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Controlling Moisture in Printed Circuit Boards

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Abstract

Moisture can accelerate various failure mechanisms in printed circuit board assemblies. Moisture can be initially present in the epoxy glass prepreg, absorbed during the wet processes in printed circuit board manufacturing, or diffuse into the printed circuit board during storage. Moisture can reside in the resin, resin/glass interfaces, and micro-cracks or voids due to defects. Higher reflow temperatures associated with lead-free processing increase the vapor pressure, which can lead to higher amounts of moisture uptake compared to eutectic tin-lead reflow processes. In addition to cohesive or adhesive failures within the printed circuit board that lead to cracking and delamination, moisture can also lead to the creation of low impedance paths due to metal migration, interfacial degradation resulting in conductive filament formation, and changes in dimensional stability. Studies have shown that moisture can also reduce the glass-transition temperature and increase the dielectric constant, leading to a reduction in circuit switching speeds and an increase in propagation delay times. This paper provides an overview of printed circuit board fabrication, followed by a brief discussion of moisture diffusion processes, governing models, and dependent variables. We then present guidelines for printed circuit board handling and storage during various stages of production and fabrication so as to mitigate moisture-induced failures.

1 Introduction

Rigid printed circuit boards (PCBs) can be composed of various kinds of materials that provide the characteristic attributes necessary for the electrical and mechanical operation of products for different applications. The three main classes of PCBs are ceramic substrates with metal circuit traces screen printed on the substrate, silicone resin-based substrates which are used mainly when low characteristic impedance is required at high frequencies, and a third type of base material from the organic family, where low-cost phenolic resin reinforced with paper is used for low-end applications, and epoxy resin reinforced with woven glass cloth is used for mid- and high-end applications.

The epoxy glass composite is made by impregnating rolls of woven glass cloth with resin and then laying up the necessary number of layers of impregnated cloth between sheets of copper foil and pressing them in hydraulic presses. In today’s consumer, telecommunication, handheld, military, and industrial electronics fields, glass-based materials are generally used. These are covered by National Electrical Manufacturers Association (NEMA) specifications. The most common material system is the FR-4[1], which provides a balance of electrical and mechanical properties. FR-4 systems are the most common PCB materials, and continuous high-volume use over the past few decades has made their processability very familiar to PCB manufacturers. The glass-transition temperature (T_g) of FR-4 (125 to 135°C), its dielectric constant, and its cost are acceptable for most applications. Various high-temperature FR-4 (HTFR-4) materials are also available to the electronics industry. These are made by introducing additives, such as tetrafunctional epoxy, polyimide, or bismaleimide triazine, to standard FR-4. The subsequent T_g of HTFR-4 is typically between 170°C to 180°C.

This paper focuses on moisture-related issues in PCBs and provides guidelines to reduce the impact of moisture on the reliability of printed circuitry boards. The controls and guidelines provided in the paper can be implemented at different stages of PCB production.

FR-4 laminate is a composite of epoxy resin with woven fiberglass reinforcement, and it is the most widely used printed circuit board (PCB) material. The steps involved in the fabrication of a printed circuit assembly and typical constituents of

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[1] FR-4 is the National Electrical Manufacturers Association (NEMA) grade. FR represents flame retardant (to UL94 V-0) and type 4 indicates woven glass–reinforced epoxy resin.

