

# **Investigating R&D Committee on Power Module Insulation and Evaluation technologies**

Technical Committee on Dielectrics and Electrical Insulating Materials

## **1. Objective**

In recent times, attention to power electronics has been increasing with regard to energy saving and global environmental protection. Examples of related applications include inverter control of home electric appliances, elevators, electric railcars, and electric vehicles. Moreover, the electrification of aircraft is being examined. Power semiconductor devices play a central role in such power conversion and control, and devices packaged by wiring multiple power semiconductors act as power modules. These power modules require miniaturization, high density, high efficiency, and high reliability; one of the main problems faced in this context is reliable electrical insulation. Current power module classes range from several hundred volts to several thousand volts. Although breakdown modes may differ between such low- and high-voltage classes, they can be handled using common evaluation methods.

Therefore, investigating the need for electrical insulation reliability evaluation methods is vital to the development of power modules for high-voltage applications. On the other hand, new insulating materials (substrates, encapsulants, etc.) are being sought for the development of new power modules, and possible candidate materials are also being considered. However, the potential of these new materials is unknown, and evaluation techniques for their applicability have not been established. Thus, we wish to establish this investigation committee to adapt suitably to the present conditions, examine trends in the evaluation techniques needed for power module development, and identify possible application of new insulating materials.

## **2. Background and internal and external research activities**

The understanding of high-field electric phenomena is becoming increasingly important because of the increasing demand for miniaturized, high-voltage, and special environments (high and low temperatures, stress repetition, low pressure, etc.) for the use of power modules. For example, in electric power equipment, insulation evaluation was mainly performed using AC voltage in the past; however, the focus is steadily being directed toward the use of power modules. However, actual power electronics equipment is exposed to not only AC but also DC and its inversion, as well as repetitive impulse voltage. Thus, the associated high-field electric phenomena are highly complicated, and many aspects remain yet to be elucidated.

On the other hand, even though suitable evaluation techniques are not yet available for material manufacturers, the aforementioned characteristics still need to be ascertained.

The previous IEEJ committee established to deal with this subject was on inverter surge insulation and partial discharge measurement under repetitive voltage impulses. The findings of this committee appeared in IEEJ Technical Reports No. 1218 and 1407. However, these results were obtained using motor-side approaches, and no committees has focused on power modules as sources of inverter generation.

Currently, study groups and consortia of various academic societies are working toward power device assemble technologies. However, there is hardly any investigation of electrical insulation technology for power modules. It is fitting that this shall be addressed by the committee proposed herein. It shall commence work under the ambit of the Dielectric and Insulating Materials Technology Committee of the IEEJ, the industrial impact of which is expected to be significant.

### 3. Investigative matters

- (1) Latest trends in power module technology development  
(applications, structure, voltage, and electric field classes, etc. surveyed based on published articles)
- (2) Reliability evaluation techniques for power module insulating materials  
(under high temperature, under large current, heat cycle, insulation characteristics, space charge, minute current, partial discharge, combined stress, mechanical and electrical long-term life, high-temperature humidification bias test, high-frequency acceleration equivalence, unit test/product test, etc.)
- (3) Latest insulating materials applicable to power modules  
(ceramic substrate, resin substrate, encapsulant, etc.)

Based on the above research and investigation targets, 12 meetings will be scheduled for three-year activities. Specific themes will be set at each meeting as general information is exchanged, and lectures by specialists (including non-committee members) will be scheduled. In the lecture activities, materials equivalent to the workshop will be prepared, which will contribute to the preparation of subsequent workshop materials and technical reports. The committee will also survey trends in overseas technological development and research by reviewing reference papers and sharing the latest information within the committee. In addition, the trends in overseas technological development and research will be surveyed by reviewing reference papers and sharing the latest information within the committee.

### 4. Expected effects

Based on the background of research and aforementioned research activities, this committee will diligently organize and consider each item, including mutual friendly competition, while clarifying and disseminating near-future technical development items and summarizing technical information, including recommendations.

### 5. Term of investigation

December 2018 to November 2021 (3 years)

### 6. Committee members (As of April 2021)

| Position    | Name              | Affiliation  | Member/Non-member category of IEEJ |
|-------------|-------------------|--|------------------------------------|
| Chairperson | Masahiro Kozako   | Kyushu Institute of Technology                                   | Member                             |
| Member      | Yuta Ichikura     | Toshiba Infrastructure Systems & Solutions Corporation           | Member                             |
| "           | Yusuke Imai       | National Institute of Advanced Industrial Science and Technology | Non-member                         |
| "           | Yoshimichi Oki    | Waseda University  | Member                             |
| "           | Takashi Ota       | Panasonic Corporation  | Member                             |
| "           | Keigo Owashi      | Sekisui Chemical Co., Ltd.                                       | Non-member                         |
| "           | Shigemitsu Okabe  | Japan Science and Technology Agency                              | Member                             |
| "           | Kazunori Kadowaki | Ehime University   | Member                             |
| "           | Ryota Kitani      | Osaka Research Institute of Industrial Science and Technology    | Member                             |
| "           | Jumpei Kusukawa   | Hitachi, Ltd.  | Member                             |
| "           | Akiko Kumada      | The University of Tokyo  | Member                             |
| "           | Hiromi Kurashima  | Sumitomo Electric Industries, Ltd.                               | Non-member                         |
| "           | Muneaki Kurimoto  | Nagoya University  | Member                             |

| <b>Position</b>     | <b>Name</b>        | <b>Affiliation</b>   | <b>Member/Non-member category of IEEEJ</b> |
|---------------------|--------------------|--|--|
| Member              | Norio Kurokawa     | He retired from Japan Electrical Insulating and Advanced Performance Materials Industrial Association. | Non-member                                 |
| "                   | Toshio Shimizu     | Toshiba Mitsubishi-Electric Industrial Systems Corporation   | Member                                     |
| "                   | Yusuke Daiko       | Nagoya Institute of Technology   | Member                                     |
| "                   | Tatsuo Takada      | Tokyo City University  | Member                                     |
| "                   | Katsumi Taniguchi  | Fuji Electric Co., Ltd.  | Member                                     |
| "                   | Masayoshi Nagata   | University of Hyogo  | Member                                     |
| "                   | Motoharu Haga      | Daicel Corporation   | Non-member                                 |
| "                   | Hiroaki Miyake     | Tokyo City University  | Member                                     |
| "                   | Yoshinobu Murakami | Toyohashi University of Technology   | Member                                     |
| "                   | Yasumasa Morishima | Furukawa Electric Co., Ltd.  | Member                                     |
| "                   | Suzuya Yamada      | Denka Co., Ltd.  | Non-member                                 |
| "                   | Kei Yamamoto       | Mitsubishi Electric Corporation  | Non-member                                 |
| Secretary           | Nobuhito Kamei     | Rimtec Corporation   | Member                                     |
| "                   | Yuji Hayase        | Fuji Electric Co., Ltd.  | Member                                     |
| Assistant secretary | Naoya Kishi        | Zeon Corporation   | Member                                     |

#### **7. Activity schedule**

Committee meetings: 4 times/year; Secretariat: 1 time/year; Technical meetings: 2 times/3 years

#### **8. Reporting format**

A technical report shall be prepared to present the results.