Super subtractive process of FPC for small size LCD module

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Abstract

According to thin and light form-factor and additional function of today's electronic devices, it is required to decrease the pattern pitch of FPC. The high density demand is more and more important trend, especially, for small size LCD module. Based on this requirement, the manufacturing process is advancing from subtractive method to super subtractive method.

The super subtractive method has two critical processes. The one is to achieve a small via hole by laser drill, and the other is to achieve a finer photo-lithography by proximity exposure process. In order to make micro through holes or micro blind vias, we used UV-YAG laser, and to perform high density pattern we used the resister material as thin dry film which has photo sensitive property.

1. Introduction

FPCB(Flexible printed circuit board) offers several advantages compared to rigid PCB. It is lighter, thinner, flexible, is not easily damaged by thermal and mechanical stress. According to these properties, FPC becomes essential circuit board to many electronic products, especially to portable products such as mobile phone, digital camera, MP3, and to FPDs such as LCD, PDP, and so on. .

The FPC is widely to applied main/sub display board, LDI(LCD driver IC) board, and ISM(image sensor module) board in mobile phones, is widely applied to connect mother board and display panel in flat panel displays (such as LCD, PDP, and OLED), and is widely applied to flexible cable in consumer electronics such as Camcorder, PC, pick-up and so on.

FPC is one of the core components of LCD module. As the market volume of mobile phone is outstandingly increases, the demand of small size LCD module and FPC also outstandingly increases. According to thin and light form factor and additional function of LCD module, it is required that the IC chip and other component which are surface-mounted on the pad of FPC also have high-density. Usually the IC bare die is bonded by Au-Sn melting or ACF bonding onto FPC. For the flip chip assembly of IC and small electronic components onto FPC, the following are required: First, fine pitch and high density circuit patterning FPC corresponding to the I/O terminal pitch of the IC. Second, co-planarity of IC bump height and co-planarity of FPC pads.

Usually the FPC circuit is formed by subtractive method which is influenced by the exposure factor, etching property of copper and formation process of via hole , therefore in order to achieve high density patterning on FPC, we must overcome the limitation of hole size due to mechanical drilling, the scattering of UV-ray due to exposure light and dust, and the undercut etching due to homogeneous etching property of copper layer.

2. Super subtractive method

In common subtractive method, the photo-resist dry film is laminated onto copper layer and pattern mask is aligned in order to perform the selective photo-lithography. After exposure onto pattern mask, the unnecessary parts of copper layer are dissolved and removed with etchant to form a circuit. It is generally said that a pattern pitch of 120 microns (L/S=60/60 microns) or less cannot be achieve by the subtractive method due to thermal effect during mechanical drill, scattering effect during exposure, and undercut effect during copper etching.

For high density interconnection, the circuit formation is not only to achieve a finer pitch but also to achieve a small vias with high accuracy. Based on these requirement, we established a super subtractive method. We, ACT can produce a circuit pattern with a minimum pitch of 60 μm, a minimum via hole size with 80~100 μm by using super subtractive process.

In super subtractive method to reduce the scattering factor during exposure, we not only used thin dry film less than 15 microns instead of normal 30 micron thickness but also used proximity exposure instead of contact type exposure. To reduce the undercut effect due to homogeneous etching property, we used thin copper layer less than 12 microns instead of normal 18 micron thickness. To reduce the via hole size less than 100 microns, we used UV-YAG laser drill instead of mechanical drill.

2.1 Via hole formation

When we form via holes by mechanical drill, a lot of heat due to high angular speed of mechanical drill is generated. It is generally said that the mechanical drill has from 180,000 to 300,000 r.p.m range to form via hole in FPC. Therefore the dielectric polymer that is normally polyimid is melted during drill process and a lump of molten dielectric i.e., smear is adhered to the surface of via holes. There is maybe some kinds of problem due to smear if we don't remove this smear before electro plating.

The more thermal effect is generated as the hole diameter becomes smaller. It is generally said that a hole diameter of 150 microns or less cannot be achieve by the mechanical drill because of the outstanding thermal effect.

To reduce the smear due to thermal effect during via hole formation which has the small hole size less than 100 microns, we used Laser drill instead of mechanical drill. Laser drilling technology has been around for nearly 30 years, but has only recently found acceptance in the FPC maker as a technology for producing vias, especially within surface mount pads. When producing micro-vias by laser drilling in a CCL (base material of FPC and laminated with copper foil and dielectric polymer layer), the laser beam diameter must be the same or smaller than the intended diameter of the vias. Our method is to make sure the lenses used with diameter can be used sure the lenses used with diameter can be used as in the case of the UV lasers so that trepanning can occur. Trepanning is the method whereby a small diameter beam is moved in a circular manner as if you were using a reciprocating saw and cutting a hole in a plywood sheet.