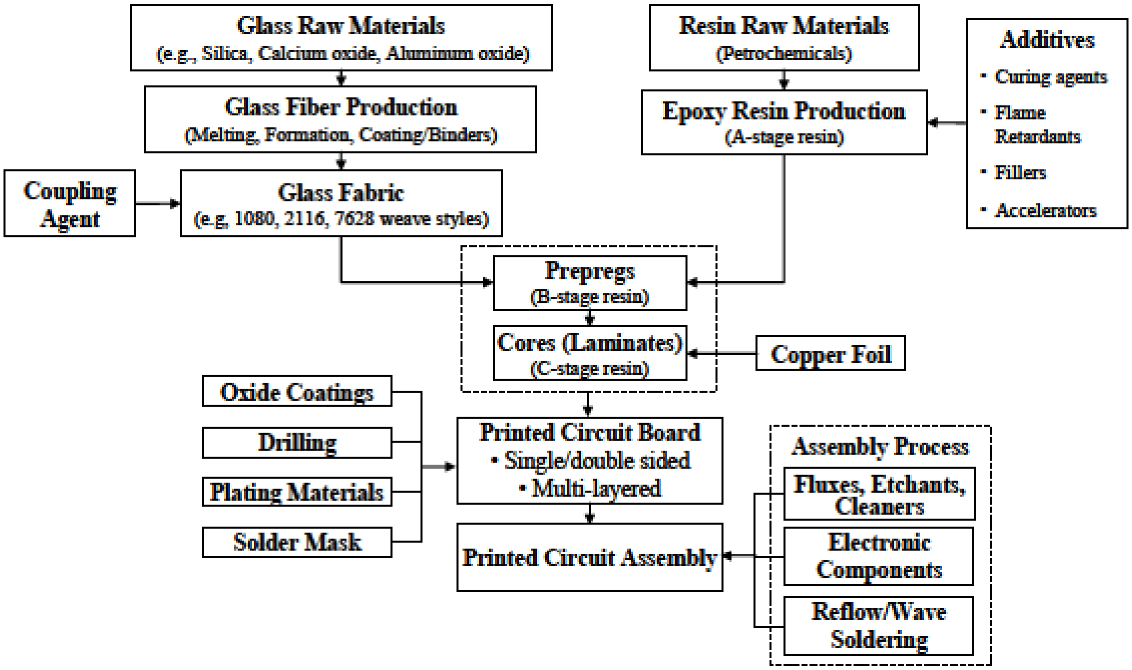

Figure 1: FR-4 printed circuit assembly fabrication.

The woven glass (generally E-grade) fiber cloth acts as reinforcement for the laminate and primarily provides mechanical support; it also affects the electrical properties. Glass fabric is woven with two sets of fiber yarns (the fibers are combined into strands of multiple fiber yarn). Warp yarn fibers lie in the machine direction of the fabric, while those of the fill yarn lie perpendicular to the warp direction. Coupling agents such as organosilanes are coated onto the fabric to improve adhesion between the inorganic glass and organic resin.

The resin system acts as a binder and load transferring agent for the laminate and primarily consists of bi-, tetra-, or multi-functional epoxy groups. Additives such as curing agents, flame retardants, fillers, and accelerators are added to the resin to tailor the laminate's material properties. Curing agents such as dicyandiamide (DICY) and phenol novolac (phenolic) enhance the cross-linking of the epoxy matrix. Phenolic-cured epoxy systems have better thermal resistance, chemical resistance, humidity resistance, and improved mechanical properties, but less desirable processability (e.g., drilling) compared to DICY-cured systems [1]. Flame retardants are added into the epoxy matrix to reduce the flammability of the laminate material. Tetrabromobisphenol-A (TBBPA) is the most commonly used halogenated flame retardant for epoxy resin systems. Phosphorous-based compounds are commonly used halogen-free flame retardants. Fillers such as silica and aluminum hydroxide are added to the epoxy resin primarily to lower the coefficient of thermal expansion (CTE) of the laminate while enhancing the flame retardancy and reducing material costs. Accelerators such as Imidazole are used to increase the rate of curing and to control the cross-linking density of the epoxy system.

