Introduction of Analytical Technology at Analytic Simulation and Material Evaluation Center

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Abstract

To provide highly reliable products, we conduct quality evaluation and reliability testing on parts and materials for our products at our Analytic Simulation and Material Evaluation Center. Reliability of products can be improved with the parts and components used for the products satisfying the acceptance criteria.

In the event of some product defect, it is necessary to find the root cause to avoid the recurrence of the same defect. Failure analysis through a variety of monitoring and analysis is used to confirm defects and failures. Product design and manufacturing processes reflect such analysis. In this way, product quality improvement by proactive prevention of failures is accomplished.

1 Preface

We supply a variety of products to a wide range of customers, such as power generating equipment, substation equipment, electronic appliances, and IT devices. To assure high quality, such products are manufactured by assembling various kinds of appropriate materials and parts.

Quality evaluation and reliability test are carried out on materials, components, and parts to be used for the products at the Analytic Simulation and Material Evaluation Center (the “Center”) so that highly reliable equipment can be offered to our customers consistently.

Quality item analysis is carried out in advance in accordance with our item acceptance standards for newly adopted parts and components. To ensure long term safe use and operation for the customer, reliability tests confirm the long term quality of items. If product failure should occur, we specify and identify the cause of the failure and establish measures for recurrence prevention. We reflect on the changes needed for improved product design, manufacturing processes, and usage. This practice contributes to improving the quality of our products. This paper introduces analytical technologies at the Center supporting our product quality.

2 Techniques for Proactive Prevention of Failures and Evaluation on High Reliability

2.1 Quality Item Analysis

Quality item analysis is an analytical approach used to estimate future failure probability by investigating semiconductor devices for defects in internal material or structure. At the Center, non-destructive evaluation is carried out by using X-rays to examine the possible presence of any internal defect in checking newly adopted items for product acceptance. Components of materials are then analyzed through destructive testing. Pass or fail judgment is carried out according to the item acceptance criteria designated for each point inspected.

2.1.1 Non-Destructive Inspection

Non-destructive inspection is an evaluation method to check internal conditions of the manufactured device in a nondestructive state such as semiconductor devices, mounted substrate, and casting parts by using X-rays and/or ultrasonic waves. At the Center, we also examine soldering conditions where electronic parts are mounted on circuit boards and conditions of internal defects in components. Fig. 1 shows an image of X-ray transmission in a printed circuit board. Fig. 2 shows some examples of three-dimensional Computed Tomography (CT) for various parts. Fig. 3 shows an example of three-dimensional CT images of IC chips. When internal structures of parts are checked by X-rays, it

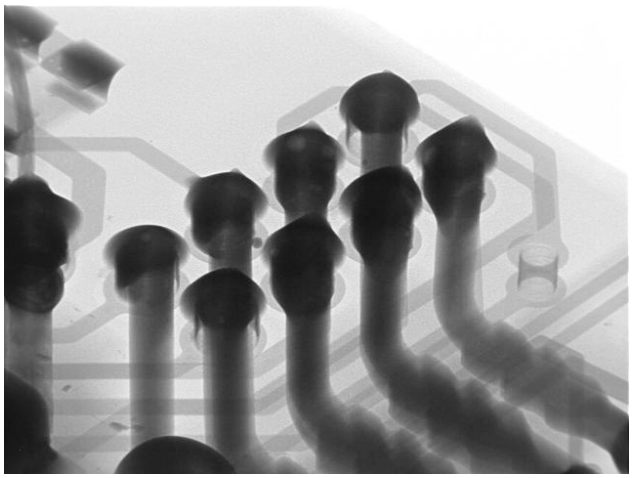

Fig. 1 Image of X-ray Transmission in a Printed Circuit Board

A printed circuit board is observed by using X-ray transmission. The situation of soldering is checked in non-destructive mode.

