CASE 36

Optimization of Adhesion Condition of Resin Board and Copper Plate

Abstract: Electronic component parts installed in resin board require shape stability, flatness, or heat radiation with good heat conductivity. To evaluate adhesion conditions, peel tests have been used traditionally. For other tests, the occurrence of bubbles is inspected by ultrasonic detection. But these methods are not easy to quantify. In this study the characteristics of a capacitor at the contact surface was used as the generic function with good reproducibility.

1. Introduction

Electronic parts installed on resin boards (e.g., motherboards) need shape stability, flatness, or heat radiation, depending on how they will be used. To this end, we need to fix a resin plate onto a more rigid plate made of material that has good heat conductivity. Therefore, a product combining a resin board and a copper plate is used. As a typical method of evaluating good adhesion, we have conventionally used the peel test to judge good or poor adhesion. This method is still regarded as being in most common use to indicate adhesion conditions per se and as the easiest to use to control an adhesion process.

In the meantime, other methods exist, such as observation of the occurrence of bubbles displayed in a monitor by an ultrasonic detection technique. However, since they are not easy to quantify, we use these methods primarily for inspection. The adhesion structure studied in our research is shown in Figure 1. Using adhesive, we glued a copper plate onto a resin board that had a metal pattern on the surface. The most critical issue was that a conventional adhesion strength test could not be used because the plastic board used is a thin film. In the peel test, after adhesion the film tends to break down when either the resin board or copper plate is fixed. Therefore, an optimal evaluation method was needed to judge adhesion condition.

2. Generic Function

Taking into consideration the function of a copper plate as a heat radiator, we would usually evaluate the relationship between electricity consumption and temperature on the copper side. However, since errors are often generated due to the attachment of the copper to a plastic board, in this research we focused on stable adhesion quality and defined a capacitance characteristic on the adhesion area as a generic function.

Looking at the fact that the copper plate and metal pattern shown in Figure 1 clamp the adhesive and plastic board, we note that this structure forms a capacitor. Although we have attempted to assess $Q = CV$ as a generic function, we cannot prepare a proper measuring instrument for this. Therefore, we took advantage of a capacitance characteristic $C = \varepsilon S/d$ (where C is the capacitance, ε the permittivity, S the surface area of an electrode, and d the distance between electrodes; Figure 2). By regarding a small change in capacitance (a high SN ratio) as a good condition both before and after an accelerated test that places a high-temperature

 Taguchi's Quality Engineering Handbook. Genichi Taguchi, Subir Chowdhury and Yuin Wu

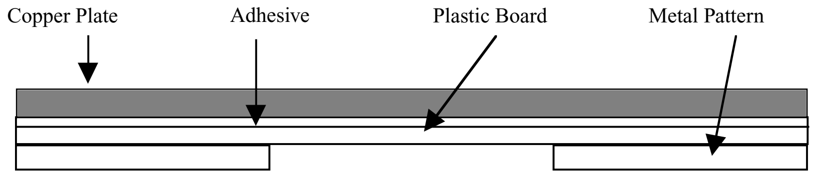

Figure 1
Joint area of resin board and copper plate

stress, we evaluated the characteristic. Since the change in permitivity is constant for the temperature change before and after the accelerated test, we assumed that it does not affect the capacitance.

Signal Factor

Assuming the sizes of electronic parts in a product, we selected an area of the metal pattern on the side of the resin board as a signal factor. As shown in Figure 3, we prepared resin boards with small (M_1), medium (M_2), and large (M_3) metal pattern areas for the evaluation. The outer surrounding area shown in Figure 3 indicates a metal pattern.

Noise Factor

High-temperature stress before and after the accelerated test were selected as noise factor levels:

N_1: shortly after adhesion (after adhesive solidifies)

N_2: after accelerated test (three sets of water absorption and reflow at a temperature of 245°C

As the experimental device in the accelerated test, we used our reflow furnace to melt solder on terminals where motherboards were mounted.

3. SN Ratio

Table 1 shows the calculations for the SN ratio and sensitivity.

Total variation:

$$S_T = 44.14^2 + 40.33^2 + \cdots + 103.88^2 = 42{,}972.83 \quad (1)$$

Effective divider:

$$r = 69.25^2 + \cdots + 213.75^2 = 70{,}506.88 \quad (2)$$

Linear equations:

$$L_1 = (69.25)(44.14) + \cdots + (213.75)(128.51) = 42{,}783.85$$

$$L_2 = (69.25)(40.33) + \cdots + (213.75)(103.88) = 34{,}581.00 \quad (3)$$

Variation of proportional term:

$$S_\beta = \frac{(L_1 + L_2)^2}{2r} = 42{,}444.94 \qquad (f = 1) \quad (4)$$

Variation of differences between proportional terms:

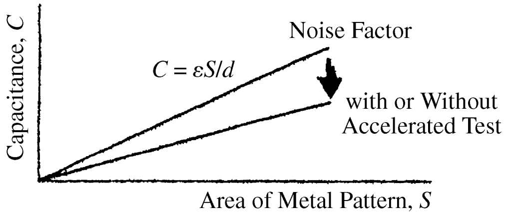

Figure 2
Generic function of resin board and copper plate

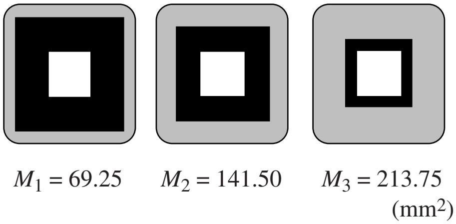

Figure 3
Signal factor for adhesion (metal pattern area)

Table 1
Capacitance data (pF)

