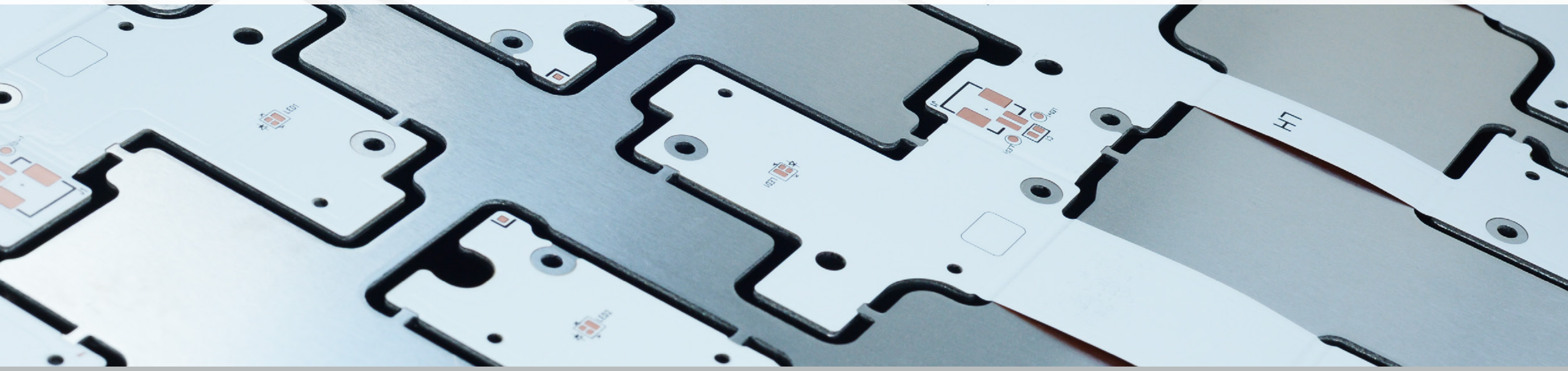
BASE MATERIAL THE BACKBONE OF EVERY PCB - SELECTING THE RIGHT ONE



INTRODUCTION

The key features for selecting the base material are: process safety, electrical, thermal and mechanical properties, the material availability, and ultimately the price of the material itself. The requirements for base materials have increased significantly due to higher process temperatures achieved through the use of SnAgCu and SnCu alloys in the lead-free soldering technology. In the case of an incorrectly selected base material, problems such as delamination, PTH cracks and pad-lifting can occur after high process temperatures and/or multiple solder cycles. The common name "lead-free material" can lead to the selection of unsuitable materials. The base material has to be compatible with the soldering process and the operating temperature of the final product.

MAJOR BASE MATERIALS FOR PCBS

- **RIGID**
  - CEM 1
  - CEM 3
  - FR 4
  - FR 5
- **FLEX**
  - PI
  - PE
  - PET
- **IMS**
  - Aluminum base PCB

BASIC CHARACTERISTICS OF FR4 MATERIALS

Following is a list of relevant and important features:

- **Tg Value: Glass Transition Temperature:** The temperature at which the rigid resin of the laminate becomes pliable and can be formed, shaped or molded. In general, a higher Tg grants greater thermal stability. It helps to prevent defects when used in high temperature application.

- **T260 / T288 value: Time to Delamination** This value determines the length of time a material can survive under a specified temperature until delamination occurs.

- **Td value: Thermal Decomposition Temperature** This marks the specific temperature at which the base material loses 5 % of its original weight due to decomposition, namely outgassing or evaporation.

- **CTE_z value: Coefficient of thermal expansion in Z-axis direction** This value must be given the most attention. CTE_z above Tg increases four to five times the CTE_z value of Z-axis expansion below Tg. Failure to comply with standards may result in delamination, barrel cracks or pad-lifting.

The Tg values and the CTE_Z values are interrelated. The higher the Tg, the better the CTE_Z. The heat resistance is determined by the curing agent and the fillers of the base materials. It is cured between Dicy (dicyandiamide curing agent) and distinguished cured novolac (phenol novolac hardener) materials.

On the one hand, improved thermal stability and lower Z-axis expansion of the cured phenolic materials (novolac systems) has to be paid for with lower copper adhesion to the Dicy-cured materials. On the other hand, switching to filled novolac hardened materials can have an impact on the impedance behavior of the final PCBA.

