

**Code of Practice for the
Use of Electronic
Components and PCBs
in Lead-Free Processing**

**M Wickham, A Brewin, L Zou
and C P Hunt**

April 2003

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M Wickham, A Brewin, L Zou and C Hunt
Materials Centre
National Physical Laboratory
Teddington, Middlesex TW11 0LW, UK

ABSTRACT

With the widening interest in, and need to implement, lead-free soldering processes, there has been much discussion and speculation on the stability and survivability of electronic devices and PCBs at lead-free soldering temperatures. This Code of Practice covers some of the issues associated with the use of these components under the more stringent requirements of a lead-free process.

Generally, there are only minor issues associated with the higher temperature processing, with the majority of components remaining within specification. There are, however, concerns with capacitors, laminates with low glass transition temperatures, and components and multilayer PCBs that are susceptible to moisture ingress. Some misalignment issues with ultra fine pitch QFPs after lead-free soldering are also highlighted.

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ISSN 1473 2734

National Physical Laboratory
Teddington, Middlesex, UK, TW11 0LW

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1 INTRODUCTION

The introduction of lead-free soldering in the UK is now inevitable due to both legislation and market forces. In many cases, the latter will ensure implementation changes in timescales well ahead of those required by legislation. The main implication of switching to a new soldering alloy is that the majority of the alternatives have higher melting points. The obvious impact of this on the soldering process is an increase in the processing temperatures. In turn, this has many ramifications for the components and this work considers the sensitivity of components to processing at elevated temperatures.

The higher temperatures needed to reflow lead-free solders (for example, 217°C for the eutectic tin/silver/copper (SAC alloy), 34°C higher than the conventionally used eutectic tin/lead (SnPb) alloy), have implications for the electronic components and printed circuit boards (PCBs). Lead-free soldering profiles are therefore hotter than their SnPb equivalents and can differ significantly depending on the thermal mass of the assemblies involved and the ability of the oven used to transfer heat evenly to the assembly. Thus work at NPL (reference 1) has shown that component temperatures can reach as high as 270 or 280°C in extreme circumstances, and regularly reach 230-245°C.

In implementing a lead-free process the major concern, and initially the biggest impediment, was the availability of compliant components and printed circuit boards. There are two issues for components in being compatible with the lead-free process. One is the metal finish on the terminations, and the other is the integrity of the component itself at the elevated processing temperature. Lead-free surface finishes are already widely available but the laminate materials used will still have to withstand the elevated temperatures of lead-free profiling.

The former issue of termination finishes, which must be lead-free, potentially impacts on solderability and thus process yield. The second issue of component and PCB integrity is considered here. Component and PCB integrity comprises two features. One is the physical robustness of the component or PCB, and the second is the functionality. Which of these is the most important varies with component type. For a wide range of active devices with silicon die, it is the packaging that is critical, the die and leadframe easily withstanding the increase in process temperature. For a number of discrete components and for PCBs, it is the structure of the device or PCB that is critical. For example the multi-layer structure of capacitors may be sensitive to alternative thermal profiles. Similarly, PCBs may be susceptible to greater deformation at elevated temperatures.

Historically, components and PCBs have been designed to withstand traditional tin-lead soldering temperatures, and particularly with components, manufacturers have recommended limits for heating during reflow that would often be exceeded under lead-free reflow conditions.

This Code of Practice covers a number of components and PCB laminate types that have been considered by members of the Soldering Science & Technology Club (SSTC) to be most susceptible or problematic if overheated during reflow. These include light emitting diodes (LEDs), capacitors, crystals, connectors and plastic ball grid arrays (PBGA). Four different types of PCB laminate are also considered. A range of tests has been carried out at the National Physical Laboratory to determine the effects of lead-free profiling (reference 2).

These included dimensional stability, weight loss and electrical functionality, and this Code of Practice is based on this work. However, it should be noted that no long term electrical reliability evaluations have been undertaken.

It should also be noted that it has not been possible to check every example of each type of component discussed. Comments included in this Code of Practice are based on work conducted on typical components as available at the beginning of 2002. If the end-user of components has any doubts about the suitability of any components to withstand lead-free processing, then it is recommended that he undertakes his own tests to determine the components suitability.

The components covered in this report are the following and were selected on the basis described above :

- Surface mount LEDs
- Polyester capacitors
- Aluminium electrolytic capacitors
- SMT headers
- Crystal oscillators
- Ball grid arrays (BGAs)
- Quad flat packs (QFPs)
- Laminates
 - FR4 epoxy-glass
 - High Tg epoxy-glass
 - BT epoxy glass
 - Polyimide-glass

If the user of this document wishes to evaluate components not included here, this document illustrates the approach to be adopted. Physical and functional properties need to be evaluated as appropriate, and illustrated here for the above components.

2 SURFACE MOUNT LEDS

2.1 LEDS BACKGROUND

Two main types of surface mount LEDs are available - leadless chip LEDs and gull wing types (see Figure 1). Both are based on GaAsP/GaP technology. The industry has expressed concerns that LED polymer casings could soften at lead-free reflow temperatures causing dimensional changes, and also that the optical performance of the devices could be impaired.



Figure 1. SM Chip LED and Gull Wing LED.

Recommended reflow profiles are supplied by some LED manufacturers, and a typical profile is shown in Figure 2. These are clearly intended for SnPb profiling, with a maximum permitted temperature of 230°C. As this temperature is only 13°C above the melting point of the preferred lead-free alloy, and as the thermal mass of these components is low, it is clear that it would be difficult to restrict the temperature of these devices passing through a lead-free profile to below this maximum.

