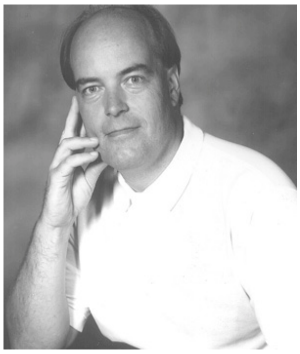
Lead-free Wave Soldering Process Issues



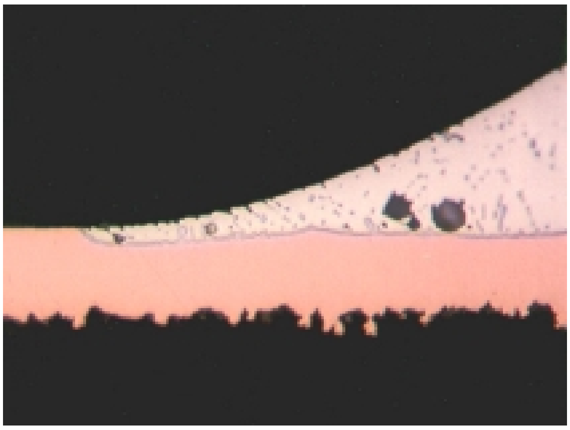
Bob Willis

Wave soldering is the main assembly process which will be impacted by a change to lead-free alloys. Now, with the signing of the WEEE directive in Europe, it is inevitable that lead-free is on the way and every engineer needs to consider the implications to his process. Another option is for design engineers to focus on reflow and phase out wave soldering, something which is unlikely to happen in many companies.

Examples of some of the wave soldering process issues that engineers need to consider are listed here:

Increased solder shorts
Solder fillet lifting/pad lifting/joint tearing
Increased board sagging
Wave solder bath/ducting erosion
Better topside temperature control
Potential copper track erosion

In this article we will concentrate on one issue, copper erosion of surface tracking on the printed board in contact with the wave. To date this issue has had little attention but potentially when looking at the following image some engineers may have concerns. Example microsections have been shown in international seminars and discussed in technical forums but no details on the process used have been issued.



Example microsection produced as part of the evaluation showing copper erosion on the copper track. (IDEALS Lead Free Project)

When this issue was first discussed with other engineers a few months back very few people had observed the phenomena. In fact, a review of all the author's previously produced microsections showed little evidence of the problem. During a review of many of the lead-free sections produced by National Physical Laboratory (NPL) no significant evidence of erosion could be found.

It is fair to say that increased copper dissolution into the solder wave was considered inevitable due to increased wave soldering temperatures and high tin contents in alternative alloys. Concerns were expressed at the impact of high copper levels but this really relates to our experience with tin/lead alloys. Copper is the main contaminant found during normal production; it does impact the soldering yield by increasing solder shorts. Higher copper levels do make a difference to the visual appearance of the joint. However, it has never been shown to impact on joint reliability. With lead-free copper it is already part of the alloy, between 0.5 - 0.7% added to the mix, as it is a cheap filler metal.

To examine the possibility of copper erosion during wave soldering a short trial was conducted with three different printed board surface finishes:

OSP on copper
Gold over nickel
Silver

The boards were standard 1.6mm FR4 laminate with plated through hole and photo imagable solder resist. The hole size was 0.9mm after plating, one row of holes was used for assessment with one hole linked to an exposed track. In addition, two parallel tracks exposed for soldering were examined. Half of the track length was covered with Kapton tape to protect the surface from soldering, the aim being to solder part of the tracks. This allowed comparison of the original copper thickness on each board and the remaining copper thickness after soldering.

