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Change in physical properties of conductive paste by applying ultrasonic vibratio

導電性ペーストに超音波振動を付与した際の物理特性の変化

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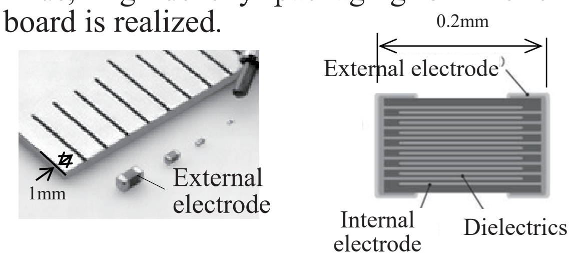
1. Introduction

It is well known that adding ultrasonic vibration to a liquid causes changes to various physical properties. As examples of this the reduction of the surface tension and viscosity are known to occur [1][2]. The external electrode of an electric component such as a multilayer ceramic chip capacitor (MLCC) is formed through the coating of a liquid conductive paste on the chip itself as an external electrode instead of a lead wire. However, the shape of the external electrode after the coating is affected by surface tension. Namely, the coating is not sufficiently uniform. For this reason, the current coating process cannot be used for downsizing and achieving the increased reliability of future MLCCs. In this study, to resolve this issue, a real-time method for controlling the surface tension of a conductive paste by ultrasonic vibration is reviewed.

2. Summary of MLCCs and external electrodes

Currently, 80% of the condensers produced in the world are MLCCs. About 400-500 MLCCs are used in each smartphone and they are used in all household appliances and electronic equipment. As shown in Fig. 1, multiple thin dielectrics and internal electrodes are alternately layered in MLCCs. The external electrode electrically connects their multilayer electrodes, and is used as a terminal when MLCCs are mounted on circuit boards. As a result, surface mounting is possible and downsizing and spacing saving are achieved. Thus, high-density packaging on the circuit board is realized.

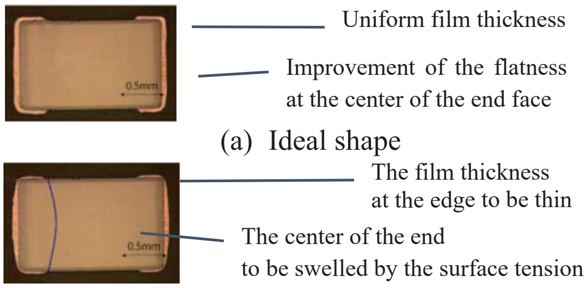


(a) Overview　　(b) Cross-sectional structure

Fig. 1　Overview of MLCC.

3. Issue regarding shape of external electrode

The issue regarding the shape of the external electrode of MLCCs is that there is a difference between the ideal shape and the present shape, as shown in **Fig. 2**, which shows the cross-section structure in the vertical direction. Namely, the edge is thin and the center of the end face is swollen, similarly to a matchstick, owing to the effect of the surface tension. This not only decreases the performance of MLCCs but also increases the number of defective devices.



(a) Ideal shape

(b) Present shape

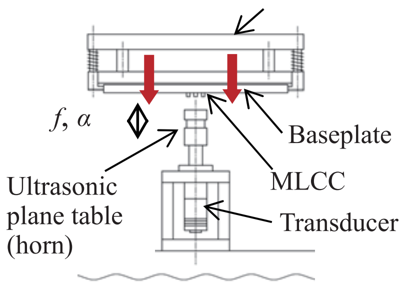
Fig. 2 Comparison of the external electrode shape.

4. Experimental apparatus and method

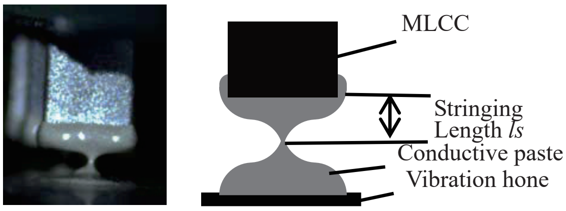
4.1 Measurement of stringing

The experimental setup is shown in **Fig. 3 (a)**. An MLCC was fixed on the baseplate of a commercial dipping device. An ultrasonic plane table was constructed using an ultrasonic vibration horn with a half wavelength. The experimental process included two processes, dipping and blotting. In the dipping process, a conductive paste was painted over the plane table with a constant thickness, and then chips were dipped in the paste. In the blotting process, the dipped chips were placed in contact with an empty plane table to remove excess paste.

