Analytical Techniques at the Analysis Center

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Abstract

Our Materials & Semiconductor Device Analysis Center conducts quality and reliability evaluations centered on materials and parts to provide customers with highly reliable products and services. In a quality evaluation to prevent a failure, we conduct an evaluation of electrical characteristics, the analysis of non-defective products by physical and chemical analysis. In an evaluation of reliability, we conduct various accelerated tests assuming corrosive gas, temperature, humidity, and power cycle. Should any defect occur in a product, we investigate the root cause using non-destructive observation and various analytical techniques cultivated over many years, and an elimination of the root cause is reflected in the product design and production process to prevent the recurrence of the same failure. In the field of services such as maintenance, in addition to installation environment surveys and analysis support for hazardous regulated substances, such as trace amounts of Polychlorinated Biphenyls (PCBs) and Restriction of Hazardous Substances (RoHS) regulated substances, we also provide regular analysis support for locally used materials. In doing so, we propose replacement or renovation to customers.

1 Preface

We are supplying a wide range of products to various customers, such as power generation equipment, substation equipment, electronic equipment, and information equipment. These products are composed of a wide variety of materials and parts, and high-quality is required for each. In particular, to adopt high-quality new parts, non-defective product analysis is made in advance from electrical, physical and chemical viewpoints in accordance with the parts adoption standards.

In addition, we carry out long-term reliability tests to confirm the quality so that our customers can use it with peace of mind for many years. Should any problem occur with a product, we not only identify the cause of the failure by analysis, but also run in parallel with the development and design Business Units (BUs) and the manufacturing BUs to develop tasks to prevent such reoccurrence. This paper introduces the analysis technology of our Materials & Semiconductor Device Analysis Center (the “Analysis Center” hereafter) that supports product quality, reliability, and maintenance services.

2 Prevention of Reoccurrence of Failures and Support for Proactive Prevention of Failure

2.1 Support for Preventing Recurrence of Failures

Failure analysis is a method of investigating the status of defective products that occur at the site or in the manufacturing process by investigating the cause of the failure. Based on various analysis results for investigating the cause of failure, the Analysis Center proposes improvements in product design, manufacturing process, and usage method together with factories and design and development BUs, and promotes prevention of recurrence of failure. As shown in Fig. 1, in the example of corrosion of piping part, the cause of corrosion and the origin of corrosion are clarified by analyzing the components of rust and macroscopic cross-sectional observation technology of the corroded part. Clarifying the mechanism of corrosion leads to design improvement and recurrence prevention.

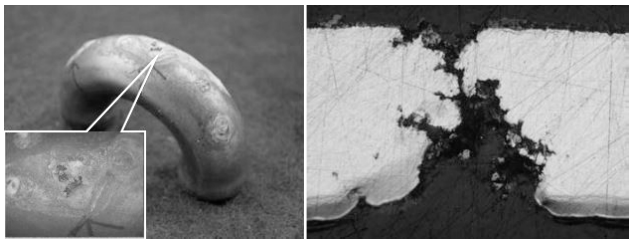

Fig. 1 Example of Corrosion in Piping Part

To ascertain the cause of corrosion in piping, the corroded part is processed into a cross-sectional shape for observation in detail.

2.2 Support for Proactive Prevention of Failure

2.2.1 Non-Defective Product Analysis

Non-defective product analysis is a method for analyzing and evaluating electrical characteristics and internal structure in order to prevent potential defects caused by electronic components and modules incorporated in products. The non-defective product analysis technology that we possess is introduced below.

(1) Electrical characteristic evaluation

This is a method for evaluating the characteristics that determine the performance of semiconductor devices from the relationship between voltage and current. This includes not only the selection of non-defective products and defective products, but also the (operating) margin.

Characteristics and temperature dependence of the parts can be grasped non-destructively. In the case of static property evaluation using a semiconductor analyzer, the relationship between voltage and current in a semiconductor device can be efficiently measured, and characteristics such as device threshold value and insulation deterioration can be observed. In recent years, we have established a technology for evaluating temperature dependence in low to high temperature environments and a technology for highly accurate screening of various factors, such as minute defects inside the device that become apparent at the operating temperature.

Fig. 2 shows an example of the saturation voltage characteristics between the collectors and emitters ("$V_{CE(sat)}$" hereafter) of an Insulated Gate Bipolar Transistor (IGBT) due to temperature dependence. Since $V_{CE(sat)}$ depends on the magnitude of the power loss of the IGBT, it is the most important parameter in the electrical characteristics. It is possible to confirm the difference in $V_{CE(sat)}$ due to temperature changes and the effect of characteristics due to temperature.

