Current Distribution Based Power Module Screening by New Normal/Abnormal Classification Method with Image Processing

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journal or publication title	Power Semiconductor Devices and IC's (ISPSD), 2017 29th International Symposium on
page range	407-410
year	2017-07-24
URL	http://hdl.handle.net/10228/00006268

doi: info:doi/10.23919/ISPSD.2017.7988970

Current Distribution Based Power Module Screening by New Normal/Abnormal Classification Method with Image Processing

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***Abstract*— We developed a screening equipment for ceramic substrate level power module of IGBT. The equipment realizes a new screening test with current distribution. The equipment acquires magnetic field signals over bonding wires and finally classifies to normal/abnormal module automatically. We established statistics based normal/abnormal classification with image processing. It is expected to be applied for screening in a production line and analysis to prevent the failure of power modules.**

***Keywords*— current distribution; current crowding; IGBT; power module; classification method; image processing**

I. Introduction: Proposal of new screening of power module

High performance Insulated Gate Bipolar Transistor (IGBT) modules are widely applied to various fields, such as hybrid electric vehicles (HEVs), railway traffic and wind power generation, and are becoming a key component of social infrastructure. It is particularly important to prevent the imbalanced current in a chip or among chips triggering destruction by partial high temperature or partial avalanche breakdown. Current distribution has already been reported, and the research results suggest the high possibility of imbalanced current [1, 2]. However, the conventional screening method does not employ a current distribution test because commercially available current sensors are big for the size of IGBT chips [3, 4].

We propose a current distribution based screening with film sensors for ceramic substrate level power module [5-11]. The new normal/abnormal classification method by statistical approach with several advanced information processing is employed for accurate screening [12, 13].

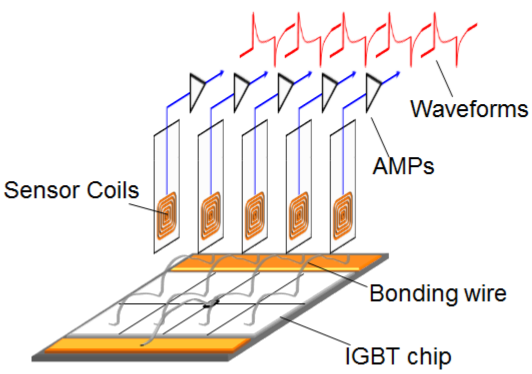

Fig. 1. Schematic view of measurement method of magnetic flux signals.

II. Configuration of screening equipment

The developed screening equipment consists of new kinds of 16-channel film sensor array modules over bonding wires, replaceable test head, power circuit for inductive load switching and digitizer with LabVIEW program (see Fig. 1 and Fig. 2).

The film sensor array module consists of 16 sheets of film sensor with amplifiers by printed circuit board (PCB) technology, and is placed over the bonding wires of each chip to acquire magnetic field. Although analog amplifiers increase the signal to noise (S/N) ratio, the amplifier boards are directly affected by switching noise from near wiring and contact pins. Therefore, the amplifier boards are surrounded by a shield case.

The test head is placed in the central part of the equipment. Sensor array modules are mounted by arms over the IGBTs on power module on the stage. The stray inductance of the circuit is reduced by the special contact pins, parallel plate wiring and the close layout of the high side/low side modules. The screening equipment can test all kinds of the module by replacing a test head.

The power circuit can test switching characteristics up to 1000 V and 1200 A. There are five steps – from 50 µH to 500 µH – of load inductance for double pulse switching. It also has a security mechanism comprised of over current protection, an electric discharge switch, and an emergency button.

The role of the digitizer with the LabVIEW program is "digital calibration for sensor array module", "signal processing including normal/abnormal classification" and "display of the information for normal/abnormal classification (see Fig. 3).

