Selective Soldering Defects and How to Prevent Them

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Introduction

Two major issues affecting the soldering process today are the conversion to lead-free soldering and miniaturization. Miniaturization means, among other things, more SMD components on the printed circuit board. With regard to the soldering techniques that are used to make the solder joints, this includes more reflow applications. The through-hole components on the assembly should be automatically soldered to ensure optimum quality. The way to make these connections will depend on the number of joints to be soldered, but for most products, selective soldering will be the best alternative to wave soldering in pallets or hand soldering.

This soldering technique can be very successful, but is also sensitive to some typical defects. The high melting points of the lead-free solders and the fact that the solder is only supplied locally require high operating temperatures that increase the risk for some specific defects, including the following:

- Fillet lifting
- Solder stringing
- Solder bridging
- Solder balling
- Copper pad dissolution.

The high temperatures create a challenge for the flux. Too little flux will result in solder defects, whereas too much flux will leave residues that may result in electro-migration. This paper will discuss these typical defects and describe how to optimize the process parameters in order to prevent them.

Fillet lifting

Pad lifting, fillet lifting and fillet tearing are effects resulting in part from the differences in thermal expansion coefficients of the PCB base material, the epoxy/glass FR-4 laminate, and the copper barrels and copper tracks on the PCB.

During contact with the solder, there is a relatively large thermal expansion of the board material in the Z-direction. This expansion causes a deformation of the joint pad, giving a conical shape to the pad. This is because epoxy has a much larger coefficient of expansion than the copper hole-wall metallization. Even after the joint has passed the select wave or dipped into the solder of the nozzle, board expansion continues because much of the solidification heat has been transmitted to the adjacent board material.

After the board has left the solder, thermal migration from the solder device to the connection ceases and the connection begins to cool to ambient. During this phase, the solidification heat will spread to the joint area (see Figure 1), contributing to additional temperature rise for all parts in or near the joint. Once all of the solidification energy has been emitted, the joint begins to ramp down to ambient. When the joint begins to solidify, the board material cools down and returns to its original planar shape. This movement will introduce considerable stress to the surface of the solder joint, which is still very weak at this stage. This stress may cause pad lifting; or, if the adhesion between pad and board is at that point stronger than the solder, it can cause cracks in the solder surface, known as fillet tearing.

Fillet lifting is described in IPC-A-610D 5.2.10. Separation of the bottom of the solder from the top of the land on the primary side (solder side) of the plated through-hole connection is acceptable.

In general, it is difficult to eliminate this defect. Improvements can be made by selecting a proper board material with a smaller z-expansion coefficient, reduce the pad size on the secondary side of the plated-through-hole, or print the solder resist over the pad.

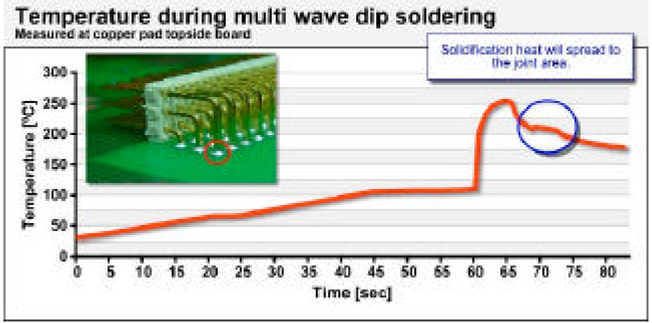

Figure 1: During this phase, the solidification heat will spread to the joint area, contributing to further temperature rise of all parts in or near the joint.

Solder stringing

The next defect issue focuses on the optimization of the multi-wave soldering process in relation with reducing solder stringing. Stringing refers to the solder residues that can be found just outside the nozzle area, having a contour related to the nozzle rim. These residues are basically the result of solder webbing. The strings contain solder particles with different shapes, thin solder oxide webs and solder balls in different dimension but mostly very small. Solder stringing around the multi-wave nozzles can be eliminated with the correct setting of the flux amount and the full coverage of the nozzle area with flux. Solder resist without flux in solder will cause solder stringing.

