VIA Reliability Evaluation of Embedded MLCC through Pressure Cooker Test

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Abstract. A via reliability test of PCB board using embedded MLCC was evaluated by HALT and Pressure Cooker Test PCT. The reliability of HALT was evaluated at 125 °C, 4Vr, and 12Hr. The purpose of this test was to verify the stability of the MLCC by predicting the lifetime of the PCB. The PCBT conditions were measured at 85% humidity and 2 atm, and the reliability of the PCBs under severe conditions than HALT was evaluated. The basic characteristics of MLCC size are 0603 (600x300um), Capacitance 100nF, thickness 150µm. The initial electrical characteristics of the MLCC were measured at a rated voltage (10V) with a capacitance value of 98 ~ 103nF, a loss rate of 0.048%, and an insulation resistance of 1.08 x10¹⁰ (Ω). The HALT test results showed that all the measured samples showed a value of 1x10⁷ Ω or more, and passed for the HALT test. The PCBT test resulted in failure, and the first sample fell below the poor insulation resistance at the start of the PCBT test. In the case of the second sample, the insulation resistance dropped to less than the defective insulation resistance for more than 30 hours, and the third sample has an appropriate insulation resistance of 1.0x10⁶ Ω even for more than 60 hours. It is confirmed that there is the greatest the possibility of failure in the part between the embedded chip and via that Cu plating is performed to form via by fill plating. Therefore, it is necessary to optimize the plating thickness and size conditions because the embedded MLCC has a high probability that defects mainly occur in VIA crack or delamination.

Introduction

With the development of modern electronics, other related industries such as telecommunications and IoT (Internet of things) are growing rapidly. As communication devices such as smart phones are improved to become low-power, multifunctional, and high-speed devices, efforts are being made to reduce the influence of high-frequency noise generated in the AP (application processor). In order to reduce the noise due to high frequency, there is a tendency to embedding R, L and C passive elements and active device chips in the PCB substrate as shown in Fig. 1.[1] Particularly, passive devices, which occupy more than 50% of the total electronic circuit area, have mounted discrete chip resistors or discrete chip capacitors on the surface of the PCBs. Recently, PCBs incorporating passive elements such as resistors or capacitors are being developed on demand.[2] Such highly integrated printed circuit boards require a high reliability in more extreme environments. The micro-pattern of the printed circuit board is placed in an unstable electrochemical condition in a high temperature, high humidity and high voltage environment. This causes a weak reliability and also causes a lot of losses. This is reported as a study of metal ion migration and whiskers in electronic components. In general, it is reported that moisture and contaminants existing on the surface of a printed circuit board with fine pattern are grown as conductive metal dendritic filaments on the circuit when a voltage is applied.[3-4] Embedded passive components have advantages in reliability environment such as humidity, temperature and physical environment such as warpage. The advantage of PCBs with embedded decoupling capacitors is that they are connected between the power supply and ground to
separate the DC bias and the signal, and reduce the SNN (simultaneous Switching Noise) in the high-speed switching circuit. In addition, the current path can be greatly reduced because it can be placed closer to the IC than the surface mount type capacitor. In this study, MLCCs with a size of 1005, a thickness of 150µm, and a capacitance of 0.1µm were embedded in a PCB with a thickness of 1T. The embedded MLCC were evaluated by HALT (Highly Accelerated Life Testing) and high temperature and high humidity PCBT (Pressure Cooker Test PCT). The electrical characteristics of embedded MLCC analyzed for a high probability that defects mainly occur in VIA crack or delamination.

Experimental Details

Fabrication of Embedded PCB for a Reliability Test

The embedded PCB module is designed to embedding the 0603 MLCC (capacitance: 100nF, thickness: 150µm) in the PCB. MLCC as decoupling capacitor were embedded in 2-3 layers and 5-6 layers with 6 layer of PCB and the total thickness of about 1mm. Low profile MLCC were embedded by using PCB process in sequence such as lamination, via processing, plating and circuit formation. To improve the properties of electrical noise in high frequency, MLCC was placed directly beneath the surface of PCB to minimize the length of the electrical circuit. The external electrode of the MLCC was coated with a Cu material, and its width of electrode was 300µm and its length was 200µm. Via was formed by using CO₂ laser to electrically connect to external IC from embedded MLCC in PCB. The size of a formed via is 100µm on the top and 70µm on the bottom.

![SMT for MLCC in cavity hole](image1)

![A cross-sectional photograph](image2)

![The fabricated module of the embedded PCB](image3)

Figure 1. Figure headings.

