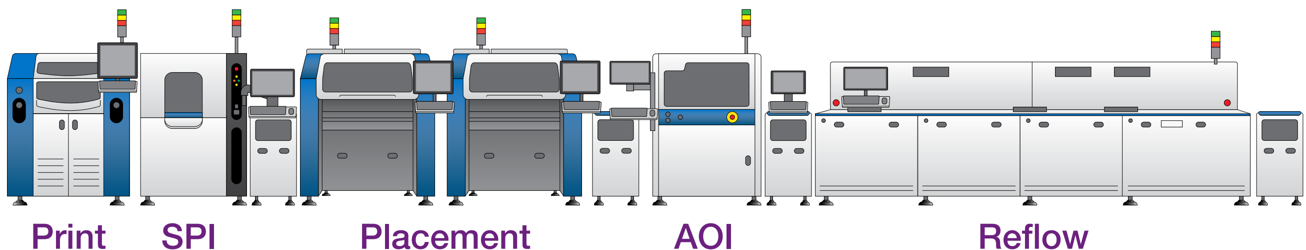
What's going on during reflow?

Application Note



The Heated Stage Reflow Simulator for the Quadra® X-ray Inspection Systems is an extremely powerful tool. Watching in real-time provides a new perspective on defect formation and inspection.

Heated Stage Reflow Simulator

It is a high priority of SMT manufacturers to minimize solder defects. Doing this requires an understanding of the conditions by which reflow can go wrong. By gaining this insight, one can greatly improve the quality of products manufactured. X-ray inspection has provided great insight, pre and post reflow. The Heated Stage provides yet further insight to understand defect formation during reflow, by seeing it as it happens.

Figure 1 : Heated Stage Reflow Simulator inside Quadra X-ray Inspection System.

Head-In-Pillow

One of the most commonly looked for defects is Head-In-Pillow or HIP. Often seen in Ball Grid Array (BGA) device connections post reflow, where the BGA ball and solder paste on the PCB pad do not form a cohesive joint.

Figure 2: Optical image of a HIP defect.

Pre-reflow factors that can cause HIP include insufficient paste, bad placement, contamination/oxidization (during handling or storage) and BGA ball and solder paste alloy differences. During reflow, board/component warpage, poor wetting and co-planarity issues can also create this problem. Of course, ill chosen temperature profiles can exacerbate these conditions further.

Figures 3, 4 and 5 are X-ray images showing HIP forming in real-time. Figure 3 shows a BGA after placement but before heating. The solder begins to reflow at 230°C as shown in Figure 4. Figure 5 shows the HIP defect fully formed and clearly different from the other connections.

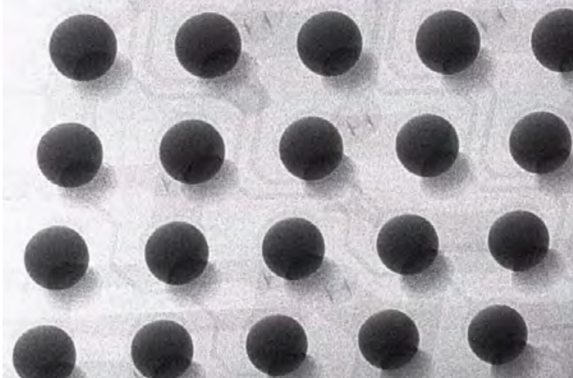


Figure 3: X-ray image from the Heated Stage before reflow. BGA placed on solder paste deposits.

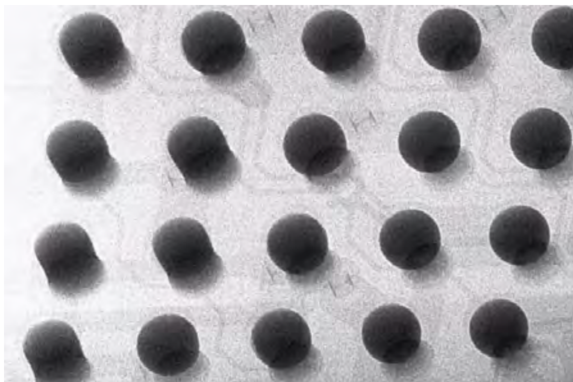


Figure 4: X-ray image from the Heated Stage. Reflow begins on outer connections first at around 230°C .

