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**Measuring the Reliability of
Technology Demonstrator
Manufactured with Isotropic
Electrically Conductive
Adhesives**

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Measuring the Reliability of Technology Demonstrator Manufactured with Isotropic Electrically Conductive Adhesives

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ABSTRACT

Electrically conductive adhesives are attracting interest as a possible replacement for solder in the assembly of some electronics equipment. Previous work had demonstrated assembly reliability on test assemblies, and investigated the effects of ageing regimes, component and PCB termination materials. In this phase of the work, a technology demonstrator – a currently offered commercial product (fire detector) – has been manufactured using ICA materials. Subsequently, these assemblies have been subjected to damp heat stressing to ascertain the likely field performance, which has been benchmarked against that of a conventionally soldered system.

Whilst the reliability of the circuits assembled using the two ICA materials did not mirror that of the soldered circuits, their performance was encouraging, and certainly warrants further study. By optimising materials choice and process development, the CAs could find viable applications as a lead-free solder replacement. One ICA material produced joints whose reliability was close to that of the soldered joints - all the assemblies survived 1000 hours at 85%RH/85°C, although two circuits required reworking of SOT23 components.

Processing yield issues were experienced using the two ICA materials, associated with the formation of shorts under some R0603 components. However, the fact that these were restricted to one component type and three specific locations, strongly suggests that they could be eliminated by normal process optimisation techniques. Components with few leads and small bond areas (e.g. SOT23) would benefit from additional mechanical support to improve their tolerance of mechanical handling.

The work has confirmed the suitability of using damp heat testing as a tool for assessing the reliability of joints made using ICA materials.

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1 INTRODUCTION

Tin-lead solder has been used as the primary interconnection material by the electronics production industry for over 60 years. The introduction of European legislation in 2006 will force industry to change, by requiring the removal of lead from the solders used in the manufacture of a wide range of electronics goods. Replacement lead-free solder alloys are now available but they generally have a higher melting point than the alloys that they replace. This is expected to cause a number of end-user problems in the assembly of temperature sensitive components such as liquid crystal displays, electrolytic capacitors and optoelectronics. Electrically conductive adhesives might provide many users with an acceptable alternative to solder for the assembly of these types of components.

The restrictions on the use of lead in solders will also cause problems for those who use solder alloys which melt at different temperatures, in sequential soldering operations. There are very few higher melting point alloys, which do not contain lead. However, electrically conductive adhesives could be used for initial soldering operations as they will not melt during later lead-free soldering. Indeed, conductive adhesives (CAs) are used extensively for component die-attach materials, which are subsequently soldered to electronic assemblies. CAs could also be used for the lower fabrication temperatures with lead-free solders being used for the initial operations.

Although many electrically conductive adhesives have been available for some time, the industry has perceived them as materials having low reliability, low mechanical strength and relatively high cost compared to solder. However, with the introduction of lead-free soldering, these materials have become more attractive.

Previous work in this project, has demonstrated assembly reliability on test assemblies, and investigated the effects of ageing regimes, component and PCB termination materials, as well as the effect of bond area on reliability (References 1, 2 and 3). In this final phase of the project, an assembly design in current production by a UK fire detector manufacturer was assembled using two electrically conductive adhesives, and the assemblies and joints subjected to damp heat stressing to determine the likely field performance. As a benchmark control, SnPb-soldered assemblies were also tested.

2 METHODOLOGY

2.1 TEST VEHICLE DESIGN AND DETAILS

The demonstrator circuit chosen was a commercial temperature sensor from a fire alarm system. A populated assembly is shown in Figure 1. The assembly utilises a range of common surface mount components including chip resistors, chip capacitors, diodes and SOTs, all of which had lead-free terminations finishes. The PCB was manufactured from double-sided FR4 laminate 1.6 mm thick. The surface finish used was immersion gold on electroless nickel (ENIG).

