Lubricant Pretreated Aluminum Sheet for Printed Wiring Board Drilling

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A new type of entry board, called "FAE sheet", was developed using a unique lubricant film laminated on an aluminum sheet. The FAE sheet has significantly improved drilling qualities such as hole accuracy, hole wall roughness and drill bit life, even under severe drilling conditions. The improvements have been derived mainly from modifications in the resin system, especially in regards to lubrication behavior such as melting temperature, melting viscosity and heat capacity. In addition, FAE sheet can conform to various drilling conditions since the film thickness and aluminum thickness can easily be adjusted.

Introduction

Recently, there have been significant improvements in electronic devices through increased densities and performance. Printed wiring boards (PWBs) play a significant role for such developments. PWBs have contributed to downsizing and performance of electronics products, such as mobile phones, digital home electronic appliances and personal computers.

Generally, PWBs comprise conductive layers made of copper film and insulating layers made of organic resin reinforced by paper and glass fabric, in which the layers are laminated in alternate manner. Through holes for insetting leads and / or holes for connecting between conductive layers are drilled, when mounting electronic parts, such as semiconductor chips, on the PWBs. Resin film or metal plates are generally used to prevent burrs from the copper films, or scratches on the copper films, to be generated, or formed, on the outermost surface of the PWBs. These plates are placed on the topmost layer of the PWBs to be drilled and are categorized into types; i.e., entry boards placed on the side penetrated by drills and back up boards placed on the lower side of the PWB.

As the density and performance of electronic devices grow, higher density wiring and more accurate mounting are required for PWBs and the requirements for drilling accuracy are becoming increasingly stringent.

Examples include the need for drilling a greater number of small diameter holes per unit area, with small hole to hole distances, and for drilling holes with high aspect ratios into stacked PWBs to increase productivity. Under such circumstances increasing importance is put on the characteristics of the above mentioned plates used for drilling.

Figure 1 shows a cross sectional structure of plated through holes of a 6 layered PWB. The PWB is to be drilled with through holes in the land portions, disposed on the wiring pattern, and such drillings occupy the largest portion of the drillings. The drillings affect the performance and costs of electronic devices, making it important to secure the qualities and economics of the drillings. The entry boards, placed on the drill penetration side, play an important role for the quality of the through holes.

Conventionally, aluminum sheets, 100 to 200 μm thick, are used for the entry boards. However, as the diameters of the through holes to be drilled become smaller and, in addition, drilling loads increase to increase productivity, it is becoming difficult to achieve the required quality of drilled holes using aluminum sheets.

The development of a new entry board which improves hole quality is now required, because conventional use of aluminum sheets restricts the quality of drilled holes.

Kobe Steel developed a "CAE sheet" as a new entry board, solving problems associated with conventional aluminum sheet [1), 2)], and started production and sales from SUN ALUMINIUM IND, LTD., one of the Kobe Steel Group companies. In order to improve hole qualities further under more severe drilling conditions, we developed our original entry board (Film laminated Aluminum Entry board, FAE) in which aluminum sheet surfaces are treated with a special lubricant coating [3), 4)].

Figure 2 shows an example in which the FAE sheet is applied to the drilling of a PWB. This paper

