

Understanding the Technology 3

Failure Analysis Methods

Part 3: Failure analysis using the scanning electron microscope

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The Scanning Electron Microscope (SEM) is a frequently used surface analysis device capable of very high magnification with the ability to obtain three-dimensional images. The SEM not only enables the observer to capture micro information about the surface of a specimen, but also offers capabilities such as qualitative and quantitative analysis and elemental mapping analysis that serve as preliminary steps to structural analysis of a specimen. This report will make use of various examples to introduce failure analysis methods that take advantage of SEM capabilities.

1. Effectiveness of SEM observation

Table 1 compares features of SEM observation with other methods of specimen surface analysis.

Table 1 Features of surface analysis methods

SEM	<ul style="list-style-type: none"> • High magnification (100x to 100,000x) with a large focal depth of field capable of observing surface unevenness • Images displayed in monochrome • Pre-treatment of specimen surfaces may be required
Optical microscope	<ul style="list-style-type: none"> • Magnification to about 100x with a stereoscopic microscope, and about 500x with a metallographic microscope • Images in color, permitting ease of locating observation sites • Extremely easy to use without experience
Digital microscope	<ul style="list-style-type: none"> • Capable of observing large objects • Group observation possible using video monitors and printers

Since the SEM is capable of observing micro abnormalities at high magnification, it is mainly used for observing defects in materials and surface contaminants on specimens.

2. Observation methods utilizing the SEM

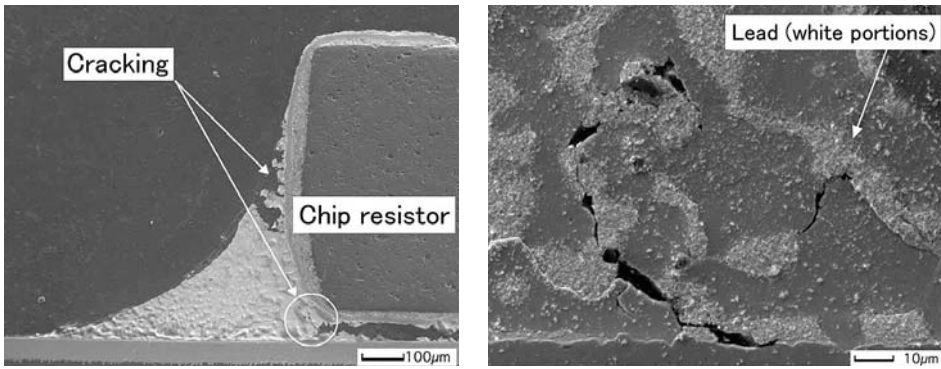
The SEM works on the principle of scanning an electron beam that it has used to irradiate the specimen. The reflected electrons (secondary electrons) are detected and displayed on a monitor in light and dark shades according to the amount detected. The surface image consists of the extreme surface (about 10 mm) of the specimen. The specimen must have a suitable composition to permit the use of an electron beam, and must be inside a high-vacuum chamber. The specimen must not generate any outgases such as moisture, and so the specimen must be dry before observation. If the specimen becomes electrically charged by the electron beam irradiation the image cannot be seen clearly, and, as a result, insulating materials must be pre-treated with a conductive coating such as platinum. Many specimens require pre-treatment before SEM analysis.