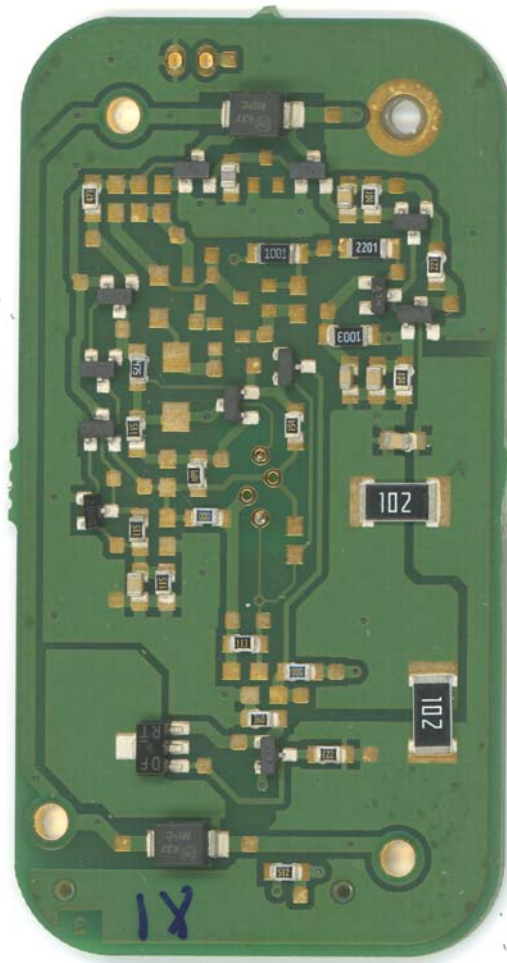


Figure 1 : Example of demonstrator substrate

2.2 STENCIL DESIGN

Earlier results from this project (Reference 1) indicated that chip component reliability was satisfactory with the conductive adhesive printed on the inner half of the component lands. For the gull-wing components, a full land print was utilised to overcome any variations in component lead bend. These are illustrated in Figure 2 and Figure 3. The stencil thickness used was 75 μm .

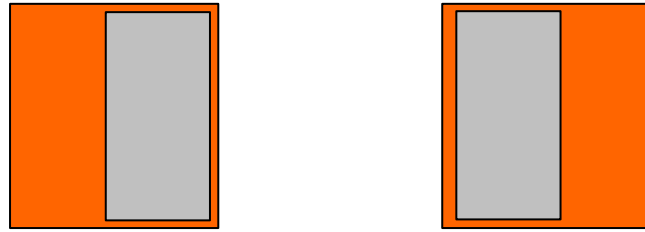


Figure 2. Chip resistor ICA stencil pattern

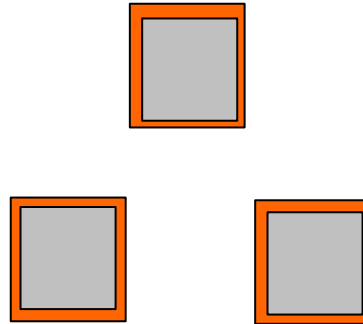


Figure 3. SOT and diodes ICA stencil patterns

2.3 ISOTROPIC CONDUCTIVE ADHESIVE DETAILS

Experimental work was undertaken using two isotropic conductive adhesives. These adhesives were both single component, silver-loaded epoxy adhesives requiring storage at -40°C to prevent cross-linking in the adhesives prior to assembly. Both materials were chosen as being suitable for curing in a reflow profile.

2.4 TEST VEHICLE ASSEMBLY

The assembly of the circuits followed normal surface mount assembly practices. Circuits were assembled as a panel of ten substrates. The conductive adhesives were applied to the PCBs in the same fashion as solder paste, using stencil printing through $75\text{ }\mu\text{m}$ stainless steel laser-cut stencil. Normal 60° metal squeegees were utilised. After stencil printing, the components were placed using an automatic placement system. Both materials were cured in a 5-zone reflow oven using a modified SnPb reflow profile. This material was cured for 5 minutes at 150°C . As a comparison, Apollo Fire Detectors circuits were assembled using SnPb solder and their normal manufacturing processes.