A prepreg is fabricated from a glass cloth impregnated with semi-cured epoxy resin. Multiple prepregs are thermally pressed to obtain a core or laminate. Copper foil is then typically electrodeposited to obtain a copper-clad laminate. Several prepregs and cores (with copper cladding etched as per the circuit requirements) are stacked together under temperature and pressure conditions to fabricate a multi-layered PCB. Through-holes and micro-via interconnects are drilled in the PCB as per the application-specific design data and then plated with copper. A solder mask is applied on the board surface, leaving exposed only the areas to be soldered. Flux is applied at regions where the electronic components are to be soldered. The boards are then subjected to reflow and/or the wave soldering process, depending upon the type of components (surface mount or through-hole) to complete the printed circuit assembly.

Polyimide (PI) is the second most common resin in use today. Its advantage lies in its high T_g of 260°C, which stems from the addition of methylene dianiline and maleic anhydride. This property is beyond most soldering profiles, and helps in high-performance/high-temperature applications where operational environments exceed the T_g of both FR-4 and HTFR-4. The resin's chief disadvantage is its tendency to absorb higher levels of moisture and its higher cost.

Table 1: Typical Constituents of FR-4 Laminates

Constituent	Major Function(s)	Example Material(s)
Reinforcement	Provides mechanical strength and electrical properties	Woven glass (E-grade) fiber
Coupling agent	Bonds inorganic glass with organic resin and transfers stresses across the	Organosilanes
Resin	Acts as a binder and load transferring	Epoxy (DGEBA)
Curing agent	Enhances linear/cross-polymerization in the resin	Dicyandiamide (DICY), phenol novolac (phenolic)
Flame retardant	Reduces flammability of the laminate	Halogenated (TBBPA), halogen-free (phosphorous compounds)
Fillers	Reduces thermal expansion and cost of the laminate	Silica, aluminum hydroxide
Accelerators	Increases reaction rate, reduces curing temperature, controls cross-link density	Imidazole, organophosphine

Cyanate ester (CE) has a T_g of over 240°C, paralleling the thermo-mechanical stability of polyamides. Its biggest asset, however, is its low dielectric constant. Unfortunately, the purification technique that CE undergoes during processing makes it more expensive than traditional resins.

Bismaleimide triazine (BT) resins are a blend of bismaleimide and triazine (a cyanate ester) and have a T_g slightly higher than HTFR-4. BT offers the intermediary advantage of better thermo-mechanical and electrical properties than epoxies, but lower cost compared to PI and CE. BT is the resin of choice for many laminates used in plastic ball grid array (PBGA) packages. The dielectric and thermo-mechanical properties of these common laminate types are summarized in Table 2

Table 2: Typical

Resin	Dielectric Constant (1MHz)	T_5 (°C)	CTE (X-Y) below T_5 (ppm/°C)	CTE (Z) below T_5 (ppm/°C)
FR-4	3.55	125	15	60
HTFR-4	4.15	175	15	50
PI	4.30	260	12	50
CE	2.90	245	12	40
BT	3.25	185	13	50

The transition to lead-free soldering of printed circuit boards using solder alloys such as SnAgCu has resulted in a peak reflow temperature increase of 30–40°C for longer time periods during assembly compared to eutectic SnPb solders [3], [4], [5], [6]. The rework and repair of assembled circuit boards also contribute to additional high temperature exposures. These high temperature exposures can alter the circuit board PCB material properties, thereby creating a shift in the expected reliability of the board and the entire electronic assembly.

The high temperature exposures associated with lead-free soldering assembly conditions result in variations in the material properties of certain FR-4 PCB material types [7], [8], [9], [10], [11], [12], [13]. The exposures tend to lower the T_g and out-of-plane CTE of the PCB materials. An increase in moisture absorption was observed in most of the PCBs due to exposures. The exposures did not affect the PCB materials to the extent of changing their decomposition temperatures (Td). The variation in material properties due to lead-free soldering exposures can be attributed to the degree of cross-linking and to the extent of moisture absorption in the PCBs. In general, the type of curing agent was found to have a more pronounced effect on the response of materials to exposures than the type of flame retardant or presence of fillers.