3. Evaluation examples

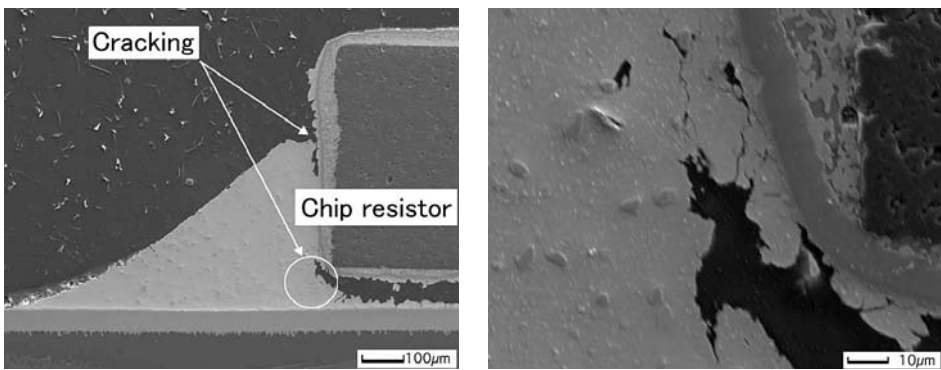
3-1 Analyzing solder joints

We performed comparative analysis of joint deterioration caused by temperature stress with various types of solder. Photo 1 shows cross-sectional observation of chip resistor soldered joints after being subjected to the Temperature Cycle Test (temperature: -40 +125 ; exposure time: 30 minutes; number of test cycles: 2000). Cracking is observed in both the fillet and the bottom face of the chip resistor.

Looking at the solder structure, eutectic lead solder demonstrates a larger granular crystal structure, and cracking can be observed from the lead phase (the white portion in the SEM images) in the solder structure. On the other hand, lead-free solder demonstrates no large granules in the solder structure, and cracking is observed in the interface between the solder and the soldered component. In this way, the SEM can be used to observe differences among various materials related to changes in the solder structure and differences in failure conditions.



(a) Sn-Pb eutectic solder



(b) Lead-free solder (Sn-Ag-Cu)

Photo 1 Cross sections of chip resistor solder joints after the Temperature Cycle Test

3-2 Analyzing migration

We performed SEM analysis of ionic migration (electrochemical migration) affecting the electrical insulation of printed circuit boards (PCBs). Photo 2 shows ionic migration between copper electrodes on glass fabric epoxy substrate. Ionic migration grows on the resin from one electrode toward the counter electrode, leading to short circuiting (Photo 2-a). We were able to confirm that as the migration growth expands (Photo 2-b), it grows outward from one point on the end of the copper electrode toward the counter electrode, and fans outward as it continues to grow. From this, we can infer that metal ions are eluted from this one point of origin, and spread toward the counter electrode. Utilizing SEM observation, we were able to pinpoint growth position and shape.

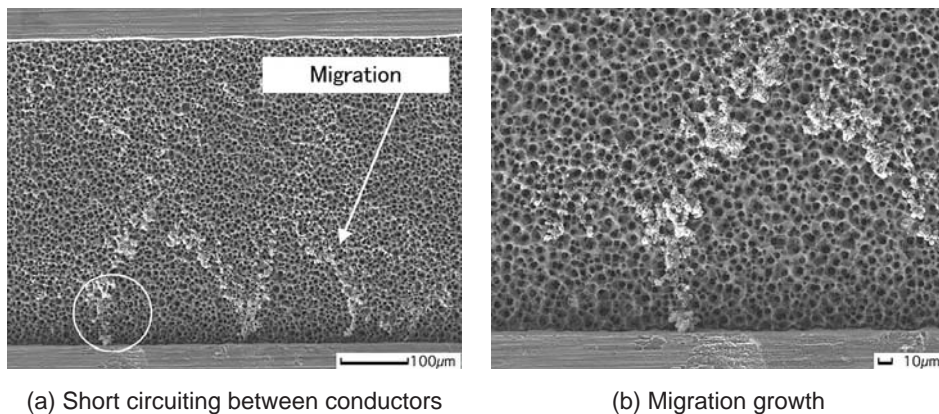


Photo 2 Migration growth between PCB electrodes

3-3 Analyzing metallic corrosion

Using zinc sheet metal as a specimen, we made an initial reference evaluation of the JIS C 0023 "Basic Environmental testing Procedures. Part 2: Tests - Test Ka: Salt mist" (conditions: temperature, 40 °C; RH, 93%; saltwater concentration, 5wt%; exposure time, 336 hours). Pre- and post-test observation showed significant corrosion to the surface caused by the saltwater. (Photo 3)