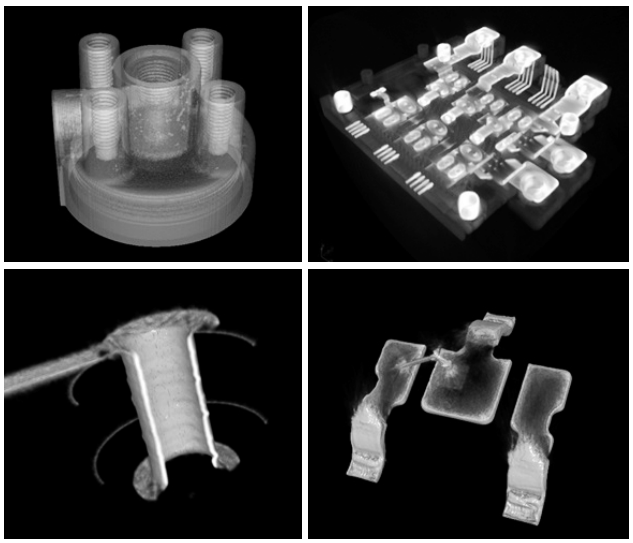

Fig. 2 Some Examples of Three-Dimensional CT for Various Parts

An internal structure is observed based on images of 3D CT for various parts (aluminum casting, IGBT, through-hole, diode).

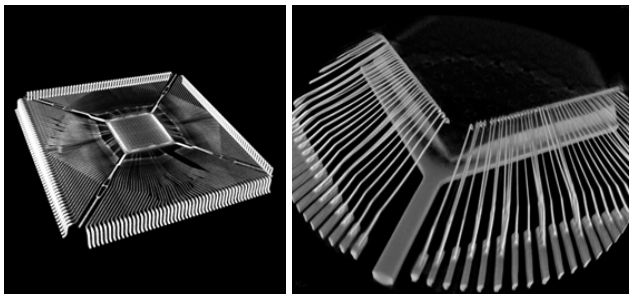

Fig. 3 Example of Three-Dimensional CT Images of IC Chips

An internal structure is examined from three-dimensional CT images of IC chips.

is possible to identify the presence of defects and foreign matters that might lead to failures in the future.

2.1.2 Internal Inspection

Internal inspection is an evaluation approach to examine the quality of IC chips inside the semiconductor devices. It is necessary to open the resin-made packages of semiconductor devices mounted on electronic circuit boards. Fig. 4 shows an observation example of an IC chip by X-ray transmission. Fig. 5 shows an example of a decapped IC chip. Even for very small items, we established a means of opening the package, without destroying internal fittings like bonding wires.

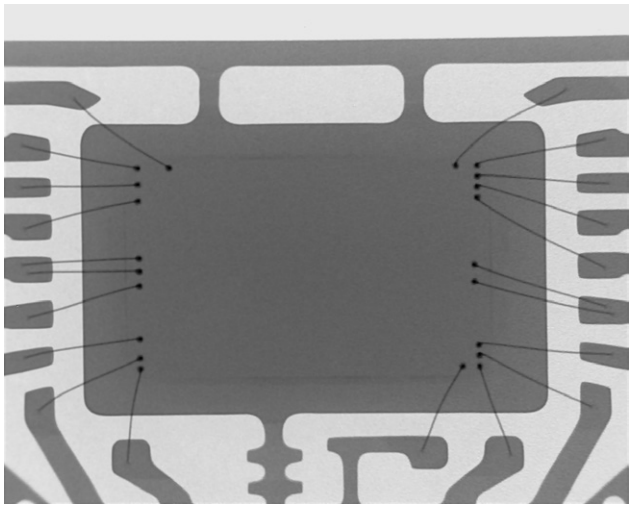

Fig. 4 Observation Example of an IC Chip by X-ray Transmission

A semiconductor device is observed by using an X-ray transmission approach. Wiring structure and presence of voids can be examined for IC chips in non-destructive mode.

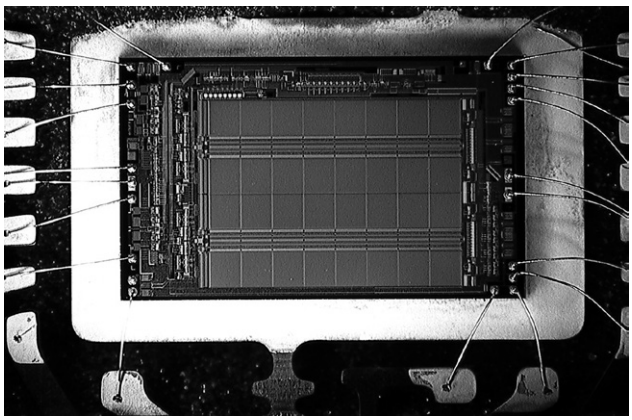

Fig. 5 Example of Decapped IC Chip

A resin-made package of a semiconductor device is decapped and the structure of an IC chip inside the resin coverage is observed.