2 Effects of Moisture in PCBs

Moisture can reduce the quality of lamination, metallization, solder mask, and manufacturing steps associated with board fabrication and assembly. Moisture reduces the glass-transition temperature (T_g) so that excess thermal stresses can cause damage [34], [35]. Moisture also increases the dielectric constant, leading to a reduction in circuit switching speeds and an increase in propagation delay times [36], [37], [38]. Moisture ingress can also facilitate ionic corrosion, leading to both open and short circuits. Additionally, moisture that accumulates at the interfaces of the resin and fiberglass can cause interfacial degradation, resulting in conductive filament formation [39], [40], [41], [42], [43]. The common failure mechanisms attributed to moisture absorption in PCBs are listed below. Familiarity with these mechanisms is an essential input in selecting the most appropriate strategy for reducing moisture in PCBs:

- Entrapped moisture can cause blistering or inner layer delamination [14], [15].
- Excessive moisture increases dielectric constant (Dk) and dissipation factor (Df), leading to changes in circuit switching speed [16].
- Since moisture acts as a plasticizer, it reduces the glass-transition temperature (T_g), which in turn increases stresses on PCB features such as plated through-holes [7], [8].
- Oxidation of copper surfaces leading to poor wettability of finishes and solder [17].
- Ionic corrosion causes electrical opens or shorts [17].
- Interfacial degradation can result in a reduced time to failure due to conductive filament formation (CFF) [40], [41], [42], [43].

3 Mechanisms of Moisture Transport

Bulk diffusion within the epoxy matrix is the result of the motion of molecules along a concentration gradient (high concentration to low concentration). Surface topology and resin polarity are the primary aspects that affect the equilibrium moisture content [23]–[31]

The concept of capillary action is similar to wicking, but a distinction lies in that wicking is used to describe enhanced moisture absorption due to voids or cracks at the interface, while capillary action is generally used to describe enhanced moisture absorption due to voids or cracks present inside the bulk. The sites for wicking and capillary action are present in the form of voids or cracks that may form by the addition of fillers.

For many polymeric resin systems, bulk diffusion is the dominant form of moisture transport. Bulk diffusion can be classified as Fickian [18], [19], [20], [21]. For Fickian diffusion in a plane sheet with thickness *l* exposed on both sides to the same environment (Figure 2), the moisture content, M_t, at time *t*, is given by equation 1.

$$\frac{M_t}{M_\infty} = 1 - \sum_{n=0}^{\infty} \frac{8}{(2n+1)^2 \pi^2} \exp\left(\frac{-D(2n+1)^2 \pi^2 t}{4l^2} \right) \tag{1}$$

where $M_{\square}$ is the equilibrium moisture content, and *D* is the diffusion coefficient, or diffusivity, given in $(\text{length})^2(\text{time})^{-1}$. By using this relationship, one assumes that diffusion is one-dimensional, i.e., diffusion through the laminates' edges is negligible, and the laminate surfaces instantaneously reach the equilibrium moisture content.

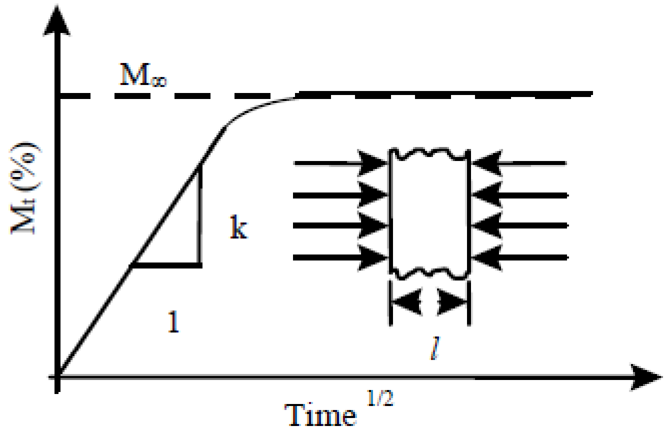

Figure 2: Fickian sorption by a plane sheet exposed on both sides to the same environment.

