Vitronics Soltec

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Joint solderability demands for lead-free wave soldering

Introduction

With the introduction of lead-free wave soldering we are often faced with a hole fill that is not as good as when tin-lead solder was used.
There is no simple panaceas to improve the hole fill of joints that were already designed "at the edges" for the tin-lead wave soldering process.
For such joints a new design, based on this new thermal demands, is necessary.

Solder melting points

In case of using lead-free solders we are faced with the fact that we use solder with a much higher melting point than the common tin-lead solder. The melting point of tin-lead solders starts with 183°C for the eutectic solder composition Sn63Pb37. For the Sn60Pb40 composition there is a melting range of about 6°C, so that it is fully molten at 189°C.
So with a solderpot temperature of 250°C the common tin-lead solders give room for a good process window. This 250°C is a common soldering temperature for wave soldering using tin-lead solder. This gives a thermal process window of about 60 - 65°C.

With lead-free solders the picture is not so straight. There are a lot of different lead-free solder alloys, having common melting points from 217°C up to 221°C. This means that a small shift in the solder composition will create a melting range. This again will increase the temperature where the alloy is fully molten.
On the other hand the solderpot temperature is for such processes commonly restricted to 260°C - 265°C to prevent the risk of thermal damage for the components. But also not to exhaust the flux too much as this will give more solderbridging.
This gives a thermal process window of about 40 - 45°C. Not only this window is considerably smaller. The fact that the process runs at higher temperatures makes it also more critical.

The importance of the process window

We must realise that only molten solder is able to fill a solder joint.
Next to that we must know that during the solderprocess the solder in the joint area is dropping in temperature since the solder in the joint has to heat up the joint area to the liquidus temperature of the solder. This area contains the lead, solderpads and hole wall, which has initially a much lower temperature.
In the joint area only the solder amount that is in the joint is able to transfer the heat to all joint parts involved.

If the temperature of the solder alloy that is in contact with the joint area drops below the melting temperature further wetting will definitely stop.

For a good solder quality and hole fill we have to deal with the following contradiction:
For good hole penetration of a liquid we need a small gap (capillary). Due to its small dimensions this gap contains just a small amount of solder.
On the other hand we need for a good heat transfer a relative high solder volume in the joint area to keep the solder molten during the soldering process.

Keep in mind that we start the wetting process with molten solder. During the wetting process when the solder will wick up in the capillary gap, the solder will drop in temperature. This is due to the fact that the board and the components act as a heatsink, because they have a (much) lower temperature than the solder. This lower temperature is certainly true for the relative cool topside of a board. But also the innerlayers of a multilayer board that are connected to a hole barrel will act as an effective heatsink during soldering. That is the reason that the solder will in that case solidify somewhere in the joint, unable to fill it completely.
A longer dwell time will not help once the solder is "starved" (solidified) in the joint.
We can only get a full hole fill when the topside of the joint has been at least at the melting temperature of the solder during the solder process. Only in that case the solder can wick up to the topside of the joint.
To get a good holefill during soldering, not only the surface solderability must be perfect, but also the thermal layout of the joint must make it possible to get the solder liquid until the hole is completely filled.

Joint design

A good joint design in relation to the solder process parameters needs calculations on models. A good example of basic thermal calculations can be found in the book Soldering in Electronics Second Edition from R.J. Klein Wassink, Chapter 3.3.
Such calculations must however also include the thermal design aspects of the board with its inner-layers. This can make these calculations rather complex. The outcome of such calculations might give insight that certain joints are unable to be filled completely, given the process restrictions as described in Fig. 3.16 from that book chapter.

Surface solderability

Separate from the thermal aspect there is the aspect of surface solderability.
If the surface solderability is insufficient on either the board or the component lead, no good solder wetting can take place even when the thermal joint design is perfect.

In a lot of cases this aspect is neglected, whereas often wave soldering is an operation that follows after a reflow process.
After a reflow process, the surface solderability of the original board might however considerably be deteriorated. Using nitrogen during reflow might reduce this deterioration.

Keep in mind that the solderprocess needs a certain level of solderability to make good joints. If that level is not met for the board and the components, one has to realise that the solder process can not compensate for this lack of solderability.

Only active fluxes might be able to compensate for some loss of surface solderability. Since that is often not a viable option in view of the behaviour of the flux residues, one has to assure that the solderability level is in accordance with the process needs. This is an absolute demand to obtain a good solder quality.

The demands for solderability are well described in the book Soldering in Electronics chapter 7. Although the levels are defined for tin-lead solder, the described methods are still viable once adopted for the melting temperature of the lead-free solder that is used in the process.

For the latest information and updates on lead-free solderability test requirements we refer to the IPC