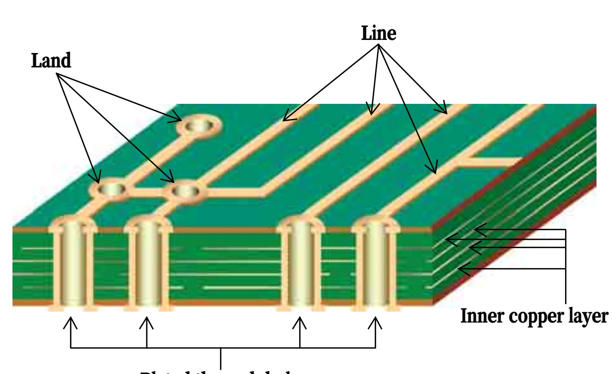

Fig. 1 Cross section schematic view at plated through holes of 6 -layered PWB

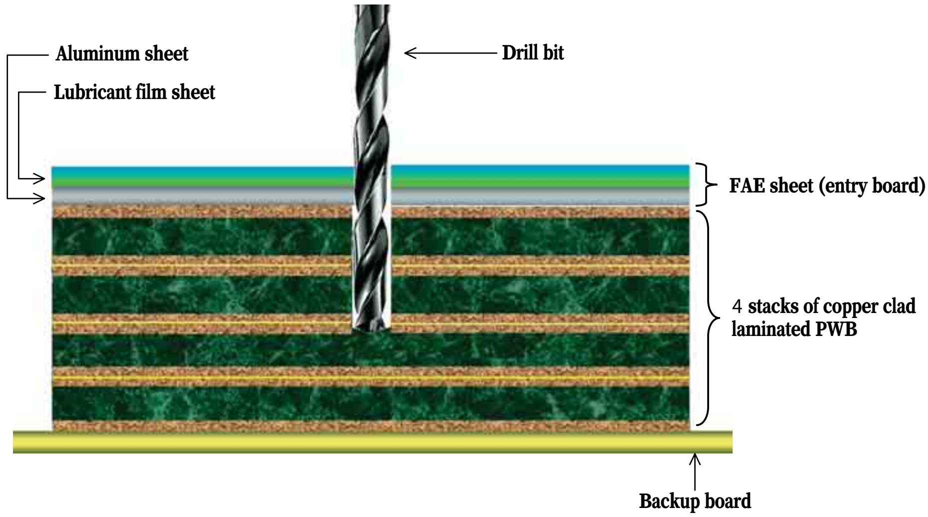

Fig. 2 Schematic structure of FAE sheet application to drilling of PWBs

introduces the outline and characteristics of the FAE sheet.

1. Outline of FAE sheets

1.1 Quality required for drilling

When an aluminum sheet is used as an entry board for drilling of through holes with small diameters, the following problem arises:

- hole positioning accuracy failure
- hole wall roughness failure
- drill breakage
- generation of drill smear

Requirements for PWBs differ depending on applications and drilling conditions. In the case that a build-up, multi-stack, PWB is drilled with a φ0.25 mm drill bit under the condition shown in **Table 1**, the following specifications are generally required to be satisfied.

1) The hole wall roughness should be less than 15 μm in maximum.
2) The hole positioning accuracy, in terms of both the maximum displacement from the center value and the average +3σ (σ: standard deviation), should be less than 40 μm.
3) Drills should have a total life of 20,000 hits under three times re-grindings of the tip, with drill breakage frequency during drilling in the order of ppm.
4) No drill smear should be caused on any of the holes by heating of the inner resin layers by the drlling heat. Such smear leads to plating failures and/or plating erosion, casing conduction failures and heat resistance failures.
5) Shape distortions, called "nail-head", caused from inner layer copper film burr by drill wear, should be less than 40% of the total number of copper layers, when they exist.

There is an increasing demand for ultra-small diameter drilling in the φ0.10mm range for higher wiring densities and high precision mountings. The key requirements for the ultra-small diameter drilling are hole positioning accuracy and drill breakage prevention. As the hole diameters become smaller, the requirements for hole positioning accuracy become more stringent and an increased number of holes is required to be drilled in a PWB, making the drilling loads higher.

Table 2 shows the drilling condition for a typical φ0.105mm drilling. General specifications, required for the drilling, are that the hole positioning accuracy, in terms of both the maximum deviation from the center value and the average +3σ (σ: standard deviation), is less than 30 μm and drill breakage frequency, during drilling, is in the order of ppm and

Table 1 Drilling process conditions using φ0.25 mm drill

Drill diameter	0.25 mm
Drill bit type	Cemented carbide drill
Spindle speed	160,000 min^{-1}
Infeed rate	3.0 m/min
Chipload	18.75 μm/rev
Number of hits	5,000
Hole to hole distance	0.45 mm
Type of PWB	FR-4 double sided copper clad laminate, t=0.8 mm
Stack heights	4 stacks
Backup board	1.5 mm bakelite
Depth into backer	0.3 mm
Pressure foot	125 N
Vacuum force	150 hPa

Table 2 Drilling process conditions using ϕ0.105 mm drill

Drill diameter	0.105 mm
Drill bit type	Cemented carbide drill
Spindle speed	300,000 min^{-1}
Infeed rate	2.4 m/min
Chipload	8.0 μm/rev
Number of hits	5,000
Hole to hole distance	0.30 mm
Type of PWB	FR-4 double sided copper clad laminate, t=0.4 mm
Stack heights	2 stacks
Backup board	1.5 mm bakelite
Depth into backer	0.15 mm
Pressure foot	125 N
Vacuum force	150 hPa

the hole wall roughness is less than 10μm at maximum.

