DRILLING OF MULTI-LAYER PRINTED WIRING BOARD OF AFRP USING CO_2 LASER

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SUMMARY: The multi-layer PWB (printed wiring board) made of AFRP for laser drilling is chosen as a subject of our study. The drilling conditions of drilling the blind via holes and the quality of the drilled holes are examined using a CO_2 laser source against this composite material. As a result, it is shown that there are the processing conditions which AFRP is drilled without drilling through the copper foil of the inner layer. Laser drilling is an effective method to perform the blind via holes. Additionally, it is feasible to drill the hole with promising tapers against plating for electric circuits using a laser source.

KEYWORDS: Drilling, Multi-layer printed wiring board, CO_2 laser, AFRP, Blind via hole

INTRODUCTION

Because of the increasing demand for reducing the size of the electric devices, the printed wiring board (PWB) has become been smaller. Therefore, the use of the multi-layer printed wiring board has been considered as an effective method to increase the package density. PWB manufactures worldwide are testing various ways to make multi-layer boards. Among them, laser drilling therefore has been considered as an effective way to machine smaller blind via holes (less than diameter 0.3 mm) in the multi-layer PWB. Thus, the authors have discussed the characteristics of laser drilling the glass/epoxy composites for the PWBs.[1-3]
On the other hand, aramid fiber reinforced plastics (AFRP) are suitable for laser machining among many kinds of FRPs.[4-6] They are also considered as an effective material for multi-layer PWB boards. Therefore, the multi-layer PWBs made of AFRP for laser drilling are chosen as a subject of our study.
First, SEM observations of rim quality are carried out. Additionally, the affected damage caused by heat around the hole was observed by optical microscope. The relations between the damage and the laser irradiation time were thereby investigated.
Second, conditions which are promising for the formation of blind via holes are researched. Especially, irradiation time per pulse and number of pulse were varied.
Finally, metallization with these holes was investigated from the viewpoint of plating reliability in circuit registration.

EXPERIMENTAL EQUIPMENT AND MATERIALS

Figure 1 shows the multi-layer PWB (4 layers). The electric chips are mounted on the outer layers, and the electric circuit patterns are conducted by through holes between the outer layers. On the other hand, the blind via holes are used to conduct between the outer and the inner layers. In this case, the inner layer circuits are made of the copper clad laminate. The conduction between them is formed by plating the through holes and the blind via holes with copper. Generally, the through holes have been drilled by the drill tools. However, in the case of small holes (less than diameter 0.3 mm) and thin layers, it is difficult to drill the blind via holes by this method. Thus, the multi-layer PWB made of AFRP is developed for application of laser drilling.

Figure 2 shows machining processes of the multi-layer PWB using a laser source in the present report. First, patterns are etched on the core plate (thickness 0.8 mm) made of GFRP. Next, AFRP are laminated on it. These layer built up has a thickness of 0.3 mm. The blind vias are formed by laser irradiation from the outer layer side, since the base copper foil (pattern: thickness 18 μm) tends to reflect light strongly below the ablation threshold of copper. Finally, through holes are drilled in order to conduct the outer patterns. Pattern formation is completed after copper plating and etching process.

A CO_2 laser of the SYNRAD mod. 57-1-28W type was used. Table 1 shows the specifications of laser machine. The spot diameter is 0.3 mm. The layer built up is the type of aramid nowoven fibric / epoxy (CEL-541: Shin-Kobe Electric Machinery Co., Ltd.).

Fig. 1: Multi-layers printed wiring board

Table 1: Specifications of laser machine

Wave length	10.5 μm
Power	100 W
Beam mode	TEM00
Beam diameter	4 mm
Spot diameter	0.3 mm
Divergence	3.5 mrad

RESULTS AND DISCUSSION

Drilled Hole Using a Laser Source

Figure 3 (a),(b) show the SEM photographs of drilled hole. From Fig.3 (a), the black substance damage (carbonizing zone) caused by heat is seen after the laser drilling where irradiation time is long. On the other hand, from Fig.3 (b), this black zone hardly appears when irradiation is very short time. However, the laser drilled hole has a uniform taper to the

Fig. 2: Production process of multi-layers circuit board

(a) Irradiation time 100 ms *(b) Irradiation time 5 ms*

Fig. 3: SEM photographs of drilled

Fig. 4: Definition of damaged width and taper angle

Fig. 5: Relation between irradiation time and the damaged width

Fig. 6: Relation between irradiation time and hole entrance diameters

side wall. Therefore, the damaged zone (black zone) and taper angle were defined as shown in Fig.4. Figure 5 shows the relation between irradiation time pre pulse and the damaged widths. From Fig.5, it is apparent that no carbonizing occurs when irradiation time pre pulse is less than 5 ms.

Figure 6 shows the relation between irradiation time pre pulse and the hole entrance diameters. Figure 7 shows the relation between irradiation time pre pulse and the taper angles. From these figures, it can be seen that irradiation time pre pulse has more influence on the

*Fig. 7: Relation between irradiation time and taper angles 2*q

*Fig. 8: Relation between number of irradiation and taper angles 2*q

Fig. 9:Drilling conditions and formation of blind via holes

taper angles than on the hole diameters. The taper angles to the side wall decrease as irradiation time pre pulse increase.

Figure 8 shows the relation between irradiation number and the taper angles. From Fig.8, it is also apparent that the taper angles to the side wall decrease as the number of irradiation increase.

As a result, it is clear that the laser drilling conditions where irradiation time pre pulse is less 10 ms are needed to prevent the carbonizing near the drilled hole. The laser drilled hole has a uniform taper to the side wall.

Fig. 10: Blind via hole after plating

*(a) 2*q*=20 deg.* *(b) 2*q*=30 deg.*

Fig. 11: Metallization of taper angles

Formation of blind via hole

In this session, conditions which are promising for the formation of blind via holes are researched. Figure 9 shows the relations between the formation of blind via holes and drilling conditions. In figure, triangulation plots indicate the incomplete via hole due to small input energy. Black circle plots indicate the complete via hole. Square plots indicate the through copper foil due to much input energy. From these results, it is found that input energy pre pulse is an important factor in order to form the blind via holes. The method to repeat the short irradiations is effective to prevent the damage for the copper foil. Especially, the irradiation time 0.5 ms pre pulse are considered as a promising condition in this study.

Characteristics of metallization

Figure 10 shows the cross section of the blind via holes after copper plating. This figure indicates the thick plating on the bottom. This is why the inner copper foil has a affinity in electroplating.

Figure 11 (a),(b) show the cross sections of the side wall after metallization. These wall shown in figures indicate taper angle 20 degrees and 30 degrees respectively. In figure (a), no metallization area is observed at a corner. On the other hand, in figure (b), sufficient plating is carried out at it. That is; there are better metallization du to improving the fluidity in via holes. It is found that the use of a laser source makes it feasible to drill the holes with promising taper angles against plating the blind via holes.

CONCLUSION

The multi-layer PWB made of AFRP is evaluated for application of laser machining. It is shown that there are the drilling conditions which AFRP is drilled without drilling the copper foil of the inner layer. Laser drilling is an effective method to perform the blind via holes. Additionally, it is feasible to drill the hole with promising tapers against plating using a laser source.

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