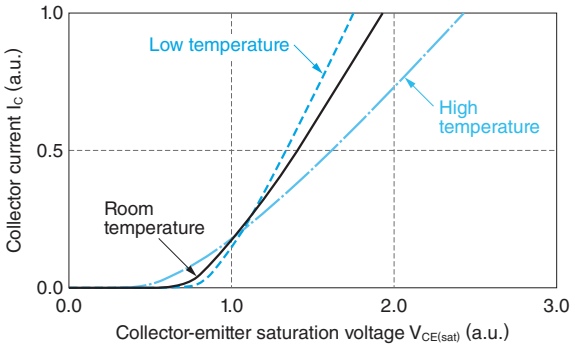

Fig. 2 Example of Saturation Voltage Characteristics between Collectors and Emitters

The graph shows that the saturation voltage is low at a low temperature and high at a high temperature.

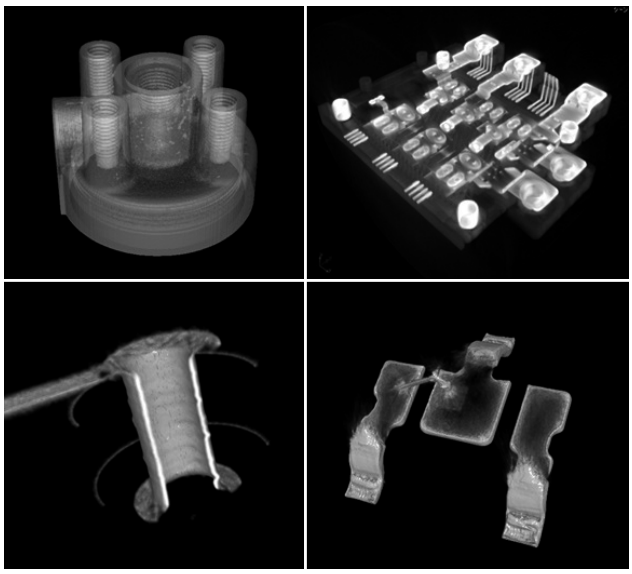

Fig. 3 Three-Dimensional X-Ray CT Observation of Various Parts

Based on 3D X-ray CT images of various kinds of parts (aluminum casting, IGBT, through-hole, diode), an internal structure can be visualized in three-dimensional mode.

(2) Non-destructive inspection

This is a method to evaluate manufacturing quality by visualizing the internal structure by inspecting semi-conductor devices, mounting boards, cast parts, etc. in a non-destructive state using X-rays and ultrasonic waves. The Analysis Center observes the soldered state and inside of electronic components on the mounting board for eliminating the potential failure risk that may occur in the market. Fig. 3 shows an example of the three-dimensional X-ray CT observation of various parts, and Fig. 4 shows an example of ultrasonic observation of an Integrated Circuit (IC) chip. By non-destructively inspecting the internal structure of parts, the

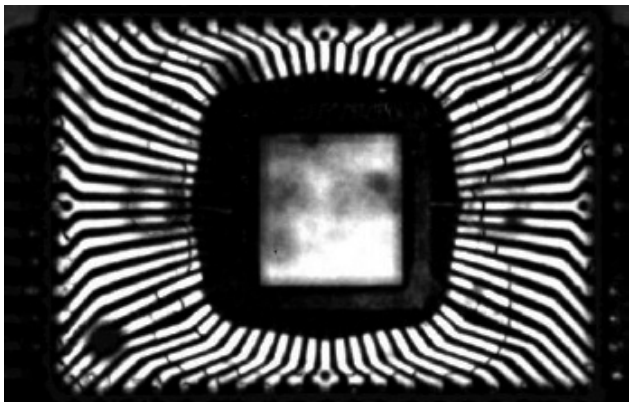

Fig. 4 Ultrasonic Observation of IC Chip

When ultrasonic waves are used, the internal structure of an IC chip can be visualized.

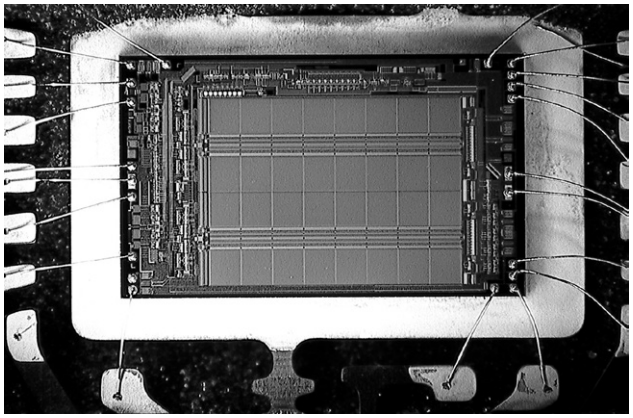

Fig. 5 Image of Open-Sealed IC-Chip Observation

A resin package of a semiconductor device is opened to observe the IC-chip structure inside the resin package.

presence or absence of defects or foreign matter that will affect future failures is evaluated.