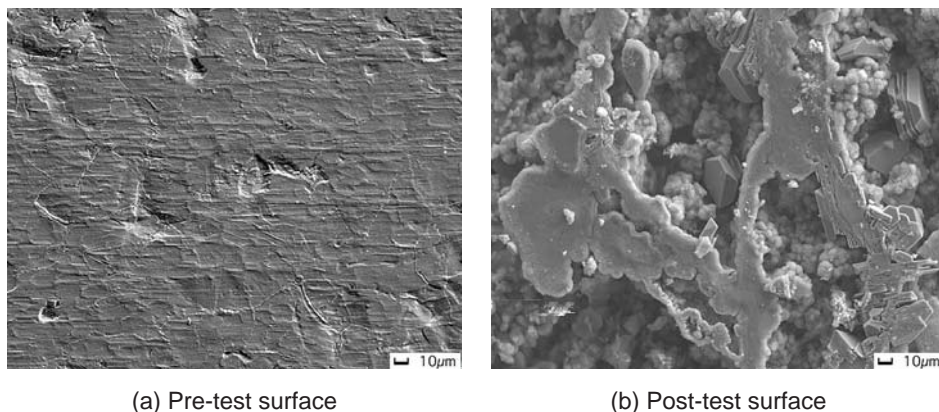


Photo 3 Corrosion of zinc sheet metal caused by the Salt Mist Test

3-4 Analyzing contaminants in fiber

Degradation of the fiber (wet-bulb wick) used to detect wet-bulb temperature inside the temperature and humidity chamber will affect temperature and humidity control of the test. Because of this, we observed the surface of the wet-bulb wick after performing a Constant Low Humidity Test (test conditions: temperature, 30 °C; RH, 20%; exposure time, 240 hours) in the temperature and humidity chamber. The results showed impurity adherence inside the wick, affecting temperature and humidity control. (Photo 4)

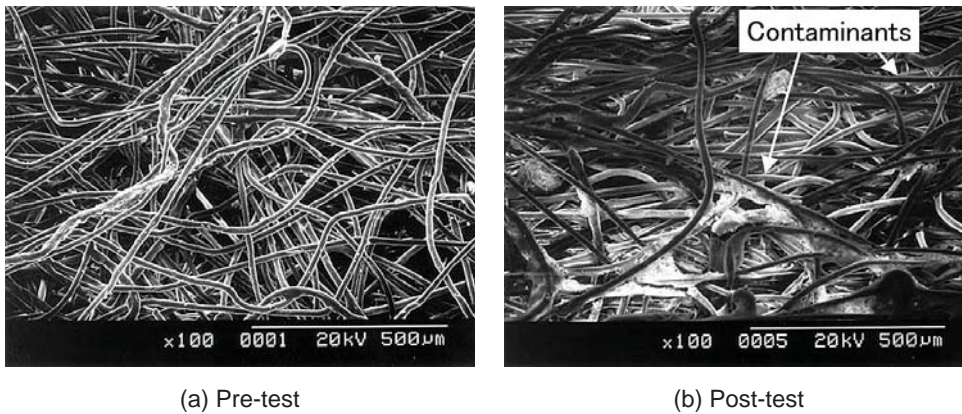


Photo 4 Impurity adherence inside fiber (web-bulb wick)

4. Conclusion

Starting in issue No.14, we have looked at failure analysis methods in three successive articles. We have avoided digging too deeply in the analyses so that we might provide understandable material to persons who have not yet begun analysis as well as for those who are beginners to failure analysis. However, shedding light upon the diverse and complex causes of failure seen in recent years will obviously require much more high-level failure analysis, and without this analysis, reliability cannot be maintained.

We hope you have enjoyed these articles. We plan to continue to introduce real-world examples in the hope that you will find them useful.

[Bibliography]

- 1) "Guide Book for Failure Analysis," Union of Japanese Scientists and Engineers, 1986
- 2) "Failure analysis of devices and parts," JUSE Press Ltd., 1992