Topics

Standardization Activities of Reliability Evaluation Methods for High-Capacitance Multilayer Ceramic Capacitors in TWA24

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High-capacity multilayer ceramic capacitors (MLCCs) are essential electronic components for modern electronic devices. Smartphones and notebook PCs contain approximately 800 to 900 MCLLs per unit. As automotive and aerospace applications progress in the future, MCLLs are expected to face higher requirements not only for basic characteristics such as chip size, capacitance, and temperature stability, but also for reliability. However, there is still no standardization of reliability evaluation methods for MLCCs. In light of this situation, the VAMAS Technical Working Area TWA24 began in 2016 to develop a draft standardization proposal for reliability evaluation and analysis methods for MCLLs. After several domestic round-robin tests (RRT), an international RRT was conducted in 2019 with the participation of six institutions, and it was confirmed that the proposed evaluation and analysis methods are effective for reliability evaluation of MLCCs. This paper presents the background to the initiation of this international RRT and the results obtained in this international RRT.

1. Introduction

High-capacity multilayer ceramic capacitors (MLCCs) are electronic components used in almost all electronic devices for noise suppression and voltage stabilization. MLCCs are capacitors with a multi-layered structure of dielectric layers and internal electrodes, as shown in Figure1, and the capacitance can be increased by making the dielectric layers thinner or increasing the number of layers to increase the specific surface area of the electrodes.The miniaturization of electronic devices and the increase in the number of high-performance ICs have led to demands for smaller and higher capacitance MLCCs, and today, 0201(0.2 mm×0.1 mm)size products are also being manufactured.

International standards have already been established for MLCCs, including those for chip size, capacitance, and temperature stability[1)]. However, there is still no standardization on the reliability evaluation method of MLCCs and the prediction of product lifetime. With the spread of electric vehicles and the increasing sophistication of autonomous driving, more and more MLCCs are expected to be used for automotive applications, and higher reliability is required for MLCCs used in automotive applications than those used in general electronic devices. Therefore, the standardization of MLCC reliability evaluation methods will be beneficial to both MLCC manufacturers and users.

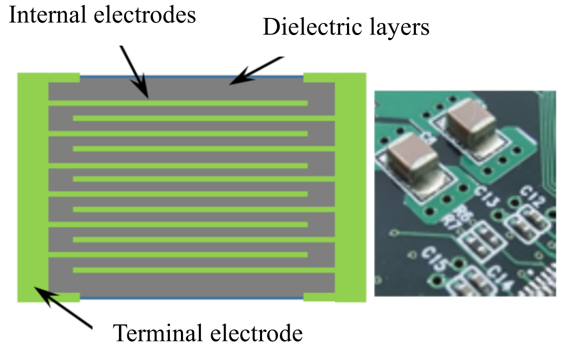

Fig. 1 Structure and appearance of MLCC

2. Standardization activities in TWA24

The MLCC Reliability Evaluation Committee, chaired by Prof. Tsurumi of Tokyo Institute of Technology, was established in 2016 and started activities to standardize the reliability test methods for MLCCs. This committee was set up as part of the standardization activities of the VAMAS Technical Working Area TWA24, and four major Japanese

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MLCC manufacturers, Murata Manufacturing Co., Ltd., Taiyo Yuden Co., Ltd., TDK Corporation, and Kyocera Corporation, participated in the committee.

Several local round robin tests (RRTs) were conducted by this committee to identify the causes of differences in lifetime prediction. As a result, by the end of 2018, we obtained a reliability assessment method and analysis method that resulted in nearly identical results from each company, then the international RRT using this test method was approved at the 44th VAMAS Steering Committee Meeting held in May 2019.

After that, we invited more organizations to participate in the international RRT, and two companies, Samsung Electronics C (Korea) and Yageo/KEMET (Taiwan/USA), joined us in addition to the four Japanese companies that had participated in the MLCC Reliability Evaluation Committee. In August 2019, 1000 units of Murata MLCCs (22 uF and 1608 mm chip size) from the same production lot and the measurement procedure manual describing how to set up samples and measurement conditions were sent to each participating company to start the international RRT.

