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High-performance PWBs

Future needs of the electronic industry predetermine nuances of freedom in such properties as thermal resistance, ultra-thin dielectrics, and small-hole formation to provide the foundation for MCM-L, PCMIA, smart cards, and high-density multilayer technologies.

The cost advantage of organic substrates over ceramic has opened new avenues for PWBs. To respond to this opportunity, improvements in copper foil and laminate technology are crucial.

Copper Foil Technology

Standard copper foils have large grain boundaries and are columnar in shape. A unique metallurgy and lower-profile geometry obtained by new techniques in electrodeposition provide a structure vital for etching fine lines. These fine-grain foils comply to the requirements of IPC-ML-150, and permit the formation of more precise fine lines essential for impedance control. Supplementary benefits include high-temperature fatigue resistance and facile handling as a result of improved toughness.

Laminate Technology

Currently, the most widely used laminate material in the printed circuit board industry is known as FR-4, or epoxy-glass. Cost effectiveness and ability to satisfy electrical/chemical exactions of most applications account for its popularity.

At the same time, the need for miniaturization and faster process speed will necessitate the use of new material with properties unapproachable via epoxy/glass.

The mechanical strength of fibers provides the structure of copper-clad laminates. Traditionally, this structure has been from woven epoxy/glass fabrics of various weave styles and filament diameters. During the past 25 years, both epoxy resins and woven glass cloth have undergone substantial improvements to accommodate precision electronics applications.

Surface mount technology dictated improvements in bow/twist dimensional stability and thermal resistance (higher Tg). The increased layers imperative for higher circuit density in multilayer boards also impose pressures on dimensional stability, Z-axis expansion and thickness tolerance.

Standard FR-4 materials have a glass transition temperature between 115 and 130 °C. By blending multi-functional and tetra-functional epoxies, laminate suppliers have been able to produce mid- (Tg 130–150 °C) and high-range (Tg 170 °C) epoxies.

Advantages of multi-functional and tetra-functional epoxies include:

- Superior performance through multiple thermal excursions
- Reduction in heat damage to plated through-hole area, such as barrel cracking and inner-plane separation, related to Z-axis expansion
- Improved moisture and chemical resistance, resulting in less solder outgassing defects
- Improved peel strengths at higher temperatures, because laminate does not soften at lower temperatures

Future Needs In Laminate Technology

The use of advanced laminate material with higher performance properties than multifunctional epoxies will accelerate. In order to remain competitive, faster processing and greater signal integrity/processing with high-speed computing will be necessary for future electronic products.

To obtain these properties, enhancements in both the carrier and resin systems will be employed. The carrier material provides the structure for copper-clad laminates through mechanical strength of fibers. As previously mentioned, this structure

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traditionally has been achieved with woven epoxy/glass fabrics of various weave styles and filament diameters.

Also on the horizon are single-ply, woven epoxy/glass fabrics. Fabricators have capitalized on this material, boasting cost efficiency and production of multilayers with thinner dielectrics and more consistent dimensional stability.

Non-woven aramid random fiber material has the unque property of lower density (15 percent lighter than conventional boards), as well as the propensity of micro-via generation by either plasma or laser.

Resins provide the bond between the copper and the substrate in multilayer PWBs, and have a strong influence on final electrical/mechanical/physical properties. To satisfy future needs, PWB laminate material must provide higher thermal stability, with respect to glass transition temperature > 170 °C, lower thermal expansion x-y CTE < 9 ppm/°C, and a lower dielectric constant. Cost and application information on advanced resin systems are noted in the table.[1]

Application	Resin	Tg, °C	Cost*
High-volume—medium & high technology—low-cost PCMIA	Multifunctional epoxy	140	1.0
Thick M/L, backplanes, BGA, under-hood PCMCIA, PGA	Multifunctional epoxy	170	1.3
MCM-L, CA, BGA, high-speed computing, PGA	BT/epoxy	180	1.5
Military hardware	Polyamide	260	2.3
High-reliability avionics	Toughened polyamide	220	2.4
Controlled CTE MCM-Ls, laser microvia MCM-Ls, PCMCIA	Thermount polyamide	220	TBD
High-speed computing telecommunications hardware, high-frequency electronics, high reliability	Cyanate ester	250	2.5

* 1.0 based on a six-layer multifunctional epoxy material, Tg 140 °C.

Material/fabrication costs and process issues must be carefully scrutinized when upgrading to enhanced resin systems. Currently, only the more avant-garde PWB manufacturers can efficiently process high-performance laminate material.

Case studies of initial introduction of multilayers prove that late entries in this area neither thrived nor survived. More PWB manufacturers, therefore, must participate in order to satisfy anticipated demand. *P&SF*

Reference

1. Clyde F. Coombs, *Printed Circuit Handbook*, Ch. 9.5.1, McGraw-Hill, Inc., NY (1996).

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