

Pb-free Impact on PCB Purchasing Whitepaper

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Preface:

To date, volumes have been written about the European Union's (EU) directive on Restrictions on Hazardous Substances (RoHS), WEE, and requirements for lead-free (Pb-free) products. You can go to virtually any search engine and put in the words, "Pb-free requirements" or "RoHS" and get a considerable amount of definitions, analysis, and general articles.

So, rather than re-inventing the wheel, we'll concentrate on basic information you, as a buyer or purchasing agent, can use to make your life easier. The following information helps you to understand some of the key particulars involved in selecting Pb-free PCBs and their associated costs.

What's Your PCB Application?

If the Pb-free PCBs you are purchasing are to be used in medical, industrial, military/aerospace, consumer, computer, or network systems, the Pb-free PCB requirements for each of these system applications are vastly different from one another with different costs and delivery times. So, it's a good idea to get a sound understanding of the [Pb-free PCB design, fabrication](#), and design steps associated with your particular PCB application.

Higher Temperature Requirements for Lead Free Process

The higher temperatures used for Pb-free processing and rework place greater stress on components and boards, which is further aggravated by cumulative heat exposures. The combined reflow and rework heat cycles can result in a single assembly being exposed to as many as five thermal heat excursions that includes two reflow passes, a wave solder pass and two localized heating passes for rework.

The internal package structure within components and PCBs must survive all processes and still provide long-term reliability. Component effects include increased moisture sensitivity levels (MSL), thus resulting shorter exposed floor life, while PCB laminates must minimize internal layer de-lamination, via cracking and board warpage.

SMT first pass reflow processing typically has the following characteristics:

- Four to six minute cycle times
- Temperature ranging from 230 to 250°C for joints and body temperatures
- Delta T ranges from 5 to 20°C on single assembly
- Time above liquidus ranging from 60 sec to 90 seconds.

The minimized superheat required for [Pb-free assembly](#) and rework means that profiling becomes critical. It is not uncommon for an engineer to attempt to use one profile for a family of assemblies of similar size and complexity. This is usually workable in an SnPb process since it is characterized by a generous process window. As long as all the assembly reaches about 200° C, one can be reasonable confident that all the components will properly solder. This approach does not work with Pb-free assembly and rework, which requires more precise reflow temperature cycles

Solder Pastes, Materials, Surface Finishes, and Costs

There are literally hundreds of Pb-free alloys either in use or being offered for consideration. But there is no direct drop-in replacement for SnPb solder, nothing that is as effective as Sn/Pb, cost the same or less, and is non-toxic. Every Pb-free replacement alloy has some deficiency as far as cost or performance when compared to Sn/Pb.

Tin-Silver-Copper (SAC) alloys with a composition of 95.5 Sn, 3.8 Ag, and 0.7 Cu are widely regarded as the most suitable choice in the near future for Pb-free soldering. The liquidus temperature of SAC alloys is 217 to 220°C, which is about 34°C above the melting point of eutectic SnPb. This higher melting range requires peak temperatures to achieve wetting and wicking to be in the range of 235 to 245°C. Lower peak temperatures can be used with SAC solders such as 229°C. By adding Cu to Sn/Ag, the melting point is reduced; wetting is improved; and long-term reliability increases. Also, SAC is not as sensitive to Pb contamination as Bismuth-containing alloys and can be used with SnPb-plated components with no major problems.

Tin-Zinc (91Sn 9Zn) and Tin-Bismuth (58Bi 42n) are two attractive alloys due to their low melting points of 199°C and 138°C, respectively. Tin-Zinc is ideal for soldering on to aluminum. It is attractive as a replacement for SnPb because constituent metals are inexpensive. However, Zinc reacts with both acids and bases, and as a result, solder paste with this alloy has a very short shelf-life.

The low melting point of Tin-Bismuth makes it attractive since there is considerably less thermal shock to the assembly during reflow and less energy is required. But this is a brittle alloy with poor shear strength, plus it is sensitive to Pb contamination.

Different surface materials with a higher temperature cycle range are required for Pb-free assembly. In this case, higher temperature FR4 material is required such as FR406 or FR408.

Also, PCB surface finishes are different and depending on cost and board application, immersion silver or gold or OSP can be used to withstand the higher temperatures when the board goes through the reflow oven.

There are two considerations involved in preparing a bare board for Pb-free assembly. One is board thickness; the other, the surface finish. If the PCB is thicker than the regular 62 mils, then a specific amount of solder and flux is needed. If it is even thicker than that, or for instance, 93 mil thick, then the board will require more flux activity to soak the pad. Plus, it will require more flux. Contact time, bump speed, and peak temperature must be increased. Lastly, a [nitrogen reflow](#) instead of regular hot air reflow may be considered to make boards more cosmetically pleasing.