	M_1 (69.25)		M_2 (141.50)		M_3 (213.75)	
No.	N_1	N_2	N_1	N_2	N_1	N_2
1	44.14	40.33	86.63	67.73	128.51	103.88

Table 2
Control factors and levels

Control Factor	Level 1	2	3
A: storage condition of copper plate	Normal temperature and humidity	High temperature and humidity	—
B: storage condition of plastic board	Dry	High temperature and humidity	Normal temperature and humidity
C: adhesion load	Small	Mid	Large
D: adhesion temperature	Low	Mid	High
E: adhesion time	Short	Mid	Long
F: leave-as-is time	Short	Mid	Long

Table 3
Confirmatory results (dB)

	SN Ratio		Sensitivity	
Configuration	Estimation	Confirmation	Estimation	Confirmation
Optimal	−11.97	−13.74	−3.89	−4.50
Current	−19.72	−19.17	−4.79	−4.66
Gain	7.75	5.43	0.89	0.16

$$S_{N\beta} = \frac{(L_1 - L_2)^2}{2r} = 477.165 \qquad (f = 1) \qquad (5)$$

Error variation:

$$S_e = S_T - S_\beta - S_{N\beta} = 50.72878 \qquad (f = 4) \qquad (6)$$

Error variance:

$$V_e = \frac{S_e}{4} = 12.6822 \qquad (7)$$

Total error variance:

$$V_N = \frac{S_{N\beta} + S_e}{5} = 105.5788 \qquad (8)$$

SN ratio:

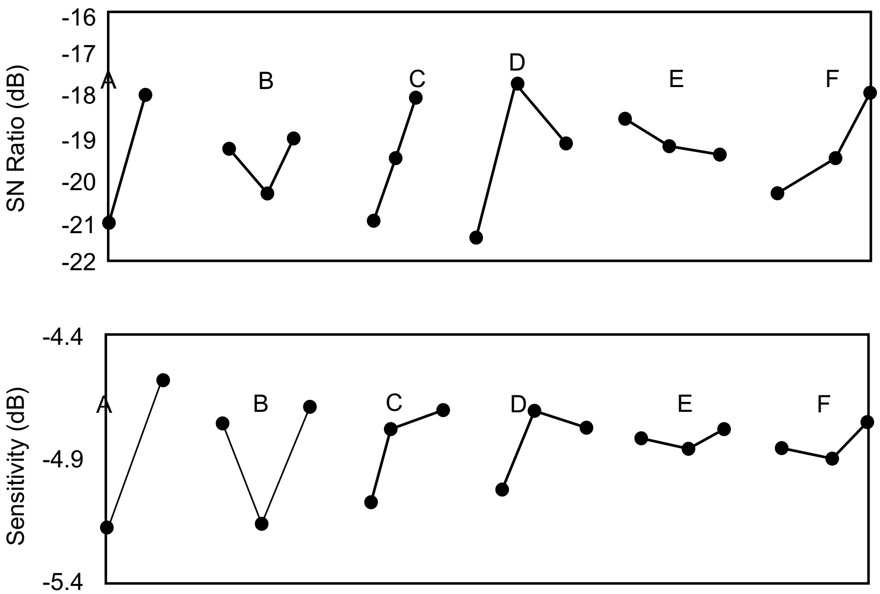

Figure 4
Response graphs

$$\eta = 10 \log \frac{(1/2r)(S_\beta - V_e)}{V_N} = -25.4514 \text{ dB} \quad (9)$$

Sensitivity:

$$S = 10 \log \frac{1}{2r}(S_\beta - V_e) = -5.21565 \text{ dB} \quad (10)$$

4. Optimization Configuration and Results of Confirmatory Experiment

As control factors, we selected factors that can be controlled during adhesion (Table 2), such as pressure- or heat-related parameters, storage conditions of adhesives, or as-is conditions. Table 3 shows the results of the confirmatory experiment under the optimal and current conditions. This table and the response graphs in Figure 4 reveal that the gain in SN ratio has 70% reproducibility, which is regarded as somewhat poor. Whereas under the current configuration the estimation and confirmation are extremely consistent, under the optimal configuration, the confirmation is somewhat smaller. One possible reason is that the condition of high temperature and humidity as the optimal level of factor A tends to cause errors, because this condition approximates that at the point when the adhesive solidifies. To improve reproducibility, it seems that we need to separate temperature and humidity when evaluating.

Based on several assumptions, we calculated the cost/benefit ratio obtained from our functionality optimization. Assuming a change in capacitance when there is a peeling problem at the adhesion area, caused by voids, we computed the following loss function:

$$\sigma^2_{\text{optimal}} = \frac{\beta^2_{\text{optimal}}}{10^{\eta_{\text{optimal}}/10}} = 6.426 \quad (11)$$

$$\sigma^2_{\text{current}} = \frac{\beta^2_{\text{current}}}{10^{\eta_{\text{current}}/10}} = 31.12 \quad (12)$$

Now, setting $A_0 = 2000$ yen and $\Delta = 11$ pF (assumed value), we have

$$L_{\text{optimal}} = \frac{A_0}{\Delta^2 \sigma^2_{\text{optimal}}} = 106.2 \tag{13}$$

$$L_{\text{current}} = \frac{A_0}{\Delta^2 \sigma^2_{\text{current}}} = 514.4 \tag{14}$$

In sum, a loss of 408.2 yen/piece is eliminated through this optimization. In the case of monthly production volume of 10,000 units, the cost/benefit ratio amounts to 4,082,000 yen/month.

Reference

Yugo Koyama, Kazunori Sakurai, and Atsushi Kato, 2000. Optimization of adhesion condition of resin board and copper plate. *Proceedings of the 8th Quality Engineering Symposium,* pp. 262–265.

This case study is contributed by Yugo Koyama.