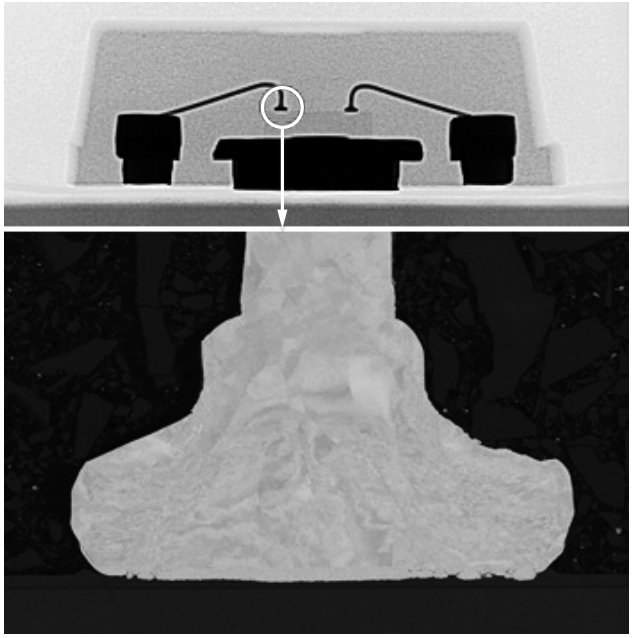

Fig. 6 Cross-Sectional View of an IC Chip Wire Joint Section

A cross-section of wire connections of an IC chip is observed and the wire bonding condition is examined.

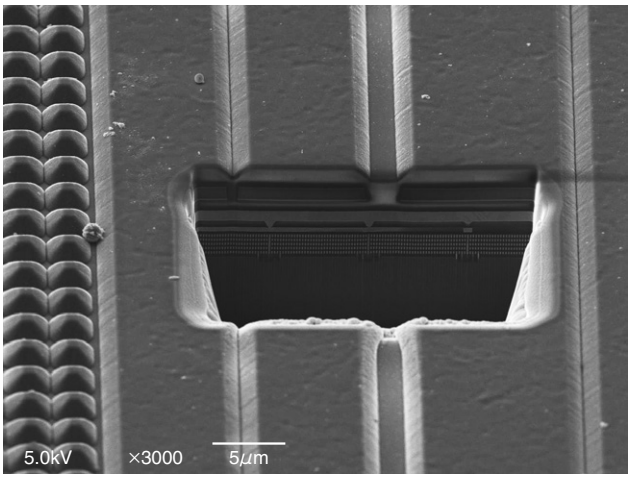

Fig. 7 Example of IC Chip Cross-Section Processed by FIB

The cross-section of an IC chip is processed by FIB. The IC chip structure is examined.

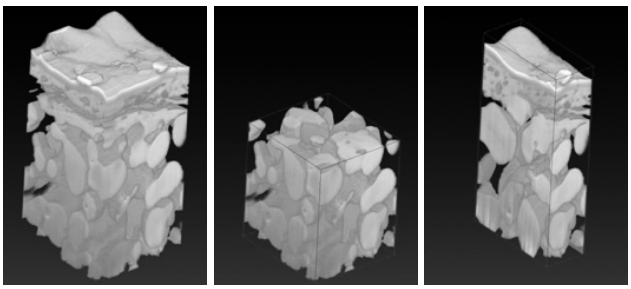

Fig. 8 Example of Three-Dimensional Structure Analysis by FIB Processing

Form of particles and situation of particle dispersion in metallic materials are analyzed by three-dimensional structure analysis.

2.1.3 Cross-Sectional Structure Inspection

Cross-sectional structure inspection is an inspection method to check the internal structure of an IC chip by making an image of its cross-section. In this case, structural analysis is carried out on the IC chip in order to examine the conditions of solder joints and galvanization in semiconductor devices mounted on electronic circuit boards. **Fig. 6** shows a cross-sectional view of an IC chip wire joint section and **Fig. 7** shows an example of IC chip cross-section processed by Focused Ion Beam (FIB). Since we introduced an electron microscope with an ion beam processor (FIB-SEM), we are able to establish a technology to accurately process and observe a very minute bonding point which was difficult with the conventional technology. Since this equipment enables continuous processing and observation to the depth of μm level, it is possible to perform three-dimensional structure analysis for metallic materials. **Fig. 8** shows an example of three-dimensional structure analysis by FIB processing. This technology visualizes the conditions of metallic particles. This contributes to increased reliability.

