy consistency once further heated up beyond certain temperature.

The TIM usage procedures are as follows:

(a) Apply the grease-form TIM onto the IGBT module. A stencil mask should be used to even out the applied grease in patterns.
(b) Heat up the grease to remove volatile solvent and change it into a rubber-like form. As the TIM is solidified, the module can be packed for transportation.
(c) Mount the modules onto a heat sink at normal temperature.
(d) Activate the device: the heat generated by the IGBT module transforms the TIM into grease and it spreads over a cooling fin evenly.

The procedure is illustrated in Fig. 1.

Table 1 shows a comparison between conventional and phase-change type thermal grease. The thermal conductivity is 0.9 W/(m•K) for the conventional

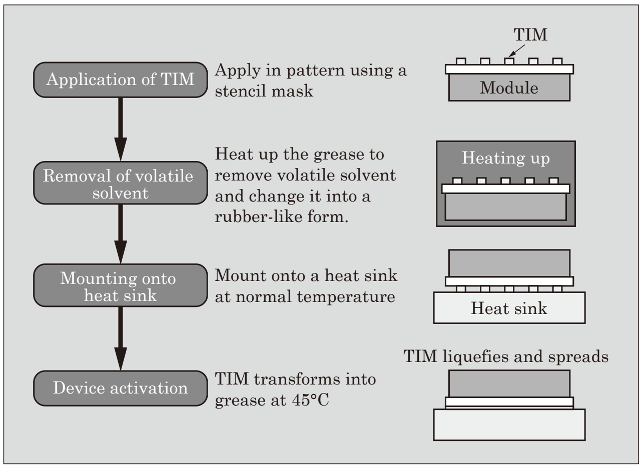

Fig.1 Phase-change TIM application procedure

Table 1 Basic specifications of TIMs

Product name	Newly developed product (phase-change TIM)	Conventional product A (thermal grease)	Conventional product B (thermal grease)
Appearance	Gray	White	White
Base oil	Non-silicon	Silicon	Non-silicon
Consistency (Pa・S)	135	39	195
Thermal conductivity [W/(m・K)]	3.4	0.9	0.9

grease, and it is 3.8 times higher for the phase-change TIM at 3.4 W/(m・K).

4. Performance of IGBT Module with Pre-Applied TIM

We conducted a performance test on the IGBT module with pre-applied TIM. The module and TIM subjected to the test are as follows:

○ Tested module: 1,200 V/600 A IGBT (2MBI600VJ-120)

○ Applied TIM: phase-change TIM

4.1 Wet-spreading property

The TIM was applied using the stencil mask designed by Fuji Electric[(3)], and dried for 20 minutes at 60 °C (manufacturer's recommendation) before the module was mounted on a glass block at a rated torque (see Fig. 2). The module activation was simulated by storing the modules in an oven at 60 °C, and test pieces were removed from the oven after the durations of 10, 30 and 60 minutes to verify the wet-spreading of TIM (wet-spreading property). The module temperature in the oven is shown in Fig. 3. We verified that the phase change from rubber-like form to grease-like form took place after 10 minutes of heating, and the grease-form TIM wet-spread satisfactorily in 50 minutes (see Fig. 4).