3. MLCC reliability evaluation method

The reliability assessment method used in this RRT is as follows. There are various reliability requirements for MLCCs, but the property targeted in this RRT is the reliability of insulation resistance. Since a MLCC is an electrical insulator, almost no current flows when a DC voltage is applied. However, if voltage is applied for a long period of time, the current will increase at a certain point, eventually leading to dielectric breakdown. In this RRT, the MLCC lifetime was defined as the time to reach a current value 100 times higher than the initial current value.

For reliability testing of MLCCs, the Highly Accelerated Life Test (HALT) is used because it provides results in a short time. In HALT, the leakage current of a sample at a higher temperature and voltage than the normal operating environment is measured, and then time to result in dielectric breakdown is obtained. In this study, accelerated tests were conducted using 100 samples under the five different measurement conditions. The results were subjected to Weibull statistical analysis [2], as shown in Figure 2, and the average lifetime η was calculated for each measurement condition.

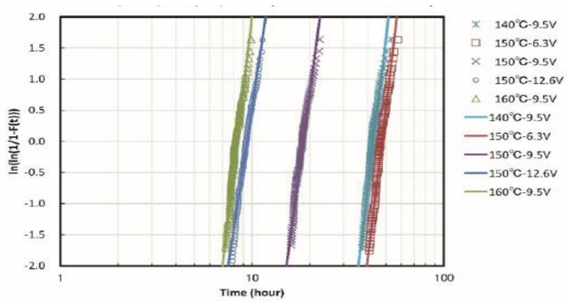

Fig. 2 Accelerated life Weibull distribution of MLCCs measured at different temperature and voltage conditions

The reason for performing the measurements under five different temperature and voltage conditions is to obtain the parameters, the voltage acceleration constant N and the activation energy E_a, which are necessary to determine the lifetime under actual operating temperature and voltage. By applying these values to the Eyring equation, the life can be calculated under actual operating temperatures and voltages.[3] In this RRT, η under each measurement condition, calculated N, E_a, and product life under reference conditions (85°C, 6.3V) were sent by each organization.

The variation of η among participating institutions under each measurement condition was relatively small, ranging from 8.6 to 12.6%. Table 1 shows N, Ea, and product life under reference conditions (85°C, 6.3V) calculated from these results. The variation of N and Ea among participating institutions was small, 6.5 to 6.7% in both cases, indicating that the proposed measurement procedure was valid. On the other hand, the product life under the reference conditions calculated using these values varied widely, with a coefficient of variation of 24.7%. Since the product life under reference conditions was calculated using η, N, and Ea under each measurement condition, it was considered that errors in these parameters were propagated, resulting in a larger variation.

Table 1 Voltage acceleration factor, activation energy and product life under reference conditions (85°C, 6.3V)

Parameter	A	B	C	D	E	F	mean	COV (%)
N	2.34	2.46	2.07	2.26	2.22	2.54	2.32	6.7
E_a (eV)	1.31	1.26	1.17	1.28	1.21	1.31	1.28	6.5
MTTF (hour)	24171	22923	12206	26119	16003	25794	21204	24.7

4. summary

In this paper, we have briefly described the international RRT for standardization of MLCC reliability assessment methods. The values of η, *N*, and *Ea* obtained in this RRT show little variation among participating institutions, indicating that these parameters are useful for comparing the product life of MLCCs. These results will be reported in a future Vamas Report.

References

1) JIS C 5101-22: 2014, IEC 60384-22: 2011.
2) JIS R 1625: 2010.
3) C. A. Randall, R. Maier, W. Qu, K. Kobayashi, K. Morita, Y. Mizuno, N. Inoue and T. Oguni: *J. Appl.Phys.* **113**, 014101 (2013).