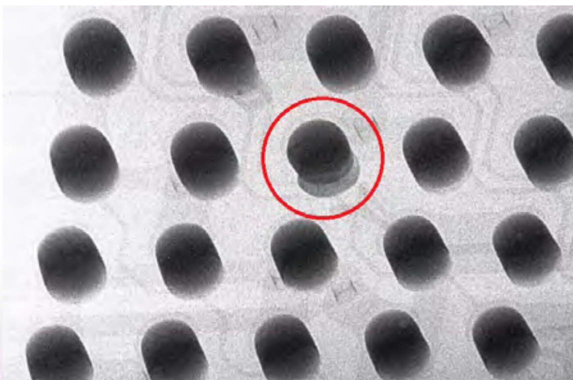


Figure 5: X-ray image from the Heated Stage showing HIP defect forming.

Underfill is not always your friend

There are ever increasing demands on portable electronics for greater functionality, higher reliability and mechanical toughness. OEMs are looking for solutions for better heat distribution and impact resistance for components like BGA. One such solution is underfill.

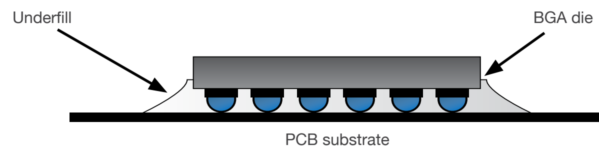


Figure 6: Underfill placement beneath BGA.

Underfill is a liquid or polymer sometimes applied to a corner or one edge of the component. The PCB and component are heated to between 125°C and 165°C. Capillary action then draws it under the device and encapsulates the connections. Once cured, underfill will minimize the expansion differences of materials so device and PCB are held together more firmly. This reduces working life stresses on the roots of the solder balls.

Should one of these high value products fail to meet quality control, usually it will be reworked. This can lead to components with underfill, near the rework area, being subjected to reflow temperatures for a second time. Under these conditions the underfill will hold the device and PCB together as designed. But now this property can be potentially harmful. What happens is revealed in real-time using the Heated Stage (Figures 7 to 9).

The following example illustrates the typical behaviour of BGAs with cured underfill that are exposed to elevated temperatures during PCB rework. The device in question is mounted in the Heated Stage and the temperature is increased. The solder joints are monitored in real-time on the X-ray system screen. The video of the process is also recorded. When the temperature reaches 230°C the solder connections start to deform and expand.

However, due to the cured underfill, there is not enough flex in the device/PCB assembly to compensate for the expanding solder, Thus resulting in solder being squeezed out, growing solder beads around the device, solder bridging and solder joints that are severely compromised (Figure 8). In some extreme cases the BGA balls simply explode (Figure 9).

The Heated Stage provides critical insight into the processes during reflow. In this case, great care needs to be taken when reworking PCBs with underfill.

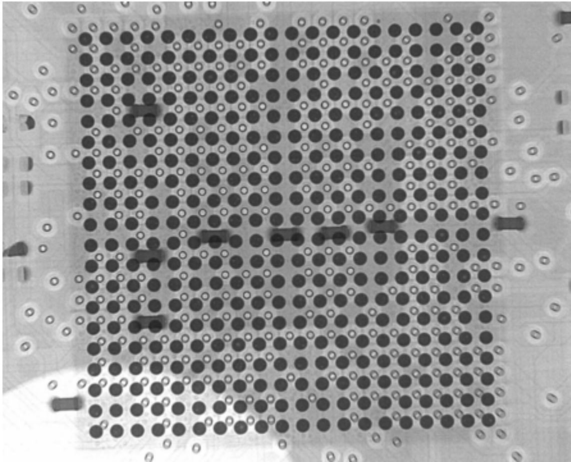


Figure 7: X-ray image from the Heated Stage. BGA with underfill before second reflow.

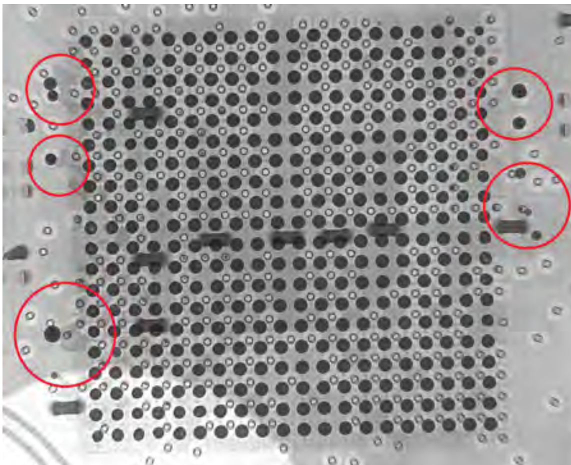


Figure 8: X-ray image from the Heated Stage. Liquidus temperature is reached. Solder is seen to be leeching out away from the device.