(3) Internal/cross-sectional structure inspection

Internal inspection is an evaluation method that opens the resin package of a semiconductor device mounted on an electronic base and visualizes the manufacturing quality inside the device microscopically and macroscopically. Fig. 5 shows an example of an image of an open-sealed IC-chip observation. Cross-sectional structure inspection is an evaluation method that prepares cross-sections of parts and inspects the internal structure to analyze the bonding and plating conditions of semiconductor devices mounted on electronic boards and the structure of IC chips. Fig. 6 shows the image of ion-beam cross-sectional processing for an IC chip. Depending on the material, the processing technology using an ion beam has a risk of being damaged by the heat generated during processing, such as deformation and melting. In recent years, to avoid the risk of damage during sample processing, a new cooling stage has been introduced to improve analysis accuracy.

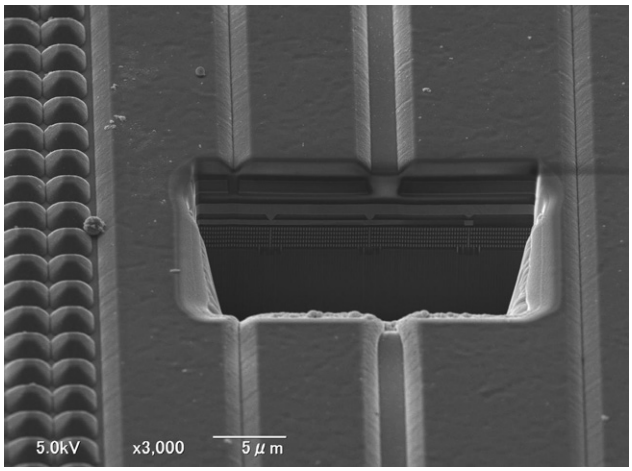

Fig. 6 Image of Ion-Beam Cross-Sectional Processing for IC Chip

The IC-chip cross-section is precisely processed to examine the cross-sectional structure of the IC chip.

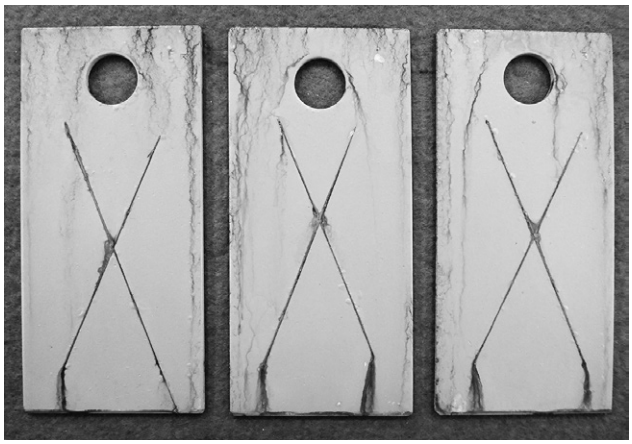

Fig. 7 Salted Water Spray Test on Painted Sheet Metal

A painted sheet metal is put into a saline water spray test to evaluate durability against corrosion caused by salt components.

2.2.2 Reliability Test

The reliability test estimates the failure rate and life by an accelerated test based on the installation environment and operating conditions for predicting and preventing the occurrence of failures caused by products, parts, and materials. Then, we evaluate if the product meets the required performance. The Analysis Center makes the best use of past failure information and various quality data, and promotes activities to independently devise and verify short-term and highly accurate test methods to standardize them in-house. Fig. 7 shows a salted

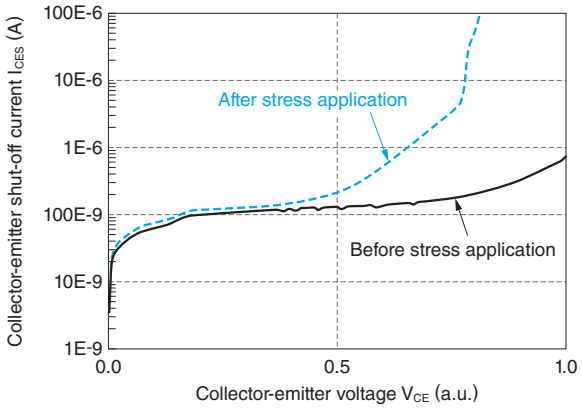

Fig. 8 **Breaking Current Characteristics between Collector and Emitter before and after THB Testing**

Changes in characteristics can be confirmed before and after the stress test by applying high temperature, high humidity, and high bias.

water spray test on a painted sheet metal assuming a salt-damaged environment. Fig. 8 shows an example of the breaking current characteristics between the collector and emitter before and after the Temperature Humidity Bias (THB) Testing (Stress Test) on IGBT Modules. After the test, it was confirmed that the breaking current tended to change, and the durability of this component by the THB Testing was confirmed.

