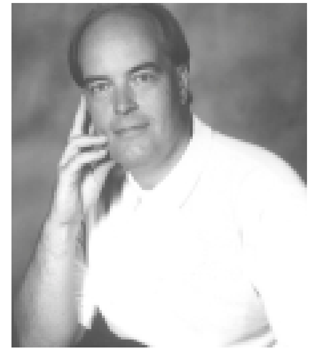
Testing Solder Joint Failures Using Dye Penetration



Bob Willis Process Guides

Today the most common methods of inspecting solder joints on Ball Grid Array (BGA), Chip Scale Package (CSP) or Flip Chip is X-ray or side view inspection using a fiber optic system. Each has its advantages and disadvantages but a combination of both is ideal provided you can justify both pieces of process equipment.

One area which is still difficult to detect is the subtle open circuit caused by wetting problems on the pad surfaces or flex of the BGA or printed board. Wetting problems are more common than some people think. This is particularly true on nickel/gold finished boards. In this case the gold is dissolved into the solder during reflow as the solder wets across the pad surface but a joint can fail to form between the base nickel. This type of defect is difficult, if not impossible, to detect with either of the traditional inspection techniques.

Movement and flexure of the BGA or board can occur due to warpage during reflow. BGAs with fiber glass substrates can distort causing the edges of the BGA to lift. The same thing can occur with parts if they "popcorn" during reflow or rework and the balls are no longer parallel with the surface of the board. Moisture can expand in the BGA during reflow; it escapes between the substrate and the plastic moulding of the BGA again causing distortion of the part.

If joints are partly soldered or intermittent this will affect the electrical performance of the chip, either its speed or performance will be altered. This type of subtle fault is very difficult to detect. Open or intermittent faults are again difficult to pinpoint on any area array packages after environmental testing. It is common to inspect joints before and after temperature cycling or mechanical flexure or vibration. The type of fault being discussed is very difficult to pinpoint hence the interest in dye penetrant testing.

Dye penetrants have been used for many years for a variety of applications, the most common being the testing of welded joints and castings prior to destructive analysis. They have also been used in surface coatings to detect minor imperfections. In the case of BGA, CSP and flip chip it is simple to mechanically break or flex the component from the board and check where the joint may have failed. The dye however provides a much better indicator of where complete or partial fractures may have taken place before the component is removed from the board. The surface of the joints can then be examined for dye penetration.

How to test BGA, CSP and Flip Chip Joints

Select the component to be tested; depending on the size of the board assembly the board may need to be cut down prior to test. The area being examined will be destroyed after dye application so cutting up the sample in advance is not a real issue. The size of the pressure vessel or the amount of dye waster may be another issue to consider.

The board or section of board should be cleaned in a suitable cleaning fluid. The idea is to remove any flux residues from around the array terminations. Flux residues around the pads or on the surface of the balls will reduce the possibility of the dye penetrating into any cracks. Depending on which cleaning fluid is used, water or solvent systems, the sample may need to be dried prior to testing.

After cleaning the flux residues the board section is placed in the dye prior to placing the sample in a sealed container. A small vacuum pump is used to remove air in the sealed container to assist the penetration process. The same technique is often used when microsectioning components and printed boards to help eliminate air being trapped. The sample should be left under the dye until any bubbles escaping virtually stop. The sample should be left a further 1-2 mins before taking the sample out of the chamber and leaving it to dry out in an oven at 50-60°C. As an alternative the sample can be cleaned in appropriate cleaning solvent prior to drying it out. This cleans up the surface around the terminations without removing the dye that has penetrated the cracks. It provides a better contrast when taking photographs as shown in the examples.

When the dye has dried the BGA, CSP or flip chip device can be removed from the board surface. Ideally it should be lifted from the surface of the board to reduce the damage to the ball terminations. A very small screwdriver can be used for standard BGAs with a standoff. Flip chip and CSP parts are often better flexed from the surface of the board. This can be done on BGA parts as well but often requires a lot of force.

