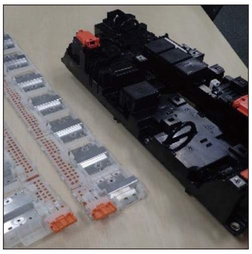

Connection Parts in BEV Battery Packs

Hideo TAKAHASHI*, Taiji YANAGIDA*, Osamu NAKAYAMA, and Hiroki SHIMODA

The increase in motor cars, specifically hybrid electric vehicles (HEVs), plug-in hybrid electric Vehicles (PHEVs), and battery electric vehicles (BEVs), is expected to be driven by policies promoting fuel economy and CO_2 emission control. In order to support the growth of BEVs, we are developing and mass-producing connection parts such as battery wiring modules, high-pressure junction boxes, and wiring harnesses for battery packs. These connection parts play a significant role in improving the performance of the battery packs by ensuring compact size, space efficiency, and high current capacity. This paper highlights the features and benefits of our battery wiring module and high-voltage junction box as essential components in the battery pack.

Keywords: electric vehicles, high-voltage battery pack, battery wiring module, high-voltage junction box

1. Introduction

Recently, the spread of electric vehicles has been accelerating in line with fuel efficiency and emissions control policies adopted by respective countries to reduce CO_2 emissions. By 2035, the sales ratio of electric vehicles is expected to increase significantly to about 88%, which is more than five times the current level. With battery electric vehicles (BEVs) expected to account for about 58%, automakers have been further accelerating the development of BEVs. Meanwhile, BEVs have issues in terms of mileage and quick charging time, which largely depend on the battery pack performance. To solve these issues, active efforts have been made to develop battery packs that can cope with higher energy density and current to achieve smaller space and higher capacity while enhancing safety. To improve the performance of battery packs, connection parts that connect the battery with functional parts also play a key role. They are expected to offer functions that contribute to downsizing and space saving, coping with higher currents, and improving safety.

Thus far, we have developed and mass-produced many high-voltage products used in battery packs. Initiatives are underway to develop technologies and products that meet the evolution of BEVs, which will rapidly increase in the future.

2. Connection Parts in BEV Battery Packs

Figure 1 shows an example of the layout of components inside a high-voltage battery pack in a BEV. Arranged in the chassis of a vehicle, the high-voltage battery pack consists of battery modules, which comprise many cell stacks, an ECU, which monitors and controls the battery condition, and functional parts, which switch on and off the power output, as well as connection parts, which connect these parts.

Connection inside the high-voltage battery pack requires many connection parts, including a battery wiring module, which connects batteries and transmits battery information, a high-voltage junction box, which performs switching and ensures safety protection, a busbar, which connects modules to apply large currents, a low-voltage wiring harness, which supplies low-voltage power and transmits information, and a high-voltage connector, which is used for fitting of the opening.

Among connection parts in battery packs, this paper focuses on the battery wiring module and the high-voltage junction box that we developed as products. These parts were used in the bZ4X model (released in 2022), a BEV manufactured by Toyota Motor Corporation.

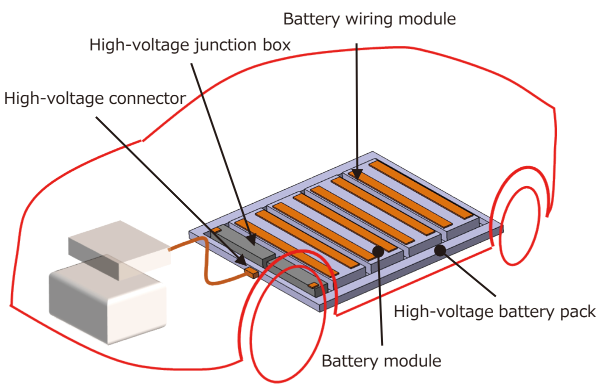

Fig. 1. Layout of components inside a high-voltage battery pack (example)

2-1 Battery wiring module

A battery wiring module consists of such parts as a busbar, wiring material, thermistor, and insulating resin. It connects the battery electrodes of battery modules and transmits the voltage and temperature information of each battery module to the ECU. A BEV, which is powered solely by the battery, is equipped with battery modules whose capacity is dozens of times more than those of an hybrid electric vehicle (HEV) to ensure sufficient mileage. Manufacturers aim to enhance the energy density of battery packs to increase both the mileage and cabin space. A battery wiring module, which is installed on battery modules, is required to be thin and ensure space saving.

