Report 1

A Consideration of Methods for Evaluating Reliability of Electronic Parts

— Concerning Methods of Continuously Evaluating Ion Migration —

Hirokazu Tanaka*1/Yuuichi Aoki*1/Shigeharu Yamamoto*1/Kunikazu Ishii*2

Many kinds of testing methods are being explored for use in evaluating reliability. This report examines methods of evaluating reliability of electronic parts and finding the causes of performance degradation and malfunction for which intermittent testing isn't effective. Evaluation is made by continuously measuring insulation resistance of printed circuit boards (PCB) while applying environmental stress, thus monitoring characteristic values throughout the time these values are fluctuating.

1. *Introduction*

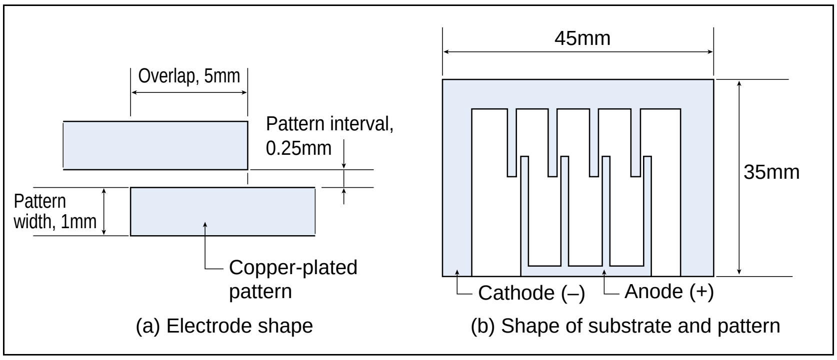
In evaluating reliability of electronic parts, many kinds of environmental tests are being performed depending on the measurement parameters and the perceived failure mode. In general, the test methods rely on intermittent measurements to make their evaluations. In other words, the initial measurements are compared with the post-test measurements. However, with this method it is extremely difficult to confirm failure caused by fluctuating characteristic values or to confirm equipment failure caused by a momentary drop in insulation resistance during continuous operation. Such problems typically occur in ion migration (IM).

For this report we evaluated characteristics by continuously measuring the fluctuation of characteristic values, and we tried to capture the causes of performance degradation and malfunction by continuously measuring while applying environmental stress to PCB specimens. This report will discuss continuously measuring insulation resistance under conditions of high temperature and high humidity and the effectiveness of continuously evaluating characteristics.

2. *Test Method*

2-1 Specimen and Test Conditions

Fig.1 shows the shape of the specimen used in this evaluation testing. The circuit pattern is made by copper plating four counter electrode patterns on a glass epoxy substrate board (Japanese Industrial Standard C 6484: GE4).



(a) Electrode shape (b) Shape of substrate and pattern

Fig.1 Shape of specimen substrate used as base

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*1 Environmental Test Technology Center
*2 Measuring Control System Dept.

Table 1 shows the test conditions. The test confirmed the fluctuation (degradation) of insulation resistance due to different surface treatments of the PCB.

Tests were prepared using the following 3 types of surface treatments for specimens.

① Clean only

② Coating with non-cleaning flux after cleaning

③ Solder treatment after cleaning and coating with non-cleaning flux

Details of surface treatments

- Clean: The substrate surface was washed with alcohol (IPA) using ultrasonic cleaning, then dried.
- Coating with non-cleaning flux: Resin type non-cleaning flux was coated evenly on the surface, then dried for 30 minutes at +100°C.
- Solder treatment: Solder dip was done for 5 seconds at +260°C in a solder bath.