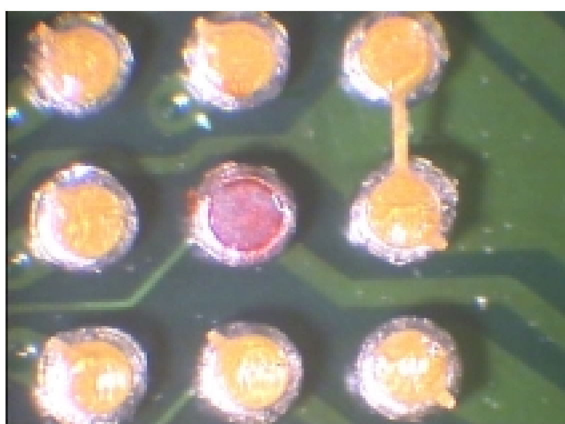


Figure 1. Example of BGA after the part has been removed from the board surface. Dye on the base of the ball to pad interface is clearly visible.

One technique, used for removing the smaller parts by Universal Instruments, reference 1 is flexing the board sample in a twisting action. Each side of the board is held with a pair of snipe nose pliers and flexed. This is ideal for CSPs and flip chips as a screwdriver often cracks the component rather than taking it off in one piece.

When the component under examination has been removed from the surface of the board you should be able to see the solder termination areas and any dye penetration into cracks or intermittent joints. Some dye systems benefit from the use of UV light which can make inspection easier but not if the dye on the surrounding area has been left on, or the surface being tested is particularly rough.

There is no standard or reference for this test method, it is purely a failure analysis technique or comparative testing procedure. Samples that have been found to be faulty may be tested and compared with parts that have been through environmental testing for the degree of cracking that may have occurred.

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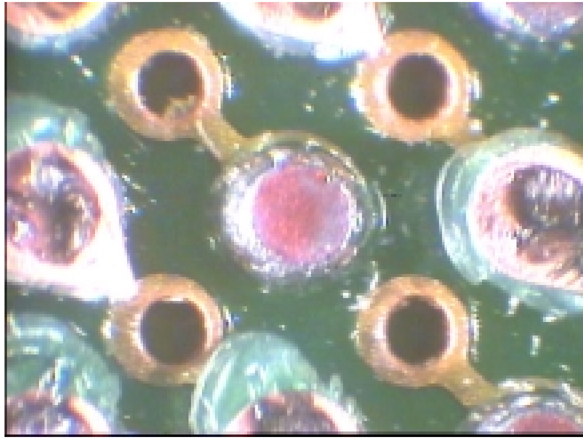

Figure 2 The second example of partial joint separation after dye testing. The dye is not visible across the complete surface of the ball.

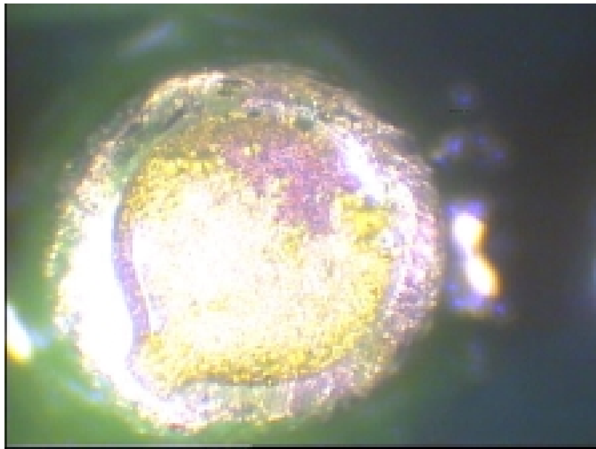

Figure 3 Dye visible across a section of the die

For further information on testing and failure analysis and process optimisation of area array solder joints contact Bob Willis via his web site **www.bobwillis.co.uk** for other examples of solder joint or component failure.

Bob produced the worlds first interactive CD-ROM on BGA Assembly and Soldering as well as training videos on X-ray Inspection and BGA Design and Assembly. His company also provides on site training and X-ray inspection wall charts for use in manufacture and assembly areas.

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