What Type of PCB Substrate Material Is Right for Your PCB?

Basic performance of PCB (Printed Circuit Board) depends on the performance of substrate material, so in order to improve the performance of PCB, you have to increase the performance of PCB substrate material first. Up to now, numerous new types of materials are being developed and coming into application to meet the requirement of PCB development.

Recent years have witnessed a transformation in PCB market with its focus on computer converted to communication including base station, server and mobile terminal. Mobile communication devices represented by intelligent phones drive the development of PCB towards high density, lightness and multiple functions. Printed circuit technology can never be achieved without substrate material whose technological requirement is closely related with the performance of PCB.

Requirement Catering to High Density and Fine Lines

- Requirement on copper foil

All of PCBs are developing towards high density and fine lines, especially HDI PCB (High Density Interconnect PCBs). One decade ago, HDI PCB was defined as PCB whose line width (L) and line space (S) is 0.1mm or below by IPC. At present, the ordinary value of L and S in present electronic industry can be 60μm and in advancing situations their value can be as low as 40μm.

Traditional method of circuit pattern formation lies in the process of imaging and etching as a result of which the smallest value of L and S is 30μm with the application of thin copper foil substrate (thickness in the range from 9μm to 12μm).

Since thin copper foil CCL features high cost and stacking with many defects, many PCB manufacturers tend to use etching minus copper foil method with copper foil whose thickness set to be 18μm. This method isn't actually suggested because it contains too many procedures with thickness difficult to be controlled and features high cost, so application of thin copper foil is better. In addition, ordinary copper foil doesn't work when the value of L and S of PCB is less than 20μm. So ultrathin copper foil should be used while the thickness of copper limited in the range from 3μm to 5μm.

Apart from thickness of copper foil, current fine circuit also lays requirement of low roughness in surface of copper foil. Usually, in order to improve the adhesion between copper foil and substrate material and to ensure defense electric strength of conductors, roughing treatment is implemented on copper foil plane and ordinary roughness of copper foil is more than 5μm.

Embedding of hump on copper foil into substrate material aims to increase its defense electric strength. However, in order to control lead accuracy far from over etching in the process of circuit etching, hump contaminant tends to be caused so that short circuit between lines may be led or insulating capacity decreased, which particularly influences fine circuit. Therefore, copper foil with low roughness (less than 3μm or even 1.5μm) is required.

In spite of roughness reduction of copper foil, defense electric strength of conductors still needs to be remained, which arouses special surface finish on the surface of copper foil and substrate material that will help to ensure defense electric strength of conductors.
• Requirement on lamination insulating dielectric sheet

One of major technological properties of HDI PCB lies in the application of Building Up Process. RCC (Resin Coated Copper) that is ordinarily applied or prepreg epoxy glass cloth and copper foil lamination seldom fail to lead to fine circuit. Now SAP and MSPA tend to be applied, which means the application of insulating dielectric film lamination with chemical copper plating to generate copper conducting plane. Fine circuit can be produced owing to the thin copper plane.

One of the key points of SAP lies in lamination dielectric material. In order to meet the requirement of high-density fine circuits, some requirements of lamination material have to be brought about including dielectric performance, insulation, anti-heat capacity and adhesion, coupled with technological adaptation compatible with HDI PCB.

Among global semi-conductor packages, IC package substrate is converted into organic substrate from ceramic substrate. Pitch of FC package substrate is becoming increasingly small so that the present typical value of L and S is 15μm and it will be smaller.

Multi-layer substrate performance should emphasize low dielectric property, low coefficient of thermal expansion and high heat resistance, which refers to substrate catering to low cost with performance object fulfilled. Nowadays, MSPA technology of insulating dielectric lamination coupled with thin copper foil is applied by volume production of fine circuits. SAP is applied to manufacture circuit pattern whose value of both L and S are less than 10μm.

High density and thinness of PCB leads to the conversion of HDI PCB from lamination with core to any layer without core. For HDI PCBs with the same functions, the area and thickness of those with interconnection at any layer decreases by 25% than those with core lamination. Thinner dielectric layer with better electric performance has to be applied in both of these HDI PCBs.

Requirement Catering to High Frequency and High Speed

Electronic communication technology has been developing from wire to wireless, from low frequency and speed to high frequency and speed. Nowadays, performance of mobile phones has been progressing from 4G to 5G with demanding requirement of faster transmission speed and larger transmission amount.

Advent of global cloud calculation era leads to multiple fold increase of data traffic with an obvious trend of high frequency and high speed of communication devices. In order to meet the requirement of high-frequency and high-speed transmission, high-performance material lies in the most essential element apart from reduction of signal interference and consumption, signal integrity and manufacturing compatible with design requirement in terms of PCB design.

The main job of engineers falls on attribute of electric signal loss to deal with PCB speed increase and signal integrity issues. As a key factor influencing substrate material selection, when dielectric constant (Dk) is lower than 4 and dielectric loss (Df) lower than 0.010, it is regarded as middle Dk/Df laminate board and when Dk is lower than 3.7 and Df below 0.005, it is regarded as low Dk/Df laminate board. At present, multiple types of substrate materials can be picked up in the market.

