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White Paper

The Complexities of a Lead-Free Transition

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The Complexities of a Lead-Free Transition

Introduction

Often when engineers and product developers think about a transition to lead-free products their focus is primarily on assembly optimization and product testing to ensure reliability. These are indeed critical aspects of a successful transition, however, there are other areas that are equally important. These include material selection, component specification/qualification, rework, failure analysis and remediation actions when failure occurs during assembly or testing.

Material Selection

One key material decision that impacts the rest of the lead-free assembly process is the surface finish on the PCB. There are many options and each has its benefits and drawbacks. The correct selection depends greatly on the complexity of the board, the assembly process, and the use environment. Common options include OSP, ImAg, ImSn, lead-free HASL, or ENIG (with some newer options also coming to market). In addition, the optimal PCB laminate must also be selected. Oftentimes the laminate is over specified (and thus higher cost is paid) or underspecified (and reliability compromised) due to a lack of understanding of the robustness of various laminates in the lead-free assembly process.

Other important material choices include the solder alloys used in surface mount, wave solder, and for the BGA balls. SAC305 is the typical surface mount alloy and it performs reasonably well for most applications. A variety of wave solder alloys are in use today including SnCu, SnAgCu, and SnAgCuNi. The best choice for your application will depend on the complexity of your wave solder requirements. SnCu is a cost effective solution if you have low aspect holes to fill on thin boards. SnAgCuNi may be the best choice for more challenging holes, however, the choice of flux and the surface finish play an important role as well. The best choice of alloy for BGA terminations will depend primarily on the dynamic strain requirements of your application. If board flexing or shock events occur in the product then you may require some of the lower modulus alloys such as SAC105 or a variety of others being introduced for this purpose.

Component Specification/Qualification

The temperature and moisture sensitivity requirements for surface mount LF components are pretty well understood and suppliers do a good job of meeting them. Temperature limits for wave solder components, on the other hand, are less understood and early adopters of lead-free found many cases of melted plastics on wave solder connectors. As a result, the use of nylon 66 has been mostly eliminated and replaced with nylon 46 or LCP.

Heat damage to other components such as electrolytic capacitors is more difficult to detect and therefore less understood. The electrolyte can boil if the time and temperature limits are exceeded but such limits are not always provided with the capacitor. A common specification might say that the component will survive 6 seconds with the leads dipped in 260°C solder. But what happens if the solder bath is increased to 270°C and what about preheat? The component engineer is left to guess what peak and duration of preheat is acceptable while the wave solder engineer continues to increase these preheat conditions in a quest to achieve hole fill requirements with less cooperative lead-free alloys.

Other lesser understood requirements involve the type of tin whisker testing that should be performed and when they should be performed (since these can be lengthy and costly tests). Several whisker mitigation techniques are available but which are most applicable to your components. To create a realistic test plan it is important to understand which finishes and configurations are most susceptible to whisker growth and what level of testing should be performed.

Another blind spot is the strain capability of various components after lead-free assembly. It is well known that SAC alloys have lower tolerance for strain, yet component manufacturers rarely provide such limits for their devices. As a result the user is left to guess whether or not they might have a problem after they perform ICT, component stuffing, or attachment of their board to the chassis. Ideally the component suppliers would perform 4pt bend testing of their components to determine the maximum strain they will survive while the assembler would use strain gauges to determine the upper limits of strain within which they can perform the necessary assembly steps.

Rework

Lead-free rework can be overlooked in the quest to meet tight development schedules. This would be a big mistake as experience shows rework is one of the most challenging aspects of the lead-free transition. It's well understood that lead-free assembly has a much tighter process window between a cold solder joint on the lower temperature end and heat damage to the component or PCB at the upper end. Experience has shown that a 9+ zone surface mount oven can achieve the necessary control, even on large and thick boards.

With rework, however, we bring operator-to-operator variation into the equation along with equipment that may have been designed for Sn-Pb rework. The rework process must be optimized for each critical component and this procedure rigidly followed. To determine the optimum rework process, extensive failure analysis must be performed to ensure no damage occurs to the component, the PCB, or neighboring components. New rework equipment may be required and/or shielding techniques may be employed to protect other components.

Analysis

Prior to RoHS, PCB assembly was performed with SnPb solder which had over 50 years of data to back it up. Consequently a strategy of testing to specification was seemingly sufficient. LF alloys have significantly different mechanical properties and their impact on reliability is less understood. A test plan needs to be well thought out with testing to failure comprising a portion of the plan. Analysis such as dye and pry or cross sectioning should be performed on the highest risk components after assembly and probe testing as well as after environmental testing. Cracks can get initiated from stress during the assembly process and pose a risk for latent field failure. Depending on the expected shipping and use environment of the product it may be prudent to perform combinatorial testing. For example, a product may undergo shock and vibration during shipping that initiates cracks, but then is expected to survive a lifetime of thermal cycling. Such a product should be thermal cycle tested after undergoing shock and vibration.

Finally, one needs to consider in advance what the acceptable test levels should be and what actions will be taken if failures occur prior to that level. For example, if a component suffers PCB pad cratering and conductor trace cracking what should be done to mitigate this? Several options exist ranging from redesign of the PCB to use of underfill or edge glue. The best option will depend on the magnitude of the failure, among other things.

Supplier Manufacturing Audits

Many electronic manufacturers now have some experience with assembly of lead-free PCBs. However, just because your prototype boards met requirements does not mean that high quality will be maintained once high volume manufacturing begins. Do you have a comprehensive and detailed lead-free PCB assembly audit plan that you can go through with the supplier? There are many important areas that can get missed which can later lead to defects (some being latent in nature because they are not easily detected).

As an example your audit plan should cover areas such as:

1. Sub-Tier supplier management
2. Process optimization procedures
    a. screen printing
    b. reflow
    c. wave solder
    d. in-circuit test
    e. hand solder
    f. rework
3. Process control procedures
4. Change control methodology
5. Segregation controls
6. Pass/fail inspection criteria and training
7. Material handling and control (paste/flux, components, assemblies)

The change to lead-free can be a good opportunity to revisit your supplier's overall process and controls, as the acceptable process window has shrunk and adequate controls are more important than ever.

How Can We Help?

The engineers at DfR Solutions have hands-on experience with all aspects of the lead-free transition discussed above. We can be of assistance to component or material suppliers, those doing assembly, or product development teams. Our role can be as simple as offering advice, teaching a class, auditing your EM, or designing a test plan.

We can also be inserted into the component qualification/assurance process. For example, we can run the testing to understand the strain limits of a component, we can expose capacitors to your thermal profile and perform detailed life analysis afterwards, we can run on-going reliability testing of components or assemblies to ensure quality is maintained after high volume production begins. We can perform the activities that you may not have the resources to tackle or simply don't want to because your company is better served by concentrating your resources on product enhancements that differentiate you from the competition. We're here to help.

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