The initial stage of diffusion can be expressed by a reduced form of equation 1:

$$\frac{M_t}{M_\infty} = \frac{4}{l}\left(\frac{Dt}{\pi}\right)^{1/2} \qquad (2)$$

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By rearranging equation 2, the diffusion coefficient is:

$$D = \pi\left(\frac{kl}{4M_\infty}\right)^2 \qquad (3)$$

where k is the slope of the initial linear portion in Figure 2.

Sorption tests were conducted [22] on seven different materials to determine the diffusion coefficient of each laminate. Two dry-baked coupons were used in each test at four environmental conditions: 50°C/50%RH, 50°C/85%RH, 85°C/50%RH, and 85°C/85%RH. The coupons were removed to assess their mass gain at increasing time intervals, i.e., the first interval lasted 15–20 minutes while the last one went up to a few days. The experiment ended once the gravimetric measurements indicated a constant mass within the scale's resolution.

Figure 3 shows typical diffusion curves for the CE-A laminates at 50°C/85%RH. Moisture content is plotted as a function of the square root of time to facilitate evaluation of the diffusion coefficient. The diffusion coefficients for thin and thick samples were calculated and averaged to form an average D (independent of thickness) for each environmental condition (Table 3).

The diffusion coefficients for each environmental condition along with the average percentage equilibrium moisture contents (independent of thickness) were introduced into equation 3 for thin and thick laminates to solve for the theoretical percentage moisture content, Mt%, which was then superimposed onto the experimental data (Figure 3).

Table 3: Diffusion Coefficients (cm^2/s

Laminate	Average D (×10^{-8})			
	@50°C/ 50%RH	@50°C/ 85%RH	@85°C/ 50%RH	@85°C/ 85%RH
FR-4 A	0.74	0.99	3.22	2.27
FR-4 B	0.82	1.23	2.74	0.93
HTFR-4	0.64	0.97	1.06	1.02
PI A	3.30	1.64	8.17	4.65
PI B	1.24	1.24	4.33	2.74
CE A	3.44	2.91	11.17	5.75
BT A	1.22	1.65	4.75	3.03

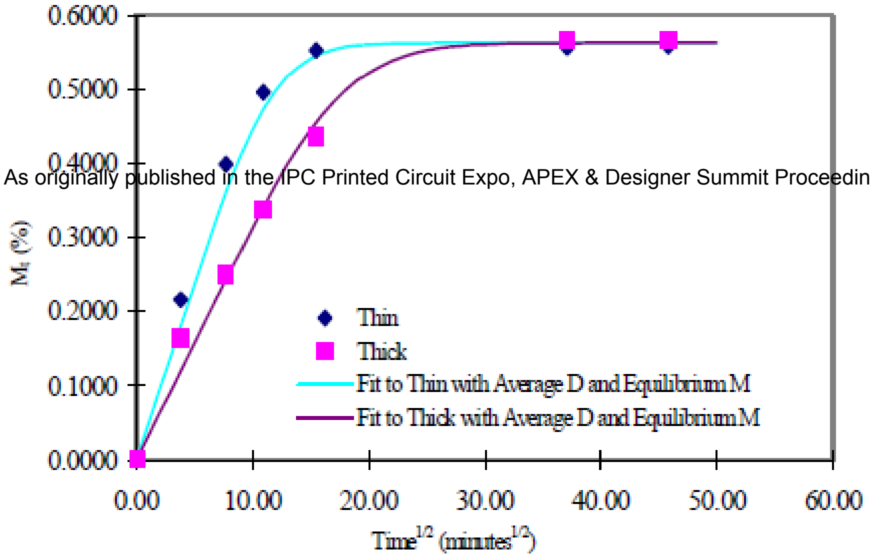

Figure 3: Diffusion curves with theoretical fit (CE-A laminates at 50 oC/85%RH).

