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High-Frequency Materials for Lead-Free Soldering

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Some OEMs' qualification procedures dictate that PCBs be subjected to multiple passes through a lead-free solder reflow cycle. The qualification requirements differ from one OEM to another but some will require 5, 6 or even 10 passes through a lead-free solder reflow process. There are a few different criteria for these tests, however the basic demand is that the PCB must remain mechanically intact and show no signs of delamination. The materials that make up the PCB can have a major impact on the ability of the PCB to survive the lead-free solder evaluations, and some materials perform better than others.

The material properties related to lead-free solder survival are typically coefficient of thermal expansion (CTE), glass transition temperature (T_g), decomposition temperature (T_d) and moisture absorption.

As a general rule, the material should have a CTE of 70 ppm/°C or less and closer to the CTE of copper, about 17 ppm/°C, which is best. Other general rules suggest a T_g value higher than 170°C, T_d greater than 300°C and moisture absorption less than 0.5%.

The high-frequency circuit material industry offers many laminates and prepregs (or bonding material) to choose from. Some of the laminates and bonding materials are robust for lead-free soldering, and others are not. Additionally, there are some bonding materials which are not intended to be used at lead-free soldering temperatures.

A broad classification of bonding materials can be thought of in two categories. Some bonding materials are thermoplastic, while others are thermoset. A thermoplastic bonding material has the attribute of being able to reflow or melt when subjected to certain elevated temperatures. The thermoset materials will not melt or reflow when subjected to elevated temperatures. However, at high temperatures, the

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concern can be related to material decomposition.

Each type of thermoplastic bonding material has different characteristics, and one of these is the melt temperature. Some common thermoplastic bonding materials used in high-frequency PCB fabrication are PTFE, FEP and chloro-fluorocopolymer (Rogers' 3001 material). As for the PTFE bonding materials, some of these are pure PTFE and others are filled PTFE. Depending on the filler, some of these bonding films can have a lower or higher melt temperature than PTFE.

The 3001 bonding material is often used for laminating high-frequency PCBs when a bonding material with low dissipation factor (Df) and low dielectric constant (Dk) is needed. The Df of this material is 0.003 and the Dk is about 2.3 when tested at 10 GHz per IPC-TM-650 2.5.5.5c (the clamped stripline test). This material is also intended to be used when subsequent processes are not beyond the melt temperature of the material. During the lamination process, the 3001 bonding film is held under pressure and brought to a temperature of about 450°F (232°C). After the lamination process is complete, the PCB should not be subjected to temperatures above 350°F (176°C); however, this is not the melt temperature of the material.

As thermoplastic materials are heated, their modulus decreases; higher temperature translates into softer material. The 350°F limit for 3001 bonding film is due to the material being very soft at this temperature, and any mechanical stress could cause delamination of the PCB.

When a bonding material with low Dk and low Df is needed and the PCB will be subjected to elevated temperatures after the lamination process, FEP is often used. This material has a Dk of 2.1 and Df of 0.001 when subjected to the clamped stripline test. The melt temperature of this material is higher than the 3001 material, so the lamination temperature is higher as well. A lamination temperature of 565°F (296°C) is recommended and PCBs using this material should not be subjected to temperatures above 520°F (271°C) in follow-on processes. Lead-free soldering temperatures are typically lower than 520°F, so FEP has been used in PCB applications where lead-free soldering is necessary.

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The other thermoplastic material suitable for high-frequency PCB bonding is PTFE or filled PTFE. This requires a special fusion lamination process, and few fabricators have this capability. Thermoset bonding materials (prepregs) are generally easier to laminate, and they are more robust for elevated temperature exposures in successive processes. While this is true, some of the thermoset systems have trouble surviving lead-free soldering. This is generally due to the materials' CTE, T_g, T_d or moisture absorption properties. A relatively new bonding material that is thermoset and robust for lead-free soldering is Rogers' 2929 material. With a CTE of 50 ppm/°C, T_g of 170°C and a T_d at 400°C, this material has proven to be a good choice for high-frequency multilayer PCBs where lead-free soldering is required.

Fortunately for PCB designers, a variety of available bonding materials can withstand the elevated temperatures often associated with lead-free soldering of high-frequency PCBs. **PCBDESIGN**

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