Up to now, commonly-used high-frequency circuit board substrate material comes primarily in three types: fluorine-series resin, PPO or PPE resin and modified epoxy resin. Fluorine-series dielectric substrate, PTFE for example, featuring the lowest dielectric performance, is usually applied for products with a frequency of 5GHz or more. Besides that, modified epoxy FR-4 or PPO substrate is applied for products with a frequency in the range from 1GHz to 10GHz.
Comparing the three types of high-frequency substrate materials, epoxy resin features the lowest price while fluorine-series resin the highest. In terms of dielectric constant, dielectric loss, water absorption and frequency characteristic, fluorine-series resin behaves the best while epoxy resin worse. When the frequency applied by products is higher than 10GHz, only fluorine-series resin works. Disadvantages of PTFE include high cost, bad rigidity and high coefficient of thermal expansion.

For PTFE, massive inorganic matters (such as silicon dioxide) can be applied as filling material or glass cloth to strengthen substrate material rigidity and to reduce coefficient of thermal expansion. Furthermore, because polyflon molecule is difficult to be combined with copper foil as a result of inertness of polyflon molecule, it’s necessary to implement special surface finish compatible with copper foil. The treatment method lies in either chemical etching on the surface of polyflon so as to increase surface roughness or adding an adhesive film so as to increase adhesion. With the application of this method, dielectric performance will possibly be influenced and further development has to be carried out to the whole fluorine-series high-frequency circuits.

Unique insulating resin composed by modified epoxy resin or PPE and TMA, MDI and BMI, coupled with glass cloth are applied more. Similar with FR-4 CCL, it also features excellent heat resistance and dielectric feature, mechanical intensity, together with manufacturability of PCB, all of which makes it more popular than PTFE-type substrate boards.

Besides some requirement on the performance of insulating material such as resin mentioned above, surface roughness of copper as a conductor is an important element influencing signal transmission loss as well, which is the result of Skin Effect. Put basically, Skin Effect is that electromagnetic induction is generated at leads in high-frequency signal transmission and inductance becomes so focused at the center of section area of lead, driving current or signal to be focused at the surface of lead. Surface roughness of conductors influences transmission signal loss and low roughness leads to little loss.

At the same frequency, high surface roughness of copper leads to high signal loss. Therefore, roughness of surface copper has to be controlled in practical manufacturing and it should be as low as possible in the situation where adhesion isn’t influenced. Much attention must be paid to signals within the category of 10GHz or more. Roughness of copper foil is required to be less than 1μm and it’s better to use ultra-surface copper foil with roughness 0.04μm. Surface roughness of copper foil has to be coupled with suitable oxidation treatment and adhesive resin system. In the near future, there will possibly be a type of copper foil that has no outline coated by resin and it features higher peel strength with dielectric loss prevented from being influenced.

**Requirement Catering to High Heat Resistance and Dissipation**

With the development trend towards miniature and high function, electronic devices tend to generate larger amount of heat so that thermal administration of electronic devices call for increasingly higher requirement. One of the solutions to this issue lies in the research and development of thermal-enhanced PCBs. Primary condition of PCB performing well in heat resistance and dissipation is the heat resistance and dissipation capacity of substrate. Present improvement in terms of thermal-enhanced capacity of PCBs lies in improvement through resin and filling adding but it only works within a limited category. Typical method is to apply IMS or PCBs with metal core that play a role of a heating component. Compared with traditional radiator and fan, this method leads to advantages of small volume and low cost.

Aluminum is a very attracting material with advantages of rich resources, low cost and excellent heat-conducting property and intensity. Moreover, it is so environment-friendly that it is applied by most metal substrate or metal core. Owing to advantages including economy, reliable electric connection, heat conductivity and high intensity, solder free and lead free, aluminum base circuit board has been
applied in consumer goods, automobiles, military goods and aerospace products. There's no doubt on heat-resistance and dissipation property of mental base boards and the key point lies in performance of adhesion between mental board and circuit plane.

**Requirement Catering to Rigid PCBs**

In modern electronic time, miniature and thinness of electronic devices leads to necessary advent of rigid PCBs and flex/rigid PCBs. Then what type of substrate material is suitable for them? This article will reply.

Increasing application fields of rigid PCBs and flex/rigid PCBs bring about new requirement in terms of number and performance. Polyimide film, for example, can be classified into multiple categories including transparent, white, black and yellow with high heat resistance and low coefficient of thermal expansion in order to be applied in different situations. Similarly, mylar substrate with high cost effectiveness will be accepted by market as well owing to its advantages including high elasticity, size stability, film surface quality, photoelectric coupling and environmental resistance so as to meet the changeable requirement of users.

Similar with rigid HDI PCBs, flex PCB has to adapt to the requirement of high-speed and high-frequency signal transmission and dielectric constant and dielectric loss of flex substrate material have to be focused as well. Flex circuit can be composed by polytetrafluoroethylene and advancing polyimide substrate. Inorganic dust and carbon fiber can be added to polyimide resin to lead to the generation of three-layer flex thermal conducting substrate. Inorganic filling material can be either aluminum nitride, aluminum oxide or hexagonal boron nitride. This type of substrate material features thermal conducting property of 1.51W/mK and is capable of resisting a voltage of 2.5kV and curvature of 180 degrees.

Flex PCBs are mainly applied in intelligent mobile phones, wearables, medical equipment and robotics, which calls for new requirement of flex PCB structure. Up to now, some new products containing flex PCB have been developed such as ultrathin flex multi-layer PCBs whose thickness has been reduced to 0.2mm from ordinary 0.4mm. High-speed transmission flex PCBs are capable of reaching a transmission speed of 5Gbps with the application of polyimide substrate material with low Dk and Df. Flex PCBs with large power apply conductors whose thickness is more than 100μm so as to meet the requirement of circuits with high power and large current. All these special flex PCBs naturally acquire unconventional substrate material.

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