The following two examples demonstrate:

At the design stage of a project, selecting the materials, properties and their electrical characteristics should be known, considered and defined. Consequently, this has an impact on the PCB manufacturing processes. For instance, the tool life of the drill bits is substantially reduced since the base material's toughness and brittleness changes depending on different end properties, achieved through varying the product's chemical and physical composition.

STANDARDIZATION

To ensure flawless quality of the PCB, the parameters for the base material must be specified. The standard reference for PCB materials is IPC 4101B.

SPECIAL MATERIALS

Meanwhile, there are hundreds of different base materials with specific properties for specific applications.

Special end properties can be achieved by using and/or combining appropriate adhesives such as cyanate ester or polytetrafluoroethylene, fillers and other support materials such as ceramic, polyimide and various hydrocarbons. An example illustrating this are applications where high-frequency and/or temperature-stressed applications are needed.

Special materials are not available in all thicknesses, as in the case of FR4. For many special materials, there are no separate prepregs available. In addition, special materials are often considerably more expensive than FR4. Depending on the application, one strategy can be to build a "hybrid" multilayer consisting partly of special materials and partly of standard base materials.

TECHNICAL CHARACTERISTICS OF FR4

For the foreseeable future, FR4 and its modifications will remain the overarching "work horse". The material is stable, the insulation is reliable, the dielectric behavior is useful, the cost is acceptable, the processing is established, and the heat resistance is good.

The modifications can be generated by altering the epoxy resin matrix. In the wake of the transition to lead-free electronics (RoHS), it has become common to share a portion of the resin volume with mineral fillers. Thus, a temperature-induced Z-axis expansion of the circuit board CTE_Z (Coefficient of thermal expansion) is delayed.

Base material with higher temperature resistance reduces stress induced failures during soldering.

We then speak of "FR4 with a higher Tg value" or even "high-Tg material". The default value for FR4 is 130°C, and higher-Tg values are 150°C or 175°C, depending on the material manufacturer.

Reaching "Tg Glass Transition Temperature" requires the epoxy glass fiber material reaching this temperature to be soft and elastic, consequently the Z-axis expansion increases significantly. This may create quality or reliability issues such as PTH cracks, pad-lifting or delamination. The result is usually a loss of the module.

On average, the continuous operating temperature of a module with FR4 material should not exceed 95°C to 100°C. A higher Tg value does not increase the duration of a module operating temperature. The continuous operating temperature of the epoxy resin matrix is essentially dependent on FR4 material and therefore should also not exceed 95°C to 100°C.

Another characteristic is the Td value (Thermal Decomposition Value), which has been previously explained. It is very important to take this into account when selecting materials.

Since the introduction of SMD technology, the requirements for base material have increased.

The reduction in mounting area per SMD components leads to an increase in SMD pads on the PCB. A reliable attachment of the components to the (small) pads is therefore even more important. If a robust connection is not achieved, the unwanted results may be the occurrence of twisted components and/or tomb stoning.

If a SMD pad is small, the available area for a reliable connection is naturally reduced. Simple mechanical stress, vibration and braking and acceleration forces (in automotive) may lead to stress on the component.

The reflow soldering reduces the adhesion between SMD pad and board by up to 75%, depending on the type of base material, PCB surface and number of reflow cycles.

Unfortunately, the choice for high-Tg value material results in the reduction of copper adhesion. High-Tg material can drop to 0.8 N/mm in standard materials with removal forces of about 2 N/mm.

There are several reports available describing the influencing factors of lead-free soldering processes and FR4 base materials.

The studies conclude the following:

- „Standard Base Materials“ (specification only FR4) are a major risk factor in the lead-free soldering with SAC / SC solders.
- Structures with a low resin prepreg (1x 7628) delaminate much earlier than structures with a high-resin prepreg (2x 1080).
- Smooth and higher copper pads on the layers reduce delamination.
- Drying the PCB reduces delamination only by 1 to 2 load steps.
- The prolonged storage of PCBs for several months may result in the delamination of the PCB.

THE BOTTOM LINE

There are many individual product factors, features and requirements. Thus, there is no “one size fits all” laminate out there. Considering this important fact, the project designer and PCB manufacturer should communicate and discuss the final product application and the requested material properties to find the best material. CML is ready to provide consultation during this important discussion to create a win-win situation for all parties involved and to help select the most appropriate material or material combination for your project.