2.2 Reliability Test

The reliability test can predict or prevent the occurrence of failure in procurement parts, products, and materials. Under accelerated test conditions based on an installation environment, potential defects become evident. We are able to estimate failure rate and operational life. This test evaluates if tested item meets the required performance. As typical examples of testing machines, **Fig. 9** shows a super-xenon weather meter and **Fig.10** shows a gas corrosion testing machine. At the Center, evaluation is made based on the past records and it has its own judging criteria conditions and level of standards. The evaluation is carried out according to the design operating condition. Since many products are positively adopted from overseas suppliers, we are accumulating our expertise in terms of quality analysis and environmental durability test for further quality improvement of our products.

Fig. 9 Super-Xenon Weather Meter

This meter is used for weather resistance testing. In an outdoor environment, the presence of deterioration possibly caused by temperature-humidity cycles, irradiation by ultraviolet rays, and exposure to rainwater is evaluated.

Fig. 10 Gas Corrosion Testing Machine

The gas corrosion testing machine is used to evaluate resistance to corrosion against corrosive gases in regard to contact parts.

3 Analysis Technology to Prevent the Recurrence of Failure

Failure analysis is a technical approach to pinpoint the cause of failure at a customer's site or in the manufacturing processes, by examining the conditions of the failure sample. The Center provides feedback through analysis results to the product design, manufacturing process and usage. This contributes in improving quality and reliability of our products. For example, as shown in Fig. 11, fracture and breakage of structural components like bolts are checked by examining the fracture surface with macro- and micro-analysis. Mechanisms of fracture

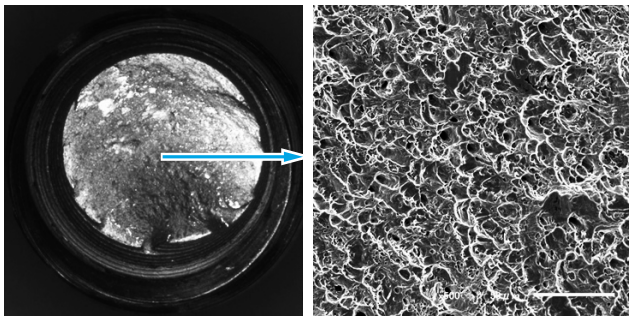

Fig. 11 Fractured Surface of a Bolt

The fractured surface of a bolt is shown. This damage was due to rapid ductile fracture caused by overloading. The cause of fracture is specified through observation of the fractured surface in the damaged item.

are analyzed by grasping the fracture mode, start of fracture, and how the fracture progressed. It monitors mechanical fatigue, shocks, and stress corrosion. Such analysis clarifies the fracture mechanism, improves design and prevents the recurrence of failures.

4 Analysis Technology for Hazardous Substances Restricted by Environmental Regulations

4.1 Analysis of Micro-Amount Poly Chlorinated Biphenyl (PCB)

Parts of power transformers, reactors, instrument transformers, and rectifiers manufactured in 1954 to 1972 used insulation oil containing PCB. Since 1972, however, production of equipment containing PCB has been prohibited. When any electrical equipment which might contain even a very small amount of PCB mixed in insulation oils is to be discarded, the Center measures the concentration of PCB in the insulation oil. This conforms to the Waste Disposal Law and the Law Concerning Special Measures against PCB Waste.

4.2 Analysis of Substances Concerned with the Restriction of Hazardous Substances (RoHS) Directives (Certification by ISO 17025)

Restrictions of hazardous substances such as RoHS and Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) are now impacting worldwide and the rules of material evaluation established. For designing environmentally-conscious products, it is essential to identify the chemical substances to be contained in the prod-

ucts. The Center received a material testing laboratory international certification (ISO17025) by a third-party accreditation body and analyzes hazardous and restricted substances.

5 Postscript

This paper introduced the outlined feature of our analysis technologies at the Center where quality evaluation, reliability testing, and failure analysis are carried out for parts and materials used in products.

The Center will continue to support the release of highly reliable products. It identifies the quality of materials and parts to be incorporated in products in a prompt and accurate manner. In any failure in a product, it uncovers the possible causes using its analysis technology. The Center will advise the solid measures for the prevention of recurrence of the same failure in close consultation with our related business units.