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Lead-free compatibility

Introduction

Lead-free soldering is demanded after 1-6-2006. Today many companies are in the transition stage going from tin-lead solder to lead-free solder, however not all components are yet available with a lead-free lead finish.
Now the question raises: "What can be used for which process?"

Next a brief overview will be given with arguments why some mixes are allowed and others are not recommended.

All components with the exception of BGAs

Components with a lead-free finish can be used either in a tin-lead process or in a lead-free process.
In either process these components will give reliable joints and no contamination in the joint or solderpot.

Components with a tin-lead finish can be used in a tin-lead process but not always in a lead-free wave soldering process.
It depends on the necessary properties of the products to be manufactured if this process can be allowed.
The finish will dissolve in the joint, which means that part of the joint may contain lead as we solder tin-lead plated component leads with a lead-free solder. Lead contamination can degrade the mechanical properties of the joint. On the other hand part of the lead from the lead finish will dissolve in the solderpot and so contaminate the solder. The lead content in the lead-free solderpot should in general be $< 0.1\%$.

For reflow soldering the amount of solder is defined. This means that the mechanical properties of the finished solderjoint are also depending on the amount of alloying elements that are dissolved from the component metallisation finish. These properties may therefore be different for each specific joint.

Example:

Let us assume that a C 0805 component with a height of 1 mm has a 5 face surface metallisation with a metallisation cap length of 0.4 mm.
The total surface of this metallisation on one side of the component is than:
$1.25 \times 1 + 2 \times (1.25 + 1) \times 0.4 = 3.05\ mm^2$.

If we assume that the finish thickness on this cap is 4 microns of 50% tin and 50% lead, than the total lead volume that can be dissolved from this cap is:
$50\% \times 4 \times 10^{-3} \times 3.05 = 6.1 \times 10^{-3}\ mm^3$.

If we assume that the solderpaste will wet half of the cap surface, only half of that lead volume will be dissolved in the joint, which is $3.05 \times 10^{-3}\ mm^3$.

The lead-free solderpaste for this joint will be applied by screenprinting, using a screen of 0.2 mm thickness at a solderpad dimension of 1.3×1.4 mm.
If we assume that half of the screened paste volume will be solder, than the solder volume at this joint will be $50\% \times 1.3 \times 1.4 \times 0.2 = 0.182$ mm^3.

To this volume the dissolved plating layer of 3.05×10^{-3}mm^3 lead and 3.05×10^{-3} mm^3 tin must be added, so that the total solder volume will be 0.188 mm^3.

The lead content in this amount of solder is then 3.05×10^{-3} mm^3 / 0.188 mm^3 = 16×10^{-3}, which is 1.6% in volume. In weight this will be 11.34 / 7.3 times as much, which is about 2.5%.

Note: One has to realise that the 0.1% contamination level, according to the RoHS*, is based on homogenous materials. Purely looking to the joints this 2.5% is not allowed since it exceeds the RoHS tolerance limit.

BGAs

For BGAs the solderpaste formula for the reflow process must be equal to the alloy of the solderbumps. So if the bumps are made from tin-lead solder, a tin-lead solderpaste should be used. On the other hand, if the bumps are made from lead-free solder a lead-free solderpaste should be used.

The reason for this is that if a BGA with tin-lead solderbumps is soldered with a lead-free solderpaste, that in that case the bump will melt before the solderpaste is molten.
This melting bump will encapsulate the paste particles including the flux.
This encapsulated flux can hardly escape because as soon as the liquid solder makes contact with the solderbump, this bump will (partly) dissolve in the liquid solder and directly change the liquid behaviour of the solder into a pasty behaviour. This makes it almost impossible for the encapsulated flux to escape. As a result this encapsulated flux will create voids in the solderjoint. As long as not all solder in this joint has become completely liquid for a sufficient time, there is no way for the encapsulated flux to escape.

In the other case, when a BGA with lead-free solderbumps is soldered with tin-lead solder, this might also create voids in the solderjoint.
As soon as the paste starts to melt and wet the solderbump, the paste that was starting to get liquid will almost immediately become pasty as the solder from the bump will (partly) dissolve into the solderpaste. As the solder from the paste becomes pasty, there is no easy way for the encapsulated flux to escape. As a result this encapsulated flux will create voids in the solderjoint. As long as not all solder in this joint has become completely liquid for a sufficient time, there is no way for the encapsulated flux to escape.

Although BGA joints soldered in a mixed technology may create joints with a sufficient reliability for common use, one must realise that the long-term reliability or the reliability under thermal stress can be negatively affected.
When such joints are subjected to thermal cycling where different stresses are working on the joint, this mixed technology might not work too well.
All recent studies indicate a decreased joint performance when mixing tin-lead with lead-free.

Conclusion

Leadframe packages

- In most cases Sn-plating will be used as lead-free solderable coating
- For leadframe packages there is full compatibility to SnPb and Pb-free soldering processes

BGA packages

- For BGA packages SnAgCu solderbumps is the chosen technology
- On board reliability is proven for lead-free soldering processes
- The soldering temperature has to be above 230°C for processability

* = RoHS Restriction of Hazardous Substances in Electrical and Electronic Equipment