Guidelines

Rigid PCBs can be categorized as single-sided, double-sided, or multilayer depending on the circuit complexity. Different process steps are required for each of these technologies, with single-sided having the simplest process and multilayer the most complex and costly process. Fabrication techniques and processes are common to the different technologies with special and more sophisticated steps required for complex multilayer boards. Many steps involved in the PCB fabrication are wet processes and some measures are required in order to remove residual moisture. Multi-layered laminate manufacturing is a process consisting of encapsulating a ply (or several plies) of glass fabric within a polymeric resin. The fabric–resin combination provides dielectric as well as mechanical and thermo-mechanical properties. However, since the resins used in laminates are hydrophilic, the assembly can be susceptible to degradation and performance failure mechanisms driven by environmental moisture. Materials used in PCB manufacturing should be protected from stresses induced during fabrication, handling, or storage. Laminators, fabricators, and end users are responsible for the protection of PCBs from excessive moisture. Parties should ensure that effective process controls are implemented. The following section provides controls and guidelines on the treatment of PCBs and raw materials during various steps of the fabrication process.

4.1 Controls Implemented During Lamination

It should be noted that the PCB lamination process in itself is a dehydrating step. In this process, the prepregs and cores are stacked together and placed into a large press which bonds all the layers into the final laminate. During lamination, the heating rate, cure temperature and cure time are controlled. In many cases, a low temperature, vacuum (low pressure) step is introduced to minimize the occurrence of internal voids, which are a preferential site for moisture entrapment. During the lamination process, the prepregs should only be handled by the edges using clean latex or nitrile gloves to prevent damage and scratching, and to also prevent cross-contamination of different epoxy resin types. It is also advisable to not reuse gloves to prevent cross-contamination. To prevent prolonged exposure to the remaining unused prepregs in a moisture barrier bag (MBB), the MBB housing the prepregs should be promptly resealed and should be stored flat (horizontally) in a in a cool, dry environment (such as a dry cabinet—typically at 23°C or lower and 50%RH or lower). MBB should have a water vapor transmission rate (WVTR) of less than or equal to 0.002/gm/100 in^2 (WVTR≤ 0.002/gm/100 in^2) in 24 hrs at 40°. Ensure an adequate seal width on the MBB.

Desiccant materials should be non-contaminating and dustless. During selection, the environmental conditions during shipping and storage should be factored in. Humidity indicator cards (HIC) should be non-corroding and should have an adequate number of divisions to resolve varying humidity levels. Once the prepregs have been removed from the MBB that was previously stored at low temperature, sufficient time should be provided for the prepreg to acclimate to ambient conditions prior to layup. The acclimatization should be conducted by keeping the prepreg in the MBB during the stabilization period to prevent moisture condensation. Bare, uncoated laminates also have higher moisture absorb rate as compared to a board covered with a solder mask. The number and duration of wash cycles also affects the moisture uptake. However, short duration wash cycles of laminates that are stored in controlled environment are not normally an issue if subsequent process steps are closely spaced in time.

It has been the practice with many PCB fabricators to bake prepregs prior to lamination. The theory behind the bake is to reduce excessive shrinkage during the lamination process and prevent formation of pockets for moisture to aggregate and cause blisters. The bake may be justified if the prepregs have been stored in uncontrolled environments for extended periods of time; however, in most cases, this bake step is unnecessary.

4.2 Controls Implemented During Inner Layer Production and After Lamination

PCBs typically experience higher moisture absorption rates after the photo imaging, etching, and drilling steps. Moisture may also get entrapped inside PCB features during the wet processes. However, steps such as solder mask bake and silkscreen cure are dehydrating and relieve the PCB of some entrapped moisture. Most solder masks require a cure in the range of 150°C to complete the soldermask. Silkscreen adds an additional bake step. Many fabricators rely on these additional bake steps to address incomplete cure in the lamination cycle.