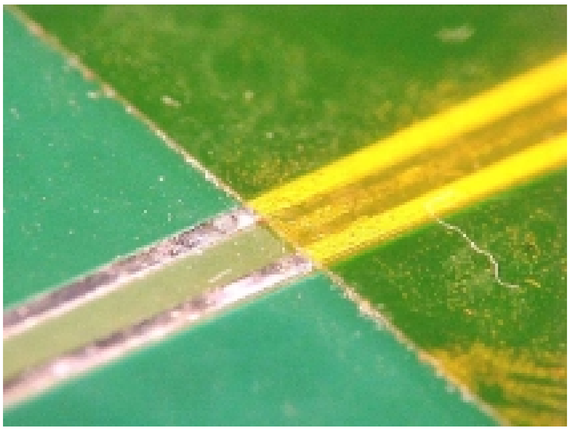


Figure shows one test area with two parallel tracks with Kapton tape applied

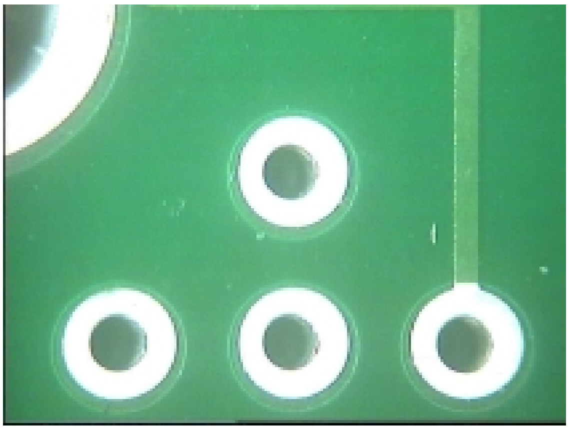


Figure shows through hole with track connection point used for examination.

The through hole component used in the study was a 96-way PCB edge connector supplied by Harting Connectors. The connector pin featured a lead measuring 0.75 x 0.75mm with a tin plated finish. The use of the multi-leaded connector allows the continued investigation of fillet lifting phenomena which appears more frequently in through hole joints; this has been previously discussed in a number of articles.

A total of six boards were provided for soldering trials, two of each of the different PCB solder finish. The gold boards were included in the trial for completeness, however, the soldering and copper erosion would not be any issue with this finish as the underlayer of nickel would protect the copper. Dissolution of nickel is much slower than copper during soldering. The boards were wave soldered by:

Tin-Technology - Soldertec, England
Electrovert, USA
Nicon Superior, Japan

The solder alloys used in these trials featured

tin/silver/copper - Sn 3.8Ag 0.7 Cu Multicore
tin/silver/copper - Sn96.5 Ag3.0 Cu0.5 Alpha Metals
tin/nickel - Sn 0.7Cu Ni Nihon Superior Co Ltd
Tin/copper Sn97.3 Cu0.7

The parameters used in the trials were approximately the same. Ideally, for a trail of this type, a common set of parameters is used with one machine. However, engineers now understand trying to run trials and change alloys in one machine is not a simple or inexpensive task. The three companies were kind enough to process the sample boards and return them for examination. The tin/copper samples were processed as part of a previous trail but on the same sample board design.

England

Flux	Multicore X33-081
Conveyor speed	1m/min
Wave temperature	260^{o}C
Pre-heat	120^{o}C topside
Contact time	4 sec approximately
Machine	Seho

Japan

Flux	Tamura EC 19S8
Conveyor speed	1m/min
Wave temperature	255^{o}C
Pre-heat	130^{o}C PTH board temperature
Conveyor Angle	4.75^{o}
Contact time	4.5 sec approximately
Machine	Electrovert

USA

Flux	Alpha 330
Conveyor speed	1.2m/min
Wave temperature	260^{o}C
Pre-heat Vectra Heat	120 & 150^{o}C
Contact time	5 sec approximately
Machine	Electrovert

Figure shows one termination point with track connection to the pad after soldering.

Samples from each of the boards were taken for microsectioning, sections were produced by the author and Multicore Solders. The Surface Electron Microscope SEM images were conducted at ROHM Electronics.

The quality of the soldering with each of the sample batches was similar with some evidence of bulbous joints and shorts. The boards produced in the USA featured poor through hole fill which was most likely related to the flux penetration into the through holes. The soldering quality of the bottom side of the board and the wetting to the through hole and lead section was satisfactory. The solderability was not in question as all the boards were from the same batches which were processed in Japan and England.

