New Evaluation Technology of EMC to Improve Electrical Reliability of High-Voltage Package

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1 Abstract

Energy policy is an important issue in the world, and power semiconductors are expected to achieve high efficiency by (1) increasing the voltage, (2) increasing the power density, and (3) reducing the energy loss. Therefore, the EMC (encapsulation molding compound) for power semiconductors is required to have further higher heat resistance and higher break-down voltage reliability. In this report, we discuss the mechanism and degree of EMC's impact to leakage current. As a result, it was found that the polarization of EMC contributes to the leakage current after applying high bias at high temperature for a long time, and the dielectric constant including space charge polarization has high correlation with leakage current as a polarization evaluation method.

2 Characteristics of the New Technology

Correlations were obtained between general electrical properties (volume resistivity and dielectric constant at 1 MHz) and leakage current by applying a new concept of dielectric constant. The correlations included space-charge polarization to leakage current, for which no correlation could be obtained by the general electrical properties.

3 Background of the Development

In recent years, power electronics-driven energy policies and associated technology developments have been vigorously promoted in different countries. Next-generation SiC power semiconductors in particular are expected to reduce power loss by band gap expansion, and hence have started to go into mass production for use in some electric railways or vehicles. Challenges, however, remain with the wafer fabrication cost at a high level. Though advantageous in terms of cost, Si power semiconductors have the drawback of a large power loss. Accordingly, the author decided to establish a leakage current reduction technology related to power losses in order to propose an encapsulation molding compound (EMC) for SiC and Si power semiconductor packages capable of further power loss reduction.

It has been expected that the electrical properties of an EMC contribute to leakage current. Because of its low correlation with general physical properties, such as volume resistance or dielectric constant (1 MHz), there has been no well-defined method for reducing leakage current. Then, assuming that leakage current increases because of the polarization of the EMC applied on chips, the author turned her attention to the polarization under high temperature bias for a long time. In this study, as reported below, the author established a technique for determining a new physical property value (dielectric constant including space-charge polarization) correlated with leakage current, which is the indicator of breakdown voltage reliability.

4 Technical Details

The leakage current must be below a specified value after the environmental test processing (for example, high temperature reverse bias or high temperature high humidity reverse bias). On the other hand, it was inferred from the test time, and the occurrence tendency or the semiconductor chip structure, that the polarization of the EMC applied on chips contributes to increases in leakage current. For EMCs, the dielectric constant is often used as the indicator of polarization. In such cases, the dielectric constant is conventionally expressed as a measurement value obtained at ordinary temperature and 1 MHz (on the order of microseconds); these test conditions, however, differ widely from those of the relevant environmental test, which is performed at high temperature over a long time. Accordingly, with the focus on the dielectric constant, including space-charge polarization under high temperature, the author studied the evaluation method and performed measurements. Additionally, measurements were taken of leakage current using our HTRB evaluation system. Use was made of the result obtained after 336 hours under specific environmental test conditions (175°C and 1,200 V reverse bias). The results of the two tests revealed the correlation between dielectric constant and leakage current including space-charge polarization (**Figure 1**).

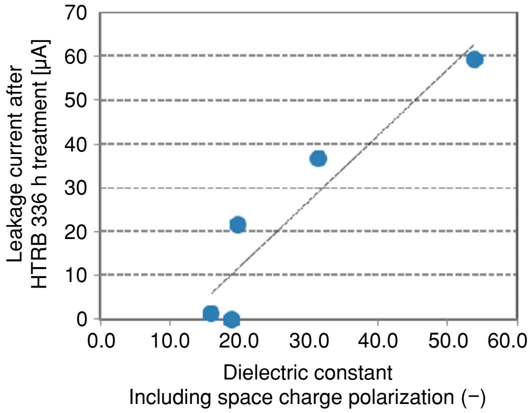
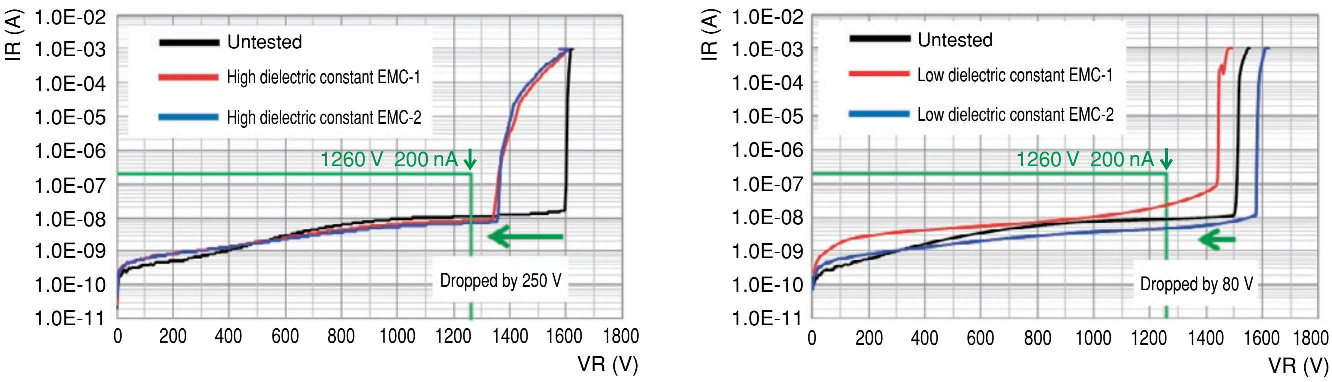


Figure 1 Relationship between leakage current after HTRB 336 h treatment and dielectric constant including space charge polarization

As for failure analysis, the packages were evaluated for I-V characteristic variations after the 336-hour HTRB test. As shown in **Figure 2**, the high dielectric constant EMC exhibited a decrease in I-V curve threshold voltage by 250 V as compared with the untested one, while the low dielectric constant EMC showed a decrease in I-V curve threshold voltage by 80 V. Thus, the results of the I-V curves also revealed the effects of the dielectric constants, including space-charge polarization on the electrical properties. In addition, an emission analysis also revealed that a high dielectric constant product easily undergoes changes in its depletion layer, which is the breakdown voltage control portion of the device, and therefore that the dielectric constant including space-charge polarization is useful for leakage current control.



(a) I−V characteristics with high dielectric constant EMC

(b) I−V characteristics with low dielectric constant EMC

Figure 2 Evaluation result of I-V characteristics with high or low dielectric constant EMC

5 Future Business Development

・Improve EMCs for high breakdown voltage power semiconductors based on this technology.

[References]

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