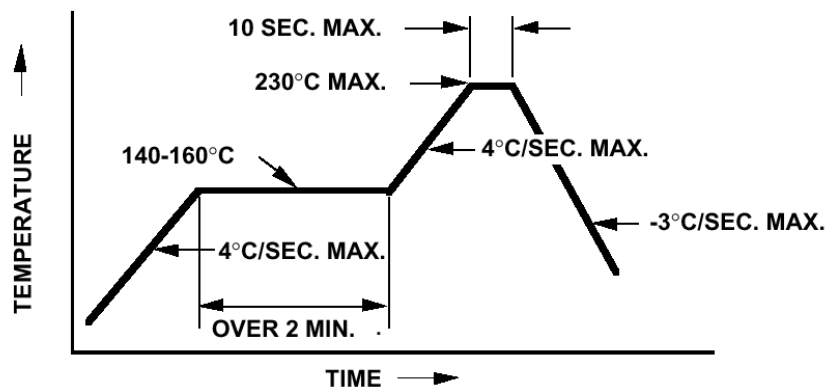


Figure 2. Manufacturer's Recommended Reflow Profile for Standard SM LEDs

2.2 ISSUES WITH LEAD-FREE PROFILING OF LEDS

During lead-free profiling, changes of typically 2-4% in the dimensions and 0.6% in the mass of LED devices can occur. These changes suggest that the polymer casing does soften. End users who are concerned about the performance of LEDs could have them checked using differential scanning calorimetry (DSC). The DSC curve highlights any changes in phase as the component heats up, and hence temperature sensitivity. An example curve from a typical SMT LED is shown in

Figure 3. In this example, no major phase changes occur in the material. The melting of the solderable finish on the component legs can clearly be seen at 180-185°C. As this metallisation is only a very small percentage of the mass of the whole component, such a signal indicates the sensitivity of the technique. There is no clear indication of decomposition of the polymer casing under 290°C. Polymer decomposition reactions start at around 300°C and are characterised by energy released by the exothermic reaction, as opposed to the energy absorbed during a phase change. There is a small step around 210°C which may be significant in causing the dimensional changes and loss of emission.

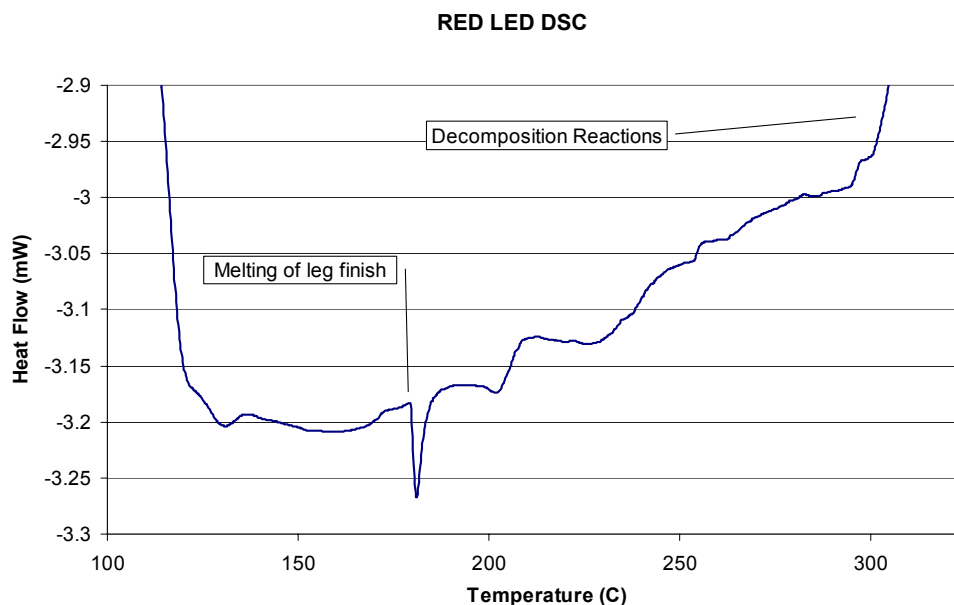


Figure 3 : DSC Curve for Gull Wing LED Component

The functionality of the surface mount LEDs should not be affected by the lead-free soldering conditions. Work at NPL has shown that the threshold voltage for light emission proved to be changed by no more than 0.5% after lead-free profiling.

The polymer casing of some SM LEDs may discolour during lead-free soldering. This will reduce the final emission of the device although the diode would still function properly. This emission reduction can be quantified using a photometer, which produces a photon count of the output from the devices. Typical results from a green gull-wing SM LED after SnPb and lead-free processing are shown in

Figure 4. This indicates that the darkening of this LED case caused by lead-free reflow reduced the emission to 40% relative to profiling under tin-lead conditions.

2.3 SM LED RECOMMENDATIONS

While the dimensional and electrical characteristics did not show any unacceptable changes, the loss in optical output may well be unacceptable. Consequently LED light emission should be monitored following high temperature profiling.

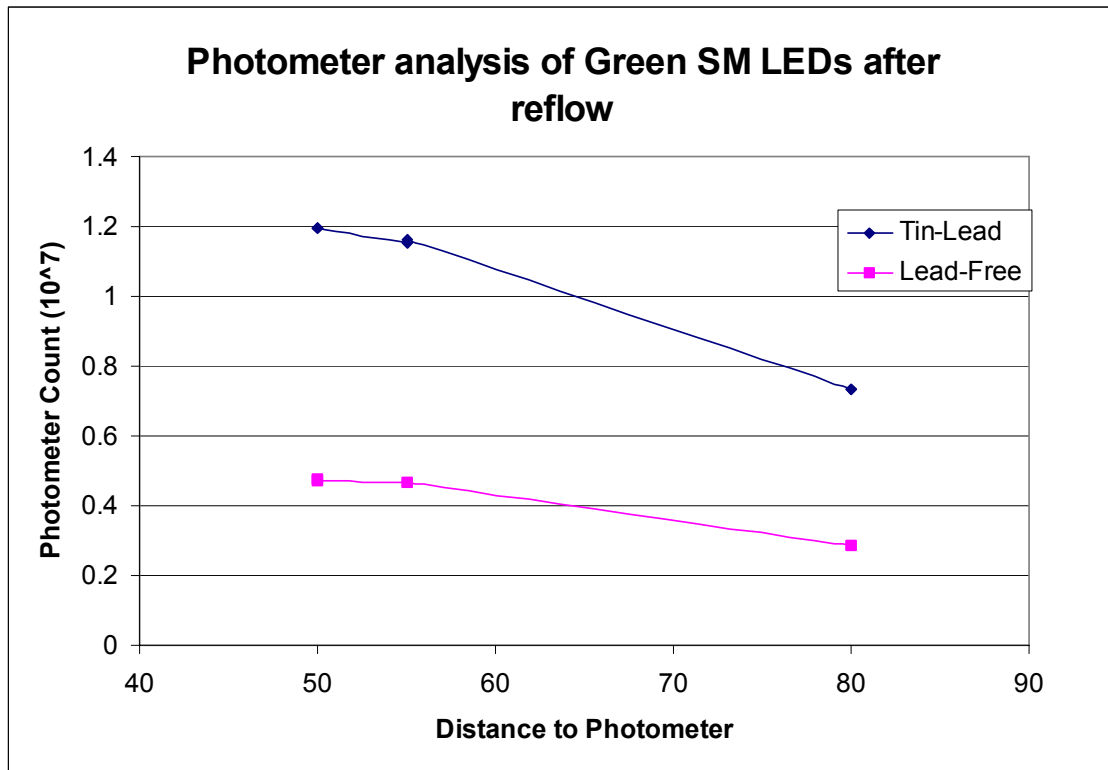


Figure 4. Reduction in LED Emission due to Darkening of Polymer Case.