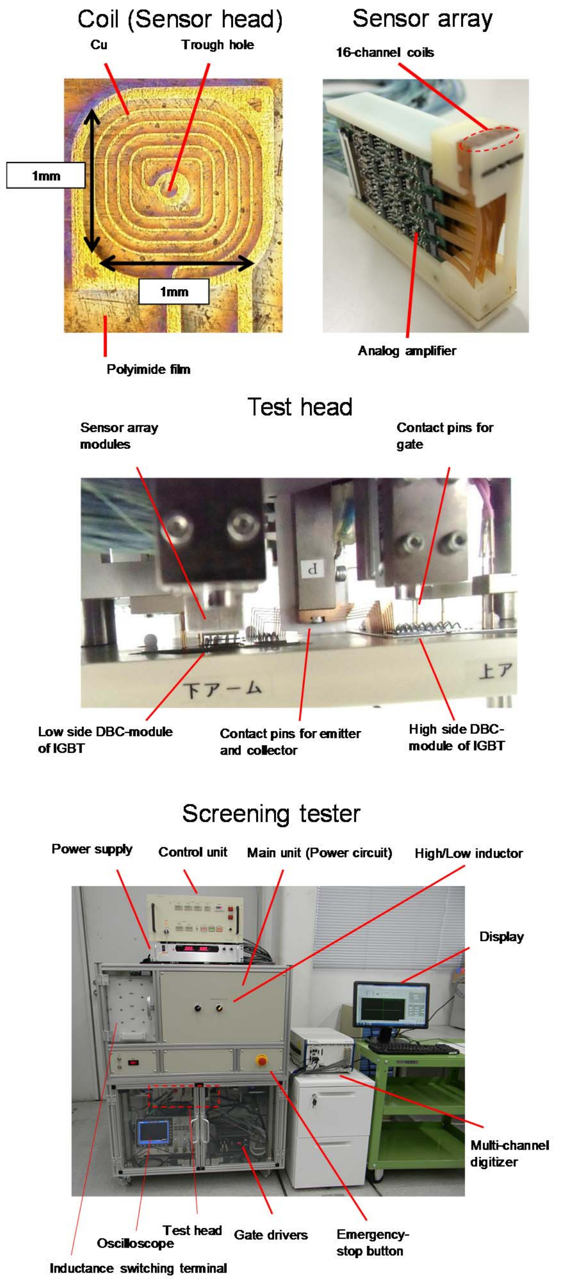

Fig. 2. Fabricated sensor array and screening equipment.

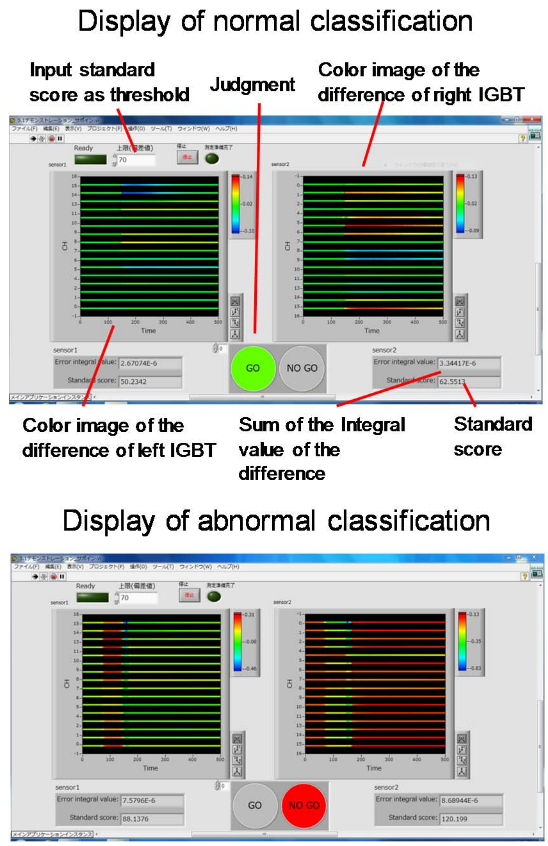

Fig. 3: Example of result display from screening equipment.

III. Current distribution imaging with normal/abnormal modules

The normal/abnormal imaging and classification was demonstrated by the ceramic substrate level power modules of 2 parallel IGBT chips with an original assembling (see Fig. 4).

The 25 modules are normal modules and 6 modules are abnormal modules with bending, disconnection and imbalanced gate resistance. The bending and the disconnection simulate defects in the assembling process. The imbalanced gate resistance simulate gate characteristic variations in chips such as a threshold voltage difference.