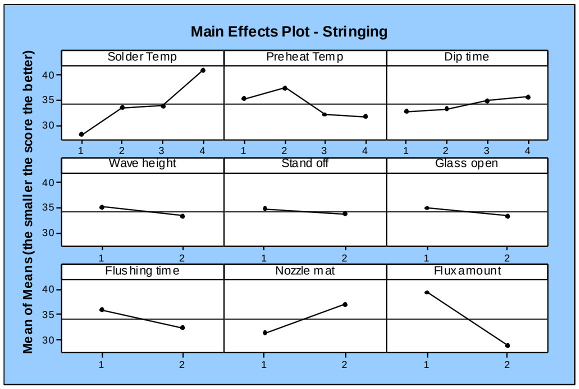

Figure 2: Impact of parameters on solder stringing. Only solder temperature (the lower the better) and flux amount (more flux is better) have a significant impact.

A large Taguchi experiment (L16 with 9 different parameters) was run to define the parameters that affect solder stringing. Only the solder temperature and flux amount were found to have high impact. In the event of solder stringing, one should try to optimize the fluxing program. It is better to have more flux at the edges of the nozzle rim and to reduce solder temperature. For SnPb, the solder temperature was reduced to 260 ºC for this product. This temperature was still high enough to achieve sufficient through-hole filling.

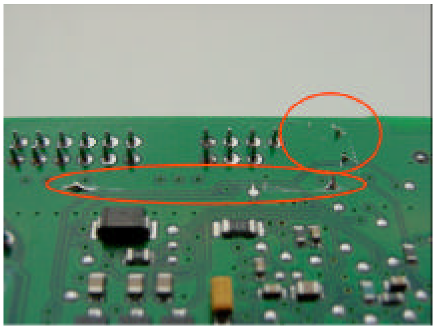

Figure 3: Solder stringing; solder residues can be found just around the nozzle area.

Solder bridging

Solder bridging in select, wave (drag), and multi-wave (dip) processes are different phenomena. In a drag process, a stable solder flow is critical. The solder should flow in the opposite direction from that of the assembly. Once the solder begins to flow to the back side (along with the direction of the board), bridges will begin to appear. A hot nitrogen air knife will force the solder to flow in the opposite direction and eliminate bridging.

If the solder begins to flow along the leads, as in Figure 4 the point where the pins leave the solder, it will shift away from the nozzle. At that point, the solder will cool down and solidify, resulting in a bridge. Horizontal soldering will reduce the potential for this unstable solder flow.

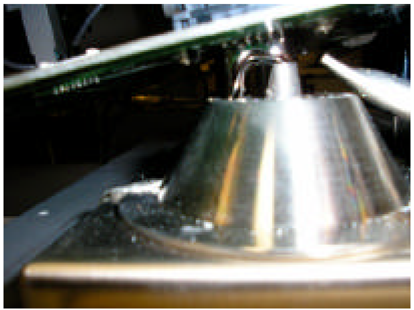

Figure 4: Unstable solder flow. The lead-free solder tends to flow along the leads away from the nozzle.

In a dip process, bridging can be avoided through the use of a proper design. Short lead length, small pads, and wider pitch between the pins will reduce the potential for bridging. A Taguchi experiment shows the impact of machine parameters. A flux amount of 10 mg/cm² or higher with a low solder temperature is the best combination. Again, this experiment shows that the preheat temperature has little or no impact on selective soldering if the boards don't have a high thermal mass. A short dip time with a slow deceleration of the solder produces the highest yields.