3 POLYESTER CAPACITORS

3.1 POLYESTER CAPACITOR BACKGROUND

Surface mount polyester capacitors are manufactured with wound layers of polymer (polyethylene terephthalate, PET) foil coated with a vacuum deposited metal forming a coil. The ends of the coils are attached directly to the external component contacts at each end of the component so the entire outside edge of the wound conductive layer makes an electrical contact.

Typical applications for PET capacitors are bypassing, coupling and filtering. One manufacturer recommends the following restrictions on the reflow soldering profile:

Preheat should be less than 150°C.

Over 180°C, 60 seconds maximum.

Peak temperature 215°C.

This maximum permitted temperature of only 215°C, is below the melting point of the SAC alloy (217°C), so it would be impossible to maintain this maximum temperature in any lead-free profile.

A typical component is shown in Figure 5.

The PET construction provides good volume efficiency and self-healing properties. This wound construction leads to vulnerability at higher temperatures and there are concerns about the physical stability of plastic capacitors.

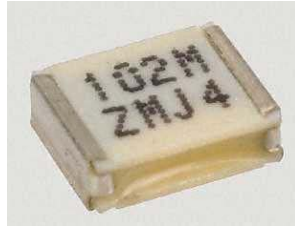


Figure 5. Polyester SM Capacitor.

3.2 ISSUES WITH LEAD-FREE PROFILING OF POLYESTER CAPACITORS

Polyester capacitors are susceptible to higher temperature reflow profiles in two important ways. Capacitance does not change much (typically less than 3% over the frequency range of 100Hz to 100KHz, which is within specification), but the loss tangent can alter significantly. Figure 6 shows the loss tangent of a typical polyester capacitor as a function of frequency, and reveals that after lead-free processing, the loss tangent of this device exceeded the manufacturer's specification by 130%. As polyester capacitors are designed for use in digital circuits at much higher frequencies than the electrolytic capacitors, this poor performance after lead-free processing is very relevant.

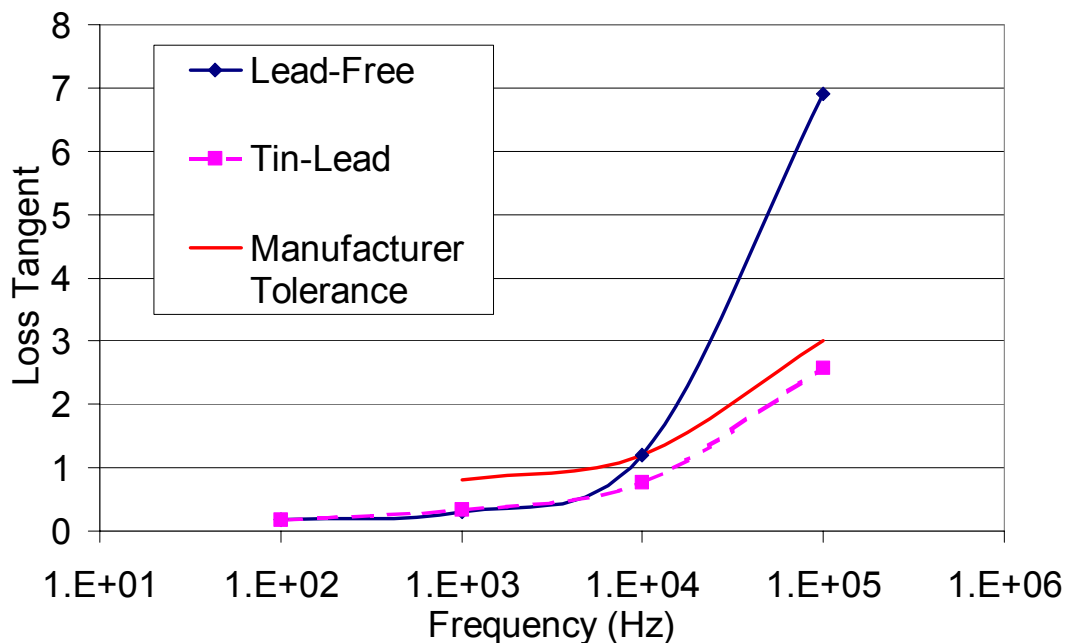


Figure 6 : Effect of Reflow on Loss Tangent for Polyester Capacitor

After lead-free processing, polyester capacitors exhibit expansion in height rather than in length or width. The behaviour is shown schematically in Figure 7.



Figure 7 : Schematic of Polyester Capacitor Expansion.

The expansion of a typical capacitor can be clearly seen in the microscope image, Figure 8, where the top of the component has barrelled.



Figure 8 : Deformation of Polyester Capacitor.

Cracks were also present on the ends of the component after exposure to lead-free reflow (Figure 9). The cracks appear to be between the end cap metallisation and the potting compound that forms the main body of the component.

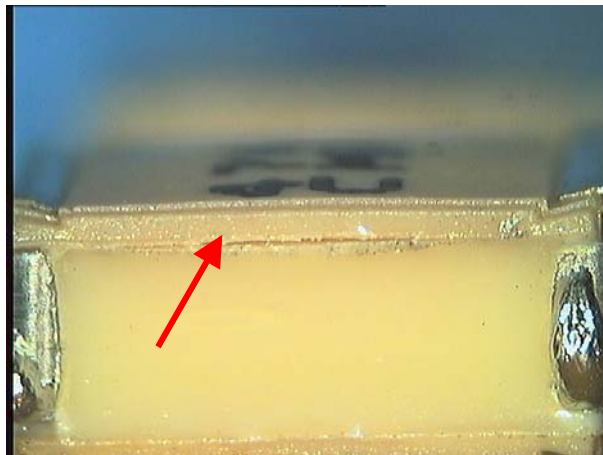


Figure 9 : Cracks in the End of the Polyester Capacitor.

