CYBEROPTICS®

Inspecting the Lead Free Solder Process

By Andy Yates, Brook Jackson, Paul Haugen

The increasing adoption of lead-free soldering in to the SMT process is possibly the greatest challenge the industry has seen. The switch involves fundamental physical and chemical changes to the process. This not only applies to the assembly process, but also to the inspection process.

In selecting an alternative to the Sn63-Pb27 solder widely used today, the five most important metrics are:

- Melting temperature
- Wetting ability
- Electrical conductivity
- Thermal conductivity
- Mechanical integrity

Each of the proposed substitute alloys that meet the physical requirements listed above add significant complexity to every stage of the SMT process and therefore increase the risk of defects. Reworking lead-free assemblies is further complicated by the higher melting points of solder (and the associated risk of component damage) so timely identification and repair of defects is an essential strategy.

Due to the reduced surface tension of lead-free solders, the component placement tolerance has tightened meaning that during reflow, there is less "pull" back to the pads. This requires that placement accuracy be better than ever before. Identifying potential defects before an assembly is reflowed is arguably the most economical strategy (cheaper and easier rework) and allows the deployment of effective statistical process control.

The reflow process is the most affected by the adoption of lead-free solders. Of the alloys proposed to replace Sn-Pb, each has a somewhat different melting temperature and significantly different wetting angle.

Early lead-free solders contained Bismuth, Zinc and other metals to try to reduce the melting point of the alloys, but these were found to increase defect rates due to weak mechanical joints. There is some evidence that the higher melting point and associated change in reflow profile can result in solder voids if the thermal cycling isn't exactly correct (the ramp up and ramp down need to be optimized).

Wetting angles depend on many factors, including the alloy, the size of the pads, the thickness of the boards and the reflow oven or wave. The combination of changed wetting angles and different reflow profiles will have a significant impact on the appearance of a lead-free joint when compared to its leaded counterpart. In addition, lead-free solder will have a different surface texture therefore will not be as reflective (typically appearing more white than silver).

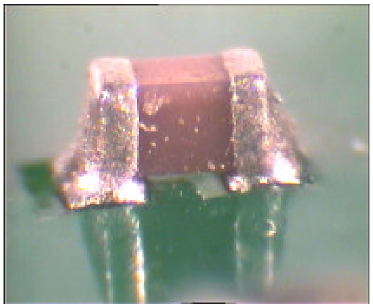

Figure 1: A reflowed 0201 with Sn-Ag-Cu solder.

All of the changes in physical and chemical properties mean adding uncertainties to a process that can sometimes seem like its bordering on physical limits. Adding automatic optical inspection to a lead-free process can significantly increase yields by the timely identification of defects.

Historically, conventional automatic optical inspection systems have been engineered to use complicated lighting from multiple angles with multiple cameras to try to understand and characterize the complicated reflectivity and specular nature of light on a solder joint. These have been designed with the first generation vision methodology.

1st and 2nd Generation Vision

Early vision engineers had limited processing power and mostly sub-optimal images with which to work. In order to cope with these limitations, complex lighting and mechanical assemblies were designed so as to achieve the best signal to noise ratio image and algorithms used to perform image analysis. The enemy of first generation vision systems was variation. In order to ensure adequate performance the vision scientist had to predict as many legitimate variations of a particular feature or component as he could and manipulate algorithms to tolerate those predictions. This approach has some fundamental flaws in that it relies on the vision scientist's ability to predict variations and then on his skills with particular algorithms to translate those variations into a parameterized space.

Solder joint inspection systems that are based upon these first and second generation vision processing techniques have been carefully created to examine shiny solder joints and have their creator's predictions of what a good solder joint can look like. Users and programmers of these systems have some scope for modifying the complex parameters that make up algorithm-based vision but again need to be aware of any variations that they may encounter. With the emergence of lead-free solders, conventional image processing is being further challenged since the visual aspects of what constitutes a good solder joint have changed.

3rd Generation Vision

CyberOptics Statistical Appearance Modeling (SAM) was originally developed to analyze soft-tissue medical images. Conventional vision techniques could not cope with the non-geometrically constrained nature of medical images and the variation in their appearance. Rather than have the user of the SAM predict how something can vary in its appearance, SAM takes a representative sample of good examples and *automatically* calculates how much variation is permissible.

Since SAM is not constrained by geometrical definitions, it can model virtually any visually repeatable object from lead-free solder joints to hand-inserted components to screw heads, making it ideal for post-placement, post-reflow, post-wave or final assembly inspection.

Summary

With tighter process tolerances and smaller and smaller passive device usage, anyone considering switching to a lead free process should consider the deployment of AOI in order to characterize the process as it is developed.