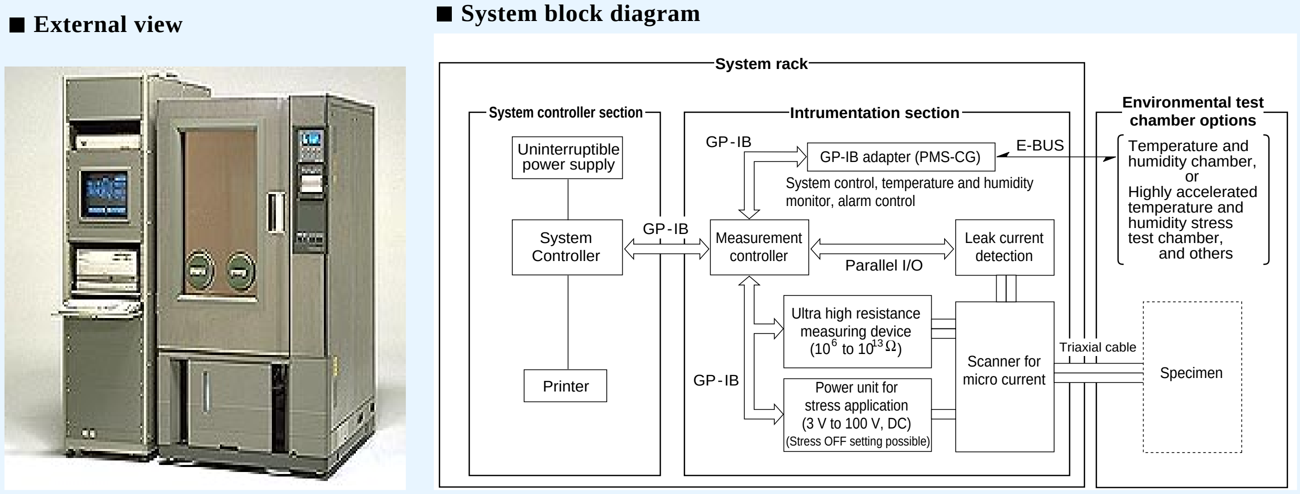
Table 1 Test conditions

Temperature and humidity	Applied voltage	Substrate surface treatment
+60°C 90%RH 500 hours	25 V DC	① Clean-only ② Coating with non-cleaning flux after cleaning ③ Solder treatment after cleaning and coating with non-cleaning flux

2-2 Evaluation system and Measurement Conditions

2-2-1 Evaluation system

Fig.2 shows an external view of the IM evaluation system equipment, a system block diagram, and gives specifications.


■ **External view**

■ **System block diagram**

■ **Specifications**

Leak current detection:

to detect sudden changes in leak current due to IM progressing and contacting counter electrode. (From leak current detection to electric field stress OFF, response time: msec/point)

Leak current detection range: 1 - 100μA (1μA step)

Stress applied current: 3 - 100V DC (1V step)

DC current measurement range: 3 pA - 100μA

Resistance measurement range: 10^6Ω - 3 × 10^{13}Ω (when 100 V applied)

Continuous testing time: Max. 9,999 hours

Measurement interval: Variable (Min. 6 min.)

Measurement time: 80 sec./25 points + charging time (user specified)

Measurement applied voltage: 3 - 100 V DC (1 V step, stress applied voltage and individual settings possible)

Number of measurement points: 25 points (Max. 300 points)

● **Example of how leak current detection works**

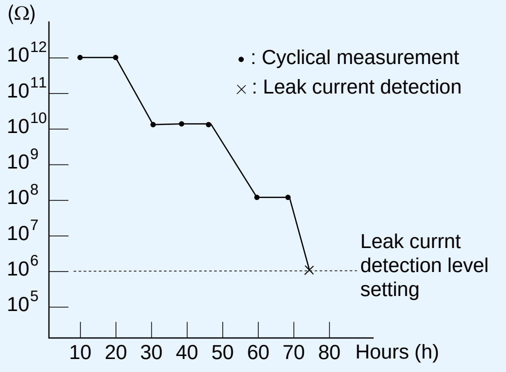


Fig.2 IM evaluation system (Model: AMI-025-P, made by Tabai Espec)

The system used for this test consists of steadily applying voltage to the specimen, changing over the scanner at fixed intervals, and measuring the insulation resistance value of each specimen. Double shielding wire with guard attached was used for wiring connections to each specimen, and external noise and test chamber noise were suppressed to the smallest amount possible.

Main capabilities required of the evaluation system:

1. To measure minute leak current, the system must be able to suppress external noise and system internal leak current, and be able to measure high resistance.
2. In response to such occurrences as IM, the system must be able to confirm fluctuations in insulation resistance and in intermittent short circuiting.
3. The system must be able to instantly detect the occurrence of leak current below the uniform resistance value.
4. When leak current is detected, the system must be able to stop voltage application to that specimen and preserve occurrence conditions.

2-2-2 Measurement conditions

Table 2 shows the measurement conditions. To measure the resistance value of the specimen in a stable state, measurement charging time was set at 30 seconds. Also, to avoid having high voltage destroy migration that had already occurred, measurement voltage was the same value as applied voltage.

Table 2 Measurement conditions

Measurement voltage (charging time)	25 V DC (30 sec.)
Insulation resistance measurement interval	Every 6 min.
Leak current detection	• Leak current detection is continuously monitored separately from the insulation resistance measurement system. • Detection is set to max. 10^6.

3. *Test Results*

Fig.3 shows test results.

① Clean-only specimens: At the initial test step the insulation resistance value dropped while repeatedly recovering and dropping. At 230 hours it fell below $10^6\Omega$ and short circuited.