3.3 POLYESTER CAPACITORS RECOMMENDATIONS

Dimensional stability and the loss tangent are issues for concern. Lead-free heating profiles can cause considerable physical deformation of polyester capacitors. Relatively low weight changes occur during the lead-free soldering process, suggesting that the electrolyte, although building up pressure inside the component does not escape. Loss tangent for these components at the higher frequencies, may change significantly after lead-free profiling, and fall outside the manufacturer's specification. The tolerance for capacitance quoted for these devices is +/-20% and this is not expected to be exceeded at any frequency between 100 and 100,000Hz for the lead-free process.

4 ALUMINIUM ELECTROLYTIC CAPACITORS

4.1 ALUMINIUM ELECTROLYTIC CAPACITORS BACKGROUND

Higher values of capacitance are often achieved using aluminium electrolytic capacitors. These normally consist of an aluminium foil wound (with paper as a spacer) into a coil, which is then filled with a liquid electrolyte, and encased in polymer and an aluminium casing. Concerns have been expressed about the expansion of the liquid electrolyte and the wound construction during lead-free reflow, and reports of damage to these devices have been received by NPL.



Figure 10 : Aluminium Electrolytic Capacitor.

4.2 ISSUES WITH LEAD-FREE PROFILING OF ALUMINIUM ELECTROLYTIC CAPACITORS

After lead-free reflow processing, the capacitance of the electrolytic capacitors should remain within the manufacturer's tolerance. However, as with the polyester capacitors, users can expect the loss tangent even at low frequencies, to be significantly affected. In tests conducted at NPL on 100 μ F electrolytic capacitors, the loss tangent increased by 120% after 6 lead-free reflows. Manufacturers of these components do not normally specify a tolerance for loss-tangent.

As with the polyester capacitors, the end user can expect little change in the width and length of these components, but the height can change dramatically. This is due to expansion of the electrolyte in the casing causing a dome-like bulge at the top and bottom of the component. The bulge at the bottom will be less noticeable due to the additional stability afforded by the

plastic base. Figure 11 shows the 100 μ F electrolytic capacitor after lead-free profiling. The bulging of the top and bottom of the cylinder body can be clearly seen. In fact this deformation is even greater during peak reflow temperatures, but the casing contracts somewhat as the component cools. It has been reported that these components can pop (reference 3). Despite the large physical deformation of electrolytic capacitors, mass changes will be very low, as no electrolyte will normally escape.



Figure 11 : 100 μ F Electrolytic Capacitor after LF Reflow

4.3 ELECTROLYTIC CAPACITOR RECOMMENDATIONS

The physical deformation of the electrolytic capacitors can be expected to be significant after lead-free profiling, and is unlikely to be acceptable (to a customer receiving electronic product) on aesthetic grounds alone. The bulging of the base means that the legs of the component can be bent out of the plane of the board as the plastic base is pushed down. This may cause problems with soldering of the legs if they do not stay associated with the PCB pads.

The capacitance of electrolytic components can be expected to remain within manufacturer's tolerances after lead-free processing, but as with the polyester capacitor, the loss tangent will be greatly affected.

5 SMT HEADERS

5.1 SMT HEADER BACKGROUND

Header connectors typically have a polymer casing, which must retain its physical dimensions after soldering in order for good mating to its corresponding plug. An example is shown in Figure 12. For this reason the higher temperature of lead-free soldering could be problematic if even small deformations occur in the polymer. The housing material is normally polyamide 66 rated to UL94V-0. Few manufacturers state any restrictions on reflow conditions.

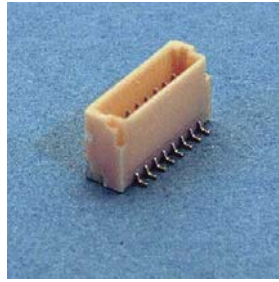


Figure 12 : SMT Header Connector.

5.2 ISSUES WITH LEAD-FREE PROFILING OF SMT HEADER

In practice no problems should be experienced with this type of component. Headers are unlikely to change much dimensionally during lead-free reflow and therefore the subsequent mating of a connector should not be an issue.

5.3 SMT HEADER RECOMMENDATIONS

The physical stability of headers should be excellent with dimensional changes being less than 1% in all axes during lead-free profiling.

6 CRYSTAL OSCILLATORS

6.1 CRYSTAL OSCILLATOR BACKGROUND

Quartz crystal resonators are widely used in electronics as highly stable and accurate frequency sources, but the oscillation frequency depends as much on the oscillator circuit as it does on the crystal. Resonators are passive, they do not oscillate without additional circuitry and a source of energy. A resonator, placed as a feedback element around an amplifier, makes an oscillator. The amplifier replaces energy lost in the resonator. The resonator controls the frequency of oscillation, and so stability of crystal devices is critical.

A quartz crystal resonator is frequently simply a circular piece of quartz with electrodes plated on both sides, mounted inside an evacuated enclosure. Quartz is ideal for resonators because it is hard, dimensionally stable, non-conductive, and most importantly, piezoelectric. A typical crystal oscillator is shown in Figure 13.



Figure 13. SMT Crystal Oscillator.

Typical reflow conditions to maintain the ± 50 ppm tolerance on resonant frequency for these crystals specified by the manufacturer are :

- Over 140°C Preheat, 100 seconds maximum
- Over 200°C, 25 seconds maximum
- Over 230°C, 5 seconds maximum

Again, as this temperature is only 13°C above the melting point of the preferred lead-free alloy, and the thermal mass of these components is low, it is clear that it would be difficult to restrict the temperature of these devices passing through a lead-free profile to this maximum.

6.2 ISSUES WITH LEAD-FREE PROFILING OF CRYSTAL OSCILLATORS

As with the headers, no problems should be encountered with crystal oscillators. Resonant frequency changes well within manufacturers' tolerances should be experienced.

6.3 CRYSTAL OSCILLATOR RECOMMENDATIONS

With some examples it has been seen that, despite lead-free profiling with conditions vastly exceeding the manufacturer's temperature and time limits for these components, the stability of quartz crystal oscillators gave no cause for concern with lead-free processing. It should be particularly noted that it has not been possible to check every example of crystal oscillator available. It is recommended that end-users of these components check the suitability of their components to withstand lead-free processing.

