Failure Analysis Methods
—Part 1: Cross-sectional observation of electronic parts—

Takayuki Nagai*

With the rapid move in recent years toward product miniaturization and high-level integration, the failure analysis that follows evaluation testing has come to play an increasingly critical role. Data obtained through failure analysis is backed up theoretically, and so such data can be used very effectively in the successive stages of product development and manufacturing.

This series of three articles will present representative methods in common use today for the failure analysis following evaluation testing. The articles will discuss the following themes.

Part 1: Cross-sectional observation of electronic parts
Part 2: Non-destructive analysis using soft X-ray apparatus
Part 3: Failure analysis using a scanning electron microscope (SEM)

1. *Effectiveness of cross-sectional observation*

Cross-sectional observation of specimens with a microscope has become widely accepted for use in research and development of metals, product evaluation, and investigation into the cause of defects. This method has now come into standard use even for evaluating electronic parts, and is employed as a procedure for uncovering the cause of failure that cannot be accurately determined from external appearance alone. External observation is ineffective in specifying the points of failure on solder joints of surface mount device, and so cross-sectional observation becomes particularly useful for investigating the composition or specifying the points of cracking.

Photo 1 Detecting points for analysis (stereoscopic microscope)

2. *Cross-sectional observation*

2-1 Pre-treatment

External observation is first performed as a preliminary procedure to cross-sectional observation. Equipment such as a stereoscopic microscope on low magnification (10× to 30×) is used to detect points to be selected for analysis. Then, when the specimens must be sliced, a cutting machine is used in such a way as to avoid damaging the specimens.

2-2 Resin mounting and sectional slicing

Sliced specimens are put into a container, and after the specimens are mounted with epoxy resin, a vacuum pump is used to remove the air bubbles, and the resin permeates the specimens. The resin is hardened at room temperature or at high temperatures, and the observation points are sliced with precision cutting equipment.

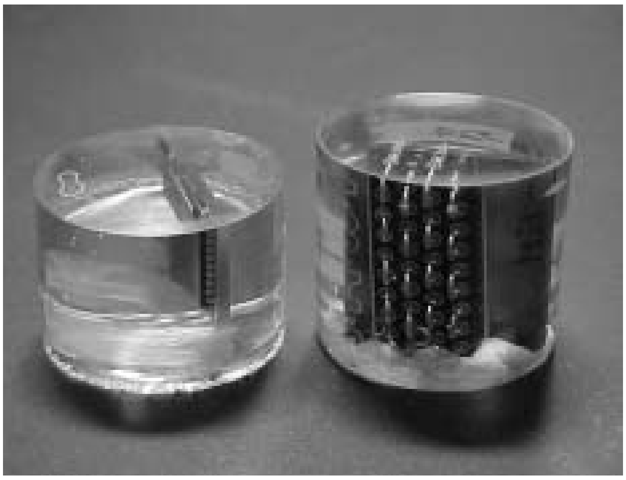

Photo 2 Specimens after resin has hardened

* Espec Environmental Test Technology Center Corp.

Photo 3 Precision cutting equipment

2-3 Cross-sectional polishing

Preliminary treatment proceeds step-by-step using polishing equipment. First, rough polishing is carried out with waterproof abrasive paper, and the observation points are identified. Then, after washing, the intermediate finishing is carried out with buffing material and diamond abrasives. This step leaves fine scratches, but creates a nice, even surface. The final step consists of finishing with silicon oxide abrasive, the best material for finishing soft metals, and finally micro-cloth buffing*[1]. This step removes all the fine scratches.

Photo 4 Polishing equipment

2-4 Cross-sectional observation

A metallurgical microscope is used for cross-sectional observation. A wide range of observations can be made at high magnification settings (50× to 500×), and so this approach is well-suited to such uses as checking alloy layers and checking for changes in the structure of metals. For more detailed observation, equipment such as a scanning electron microscope (SEM) can be used.