During production, process flow should be designed in such a way that it minimizes the hold times between steps. Controlling storage conditions also helps in reducing moisture uptake. Once fabricated, PCBs should be placed in MBBs to ensure that no moisture is absorbed during transit. To ensure that the PCBs are sufficiently dry when they are received at the assembly location, adequate process control measures should be adopted to protect them from moisture uptake. This should also help in preventing additional bake steps before assembly. Many PCB fabricators may bake the boards after the lamination step. This step is undertaken to complete the epoxy cure and eliminate any subsequent warpage resulting from uneven stress distributions. However, a properly run lamination cycle based on the guidelines of the PCB material manufacturer, accompanied by controlled cooling, should be able to produce warp-free and fully cured PCBs. This baking step may, in many cases, thermally degrade the PCB materials.

A few PCB fabricators bake after the drill step. This bake is primarily conducted in order to remove a phenomenon called “Pink Ring” [44], [45]. Pink ring is caused by a chemical attack on the inner layer surfaces that are exposed by cracks introduced at the drill step. It is believed that the bake step “relaxes” the epoxy enough to close the crack, but does not reseal the crack; thus this bake step is considered a cosmetic fix. Additionally, the bake hardens the epoxy smear and makes it difficult to remove in subsequent steps. A preferred solution to Pink Ring should be to use a good inner layer surface treatment that prevents cracking during drilling. Baking prior to hot air solder leveling is performed in order to remove residual moisture in PCBs and is another practice prevalent among many PCB fabricators. Again, if the solder mask cure step is performed as per manufacturer’s specification and there is a minimum time delay between that step and HASL, the additional bake before hot air solder leveling is unnecessary.

4.3 Controls Implemented During PCB Assembly

After receipt of the PCBs at the assembly location, start by inspecting the condition of the MBB and humidity indicator cards (HIC). Check for tears or other damage to the MBB during transit. The HIC should always be read at room temperature (23 +/– 5°C) conditions. In a typical HIC, a pink dot indicates greater than 10% humidity. If the HIC indicates that exposure time or humidity limits have been exceeded, a bake may be necessary in order to ensure dryness prior to usage. Any non-conformance should be recorded and communicated to the board laminator. If possible, the PCBs should be placed in quarantine to prevent use. If the condition of the shipment is acceptable and the HIC indicator is acceptable and if the assembly is not scheduled immediately after receipt of the PCBs, the MBBs should be resealed promptly for PCB storage. Once PCB assembly has been scheduled, it is recommended to open the MBB just prior to assembly. Limit the “out-of-bag” exposure times during production.

As discussed earlier, the moisture absorption characteristics and sensitivity of any PCB will depend on the resin system used, design, construction, the type of assembly process, the number of steps in the assembly process, and many other factors. IPC-1601 [32] suggests that for most PCB designs, the maximum allowable moisture content will be between 0.1% to 0.5% of moisture weight to the total weight. The moisture content in a PCB may be determined by using the gravimetric procedure described in IPC-TM-650, Method 2.6.28 [33]. If tests reveal that the moisture content exceeds the specified limits, both the PCB manufacturers and the assembly house should review the practices and identify areas for improvement. Regular audits of the warehouse, staging area, and production floor should be conducted to check for variations in parameters such as temperature, humidity, and handling controls. If the measured moisture content exceeds the limit, baking may be required. The baking step is required to remove the moisture that can be absorbed into the PCB due to the mechanisms discussed in Section 3 earlier.

4.3.1 Guidelines for Baking—Environment

Always set the baking oven temperature below the maximum operating temperature (MOT) and glass transition (Tg) temperature of the PCB material. However, the temperature should be always set above 100°C, which is the boiling point of water.

