Efforts toward standardization of reliability evaluation methods for high-capacity multilayer ceramic capacitors

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High-capacity multilayer ceramic capacitors (MLCCs) are electronic components installed in almost all electronic devices, but the reliability evaluation method has not been standardized yet. Demand for reliability of MLCCs is expected to become stronger in the future as automotive applications and aerospace applications progress. Based on this situation, in 2016, the MLCC Reliability Evaluation Committee, chaired by Professor Tsurumi of Tokyo Institute of Technology, was established to standardize the reliability evaluation and analysis methods of MLCC. First of all, a round robin test (RRT) was carried out using the evaluation method that the companies participating in the committee had independently performed until then. It was confirmed that it was difficult to compare the product lifespan obtained by each company with each other, because the obtained results had variations. After that, domestic RRT was carried out several times, and a standardization proposal of reliability evaluation method and analysis method was established, which defined the term of failure, test levels of applied voltage and measured temperature, and Weibull statistical processing method. An international RRT using this standardization proposal is currently underway.

1.Introduction

High-capacity multilayer ceramic capacitors (MLCCs) are electronic components installed in almost all electronic devices to suppress noise and stabilize voltage. For example, about 700 pieces of MLCCs are used in smartphones and about 800 pieces of MLCCs are used in laptops. The global market for MLCCs is about 1 trillion yen, of which Japanese companies account for about 50-70%, and Japan is strong in this sector.

As shown in Fig. 1, MLCC is a capacitor that has a multilayer structure of dielectric layers and internal electrodes. The electrostatic capacitance of a capacitor can be increased by thinning the dielectric layers or increasing the number of layers to enlarge the specific surface area of the electrodes. The international standards for MLCCs including chip size, capacitance, and temperature stability, already published[1)]. However, the standardization of MLCC reliability evaluation methods and product life prediction have not yet been made. Demand for reliability of MLCCs is expected to become stronger in the future as in-vehicle applications and aerospace applications progress, so it is necessary to meet this immediately.

Based on this situation, in 2016, the MLCC Reliability Evaluation Committee was established chaired by Professor Tsurumi of Tokyo Institute of Technology, and activities toward standardization of the MLCC reliability test method were started. The author has been attending this committee since 2017 and has seen the efforts to standardize the MLCC reliability evaluation method. In this article, I would like to introduce the past activities of this committee and what the reliability evaluation method of MLCC is like.

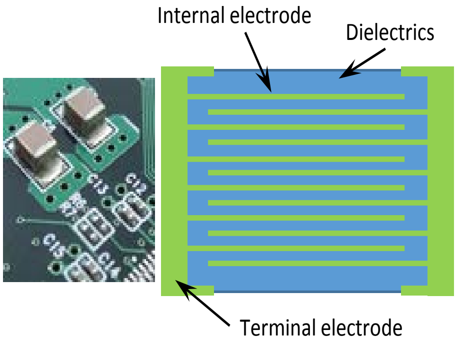

Figure 1 Appearance and structure of MLCC

2. MLCC Reliability Evaluation Committee

The MLCC Reliability Assessment Committee was set up as part of the standardization activities of the Technical

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Working Area TWA24 of VAMAS. Four major Japanese MLCC manufacturers, Murata Manufacturing Co., Ltd., Taiyo Yuden Co., Ltd., TDK Co., and Kyocera Co. participated in the committee.

In this committee, first of all, the reliability evaluation test was carried out using samples from the same lot. The procedure of the evaluation was not specified before this round robin test (RRT), which means each company used its own way for the test. Although the basic principle used for the analysis was the same, the result of RRT scattered very much and could not obtain any useful information. This is because each company used different evaluation processes such as the definition of the current value at which the MLCC is considered to have a dielectric breakdown, the test levels for accelerating voltage and temperature, and the statistical processing method of the obtained data. After that, we conducted several RRTs to investigate the cause of the difference in estimated product lifetimes, and at the end of 2018, we finally obtained reasonable results from all the participants, and then we prepared the first draft of a reliability evaluation and analysis test procedure. At the 44th VAMAS Steering Meeting held in Boulder, U.S.A. in May 2019, the international RRT using these test methods and analysis methods was approved, and the international RRT in which several overseas companies participate is currently in progress.

