Vitronics Soltec

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Formation of intermetallic crystals in lead-free wavesoldering

Introduction

The formation of intermetallics in solder during soldering is a normal process. The fact that these intermetallics are seldom found in tin-lead solder is due to the low rate at which these crysals are formed when tin-lead solders are used.
In lead-free solders these crystals grow much faster and as a result they can often be found in the solderpot.

Intermetallic crystal formation

As solder comes in contact with wettable metal, some of that metal dissolves into the solder, and at the surface of the wettable metal an intermetallic layer is formed.
Each wettable metal can to a certain level be completely dissolved in the solder and will not form an intermetallic below that level. This level depends on the solder alloy, the solder temperature and the metal that is involved. E.g. for copper this level is about 0.3% at 250°C for eutectic tin-lead solder. At higher solder temperatures this level increases, while at lower temperatures it decreases.

If more metal is dissolved in the solder beyond the solubility level, this excess wil form an intermetallic with the tin in the solder. These intermetallics of copper-tin or iron-tin as the most common intermetallics form a hard needle shaped crystal. These small diameter crystals that can have a length up to several milimeters will make the solder more sluggish when they come in the solder flow.
Most of these crystals will however collect in the corners of the solderpot where there is almost no solderflow. In such areas lumps of solder with a high amount of these intermetallics can be found in due time. These lumps are pasty or even almost solid at normal solder temperatures and they should be removed at regular intervals. They can also often be found near the pump area.

If these lumps that present the main part of the contamination are removed at regular intervals, it is not necessary to chance the whole solder content from the solderpot. The frequency of this maintenace has to be proved by checking the quality of the solderjoints. As long as the solder process quality is not affected a slight contamination by intermetallics in the solder is allowed.
Note that the solder in the pot is continuously refreshed by the addition of new solder to compensate for the solder consumption from the solderpot. Therefore it is in most cases not necessary, nor recommended, to drain the solderpot and replace the content with new solder.

Effect of lead-free solder

Due to the fact that in lead-free wavesoldering processes higher process temperatures are demanded, the formation of intermetallic crystals is more dominant than in standard tin-lead soldering processes.
Also the fact that the tin concentration is higher adds to the faster dissolution of metals like copper and iron that are in contact with the molten solder. This is due to the fact that tin is the alloying element. In tin-lead solder the lead does not form an alloy with copper or iron at normal process temperatures. The dissolution process is also affected by the presence of silver in SAC-alloys. The silver seems to make the solder more 'corrosive' in relation to the metals that are wetted by the solder.

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Effect of intermetallics on the process

If the lumps of solder/intermetallics are not removed in time, these crystals will be picked up by the solder flow in the pot. Next these crystals can come on the wave surface and so be disposed on the PCB and cause bridging between joints.
Removing the contaminated lumps and topping up the solderbath with fresh solder will eliminate this effect sufficiently in most cases.
A seeving action or stirring the solder in the pot slightly with a perforated ladle, picking up the floating crystals, will remove even more of the intermetallic remains. This is recommended if too much crystals are present in the solder flow. The effect of this will increase when the solderpot temperature is lowered before this action.

Since most of the intermetallics will be collected in the 'dead' area's, they do not have a direct effect on the process. As long as they are not growing too large in volume and are not part of the solderflow these contaminated solderlumps will stay were they are and do not have a detrimental effect on the process.
Only if these crystals come in the solderwave they can affect the process.

Effect on the wear of solderpot materials

Notice that the cause for the crystal formation can not always be avoided as long as solder can come in contact with wettable parts from the pot.
The dissolution rate is at normal process temperatures up to 260°C still so low, that there is no risk for the solderpot material within the 5 years warranty time, based on 8 hours shift per day. Only inserts that are in direct contact with the relative high solderflow speed may wear out in due time if they are not protected with a resistant coating. These effects will however not give a safety issue. If innerparts are affected or not can be checked at inspection during the regular maintenance intervals.

Note that even stainless steel will be affected by lead-free solders if not protected with a wear resistant coating.