We measured the change in surface tension under the application of ultrasonic vibration via the change in the stringing length of the paste. We defined the stringing length(*ls*) as the distance from the bottom face of a chip to the tip of the strings when the paste was allowed to fall under gravity as shown in **Fig. 3 (b)**. Namely, we considered that the smaller the surface tension, the shorter the stringing length. The main experimental conditions are listed in Table I.



(a) Experimental setup



(b) Example of stringing shape and definition of length

Fig. 3 Experimental setup and measurement.

Table. I Experimental conditions

MLCC shape	Rectangular parallelepiped 2.0×1.6×0.8 mm
Conductive paste	Ag paste, Viscosity 11.4 Pa・s
Frequency f	37.4 kHz
Amplitude α	0, 1.2, 1.8, 2.2, 3.2 μm
Coating thickness t	200 μm
Drying	Drying oven 130 ℃×10 min.

5. Experimental results and consideration

5.1 Effect of ultrasonic vibration on the stringing length

The relationship between an amplitude of ultrasonic vibration and a stringing length in the blotting process is shown in the **Fig. 4**. In the case of no ultrasonic vibration are introduced, namely, as a conventional process, the stringing length was marked at ls = 240 μm. In contrast, the stringing length was degreased by applying ultrasonic vibration, which its reduction rate increased according as an amplitude was increased. We recognized that the stringing length became ls = 140 μm at an amplitude a of 3 μm, which is degreased to approximately 40 %.

We consider that the string cutting is encouraged by applying ultrasonic vibration on the conductive paste. As a result, it is expected that MLCC moves on to the ideal shape as shown in the **Fig. 2** because its central-part-electrode thickness of the end is decreased and shoulder-part-electrode thickness is increased.

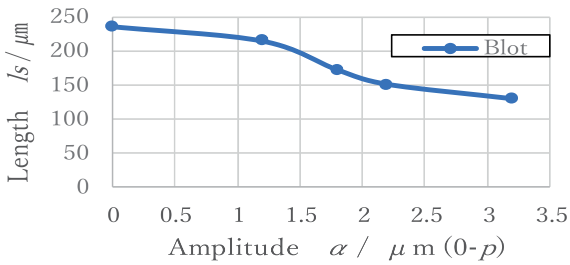
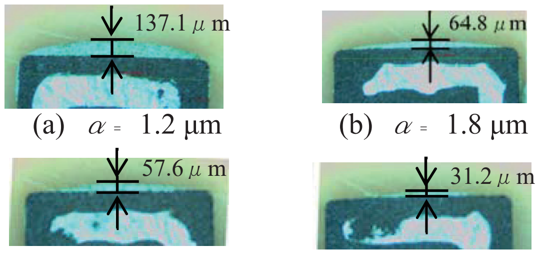


Fig. 4 Relation between the amplitude and stringing length.

5.2 Measurement of external electrode

Cross-sectional photographs of an MLCC with the conductive paste dried under the conditions in Table I are shown in **Fig. 5**. From the conventional process to the condition with an amplitude a of 1.2 μm, the thickness of the central part of the external electrode became at 137.1 μm. In contrast, the thickness was reduced to 31.2 μm when a was 3.2 μm, a reduction of approximately 80 %.

Namely, this result suggests that the external electrode thickness of an MLCC can be controlled by ultrasonic vibration. However, details of including the area around the shoulder have not yet been clarified.



(a) α = 1.2 μm (b) α = 1.8 μm (c) α = 2.2 μm (d) α = 3.2 μm

Fig. 5 Comparison of the cross-sectional shape of the electrodes.

6. Conclusion

In this research, a method of paste removal when during the coating of MLCCs with a conductive paste under ultrasonic vibration was studied. It was clarified that the stringing length decreased and the coating thickness was equalized when the method was employed.

References

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