7 BALL GRID ARRAYS

7.1 BALL GRID ARRAY BACKGROUND

A ball grid array device (as shown in Figure 14) contains a silicon chip wire bonded to a multilayer laminate (normally BT type) with tracks leading out to underside pads. The chip and bonds are then encapsulated and the device is 'bumped' with solder to provide solder balls for surface mount connection. 'Pop-corning' is a phenomenon associated with entrapped moisture when reflowing encapsulated devices e.g. BGAs. During heating residual water vapour tries to escape from within the package and causes cracks to open.

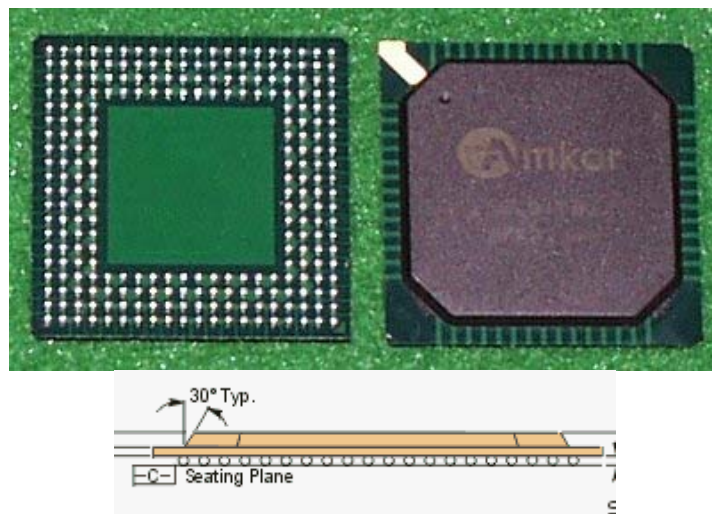


Figure 14. Plastic Ball Grid Array.

7.2 ISSUES WITH LEAD-FREE PROFILING OF BGAS

The overall height of a BGA device will decrease due to the reflowing of the solder bumps which collapse in their molten state, lowering the stand off to the laminate. This is to be expected. Otherwise, components should be dimensionally stable through lead-free reflow.

The ball grid array components, along with other types of high pin count devices have given rise to widespread concerns within the industry about internal delamination or pop-corning. Figure 15 shows a scanning acoustic microscope image of a BGA after lead-free processing. The red area indicates a region where the package has delaminated internally. The likelihood of pop-corning occurring will be increased with the higher temperatures and possible higher ramp rates associated with lead-free profiles. It is therefore recommended that normal storage procedures for moisture sensitive components are strictly followed to eliminate the possibility, i.e. components should be delivered in moisture barrier packaging and this should remain unopened until immediately prior to assembly.

The construction of BGAs may use plastics or interconnects that are not compatible with the higher temperature reflow. Manufacturers' maximum temperature exposures should be strictly followed, to eliminate or minimise any functional reliability concerns.

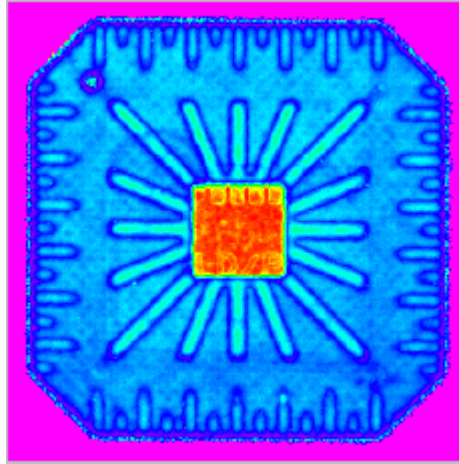


Figure 15 : Scanning Acoustic Microscope Image of BGA after Lead-free Processing

7.3 BGA RECOMMENDATIONS

High pin-count plastic packages such as BGAs are prone to delamination and pop-corning. This phenomenon is more likely to occur with the higher temperatures of lead-free reflow unless good storage and component handling procedures are strictly followed. Manufacturers' maximum temperature limits should be adhered to.

8 QUAD FLAT PACKS

8.1 QUAD FLAT PACK BACKGROUND

A quad flat pack (QFP) device (as shown in Figure 16) contains a silicon chip wire bonded to a copper leadframe. The chip and leadframe are then encapsulated in epoxy resin and the leads are formed into a gull-wing shape.

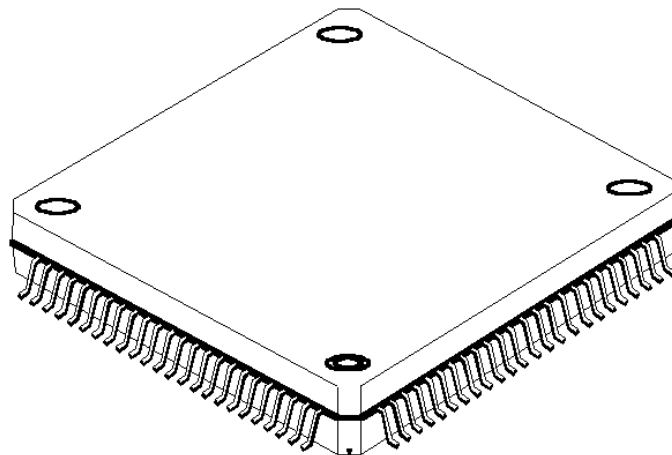


Figure 16 : Quad Flat Pack

8.2 ISSUES WITH LEAD-FREE PROFILING OF QFPS

During manufacture of assemblies for several projects, workers at NPL have noticed a problem with alignment of ultra fine pitch QFPs (0.4mm pitch). Before soldering of the devices, the components and substrates have an identical pitch as can be seen in Figure 17. This is also the case if the components and substrates are reflowed separately so that no joints are formed (also shown in Figure 17).