② Specimens coated with non-cleaning flux: From the initial step the insulation resistance stabilized at about $10^{12}\Omega$.

③ Solder-treated specimens: Short circuiting occurred at max. $10^6\Omega$ at 360 hours.

When removing the above specimens during the test and measuring at normal temperature, we were unable to observe leak current in ① or ③. The observation could not be made because continuous monitoring was not being made, and the characteristics had returned to their original values. This prevented our properly measuring the time that failure occurred.

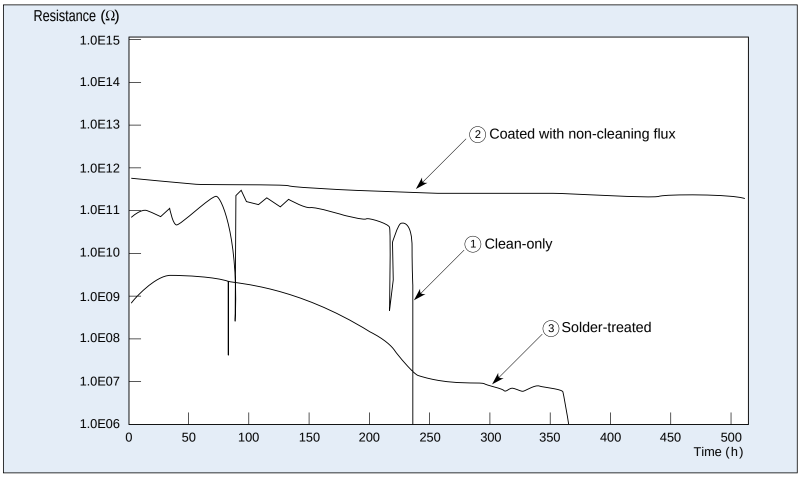


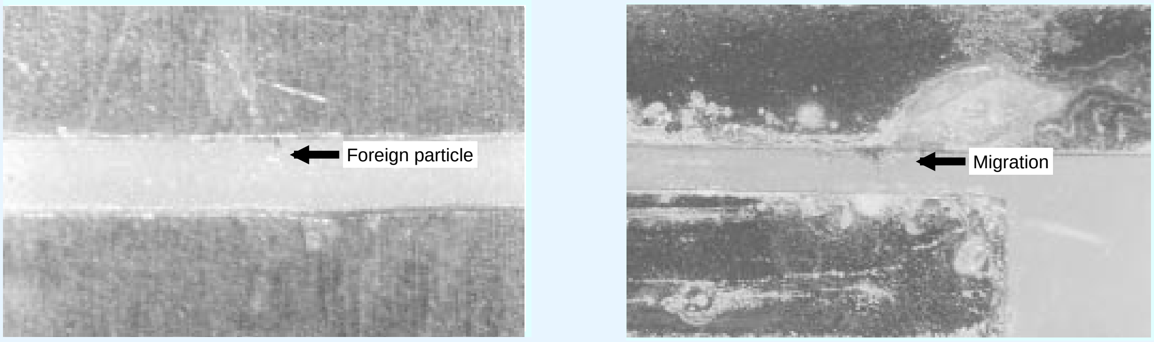
Fig.3 Fluctuations in specimen insulation resistance

Photo.1 shows the observed results.

① Clean-only specimens: Complete short circuiting has not occurred in these, but small foreign particles have become attached. — Photo.1 (a)

② Specimens coated with non-cleaning flux: We were unable to confirm IM.

③ Solder-treated specimens: The substrate copper has leaked out, and short circuiting has been caused by IM. — Photo.1 (b)



(a) Clean-only specimen

(b) Solder-treated specimen

Photo. 1 Microscopic image of specimen (30×)

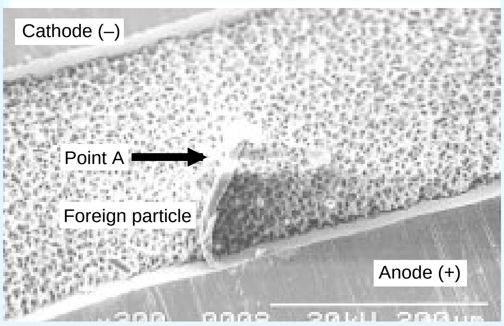
4. *Discussion*

The results show that complete migration could be observed only in the solder-treated specimens. Also, the clean-only specimens repeatedly made a step-like drop in insulation resistance then recovered.