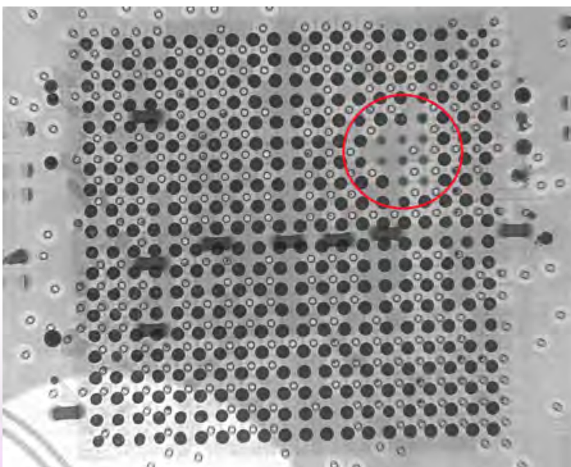


Figure 9: X-ray image from the Heated Stage. As the heat continues to rise eight connections explode.

Bond wire delamination

Some defects are impossible to see during the inspection stage at the end of the production process. This can mean that a product may have failed tests but with no clear answer as to why.

In the following example one such case is investigated (Figures 10 to 12).

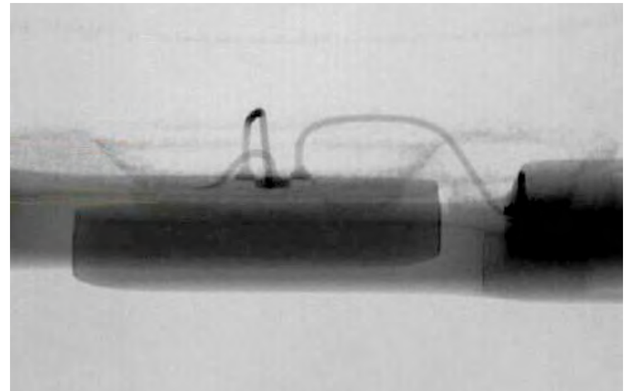


Figure 10: X-ray image from the Heated Stage. Side view of a small LED, showing the bond wires connected to the die surface before applying heat.

It was known that this type of LED failed to work post-reflow but the exact failure mode was not confirmed.

A fresh device was mounted in the Heated Stage and the effects of the reflow temperatures on the LED, were investigated in real-time.

At around 195°C one of the bond wires has become lifted (Figure 11). Critically this has happened before the solder connecting it to the PCB has reflowed.

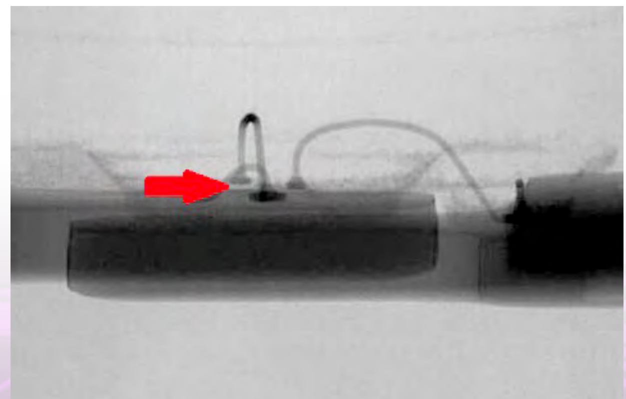


Figure 11: X-ray image from the Heated Stage. Bond wire showing clear separation from the die surface, around 195°C.

During cooling the bond wire goes back onto the surface of the die (Figure 12). This explains why the open defect could not be detected post reflow.

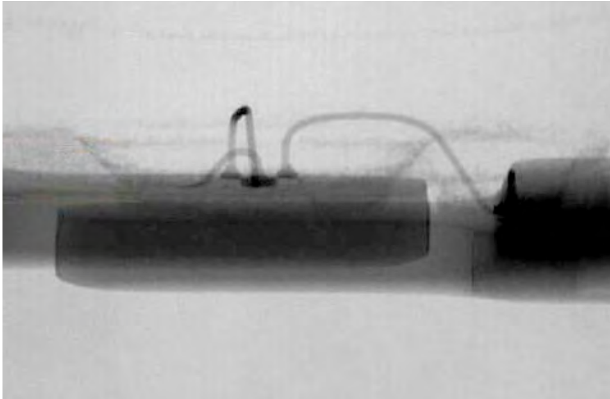


Figure 12: X-ray image from the Heated Stage. Bond wire showing no signs of defect post cooling.

In summary, the Heated Stage Simulator provides critical and unique capability for detecting bond wire lifting in LEDs during reflow.

A link to the real-time videos for each of these case studies is provided in the 'Where can I find out more' section below.

Where can I find out more?

1. Videos available via the QR code link.
2. Heated Stage Reflow Simulator Inspection Option Data Sheet.

Figure 2 courtesy of Bob Willis 2014

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