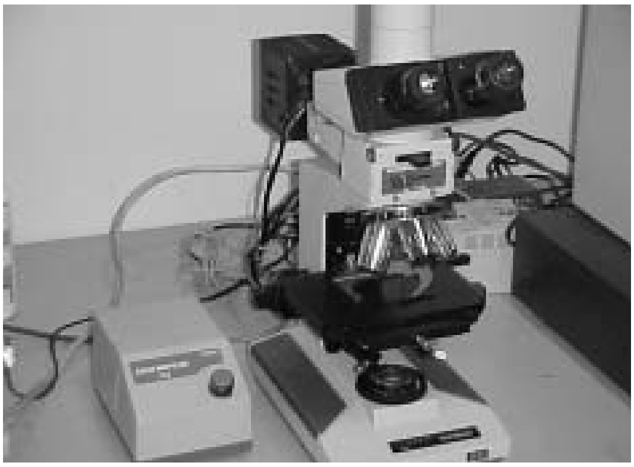

Photo 5 Metallurgical microscope

Photo 6 Scanning Electron Microscope (SEM)

3. Examples of evaluation

3-1 Analysis of solder joints

Solder is subject to cracking caused by changes in the metal structure induced by heat and by temperature changes. These cracks lead to defective continuity failure. Photos 7 and 8 show results of cross-sectional observation of surface mounting resistance. Cross-sectional observation can provide awareness of cracking in the solder fillet as well as structural changes in the solder in the vicinity of the cracks. These results indicate the presence of deformation stress on the solder fillet caused by the effects of heat and temperature changes on the parts.

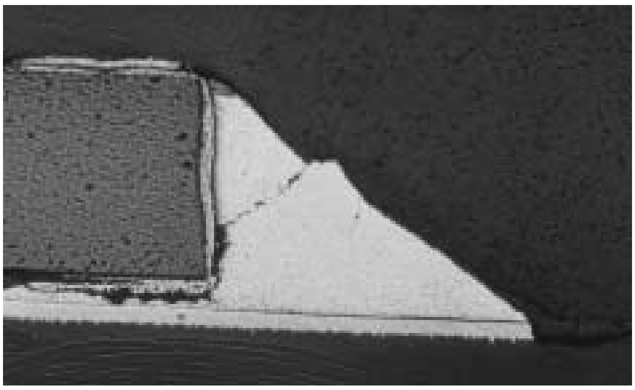

Photo 7 Solder cracking of surface mount device (50×)

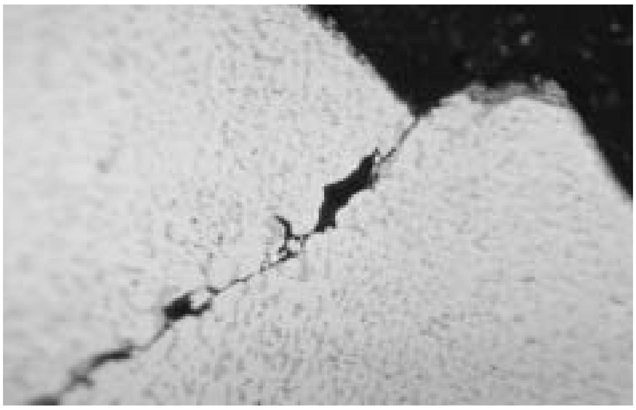

Photo 8 Structural changes in solder cracking section (200×)

3-2 Analysis of PCBs

Printed circuit boards (PCBs) generally have copper bonded onto resin. Since copper has a low coefficient of thermal expansion and resin has a high coefficient of thermal expansion, temperature cycles induce cracking in the copper foil pattern. Photo 9 shows corner cracking in double-sided PCB. The corners are most strongly affected by deformation stress, which leads to cracking. In the multi-layered PCB (Photo 10), cracking has occurred in such points as in the inner layer pattern and in the through-hole bonding.