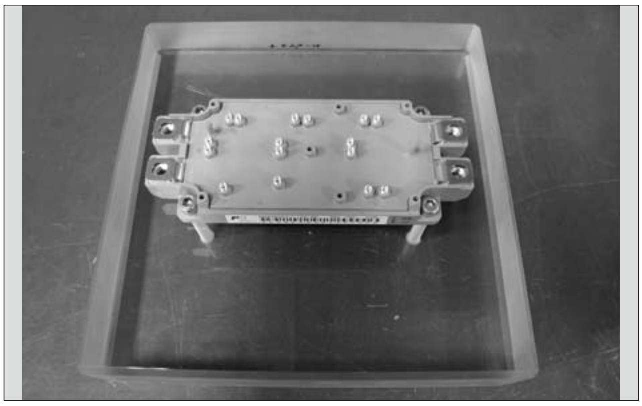

Fig.2 Glass block mounted condition

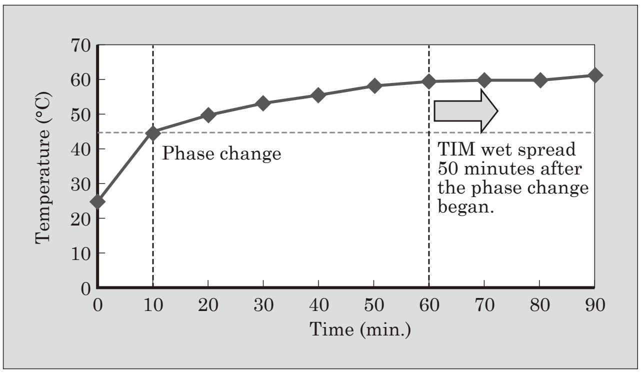

Fig.3 Module temperature when heated in oven

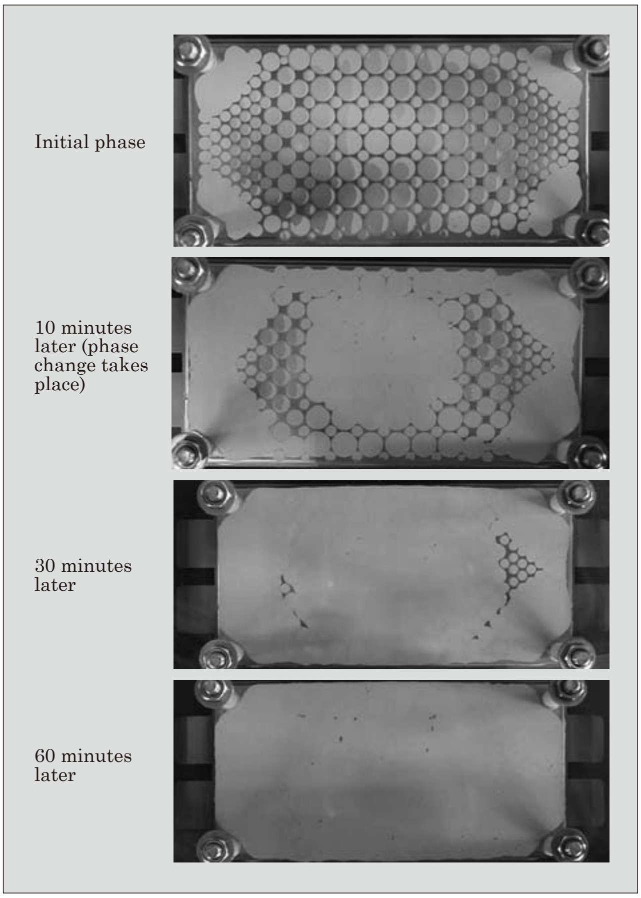

Fig.4 Wet-spreading property of TIM

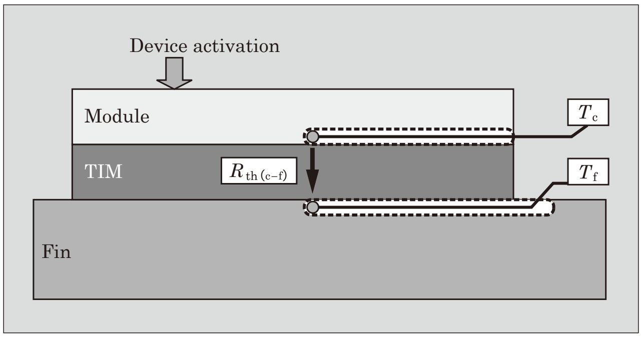

Fig.5 Thermal resistance measurement method

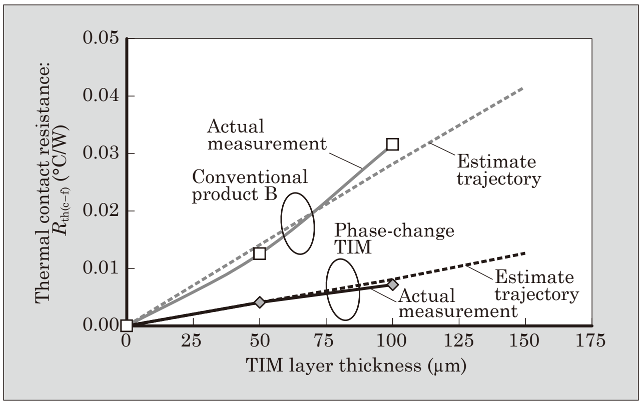

Fig.6 Comparison of thermal contact resistance

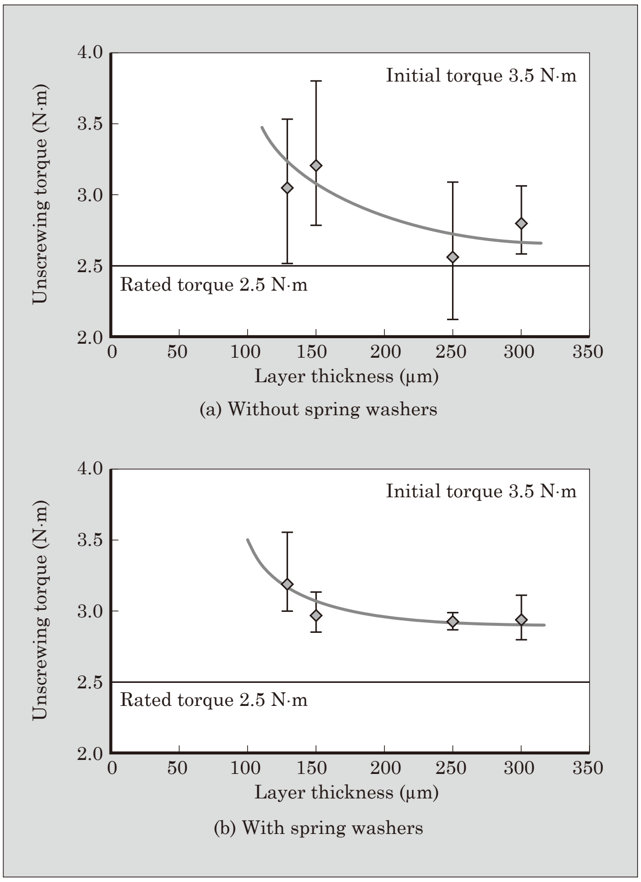

Fig.7 Torque loss assessment

4.2 Thermal contact resistance

We verified the effects in reducing thermal contact resistance obtainable by replacing 1 W thermal grease with 3 W phase-change TIM. Figure 5 illustrates the measuring procedure of thermal contact resistance. Thermocouples are attached to both the module and fin, and the thermal contact resistance was calculated using Equation (1).

$$R_{th(c-f)} = (T_c - T_f)/P \quad (1)$$

$R_{th(c-f)}$: thermal contact resistance
T_c : temperature of the module casing
T_f : temperature of the fin
P : power applied to the device

Figure 6 shows the measurement results. The measured thermal contact resistance was approximately identical with the calculated value, and it was able to be decreased to a third of the conventional one.

4.3 Torque loss

In terms of heat dissipation properties, there is another point for consideration apart from the performance of TIM: torque loss during heat-sink mounting. It is a phenomenon of decrease in the torque of the screws securing the module on the heat sink (screws loosen). It occurs when the TIM liquefies and spreads, and thereby the layer becomes thinner. This tends to occur more easily when the initial TIM layer is thicker. In addressing this issue, we recommend the use of spring washers for the fixing screws of heat sinks. We verified that using spring washers allowed