The most confusing reality about laser technology is the fact that the denser the material, the more energy is needed to vaporize it. The base structure of FPC is sandwich structure, as shown in Fig.1., of copper and dielectric polymer, i.e., the bottom and front layer is copper and the middle layer is dielectric polymer. The copper is the most dense material, but the dielectric polymer that is normally polyimid is not dense. Therefore there is big difference of energy absorption between copper and dielectric layer.

The challenge when using a very high-energy source like a laser to make vias with different dense materials is to control the energy, so as to damage the materials that react violently to the high energy. We, ACT, established several ways to control this energy. First is to use a short wave laser that can pulse at a very high rate. With this technique a very "hot" laser beam can be pulsed in rapid fashion to remove most dense materials. The absorption of the beam is also a major consideration that must be noted. It should also be noted that with the use of this high energy beam, the beam diameter is limited. So the beam diameter is limited in small size enough to remove dense materials like copper and FR4.

2.2 Proximity exposure

In subtractive method , the photo resist film, so we called, dry film is laminated onto a copper layer and the unnecessary parts of copper foil is removed by etching (i.e., selective photo-lithographic process) is the most common method to form circuit patterns in FPC. To connect bottom copper layer and front copper layer electrically, we usually form many via holes which through two copper layers and plate the hole surface with copper as shown in Fig.1. We denoted in Fig.1 only half cross section of FPC structure. Thus the bottom copper layer ia not drawn in Fig.1.

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The Cu foils nominally 17 microns or greater are widely used, and copper plating normally 10~15 microns is generally used. When this method is used, the minimum limit of pattern pitch depends on the thickness of copper foil, thickness of dry film, the gap between UV light and pattern film and the etching conditions.

It is generally said that a pattern pitch of 120 microns (L/S=60/60 microns) or less can't be achieved by subtractive method. The main reason for this lies in the thickness of the dry film to be exposed and the thickness of the copper layer to etched, which is closely and directly related to the pattern pitch. First, a thinner dry film and the proximity exposure is more suitable for the formation of fine patterns to reduce scattering factor. Second, a thinner copper layer is more suitable for the formation of fine pitch patterns to reduce the undercut during Cu etching process.

While there is no unique definition about super subtractive method, the distinct parameter for purposes here, is best seen in terms of the thickness of the base copper and the thickness of dry film . Even if it is seemingly small but it is significantly different. In super subtractive process some key parameter, such as adhesion between copper foil and dry film, the parallel-ness (collimation angle) of UV light source, the thickness of copper plating, the size of vias and so on, will impact the quality and reliability.

In super subtractive method to reduce the scattering factor during exposure, we not only used thin dry film less than 15 microns instead of normal 40 micron thickness but also used proximity exposure instead contact type exposure. The collimation angle of UV light source of proximity exposure is less than 1.5 degree. To reduce the undercut due to homogeneous etching property, we used thin copper layer less than 12 microns instead of normal 18 micron thickness

2.3 Photo-Imageable Cover-lay

The copper circuit pattern is oxidized within air and humidity , thus pattern is covered with cover coat material. In common subtractive method film type cover coat material, so called coverlay, is widely used to protect the circuit pattern. According to thin and light form factor and additional function of LCD module, it is required that the IC chip and other component which are surface-mounted on the pad of FPC also have high-density. Generally there are so many openings, we call it pads, to bond electrical component onto surface of FPC. The opening-formation property of coverlay film is not good enough to form the sufficient high density openings for pads.

Although the PIC is not necessary but optional material in super subtractive method, PIC is very useful material to achieve a good photo resolution and a good peel strength after baking as the cover-lay of FPC. The good opening-formation ability of PIC material is due to photo-chemical process of PIC material. Meanwhile opening-formation ability of film type coverlay is poor because the basic process of opening in coverlay film is mechanical process.

In order to prevent unwanted polymerization caused by thermal and photo effects during manufacturing, storage and lithographic process and also to depress post-soft bake delay, three steps of thermal curing are considered in our study.

3. Impact

We, ACT, have established super subtractive method in this study. Compare the common subtractive method with super subtractive method, the advantage is it can do the fine circuit pattern and keep good pattern thickness distribution. We summarize the main important parameter compare the subtractive method with super subtractive method in Table.1.

Items	Subtractive	Super subtractive
DF thickness	30 μm	15 μm
Exposure method	contact type	proximity type
Drill method	mechanical	laser
Cu thickness	18 μm	9, 12 μm
Plating thickness	6~12 μm	10~15 μm
Hole size	150 μm	80~100 μm
Pattern pitch	120 μm	60 μm

[Table.1] compare with subtractive vs super subtractive

The minimum pattern pitch of 60 microns (L/S=30/30 microns), and the vis hole size of 80~100 microns are achieved. Therefore we can meet the high density demands of FPC which compatible with the high density demands of LCD module. So more and more the FPC maker will approach this method for fine pattern product.

4. References

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