Vitronics Soltec

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The case of poor hole filling with lead-free soldering

Introduction

When the solder process is converted to lead-free often one find some or more joints that does not give a complete hole-fill. In the past when these boards were soldered with the common tin-lead alloys this seems never to be such a serious problem. Only in case of a bad process setting, e.g. lack of flux, these problems could occasionally occur. Now with lead-free solder these problems seems to be part of the process, since they can not be reduced even with optimal settings. In fact that is often exactly the case as will be explained.

The real differences in tin-lead and lead-free soldering

The main problem with lead-free soldering is that the solder solidification temperature is rather high, commonly 217°C for SAC-alloys or with Sn100C alloy even 221°C, so our process window has become rather small.
In lead-free soldering the topside of the joint must at least come to a temperature of 217°C or 221°C to get good hole-fill, while for SnPb37 this temperature was only 183°C. That is really the bottleneck in lead-free soldering.

These minimum temperatures are necessary since below these temperatures the solder is not liquid anymore. Only liquid solder can fill capillaries providing the solderability of these capillary surfaces is good.
A good solderability is a prerequisite for the solderprocess since the process itself can never compensate for poor solderability.
As we talk about solderability not only the solderability of the surfaces involved should be mentioned. Also the so-called thermal solderability must fit the process. It is here that lead-free solder asks for higher demands.

Can the process compensate for these higher thermal demands?

In fact for this case there are three possibilities to play with the process settings. These options are: a higher preheat temperature, a longer dwell time in the solder and/or a higher solder temperature.

If a higher preheat temperature is allowed for the flux and the board, this option should be used first. Every degree temperature rise that is put in via the preheat has not to be delivered by the solderwave. The total thermal demand for the soldering process is just an addition of the preheat temperature and the temperature that is put in by the solderwave. So a higher preheat temperature assists the process. One has however to keep in mind that this will in general offer no solution for solder joints with massive heatsink parts on the component side. Such joints gave also problems with tin-lead soldering.

There are two reasons why longer dwell times are often not the best solution. The first reason is that as soon as the solder is 'starving' in the hole, it improves directly the heat conductivity to the surrounding area and the lead or component to which the lead is connected. This means that the heat will drain off rather fast from the joint to that surrounding area. Once the solder is solidifying one has to put again the lost melting heat energy into the joint to get the solder liquid again.

This turns out to be almost a mission impossible. That is why longer dwell times are often not the best solution.

The second reason why longer dwell times may not help is that the flux may be exhausted due to this longer dwell time, resulting in hampered solder flow and more bridging or even webbing and spikes.

A higher temperature will give a faster heat transfer. This might be a good option, provided that the flux is able to handle this. Often with this possible solution the flux is again the weak link.

With these solutions one is often faced with a side effect that creates a serious drawback. Due to the higher thermal load during the solder process the mechanical tension on the copper barrel in the PTH may become so high that the barrel can crack. Often this is also the result of poor plating quality.
Via this cracked barrel vapours coming from the base material will escape via the solder joint, crating blowholes or craters.

How to provide a good solution?

As became clear, although we have some options in the soldering process, there are also serious restrictions, which can not be prevented by the process. We need the co-operation of the flux suppliers for these new challenges we have to meet.

In fact lead-free soldering needs often a redesign of the joint in view of the new thermal demands for the formation of the solderjoints. Methods to measure that are basically described in 'Soldering in Electronics' Chapter 3.4. Although most users are not pleased with this solution, it is in fact the only way to improve the solder joint quality.

One has to keep in mind that the process can never compensate for poor solderability, whether this comes from unsolderable surfaces or from a poor thermal design, or from a combination of both.
Now with lead-free soldering the design needs a review on these aspects, especially on the thermal solderability. That is up to the designer of the board and he should face that reality. Remember 217°C, or 221°C versus 183°C can make a world of difference.
The process engineers know that, next they have to make the board designers aware of that.