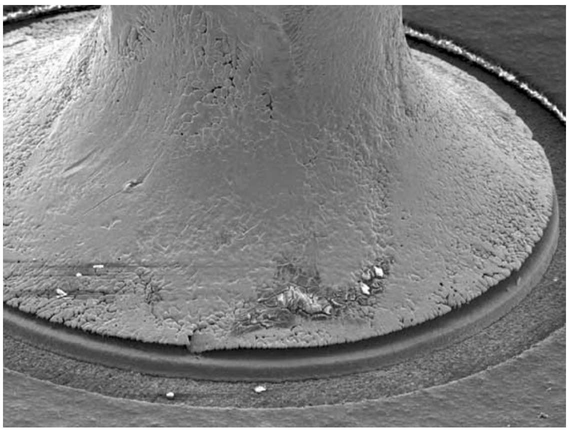


Figure shows the fillet lifting on the topside of the joint

Figure 6 shows evidence of fillet tearing

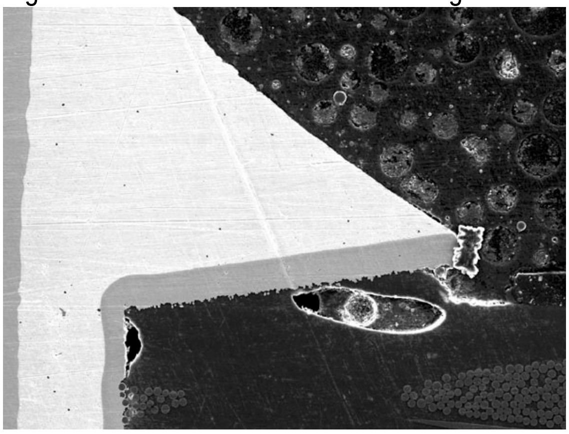


Figure shows pad lifting from the surface of the laminate on a microsection

Microsection examination showed evidence of the same three fillet issues seen during visual inspection, the fillet phenomena has been discussed in detail in other articles. The soldering quality to the plated through hole and pins were all found to be satisfactory.

Environmental trials have been conducted on joints with fillet lifting and pad lifting by NPL during another lead-free project. The testing on boards involved temperature cycling between +125/-55^{o} for over 2000 cycles. There was no evidence of solder joint failure on any of the samples tested. More recently testing has been covered in a report published by Epson Electronics on lead-free assembly. One section also looked at lead-free joints featuring fillet lifting and pad lift. Testing by Epson engineering staff demonstrated that again failure of joints did not occur even with these defects.

During the SMART Group Lead-free trip to Japan the issue of fillet lifting was discussed. Most companies were of the opinion that it did not have an impact on reliability. Only evidence of pad lifting was considered an issue as it could, in theory, lead to breaking of inter-connecting tracks. To date the author has not seen any evidence of this from any source.

Although examples of copper erosion have been highlighted in the industry there is little evidence to date of this being an issue. In the case of single sided boards the apparent erosion may have been due to preparation of the copper for OSP treatment. In this case copper is mildly etched, excessive prep may have removed more copper around the pads as other areas of the tracking would be protected by the solder mask. Where mechanical cleaning is used and incorrectly controlled the copper can be reduced around the hole leading to a apparent copper reduction. Further investigation of the problem and the examples circulated in the industry will be further reviewed and where appropriate further trials conducted.

It is interesting to note that the defects highlighted have not been shown to cause failures. At first examination we would consider them all rejectable based on our existing knowledge of tin/lead joints. That knowledge is again not necessarily based on failures but the inspection criteria for solder joints in circulation today. Perhaps we do need to re-look at some of the visual criteria we use in industry for lead-free?

Bob Willis has been running Hands-On Lead-free Assembly and Soldering Workshops for the last five years. He produced the **"Lead-free Assembly & Soldering Cook Book 3"** interactive CD-ROM with the National Physical Laboratory NPL and can assist companies implement process change. Contact Bob via email bob@bobwillis.co.uk or visit his web site www.bobwillis.co.uk

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