1.2 Development of lubricant resin

Key points required for lubricant resins to decrease hole wall roughness, an important characteristic of drilling, are as follows.

1) The resin on the aluminum sheet should melt quickly by the friction heat generated between the drill and PWB.
2) The melting resin should adhere to the drill, rotating at a high speed, to enhance lubrication.
3) Cutting chips should exit easily from the drilled hole through the lubrication effect.

Those objectives, if achieved, are expected to improve the hole roughness significantly. The lubrication effects are also known to reduce drill breakage, along with the issues associated with drill smears, such as plating failures, plating erosions and nail-heads. Resin development was carried out to optimize the following properties of a resin to take full advantage of the lubricant resin.

- Melting point
- Heat capacity
- Melting viscosity

As for the improvement of hole positioning accuracy, conventional aluminum sheet can be modified to prevent scratches, burrs and hole deformation of the outermost copper layers of the PWBs. The centrality at the time of a drill bite, which affects the hole positioning accuracy, is improved through optimizing the hardness of the resin film. In other words, by imparting an appropriate hardness to the resin film, the centrality of the drill is improved as a result of improved drill biting. In addition, the lubrication effects, as described previously, ensure that cutting chips are discharged smoothly out of the exits of the holes and, as a result, no chips tends to remain on the surface (vicinity of drilled holes) of the entry board and drill chipping is reduced.

The lubricant resin, with the above considerations, was further developed to have the following functions.

1) The lubricant resin is formed in the desired film thickness.
2) The lubrication film is melted and hot laminated to aluminum sheets directly to lower the manufacturing cost and productivity.

2. Performance of the FAE sheets

2.1 Outline of the drilling performance test

The FAE sheet using a resin, which was developed under the above considerations, was placed on a PWB to be tested for drilling and the hole qualities were compared with those obtained from the conventional aluminum sheets.

A PWB substrate was selected to have copper films on both the surfaces of a typical core of build-up, multi-stack PWB (core material; epoxy resin, based on glass-fabric, with a high glass-transition temperature: copper film thickness, 35μm: total thickness; 0.8mm). The drill diameter was selected to be ϕ0.25mm, the diameter most commonly used, and drillings were performed under the condition shown in Table 1. The testing method and the configuration of the FAE sheet are summarized in **Table 3**.

As a drilling test for holes with ultra-small diameter, the test under the condition in Table 2 was performed. The testing method and the configuration of the FAE sheet are summarized in **Table 4**. The aluminum sheet, used for the comparative example of each test, is of the same type having the same thickness as the FAE sheet tested.

Table 3 Drilling process test method

Drilling machine	H-MARK10V ※1)
Analysis machine for hole accuracy	TAKEUCHI PXL-2000 ※2)
Tested FAE sheet	
Lubricant film thickness	150 μm
Aluminum sheet thickness	150 μm

※1) Manufactured by Hitachi Via Mechanics, Ltd.
※2) Manufactured by Takeuchi Co., Ltd.

Table 4 Drilling process test method

Drilling machine	ND-6Q210 ※1)
Analysis machine for hole accuracy	TAKEUCHI PXL-2000 ※2)
Tested FAE sheet	
Lubricant film thickness	40 μm
Aluminum sheet thickness	80 μm

※1) Manufactured by Hitachi Via Mechanics, Ltd.
※2) Manufactured by Takeuchi Co., Ltd.

2.2 Hole positioning accuracy

The hole positions were measured on the rear side of the PWB, drilled under the conditions shown in Tables 1 and 2, to determine the hole positioning accuracy, using an optical, non-contact, three dimensional measuring machine. The results of hole positioning accuracy are shown in **Table 5** and **Table 6**.

Drilling of ϕ0.25mm holes, using the FAE sheet, resulted in a maximum displacement of 25.4μm and an average + 3σ (σ: standard deviation) of 27.8μm, both of which fit to the specification of less than 40μm. Conventional aluminum sheet, on the other hand, gave results (a maximum displacement of 89.4μm and an average + 3σ (σ: standard deviation) of 78.6μm) far out of the specifications.