Photo 1 shows our battery wiring module for BEVs. In this product, battery electrodes are connected in series by a busbar. An flexible printed circuit (FPC) is used for the circuit, and a chip thermistor is installed on the circuit. The FPC consists of copper foil, which is a conductor, polyimide, which is an insulating material, and an adhesion layer. It is thin and flexible and enables the soldering of chip parts. Application of the thin FPC helped reduce the wiring height by about 60%.

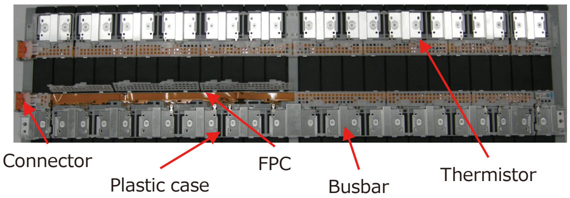

Photo 1. Battery wiring module for BEVs (product example)

Meanwhile, an FPC, whose circuit density is higher than that of an electric wire, is likely to cause a short circuit between adjacent circuits due to the high-temperature, high-humidity in-vehicle environment and the high voltage applied to the circuit (Fig. 2).

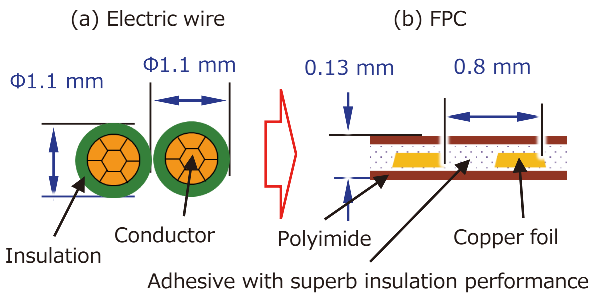

Fig. 2. Correspondence to the in-vehicle environment of the FPC

It should also be noted that dissimilar materials are used for connection between a busbar and FPC copper foil, posing an issue in terms of the connection method. To cope with a short circuit with adjacent circuits, it was necessary to select a material capable of ensuring reliability, including durability, and to verify and evaluate the design. We developed an FPC material in collaboration with Sumitomo Electric Printed Circuits, Inc., an FPC development and manufacturing division of our group, and confirmed that there was no problem.

For connection between a busbar and an FPC, we selected nickel as a material that enabled soldering with FPC copper foil and laser welding with the busbar to achieve connection (Photo 2).

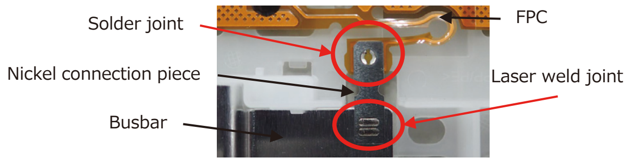

Photo 2. Connection between a Nickel connection piece and a Busbar

A chip thermistor on the FPC is used in contact with the battery. To ensure the temperature measurement accuracy, it was essential to ensure insulation performance with the battery and provide a structure that maintained stable contact. An overcoat was provided to ensure insulation performance with the battery. To ensure stable contact with the battery for temperature measurement, we developed a structure incorporating a coil spring to achieve an extension-retraction stroke and adapt to the battery tolerance and vibration displacement (Fig. 3).

Application of an FPC contributed to increasing the wiring density and reducing the thickness of the battery wiring module.

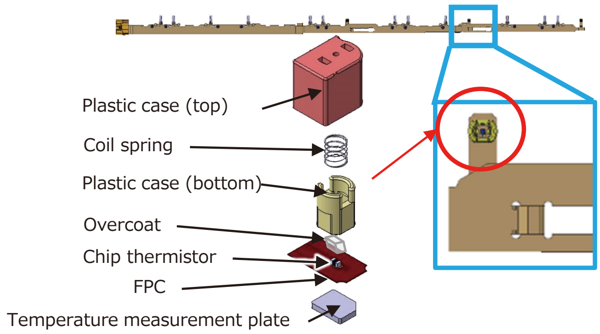

Fig. 3. Thermistor structure

2-2 High-voltage junction box

A high-voltage junction box is installed on the input-output of a high-voltage battery pack. It features a branching function integrating a relay, which switches on and off, a fuse, which shuts off a circuit in the event of an abnormality, and a current sensor, which detects the charging and discharging current values. A high-voltage junction box installed in BEVs, which are powered only by electricity, is solely responsible for ensuring safety of the power source and must meet high levels of reliability requirements compared to an equivalent used in HEVs and plug-in hybrid electric vehicles (PHEVs), which are also equipped with an internal combustion engine.