The modules were tested by single pulse test with inductive load. The DC voltage and turn-off current were 100 V and 25 A respectively. The signal over the disconnection part is decreased like “A”, and the signal over another part in the same chip and paralleled opposite chip is increased by diverted current like “B” and “C” (see Fig. 5). In still other cases, the turn-off with larger gate resistance is delayed to the paralleled opposite IGBT chips therefore most signals are decreased with larger gate resistance and most signals of paralleled opposite IGBT chips are increased in the Miller period like “D” and “E” (see Fig. 5).

IV. Method of Normal/Abnormal Classification

New normal/abnormal classification method is composed by statistical approach with several advanced information processing for an accurate classification.

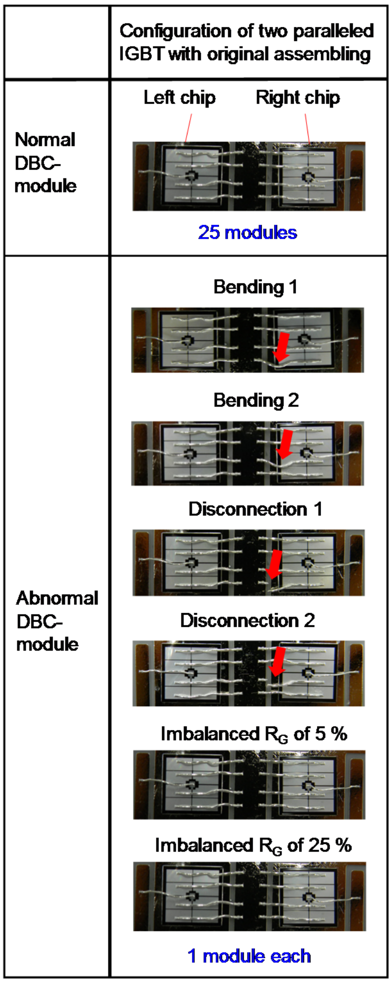

Fig. 4. IGBTs on ceramic substrate (DBC-modules) in experiment.

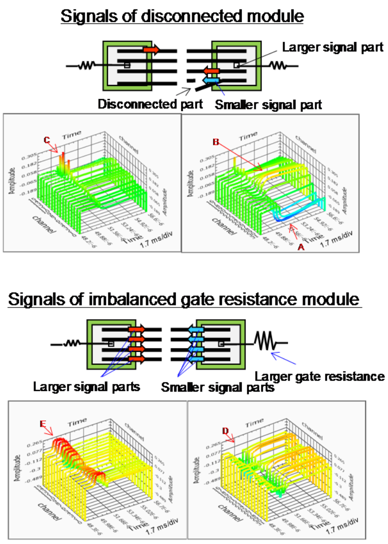

Fig. 5. Signals of abnormal modules.

The standard score of both chip is calculated from the sum of the error value to the average normal module signal and plotted to vertical axis and horizontal axis each (see Fig. 6). The results reveal that the standard score plot is applicable to normal/abnormal classification. However, a few points of normal/abnormal modules are still mixed on the border lines around standard score (right side chip) of 70. (see Fig. 7).

A kind of image processing method named local binary pattern is applied to extract the local feature representing relativity between neighboring pixels for the classification of the same sample modules. The method uses gray image pixel of 3 x 3 size from color image and the pattern value is calculated by a comparison between a center pixel value and an around one (see Fig. 8 and Fig. 9). By the use of advanced image processing method, there is no error for normal/abnormal classification (see TABLE 1). Further fast signal processing (from signal acquisition to result display) is a subject for future work.

V. Conclusion

We developed a screening equipment to realize a new screening test for power modules. The screening equipment acquires magnetic field signals over IGBT chips in a power module and finally classifies to normal/abnormal module automatically. We established statistics based normal/abnormal classification with image processing. Thanks to the image processing, power modules are accurately classified even though bending of bonding wire or slight difference of gate signal timing. It is expected to be applied for screening in a production line and analysis in order to prevent the failure of power modules.