Table 5 Results of hole accuracy comparing with FAE sheet and aluminum sheet after 5,000 hits drilling process using ϕ0.25 mm drill

Entry board	Hole accuracy performance		
	Maximum (μm)	Average (μm)	Avg. +3σ (μm)
FAE sheet	25.4	18.3	27.8
Aluminum sheet	89.4	54.8	78.6

Table 6 Results of hole accuracy comparing with FAE sheet and aluminum sheet after 5,000 hits drilling process using ϕ0.105 mm drill

Entry board	Hole accuracy performance		
	Maximum (μm)	Average (μm)	Avg. +3σ (μm)
FAE sheet	21.9	13.8	24.5
Aluminum sheet	69.3	20.6	58.4

Note) In case of aluminum sheet , only 4,038 datas were collected because of drill breakage at 4,039 hit.

In addition, for the ultra-small diameter drilling (ϕ0.105 mm), which requires more stringent hole positioning accuracy, the FAE sheet led to a satisfactory result for both the maximum displacement and average + 3σ (σ: standard deviation) being in the target specifications (less than 30μm). Conventional aluminum sheets, on the other hand, led to both the maximum displacement and average + 3σ (σ: standard deviation) far out of the specifications and exhibited a drill breakage at 4,039 hits.

The above results confirm that the use of the FAE sheet satisfies the specifications for hole positioning accuracy and reduces drill breakages.

2.3 Hole wall roughness

The hole wall roughness values were measured by a micro-section method, in which the drilled uppermost layers, after 1 to 5 hits, 2,501 to 2,500 hits and 4,996 to 5,000 hits respectively, were cut perpendicularly and subject to the measurements. The PWB measured for roughness were pre-etched of its drilled holes by potassium permanganate to remove drill smears and plated by copper.

Table 7 and **Table 8** show the maximum roughness of the hole walls. The FAE sheets resulted in hole wall roughness values satisfying the specifications for ϕ0.25mm and ϕ0.105mm drillings respectively. The result also shows a stable performance from the initial hit to the final 5,000 hits.

The aluminum sheet, on the other hand, exhibited a roughness over 15μm at the initial hit already, which continue to deteriorate until the final hit.

The above results confirm that using the FAE sheet satisfies the specification for maximum value of the hole wall roughness.

Table 7 Results of hole wall roughness comparing with FAE sheet and aluminum sheet after 5,000 hits drilling process using ϕ0.25 mm drill measured by micro section method

	FAE sheet			Aluminum sheet		
	1～5 hits	2,501～2,505 hits	4,996～5,000 hits	1～5 hits	2,501～2,505 hits	4,996～5,000 hits
Maximum roughness (μm)	9.05	7.66	8.26	22.48	25.09	28.37

Table 8 Results of hole wall roughness comparing with FAE sheet and aluminum sheet after 5,000 hits drilling process using ϕ0.105 mm drill measured by micro section method

	FAE sheet			Aluminum sheet		
	1～5 hits	2,501～2,505 hits	4,996～5,000 hits	1～5 hits	2,501～2,505 hits	4,034～4,038 hits
Maximum roughness (μm)	4.26	3.89	5.31	17.05	19.23	22.67

3. Future development of the FAE sheet

As described in the previous sections, the FAE sheet exhibits drilling qualities (hole positioning accuracy and hole wall roughness) and drill breakage characteristic, which are significantly improved, compared to conventional aluminum sheets, in both of the two severe drilling tests. It is considered that the improved results are due to the optimization of the three properties of the resin (melting temperature, heat capacity, melting viscosity) and of the resin hardness.

The success of designing the lubricant resin for severe drilling conditions has led to the start of sales and production of the FAE sheet following those of the CAE sheet.

Conclusions

The drilling conditions for printed wiring board will continue to become more stringent. The future trend will include drilling of holes with even smaller diameters (−φ0.050mm), higher hole positioning accuracy for higher mounting density and higher speed drilling for holes with high aspect ratios. Under such circumstances, the requirements for entry boards are expected to continuously increase. We will continue to improve further the lubricant entry board (FAE sheet) reported here to keep satisfying the market needs.

References

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