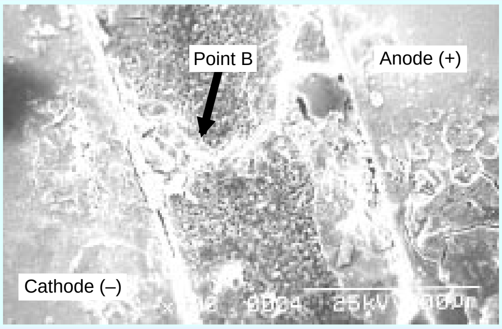
To confirm what caused these results, two specimens were analyzed in a scanning electron microscope (SEM) and an energy-dispersive x-ray micro analyzer. — Photo.2, Fig.4

Carbon (C) and copper (Cu) were detected from the clean-only specimen by elemental analysis. Accordingly, we can assume that moisture absorption by foreign particles adhering to the surface of the substrate causes ions (e.g., copper ions) to move along the substrate surface, subsequently causing short circuiting and other phenomena. — Fig.4 (a)

Observation of SEM images confirmed the occurrence of migration from the flux crack area in the solder-treated specimens. Also, the composition was tin (Sn), lead (Pb), and copper (Cu). — Photo.2 (b)

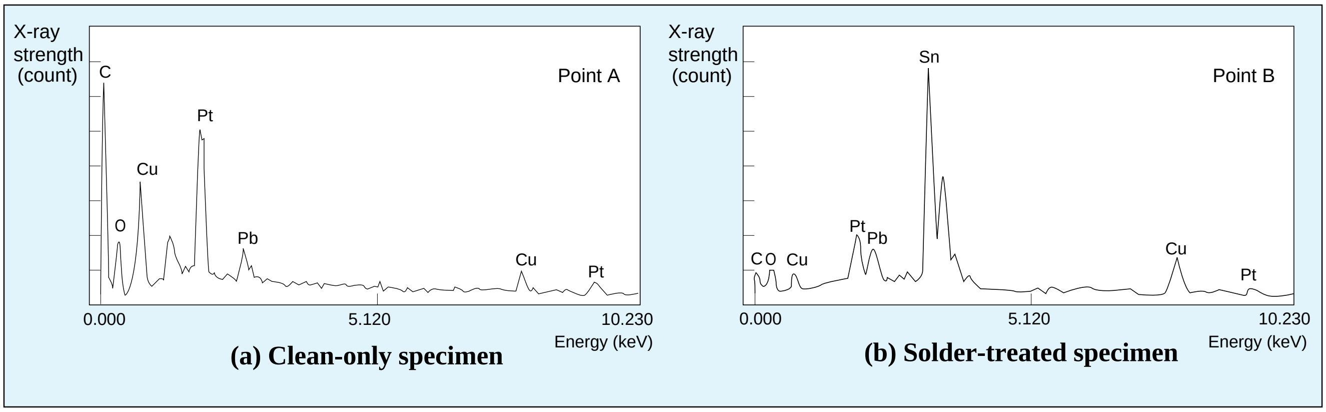


(a) Clean-only specimen



(b) Solder-treated specimen

Photo. 2 SEM specimen images (200×)



(a) Clean-only specimen

(b) Solder-treated specimen

Fig.4 Elemental analysis results from X-ray spectrum measurement (Platinum (Pt) detection is from SEM)

From this we can assume that cracks occurred in the region of the boundary between solder and flux, and that the solder and the substrate copper melted and migrated.

With the specimens coated with non-cleaning flux, we can assume that the effectiveness of the moisture resistance of the flux prevented moisture absorption under high temperature and high humidity, thus preventing migration. When evaluating the reliability of specimens in this manner, we can conclude that the dew condensation cycle test is very effective in that it can repeatedly apply high temperature cyclical stress and dew condensation stress simultaneously.

As described above, temporary recovery occurs from the drop in insulation resistance, so intermittently measuring under long-period conditions of high temperature and high humidity cannot accurately catch degradation or the time that insulation is lowered (time till failure). However, continuously measuring insulation resistance makes it possible to improve testing precision by accurately catching degradation and the time that insulation is lowered.

5. Conclusion

Continuously measuring while applying environmental stress was confirmed to be an effective method for evaluating reliability to find the causes of degradation and failure due to fluctuating characteristic values.

By continuously measuring insulation resistance, we were able to confirm temporary drops in insulation resistance and subsequent recovery that could not be measured with intermittent measurement. We were also able to continuously confirm the movement toward short circuiting.

We can assume that these phenomena also occur in the field. Because of this, we can assume that in such cases as IM, the current method of life prediction by intermittent measuring during long-period high-temperature, high-humidity conditions cannot provide effective test evaluation. Therefore, to accurately predict product life in this type of case, we can postulate that it is necessary to continuously measure insulation resistance and accurately catch the time taken to reach the level in which failure is determined.

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