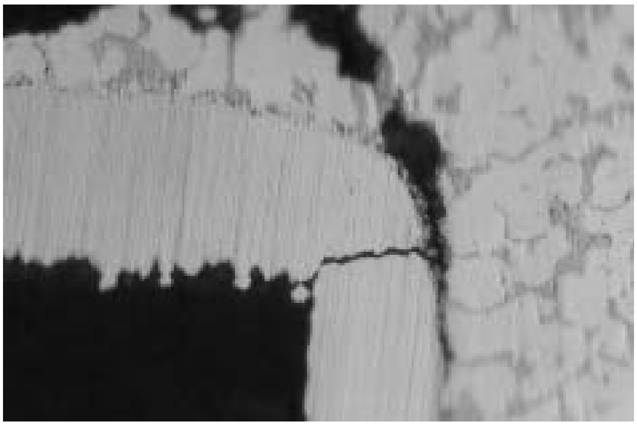

Photo 9 Corner cracking in double-sided PCB (200×)

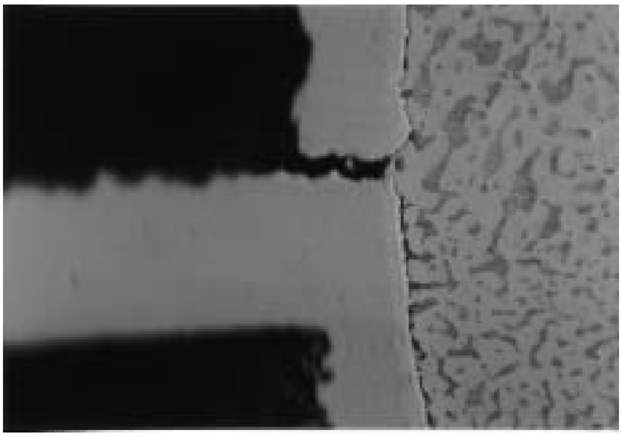

Photo 10 Inner layer cracking in multi-layered PCB (200×)

3-3 Analysis of metal corrosion

Corrosive substances such as sulfur, chlorine, and bromine lead to corrosion when adhering to metals. In this example, copper tubing has been corroded by corrosive gas, and the corrosion has reached the inside of the tubing. (Photo 11) Cross-sectional observation shows that corrosion has progressed from the outside toward the inside of the tubing. (Photo 12)

Photo 11 External observation of copper tubing corrosion (20×)

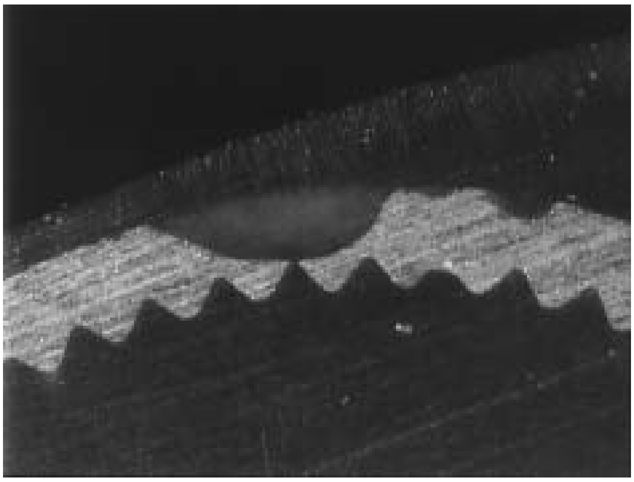

Photo 12 Results of cross-sectional observation (20×)

4. Conclusion

This article has discussed cross-sectional analysis of electronic parts, one method of failure analysis. The data obtained by cross-sectional analysis accurately indicates the condition of a product after product evaluation testing. Because of this, the cross-sectional evaluation method can be considered an extremely effective means for reliability evaluation testing.

Terminology

***1 Micro-cloth buffing**

Micro-cloth material is composed of rayon fiber embedded in a backing of cotton cloth. This cloth is the most widely-used item in the world today when material with a nap is required for buffing. Micro-cloth is ideal for finish polishing.