the heat sink to be mounted without a torque loss issue (see Fig. 7). Regarding torque loss assessment, return torque is defined as the maximum torque at loosening a screw after tightening with initial torque of 3.5 N•m. When a return torque is larger than a rated torque, we judge it normal. Although a degree of torque loss occurred against the tightened torque of 3.5 N•m, the tightened torque did not decrease less than the rated torque of 2.5 N•m even if a layer thickness is increased. It gives the equivalent result as that of using the conventional thermal paste.

5. Future Development

Currently, M254 and M629 are the two available package types of IGBT modules with pre-applied TIM. We have already commenced the development of M271 and M272 package offerings and will extend the range for other types of packages in the future.

IGBT modules with pre-applied TIM are expected to be marketed to an increasing number of customers who demand grease application of IGBT suppliers because they are improved in heat dissipation and can be transported with TIM being applied (see Fig. 8).

Fig.8 Shipping arrangement

6. Postscript

In this paper, we described the IGBT module with pre-applied TIM that improved heat dissipation properties and reliability.

We will continue expanding the product range to meet customer needs and further improve the thermal management technologies for IGBT modules by developing TIM and other high heat dissipating materials for the development of new products.

References

(1) Momose, F. Thermal management of IGBT module systems, PCIM Asia'.

(2) FUJI IGBT MODULES APPLICATION MANUAL. "Chapter 6 Cooling Design".

(3) Nishimura, Y. et al. Thermal Management Technology for IGBT Modules. FUJI ELECTRIC REVIEW. 2010, vol.56, no.2, p.79-83.

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