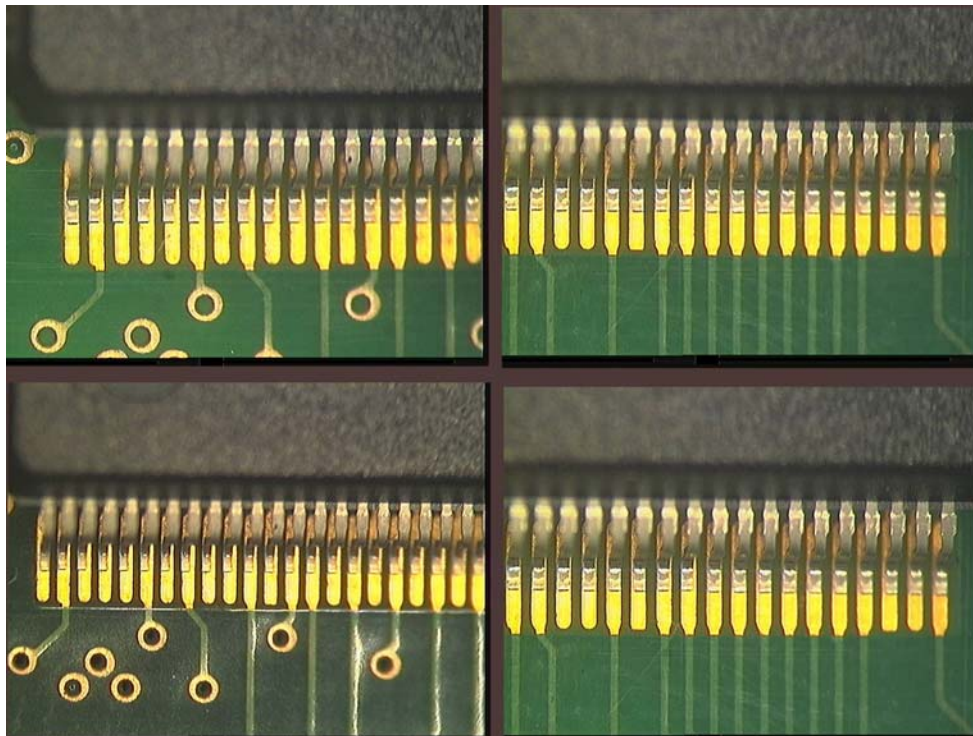


Figure 17 : Quad Flat Pack Alignment Before (top) and After (bottom) Passing Through Lead-free Profile Without Soldering

However, when the components and substrates are soldered together at lead-free temperatures, significant misalignment is noted. This misalignment is not identical for each lead down one side of the QFP but gets progressively worse from one end to the other, as can be seen in

Figure 18.

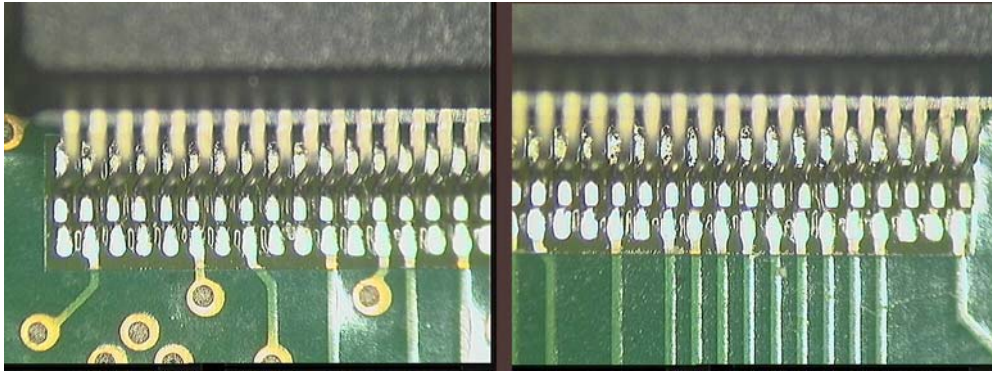


Figure 18 : Misalignment after Lead-free Soldering, Showing Opposite Misalignment at Both Ends of the Same Side

This problem is not experienced when the components are reflowed at the lower temperatures required for SnPb alloys. It is possible that at the higher temperatures required for lead-free processing, the thermal expansion coefficient mismatch between the component and the substrate is sufficient to cause the misalignment. When the structure solidifies at 217°C, this misalignment is “locked” into position. When SnPb solders are used at lower solidification temperatures, the mismatch is not so great. It may also be that the higher lead-free temperatures take the component above the glass transition temperature (T_g) of one of the constituents of the QFP or of the PCB, causing a much greater expansion than is normal below the T_g . The components used were dummy components from a major component packaging house and therefore, whilst it cannot be guaranteed that they are manufactured from typical materials, it is probably safe to assume that they are.

‘Pop-corning’ (the phenomenon associated with entrapped moisture expanding when devices are reflowed) is also an issue with QFPs.

8.3 QFP RECOMMENDATIONS

Ultra fine pitch components (0.5mm pitch and finer) may exhibit unacceptable misalignment during lead-free reflow. It is recommended that trials are performed on all ultra fine pitch devices prior to assembly to ensure they are compatible with the higher soldering temperatures.

High pin-count plastic packages such as QFPs are prone to pop-corning. This phenomenon is more likely to occur with the higher temperatures of lead-free reflow unless good storage and component handling procedures are strictly followed. Manufacturers’ maximum temperature limits should be followed.

9 FR4 EPOXY-GLASS LAMINATES

9.1 FR4 EPOXY-GLASS LAMINATE BACKGROUND

FR4 laminates are glass-fibre reinforced epoxy resins with typical glass transition temperatures, T_g , of around 140°C. They are the most commonly used substrates for surface mount assembly.

9.2 ISSUES WITH LEAD-FREE PROFILING OF FR4 EPOXY-GLASS LAMINATES

Although FR4 PCBs will expand more during lead-free profiles than SnPb profiles because of the higher temperatures reached, this should cause few problems and the PCBs will return to their original size when they cool to room temperature. However, reports have been received by NPL which indicate that thermal coefficient of expansion (TCE) mismatch between ultra fine pitch QFPs (0.4mm) and FR4 laminates during lead-free soldering, has caused problems with misalignment during reflow.

Additionally, during reflow, because of their relatively low glass transition temperature, FR4 materials can be prone to increased distortion if subjected to bending forces. These bending forces can be generated for example by uneven copper balance in multilayer PCBs, or edge only support of assemblies with a large mass of components. If these forces are present, then the degree of deflection will increase with increased reflow temperature. In trials conducted at NPL (reference 4), FR4 samples had the least resistance to bend and hence exhibited the greatest deflection - in general greater than five times that exhibited by the other three laminate types tested. A comparison with other laminate types is given in Figure 19.