To fill cu in the formed via, via were filled using electroless/electrolytic plating. Via thickness is about 70µm. Thus, the embedded MLCC is electrically connected to the outermost layer of the PCB and can be used as a passive component on the module. In order to operate a 10G RF transceiver module electrically, other passive components and active components was equipped on the 1st and 6th layers of PCB using the SMT process. As shown in Figure 1(a), MLCC is a picture of SMT for MLCC in cavity hole. Figure 1(b) is a cross-sectional photograph of a module made by Embedded PCB process. Figure 1(c) is the fabricated module of the embedded PCB.
Reliability Evaluation of Fabricated Test Modules

A via reliability of the fabricated embedded PCB was evaluated by Highly Accelerated Life Testing and Pressure Cooker Test PCT. The reliability of HALT was evaluated at 125 ºC, 4Vr, and 12Hr. The purpose of this test was to verify the stability of the MLCC and VIA by predicting the lifetime of the PCB. The PCBT conditions were measured at 85% humidity and 2 atm, and the reliability of the PCBs under severe conditions than HALT was evaluated.

Results and Discussion

Table 1 shows the characteristics of the embedded MLCC to carry out reliability evaluation. The basic characteristics of MLCC size are 0603 (600x300um), 100nF, 150µm. Using this, it is possible to analyze capacity change and loss change in the PCB internal environment on HALT and PCBT, and predict the life expectancy of the MLCC and the Via reliability of the embedded PCB through the results.

Table 1. The characteristics of the embedded MLCC.

| Characteristics              | Value          |
|------------------------------|----------------|
| Rated voltage                | 10V            |
| Capacitance                  | 100nF          |
| Loss rate                    | 0.048%         |
| Insulation resistance(@10V)  | 1.0x10^10 Ω    |

The initial electrical characteristics of the MLCC were measured at a rated voltage (10V) with a capacitance value of 98 ~ 103nF, a loss rate of 0.048%, and an insulation resistance of 1.08 x10^10 (Ω). The capacity of 98 ~ 103nF is confirmed by the tolerance within the error range of the product.

Reliability test samples for HALT and PCBT were run on 5 samples each. Figure 2(a) shows the results for the electrical properties obtained from the HALT test. The results of the HALT test conducted at 125 ºC and 4Vr for 12 hours showed no change in the insulation resistance in all samples. The HALT test can predict the life of the MLCC. In the industry, the definition of a fault on a printed circuit board is shown when the insulation resistance drops below 1x10^6 Ω, which induces signal interference between the circuits carrying the signal. As a result, the HALT test results showed that all the samples showed a value of 1x10^7 Ω or more and passed the HALT test. We have not found any problems with the embedded MLCC and VIA connections.

The life expectancy is expected to be more than 10 years considering that insulation resistance is maintained without change in capacitance and loss. Figure 2 (b) shows the results of the PCBT test. The PCBT test was conducted under harsher conditions than HALT and the tests were conducted at
125 °C, 50V, 60hr, 2atm, and 85% humidity. The results of Figure 2 (b) show three types of electrical characteristics. The first is when the resistance of the measured MLCC is less than the defective resistance at the same time as the test starts. Secondly, the insulation resistance is less than 1x10^6 Ω after 30 hours of testing. The third sample had an appropriate insulation resistance of 1.0x10^6 Ω even for more than 60 hours. From 1'sample, it was confirmed that this phenomenon was caused by crack and delamination of via connecting the MLCC electrode and the upper circuit. It is confirmed that the defect is most likely to occur in the embedded PCB process which forms via interconnection through the Cu plating after the embedded chip and chip are mounted. Therefore, it is important to identify the defective mechanism of cross-sectional and compositional analysis by various reliability evaluation methods through SEM and EDX.

Summary

In this study, a via reliability test of PCB board using embedded MLCC was conducted. HALT and PCBT evaluation tests were conducted for the reliability test. As a result of HALT test, it was confirmed that there was no defect in the substrate using the embedded MLCC and that proper insulation resistance was maintained in all samples. The PCBT test resulted in failure, and the first sample fell below the poor insulation resistance at the start of the PCBT test. In the case of the second sample, the insulation resistance dropped to less than the defective insulation resistance for more than 30 hours, and the third sample had an appropriate insulation resistance of 1.0x10^6 Ω even for more than 60 hours. It is confirmed that there is the greatest possibility of failure in the part where the embedded chip and chip are mounted and Cu plating is performed to form the wiring. Therefore, it is necessary to optimize the plating thickness and conditions because the embedded MLCC has a high probability that defects mainly occur in VIA crack or delamination. The reliability test of PCBT is the most severe test than the existing reliability test, and it can be confirmed that the defect of VIA and Embedded MLCC inside the PCB is most evident. Analysis of defects can optimize the optimal embedded PCB.

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