The baking time should be selected on the basis of the measured moisture content, the desired content, and factors such as PCB complexity, overall thickness, and PCB finish. It is recommended that baking be performed in a forced air recirculating oven, but vacuum or nitrogen atmospheres are also effective. While placing the PCBs inside the baking oven, it is important to ensure proper venting and cleanliness of the oven and sufficient gaps between the PCBs for proper circulation. The PCBs should never be stacked inside the baking oven. The oven used for baking the PCBs should be dedicated for this purpose only and should not be used for any other application. Potential cross-contamination and surface finish anomalies can occur if residues from other processes are deposited inside the oven and are consequently deposited on the PCBs.

Prior to establishing a baking profile, the laminate suppliers should be consulted in order to establish the baking limits. Additionally, the PCB fabricator and PCB finish supplier may have their own recommendations regarding temperature sensitivity of the PCB materials and surface finishes. The first step in establishing a bake profile is to test the moisture content of the PCB as described in IPC-TM-650, Method 2.6.28. It is recommended to first establish a baseline dry weight of the PCB by means of a bake. The sample can then be exposed to an elevated temperature and humidity environment, as described in section 3, in order to allow it to absorb known amounts of moisture. The moisture absorption rate measurement was also described earlier. Further, to determine the rate of moisture loss at a given bake temperature, the PCB sample should be placed in an oven and then taken out at periodic intervals for weight measurements. The duration at which the desired maximum allowable moisture content is reached should be recorded, and this bake time should be used for subsequent baking of PCBs with similar construction, geometry resin type, and PCB finish. Any time these PCB parameters are changed, the experiment should be repeated to establish a new baking profile and duration. Organizations can also create a library of such profiles and document the moisture uptake and release rates for specific PCB materials types.

4.3.2 Adverse Effects of Baking

It is possible to degrade the PCBs at certain bake temperatures that are below MOT and T_g. Degradation may also be caused by selecting a baking duration that is too long. Examples of degradation include damage to the board finish, solder mask, or laminate. IPC-1601 provides guidelines on baking and lists the adverse effects of baking, including the effects on individual PCB finishes. In addition to the potential for PCB degradation, baking also increases cost and cycle time.

4.4 Recommendations for Packaging, Shipment and Storage

After assembly, the test and inspection steps should be conducted in such a way as to reduce excessive moisture uptake. Steps such as radiological inspection (X-ray) may be conducted after the assemblies are packaged in appropriate packaging. Criteria for selection of appropriate packaging should include evaluation of moisture control during PCB fabrication process, complexity of the assembly, and the expected storage period prior to use. At a minimum, the packaging materials should fully protect the PCB during shipment and storage.

The use of a laminate witness coupon (LWC) [32] is also gaining popularity. LWCs can be used as indicators to evaluate the relative moisture absorption and condition of the PCBs and packaging materials during the various stages of the assembly process. The weight of the LWC should be measured and recorded prior to placing them in the MBB along with the PCBs. The LWC should always be placed on top of the PCBs. Soon after receipt, the LWC should be evaluated for moisture uptake by weighing the coupon using an analytical balance, and the result compared to the initial recorded value. If the moisture uptake value exceeds the specified limits, the LWC should be baked until dry to validate the result. The user should also inform the PCB fabricator when the values exceed agreed-upon limits to determine the appropriate next steps.

5 Summary

Printed circuit boards have come a long way since the time when they existed mainly as a platform for connecting components. Boards are now part of the design, as features and even components are built into layers. The electrical and thermal properties of printed circuit boards are becoming critical factors in system designs. Many board developers do not realize that moisture in boards can significantly alter board performance. Moisture can negatively affect the integrity and reliability of printed circuit boards. The presence of moisture in a printed circuit board alters its quality, functionality, thermal performance, and thermo-mechanical properties, thereby affecting overall performance. Moisture content can vary widely depending on how boards are handled. Regardless of how much protection is used, some moisture will be absorbed. Parameters will be changed, even if boards are baked to dry them before they are used; this can alter performance from the specification sheet listings. This paper summarizes moisture-related issues and provides guidelines to reduce the impact of moisture on the reliability of printed circuitry boards. The controls and guidelines provided in the paper can be implemented at different stages of PCB production.

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