The biggest issue of a high-voltage junction box is the increase in heat generation due to higher currents used in BEVs. Parts that generate heat in a high-voltage junction box include a relay and fuse. Higher currents are increasingly used to improve the driving performance of BEVs (which leads to an increase in the driving power) and reduce the charging time. The heat dissipation design has become important to cope with the increase in the amount of heat generated.

A product example of our high-voltage junction box for BEVs is shown in Photo 3. It is divided into two parts: one arranged on the positive side of the battery, and the other arranged on the negative side. A relay, a fuse, and other parts are installed on the positive side, while a relay, a current sensor, and other parts are installed on the negative side. The positive and negative terminals of a battery are connected to the input side of each high-voltage junction box. A busbar, which is connected to the high-voltage connector at the outlet of the battery pack, is connected to the output side.

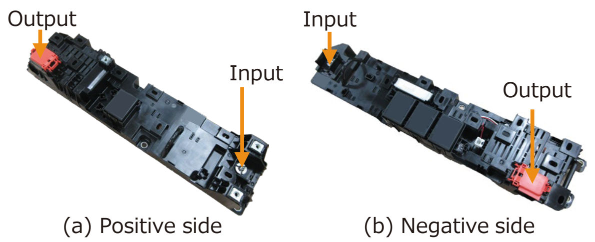

Photo 3. High-voltage junction box for BEVs (product example)

To cope with the abovementioned issue in the thermal design, this product employs a structure in which heat is transferred via the busbar, which is the conduction path, and dissipated to the enclosure cooling surface, to which the high-voltage junction box is secured, via the thermal interface material (TIM)*1 and the plastic case, as shown in Fig. 4.

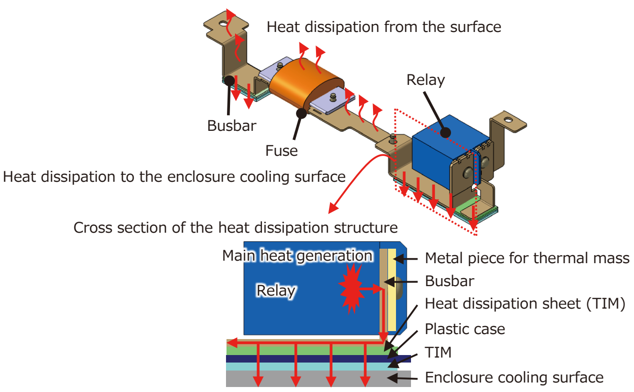

Fig. 4. Heat dissipation structure of the high-voltage junction box

This product is assembled by sandwiching the heat dissipation sheet, which is a TIM containing a thermally conductive filler based on the sheet-shaped base material, between a busbar and an insulation plastic case. The high-voltage junction box is also thermally connected with the enclosure cooling surface using a TIM to effectively dissipate the heat generated. This structure has made it possible to reduce the required sheet thickness of a busbar by about 35% from 3.5 mm to 2.3 mm. It should be noted that the decreased sheet thickness of the busbar leads to lower heat capacity and higher susceptibility to short-term heat generation. We implemented measures by tightening a metal piece, which adds the minimum required heat capacity, with heat-generating parts. This has contributed to optimizing the copper consumption, cutting the cost, and reducing the weight.

3. Conclusion

This paper reported on the characteristics of our two mass-produced connection parts in battery packs for BEVs.

(1) Battery wiring module
Use of an FPC for wiring, installation of a thermistor, and connection with an FPC
(2) High-voltage junction box
High-heat-dissipation structure to cope with higher currents

In addition to the battery wiring module and high-voltage junction box that we explained in this paper, we have developed and mass-produced many high-voltage products, such as high-voltage harnesses and high-voltage connectors. We have the capability to make coordinated and comprehensive proposals regarding connection parts in and outside battery packs. In line with the acceleration of electrification, we will promote the development of high-voltage products of higher quality and safety by combining our expertise in mass production.

Technical Term

*1 TIM: Abbreviation for "thermal interface material." It refers to a thermally conductive material to fill the gap between materials.

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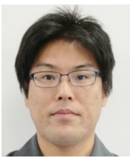

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