3. MLCC reliability evaluation method

There are various kinds of reliability required for MLCCs such as capacitance and mechanical strength, but the characteristic targeted by this committee is the reliability of insulation resistance. Since MLCC is an electrical insulator, almost no current flows even if a DC voltage is applied. However, as shown in Fig. 2, if voltage is continuously applied for long time, the leakage current will increase from a certain point, and it finally leads to dielectric breakdown. This is considered to be because positively charged oxygen defects in the dielectric material move to the negative electrode side and accumulate due to the external applied voltage, and when the amount of accumulated oxygen defects increases, the insulation deterioration phenomenon occurs at the electrode-dielectric interface.

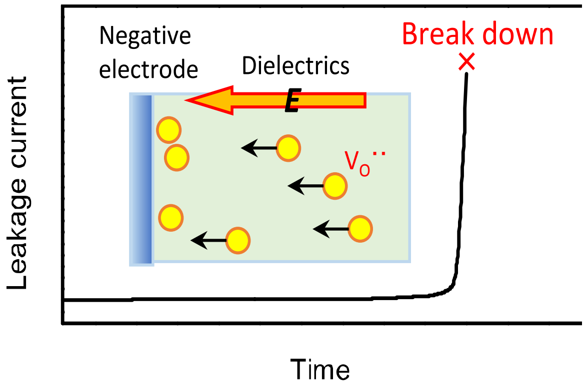

Figure 2 Relationship between MLCC leakage current and voltage application time

The MLCC reliability test uses the Highly Accelerate Life Test (HALT), which can obtain results in a short time. The leakage current of the sample is measured at higher temperatures and higher voltage than the normal operating environment, and the time until the sample is subjected to dielectric breakdown is measured. Accelerated tests using several tens to several hundreds of samples are performed, and the average lifetime is calculated by performing Weibull statistical analysis on the obtained results 2).

From the results obtained in this accelerated test, the lifetime at actual operating temperature and voltage is calculated using the following Eyring model formula3).

$$\frac{L_1}{L_2} = \left(\frac{V_2}{V_1}\right)^n \times exp\left[\frac{E_a}{k_B}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)\right] \qquad (1)$$

Here, L_1 and L_2 are average lifetime under different temperatures and voltage, n is the voltage acceleration constant, k_B is Boltzmann constant, Ea is the activation energy, V_1 and V_2 are the applied voltages, T_1 and T_2 are the test temperatures. In order to obtain the product lifetime under the actual temperature and voltage from this equation, it is necessary to obtain the voltage acceleration coefficient and activation energy. The voltage acceleration coefficient and activation energy can be calculated from the obtained average lifetime and the semi-log graph of the reciprocal of voltage and temperature, respectively. The voltage acceleration coefficient and activation energy are used to estimate the lifetime of the MLCC in the actual usage environment.

In this standardization proposal, the specifications of measuring devices, the definitions of failures, the test levels for accelerating temperature and accelerating voltage, the statistical processing procedure of data, etc., which had been set independently by each company, were defined. As a result, almost the same results were obtained from the four companies in the final domestic RRT.

4. Summary

In this paper, we briefly described the reliability evaluation method of MLCC and its standardization activities. Demand for in-vehicle MLCCs is expected to grow due to the spread of autonomous driving technology and electric vehicles in the future. The reliability of in-vehicle electronic components is required to be stricter than that of other electronic devices. We hope that this standardization activity will play a part in improving the quality and reliability of MLCCs.

References

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2) JIS R 1625: 2010.
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