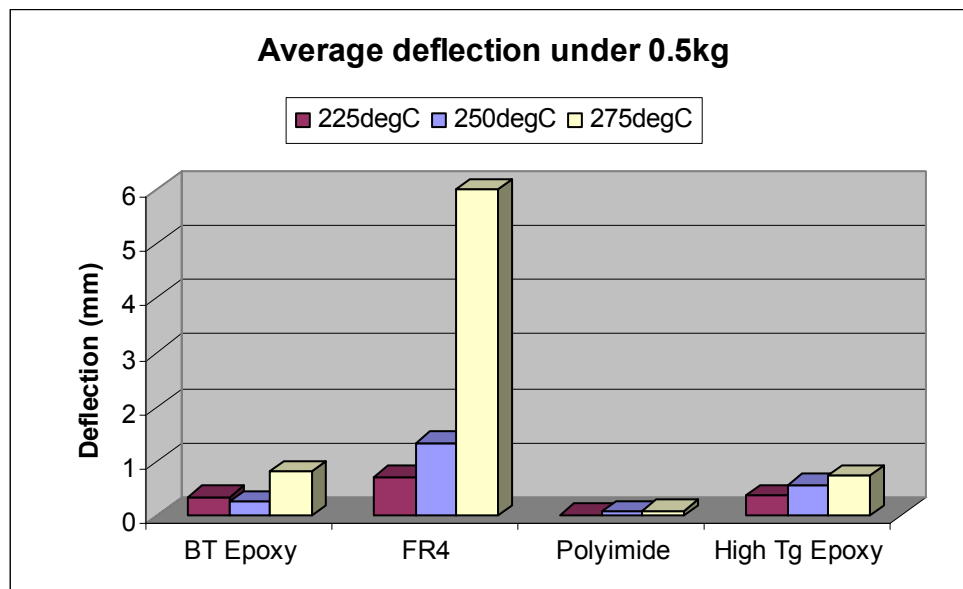


Figure 19 : Comparison of Deflection of PCB Laminate Materials Under Load at Elevated Temperatures

The increased temperatures of lead-free reflow profiling will not reduce the surface insulation resistance of FR4 based PCBs. Some darkening of the base laminate will occur but this is cosmetic only. If a multilayer assembly is susceptible to delamination, then this susceptibility will be increased with the higher temperatures and possible higher ramp rates associated with lead-free profiles. Susceptibility to delamination is a function of PCB lay-up design, exposure to moisture during storage, quality of manufacture, and reflow profiling ramp rates. Those designs with large uninterrupted power and ground planes may prove to be particularly prone. It is recommended that normal storage procedures for multilayer assemblies are adhered to, i.e. PCBs should be delivered in moisture proof packaging (shrink-wrap alone is generally insufficient) and this should remain unopened until immediately prior to assembly. Unprotected storage of sensitive multilayer PCB in uncontrolled environmental conditions should be avoided to prevent moisture take-up.

Choice of base laminate will have little effect on solderability but all laminate types will show reduced solderability after lead-free profiles compared to SnPb profiles. Thus any subsequent soldering operations undertaken on PCBs, which have previously been through a lead-free profile, may have a lower process yield than would normally be expected after the same operation using a SnPb profile.

9.3 FR4 EPOXY-GLASS LAMINATE RECOMMENDATIONS

FR4 can and is used successfully for lead-free assemblies. Caution is required when attempting to solder ultra fine pitch devices because of possible TCE mismatch above the solder melting point causing misalignment problems. Also bending forces should be avoided where possible during reflow if a planar assembly is subsequently desired. Prevention of moisture ingress into sensitive multilayer designs is prudent if PCBs are sensitive to delamination.

10 HIGH Tg EPOXY-GLASS LAMINATES

10.1 HIGH TG EPOXY-GLASS LAMINATE BACKGROUND

High Tg epoxy-glass laminates are similar to FR4 laminates but they have a higher glass transition temperature, typically in the range of 180°C. Some users report that laminates of this type can be more susceptible to thermal degradation as compromises may have been made with the resin systems to make these materials process in a similar fashion to FR4 (reference 5).

10.2 ISSUES WITH LEAD-FREE PROFILING OF HIGH TG EPOXY-GLASS LAMINATES

As with FR4, few problems should be experienced with dimensional stability with these laminate types. High Tg epoxy-glass laminates will show increased deflection when under load at increased reflow temperature, but should perform better than standard FR4 laminates. The increased temperatures of lead-free reflow profiling will not reduce the surface insulation resistance of high Tg epoxy-glass based PCBs.

If a multilayer PCB fabricated from high Tg epoxy-glass is susceptible to delamination, then this susceptibility will be increased with the higher temperatures and possible higher ramp rates associated with lead-free profiles. It is recommended that normal storage procedures for multilayer assemblies are adhered to, i.e. PCBs should be delivered in moisture proof packaging (shrink-wrap alone is generally insufficient) and this should remain unopened until immediately prior to assembly.

As with other types, high Tg epoxy-glass laminates will show reduced solderability after lead-free profiling compared to SnPb profiling. Thus any subsequent soldering operations undertaken on PCBs, which have previously been through a lead-free profile, will have a lower process yield than would normally be expected after the same operation using a SnPb profile.

10.3 HIGH TG EPOXY-GLASS LAMINATE RECOMMENDATIONS

High Tg epoxy-glass laminates can be used successfully for lead-free assemblies. Bending forces should be avoided during reflow if a flat assembly is subsequently desired although degree of bend after reflow, will be less than for FR4, under the same conditions. Prevention of moisture ingress into sensitive multilayer designs is prudent if PCBs are sensitive to delamination.

11 BT EPOXY-GLASS LAMINATES

11.1 BT EPOXY-GLASS LAMINATE BACKGROUND

BT epoxy-glass laminates use a blend of bismaleimide/triazine and epoxy resin to give enhanced thermal, mechanical and electrical performance over most epoxy materials. Such systems have high glass transition temperatures in the range 180 to 200°C.

10.2 ISSUES WITH LEAD-FREE PROFILING OF BT EPOXY-GLASS LAMINATES

As with previous laminates, few problems should be experienced with dimensional stability using BT Epoxy-glass laminates. These laminates will show increased deflection with increased reflow temperature, but should perform better than standard FR4 or High Tg epoxy-glass laminates. Trials at NPL have shown that BT epoxy laminates exhibited little change between the deflections at 225 and 250°C, but did show an increase in deflection at 275°C, indicating that the laminate would need to be used with care for lead-free soldering, particularly if the reflow profile is expected to be higher than that typically used for lead-free processing.