As for surface finishes, hot-air solder leveling or HASL is used for eutectic boards, but is not conducive to Pb-free assembly. For Pb-free assembly, there are such PCB surface finishes as electroless nickel immersion gold or ENIG, immersion silver, organic solderability protectants (OSP), and a special Pb-free brand of HASL mostly used in ASIA to do [Pb-free assembly](#).

The reason these surface finishes are so important to Pb-free board fabrication is because conductivity of immersion silver and immersion gold is considerably higher compared to tin lead used for eutectic soldering. These finishes withstand higher temperatures, and there is a very less likelihood of the pads being peeled off from the board surface when it is exposed multiple times to higher temperature cycles.

There are several tradeoffs involved with these surface finishes. Those are shelf life, cost, reflow cycles, and solder joint flatness. Immersion silver and gold are expensive metal alloys. At production levels, these finishes could cost 5% - 10% extra, depending on the amount of exposed surfaces. Therefore, it's best from a cost/performance point of view to select a finish that can be cost justified in a particular end product.

As for shelf life, HASL has about an 18 months, but OSP has only six months. Immersion silver has a shelf life ranging from 12 to 16 months, while immersion gold is the most durable at 24 months.

OSP cannot undergo more than two to three reflow cycles. If the need for rework continues, then the SMT pads on the OSP finish begins peeling off. Thus, OSP is not the best finish for rework. On the other hand, immersion silver or gold can undergo six to eight reflow cycles.

Using immersion gold or immersion silver comes with an added advantage, which results in a flatter PCB surface finish. Consequently, the flatter PCB surface finish is considerably more conducive to a perfect PCB assembly compared to HASL finish.

Questions To Ask When Re-Evaluating Your CM Supplier

1. Have you upgraded your processes to handle Pb-free?
2. Do you have one line dedicated to eutectic (lead processes) and a separate one for Pb-free for RoHS compliance?
3. How are your processes defined? At what levels have you tried the controls? What is your inspection equipment? Detail for me your quality control before the product is shipped.
4. What different services do you offer so that I can make an easy [transition](#) from a eutectic product to a Pb-free product?
5. Can you scrub the BOM for Pb-free or RoHS-compliant components?
6. Can you work with different surface finishes required to meet Pb-free thermal demands?
7. Is your inventory separated and labeled properly for Pb-free and eutectic components, fluxes, and solder pastes?
8. Explain the level of research you've done to better serve my Pb-free product needs.
9. What design techniques are you using to comply with Pb-free requirements?
10. Explain to me how you decide which flux and solder paste to use for Pb-free PCB fabrication.
11. What kind of thermal profile are you running?
12. Detail for me quality issues you've encountered as a result of RoHS compliance.
13. How do you deal with latent defects associated with Pb-free PCB products?
14. What are your capacity issues in terms of Pb-free product fulfillment?

Questions To Ask On-Site

1. You are well advised to visit an EMS provider or contract manufacturer and tour the facilities to make certain a Pb-free PCB supplier has well-defined processes in place and knows exactly how to comply with the RoHS directive. There is no certification for RoHS compliance. So, the next best thing is to personally meet with an EMS provider's management, design, fabrication, and assembly teams, plus get a detailed walk-through of the key process steps. By doing this, you and your company can attain a high degree of confidence that a truly RoHS compliant PCB product will be delivered. During the physical audit, here are some key questions to ask:
 2. What kind of thermal profile have you done for Pb-free products?
 3. Show me examples of Pb-free products you've previously done.
 4. Take me to your Pb-free line. Show it to me and explain the various steps you take when processing a Pb-free PCB product.
 5. Show me how you label your component inventory, your fluxes, your solder pastes, your soldering stations and other associated equipment.
 6. Show me where you separate eutectic and Pb-free materials.
 7. What kind of record do you have for dealing with latent defects?
 8. What measures have you taken to mitigate latent defects not seen when the product is shipped out?

Lastly, aside from these questions, it's a good idea to interview design engineers, fabrication managers, and procurement managers to get a complete understanding of the issues, logistics, and challenges they face to provide you a fully compliant Pb-free PCB product.

For further information and a [complimentary consultation](#) on RoHS and Pb-Free, call us at **1-888-NexLogic**, email us at info@nexlogic.com or visit our website: www.nexlogic.com.