Acknowledgment

This study was partly supported by the Strategic Key Technology Advancement Support Project (Acceptance No.: 24194003018) of the Ministry of Economy, Trade and Industry.

We would like to thank Seiichi Okoda at COPER Electronics CO., LTD., Ryuzo Noda, Kazunori Nagatomo and Kazuaki Matsuo at C. D. N. Corporation, and Katsuji Tashiro and Nagayuki Shinohara at HOH KOH SYA Co., Ltd. for the design and fabrication of the screening equipment.

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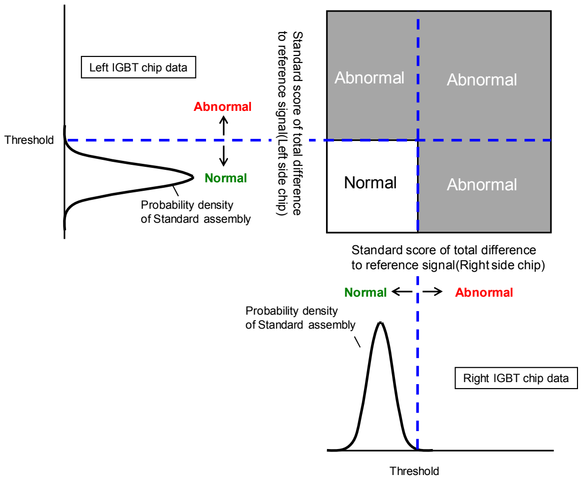

Fig. 6. Schematics of normal/abnormal classification method with simple statistical approach.

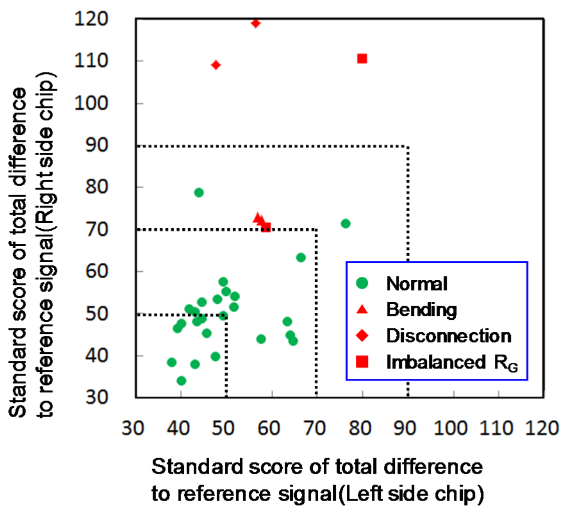

Fig. 7. Results of normal/abnormal classification with simple statistical approach.

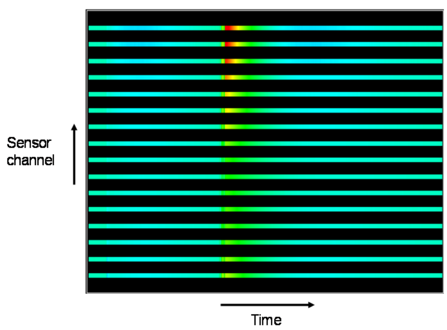

Fig. 8. Original color image before gray image for image processing.

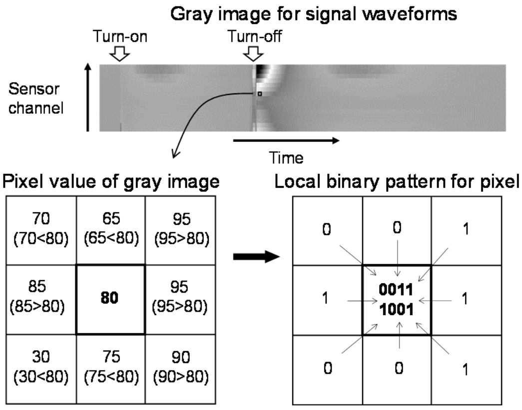

Fig. 9. Schematics of image processing method named local binary pattern.

TABLE 1. Results of normal/abnormal classification with/without image processing.

	Accuracy rate	Normal/Abnormal classification time (From signal acquisition to Result display)
Simple statistical approach	94 %	10 sec
Statistical approach with image processing	**100 %**	**13 sec**

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