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

Adachi Yutaka [1*]

[1] Electroceramics Group, Research Center for Functional Materials
National Institute for Materials Science (NIMS)

High-capacitance multilayer ceramic capacitors (MLCCs) are electronic components that are currently used in many of the electronic devices, but there is still no standardization of reliability evaluation methods. As automotive and aerospace applications progress in the future, the demand for MLCC reliability is expected to become stronger. In light of this situation, as part of the standardization activities of the VAMAS Technical Working Area TWA24, a standardization proposal for MLCC reliability evaluation and analysis methods has been developed in Japan since 2016. Currently, an international round robin test (RRT) using this standardization proposal is underway, and the results are being compiled. In this paper, the background and the reliability evaluation method used in the international RRT is introduced.

1.Introduction

High-capacity multilayer ceramic capacitors (MLCCs) are electronic components that are currently 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, and the capacitance can be increased and the chip size is reduced by making the dielectric layers thinner or increasing the number of layers to increase the specific surface area of the electrodes. Japanese companies account for more than 50% of the global market share of MLCCs, making it a field in which Japan is very strong (Fig. 1).

International standards have already been established for MLCCs, including those for chip size, capacitance, and temperature stability [2)]. 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.

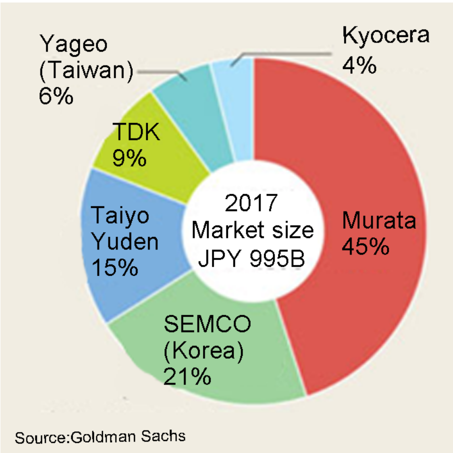

Fig. 1 Global market share of MLCCs [1)]

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 MLCC

*E-mail: adachi.yutaka@nims.go.jp

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 reasonable results from all the companies, and then we prepared the first draft of a reliability evaluation and analysis method. The international RRT using this test method was approved at the 44th VAMAS Steering Committee Meeting held in Boulder, USA, 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 were sent to each participating company to start the international RRT. Currently, we are analyzing the data sent back from the participating companies.

3. MLCC reliability evaluation method

This section provides the reliability evaluation method of MLCCs proposed this time. 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. 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 shown in Figure 2. The results were subjected to Weibull statistical analysis [3], and the average lifetime was calculated for each measurement condition.

The reason for performing the measurements under five different temperature and voltage conditions is to obtain the parameters, the voltage acceleration constant and the activation energy, which are necessary to determine the lifetime under actual operating temperature and voltage. The Eyring model equation shown below is used to determine the lifetime under actual operating temperature and voltage [4].

	6.3 V	9.5 V	12.6 V
140 °C		✔	
150 °C	✔	✔	✔
160 °C		✔	

Fig. 2 Measurement temperatures and applied voltages used in this RRT.

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

Here, L_1 and L_2 are the average life under different temperatures and voltages, n is the voltage acceleration constant, k_B is Boltzmann's constant, Ea is the activation energy, V_1 and V_2 are the applied voltage, and T_1 and T_2 are the test temperatures. As can be seen from this equation, the voltage acceleration constant and activation energy are necessary to determine the product lifetime under the temperature and voltage at which the product is actually used. In order to obtain these values, three levels of acceleration tests are conducted under constant temperature and different voltages, and three levels of acceleration tests under constant voltage and different temperatures, as shown in Figure 2. The voltage acceleration constant and activation energy can be calculated by making a semi-log plot of the average lifetime obtained under each condition versus the reciprocal of the voltage and temperature. By using these parameters in equation (1), it is possible to calculate the product lifetime at any temperature.

In this international RRT, Weibull statistical analysis results (shape parameter, scale parameter) under five different measurement conditions, voltage acceleration constant, activation energy calculated from the experimental results, and product lifetime under the reference condition (85°C, 6.3V) were collected from each organization. The validity of the reliability evaluation and analysis method proposed this time is being evaluated by comparing and examining these data.

4. summary

In this paper, we have briefly described the international RRT currently being carried out. The variation of the voltage acceleration constant and activation energy among the participating institutes was relatively small (about 6%), suggesting that the proposed method is effective. In the future, the collected data will be analyzed and discussed, and the results will be reported in Vamas Report.

References

1) https://diamond.jp/articles/-/182178
2) JIS C 5101-22: 2014, IEC 60384-22: 2011.
3) JIS R 1625: 2010.
4) C. A. Randall, R. Maier, W. Qu, K. Kobayashi, K. Morita, Y. Mizuno, N. Inoue and T. Oguni: *J. Appl. Phys.* **113**, 014101 (2013).