The increased temperatures of lead-free reflow profiling will not reduce the surface insulation resistance of BT epoxy-glass based PCBs. Susceptibility to delamination will be increased with the higher temperatures and possible higher ramp rates associated with lead-free profiles. As with all laminate types, it is recommended that normal storage procedures for multilayer assemblies are adhered to, i.e. PCBs should be delivered in moisture proof packaging (shrink-wrap alone is generally insufficient) and this should remain unopened until immediately prior to assembly.

As with other types, BT epoxy-glass laminates will show reduced solderability after lead-free profiles compared to SnPb profiles. Thus any subsequent soldering operations undertaken on PCBs, which have previously been through a lead-free profile, will have a lower process yield than would normally be expected after the same operation using a SnPb profile.

11.3 BT EPOXY-GLASS LAMINATE RECOMMENDATIONS

BT epoxy-glass laminates exhibit superior performance to both FR4 and high Tg epoxy-glass laminates for lead-free assemblies. Bending forces should still be avoided during reflow if a flat assembly is subsequently desired although degree of bend will be less after reflow than for the previously discussed laminate types. Prevention of moisture ingress into sensitive multilayer designs is prudent if PCBs are sensitive to delamination.

12 POLYIMIDE-GLASS LAMINATES

12.1 POLYIMIDE-GLASS LAMINATE BACKGROUND

Glass-fibre reinforced polyimide based laminates have glass transition temperatures around 260°C, giving greater thermal performance than BT-epoxy resin blend systems.

12.2 ISSUES WITH LEAD-FREE PROFILING OF POLYIMIDE-GLASS LAMINATES

Lead-free profiles should have little effect on polyimide-glass laminates. No changes in dimensions should be experienced and the high Tg of these laminates, means they are highly resistant to deformation during soldering. The increased temperatures of lead-free reflow profiling will not reduce the surface insulation resistance of polyimide-glass based PCBs.

The susceptibility of multilayers based on polyimide glass laminates to delamination will be increased with the higher temperatures and the possible higher ramp rates associated with lead-free profiles. As with all laminate types, it is recommended that normal storage procedures for multilayer assemblies are adhered to, i.e. PCBs should be delivered in moisture proof packaging (shrink-wrap alone is generally insufficient) and this should remain unopened until immediately prior to assembly.

As with other types, polyimide-glass laminates will show reduced solderability after lead-free profiles compared to SnPb profiles. Thus any subsequent soldering operations undertaken on PCBs, which have previously been through a lead-free profile, will have a lower process yield than would normally be expected after the same operation using a SnPb profile.

12.3 POLYIMIDE-GLASS LAMINATE RECOMMENDATIONS

Polyimide-glass laminates are an ideal choice for lead-free assemblies. Post reflow flatness should be maintained even through the hottest lead-free profiles. Prevention of moisture ingress into sensitive multilayer designs is prudent if PCBs are sensitive to delamination.

13 CONCLUSIONS

Suppliers are moving towards the manufacture of components that are compliant with lead-free soldering technologies, although currently many do not specify that their components will withstand typical lead-free temperature profiles. It is therefore prudent for the end-user to review the suitability of any components and laminates being considered for inclusion within a lead-free assembly. Little work has been undertaken to assess the long-term electrical reliability of devices after being subjected to lead-free temperature profiles, but this Code of Practice does indicate that a significant proportion of existing components are likely to survive the increased reflow temperatures. Indeed, some users have been using high temperature solders for PCB assemblies for a number of years and few reports of reliability issues have arisen from these sources.

However, some components and laminates do have limitations in their use with lead-free solders. The salient points highlighted in this Code of Practice are:

- Components are generally robust and compliant with lead-free processing, thus allaying some earlier concerns over component stability.
- Some components do exhibit significant damage as a result of the lead-free processing and give cause for concern i.e. both polyester and electrolytic capacitors, and this poor performance is attributed in part to their wound and laminated construction. Although the capacitance will remain within quoted tolerance levels, the loss tangent for these capacitors can degrade to values well outside the tolerance levels.
- Care should be taken not to darken LED casing materials due to overheating, which would reduce light emission levels.
- Issues of misalignment can occur with ultra fine pitch QFP after lead-free soldering, which do not occur with SnPb soldering.
- NPL studies have shown that temperature differentials across boards can be as much as 50°C. For large electronic products with a mixture of large and small components, or for those using smaller reflow ovens, overheating of components may be more likely, and good temperature control and profiling will be critical.
- The increased temperatures associated with lead-free soldering have little, or no, effect on dimensional stability or surface insulation resistance of the laminate.
- The higher glass transition temperature laminates exhibit better resistance to bend at higher temperatures.
- Low Tg laminates subjected to loading during lead-free reflow soldering may become warped. Such loading might arise from a variety of circumstances including uneven multilayer build, reflow of a heavily populated assembly when supported only in the four corners of the substrate, or reflow of a heavily populated assembly using an edge conveyor without additional central supports.

- Components and PCBs that are susceptible to moisture ingress and subsequent delamination are likely to have increased susceptibility during lead-free soldering due to the higher reflow temperatures and possible faster heating rates. Care should be taken to protect relevant components and PCBs by ensuring that they are delivered in suitable packaging (shrink-wrap is generally insufficient) and that they should remain in this protective packaging until immediately prior to the soldering operation.
- The solderability of the PCB pads is largely independent of laminate material, but will be dramatically influenced by subsequent heating cycles. The increased ageing associated with the lead-free profiling (compared with that of SnPb profiling) will cause a significant reduction in solderability of all laminates types. Thus if standard immersion gold finishes are used for lead-free assembly (where multiple profiling will occur – e.g. with double-sided soldering), then lower yields can be expected on the second side reflow compared with those currently achieved with SnPb double-sided soldering.
- The lower expected soldering yields after lead-free soldering operations, suggest that more aggressive fluxes or the use of nitrogen inerting might have to be used to maintain soldering yield.

14 ACKNOWLEDGEMENTS

The work was carried out as part of a project in the Materials Processing Metrology Programme of the UK Department of Trade and Industry.

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