3 Maintenance/Environmental Regulation-Related Support

3.1 Equipment Environment Evaluation

Depending on the installation conditions of a product, corrosion and moisture absorption due to dust and environmental gas may cause problems such as poor continuity and short circuit. At the Analysis Center, to ensure the safe and stable use of the product, the degree of contamination of the product due to the installation environment and the ionic components such as chlorine are investigated. Fig. 9 shows an ion chromatograph that analyzes ionic substances. Based on this survey data, we support customers in formulating maintenance plans for existing equipment and new product specifications.

3.2 Evaluation of Contact Parts

The electromagnetic relay used in the control circuit of electrical equipment opens and closes the circuit by operating the contact mechanism. Since the contact points are mechanically contacted and

Fig. 9 **Ion Chromatograph**

Floating dust in the environment is dissolved in water to analyze ionic substances such as chlorine.

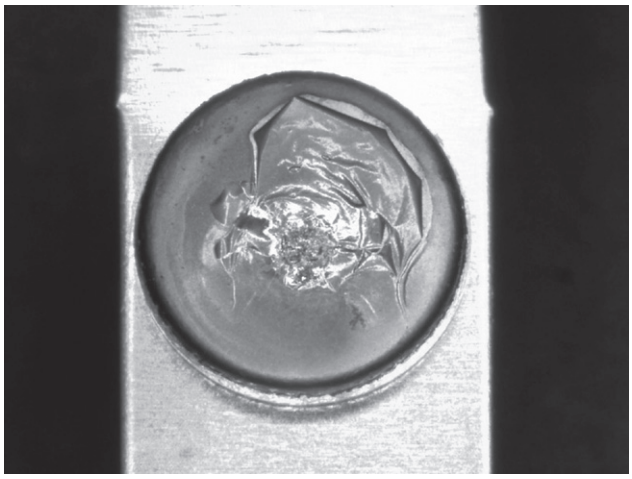

Fig. 10 **Deterioration of Contacts**

The state of deterioration due to corrosion and abrasion on the surface of each contact point is observed with the aid of an optical microscope. Together with the result of contact resistance measurement, the obtained data are used as an index for maintenance and replacement.

energized, the contact points may deteriorate over time due to corrosion, resulting in poor continuity and equipment failure. Fig. 10 shows an example of the deterioration of contacts. As one of the equipment diagnoses, the electromagnetic relays that are currently operating are collected and the contact status is analyzed regularly. This leads to the formulation of maintenance and replacement plans based on the data.

3.3 Restriction of Hazardous Substances (RoHS) Analysis (ISO/IEC 17025 Accreditation)

Restriction of hazardous substances such as RoHS and Registration, Evaluation, Authorization

Fig. 11 ISO/IEC 17025 Laboratory Certificate

In 2008, the Analysis Center acquired a certificate from the Japan Accreditation Board, authorized as a Chemical Testing Laboratory (RoHS analysis). Materials recognized as the objective target are metals and macromolecules.

and Restriction of Chemicals (REACH) has spread worldwide, and evaluation methods are now standardized. To create eco-friendly products, it is important to understand the chemical substances contained in the products. The Analysis Center acquired the international laboratory accreditation (ISO/IEC 17025) accredited by a third-party organization in 2008, and provides proper management and highly accurate analysis results. **Fig. 11** shows the ISO/IEC laboratory certificate. In recent years, we have established an analysis technology for phthalates added by the revised RoHS Directive and are screening wire coating materials and rubber members when adopting members.

3.4 Micro-Amount Polychlorinated Biphenyl (PCB) Analysis

PCB-containing absolute oil was used in some transformers, reactors, instrument transformers, and rectifiers manufactured about 50 to 60 years ago, but since 1972, PCB-based equipment has been abolished. Based on the PCB Special Measures Law, the Analysis Center provides quick and highly accurate analysis results using the precision analysis technology cultivated over many years when updating or newly delivering transformers that use insulating oil.

4 Postscript

The Analysis Center is engaged in a wide range of operations such as material parts surveys and environmental analysis. It not only provides data in close cooperation with factories, development and the key BUs, but also proposes considerations that lead to countermeasures from data analysis. “For the peace of mind and joy of our customers” is our basic philosophy and we will provide high-quality products and high quality maintenance services. We will provide it continuously. To quickly respond to stricter environmental regulations in recent years, we will further improve our analysis and testing skills and promote more active analysis activities.