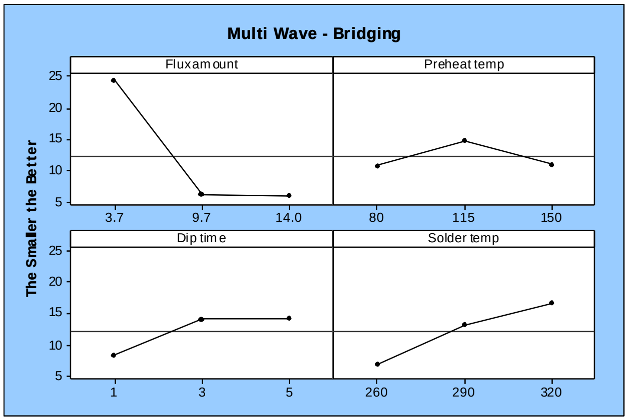

Figure 5: The results of a L9 Taguchi showing the different parameters and their response to bridging on a multi wave.

Solder balling

Solder balling is mainly the result of higher temperatures and a solder resist that becomes stickier. Also, one flux may be more prone to produce solder balls than another. In a dip soldering process, solder balls are often found between the pins, such as may be seen in Figure 6 where a solder bridge is shown with solder balls surrounding it.

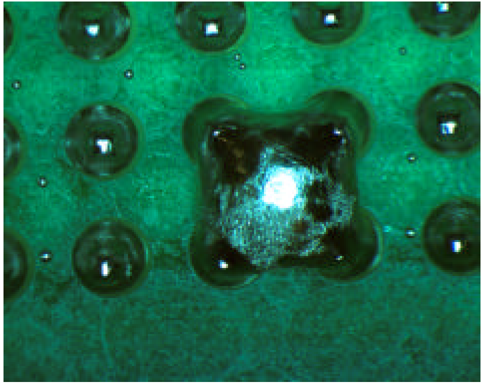

Figure 6: A bridge between four pins with a large number of solder balls in the soldering area.

Copper pad dissolution

There is a risk that the copper may dissolve into the solder due mainly to the high solder temperatures. Since lead-free solders contain a much higher tin content, at these high temperatures, the dissolution rate of copper from the board material also increases dramatically. On a select wave, where the solder joints are formed by flowing solder, it is more of a critical issue than in a dip process. Excessively long contact times (robot speed of 1 mm/sec or slower) and high solder temperatures (>300 ºC) makes the risk higher. Therefore, it is not recommended to solder the assembly a second time. This phenomenon is also seen in rework applications.

Apart from selecting the right machine settings, a thicker copper layer is also preferred, and also for this reason, the copper content in the solder should be monitored every two months to be sure that the maximum content of 1% is not exceeded; otherwise solder joint reliability may be compromised.

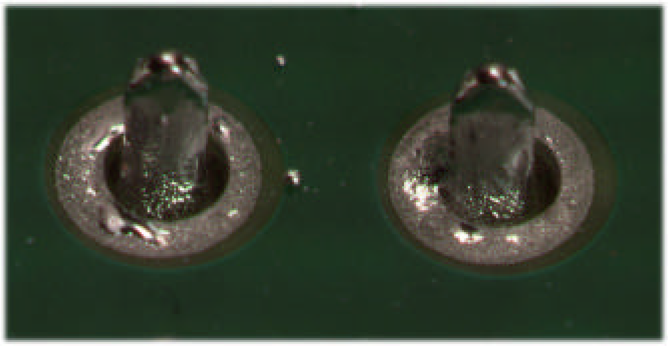

Figure 7: All the copper on the pad of this assembly has become dissolved into the solder during drag soldering at a temperature of 320 ºC.

Summary

Selective soldering can be very successful if the right parameters are selected. As with other soldering processes, the transition to lead-free makes it more challenging due to the higher required temperatures. The primary benefit of the selective soldering process is its flexibility, which makes optimization possible for every component. If necessary, one is able to apply more flux, or dip longer, for every specific component that have wetting problems, without overheating or damaging surrounded components.

Reference:

1. The physics of critical failure mechanisms, G. Schouten, EPP.