2.5 STRESS SCREENING REGIMES

After manufacture, groups of assemblies were subjected to damp heat ageing at $85^{\circ}\text{C}/85\%\text{RH}$ for 1000 hours. This regime was found in phase 1 of this project (Reference 2) to be most effective at increasing joint resistances.

2.6 ELECTRICAL CONTINUITY MONITORING

To determine the functionality of the circuits during stress screening, the thermistor in the original circuit was removed. During the periodic testing, where the circuits were removed from the stress-screening chamber, a decade resistance box was introduced in place of the thermistor, and the resistance required to trip the alarm was measured at room temperature. Circuits were considered functional if the trip resistance was within 10% of the as-manufactured resistance.

3 RESULTS

3.1 MANUFACTURING YIELD

Twenty assemblies were built using each of the two ICA materials. Yield problems were associated with both materials.

For material X, 47% of circuits passed first-time electrical test - 90% of the failures were due to shorts under R0603 components.

For material Y, 50% of circuits passed first-time electrical test. Shorts under R0603 components were again the main cause of failures (50%), with another 12.5% associated with component misplacement.

3.2 VISUAL APPEARANCE OF JOINTS

The visual appearance of typical joints formed, are presented in Figure 4.

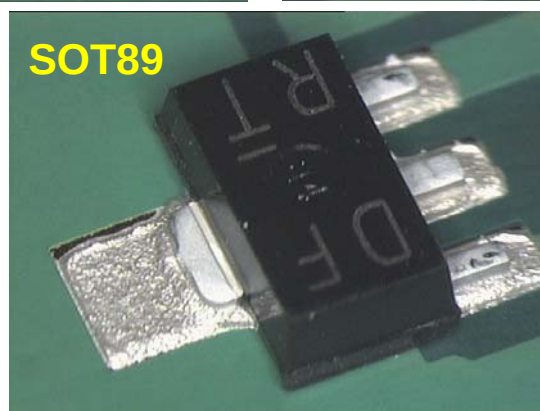
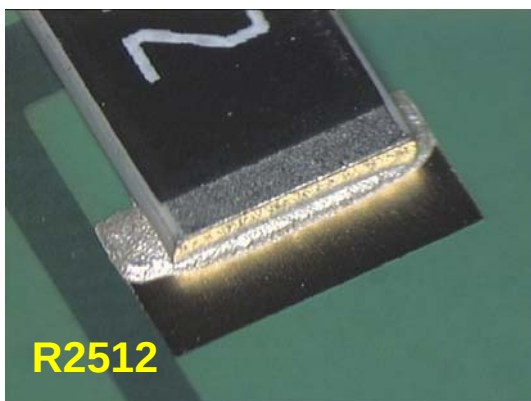
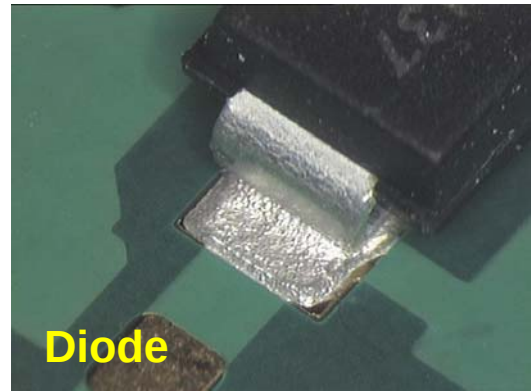


Figure 4. Typical joints

3.3 ELECTRICAL TEST RESULTS

The results on the resistances required to trigger the alarm circuit for the two conductive materials measured periodically after stress screening, are shown in Figures 5 and 6. Corresponding results for the soldered circuits are shown in Figure 7.

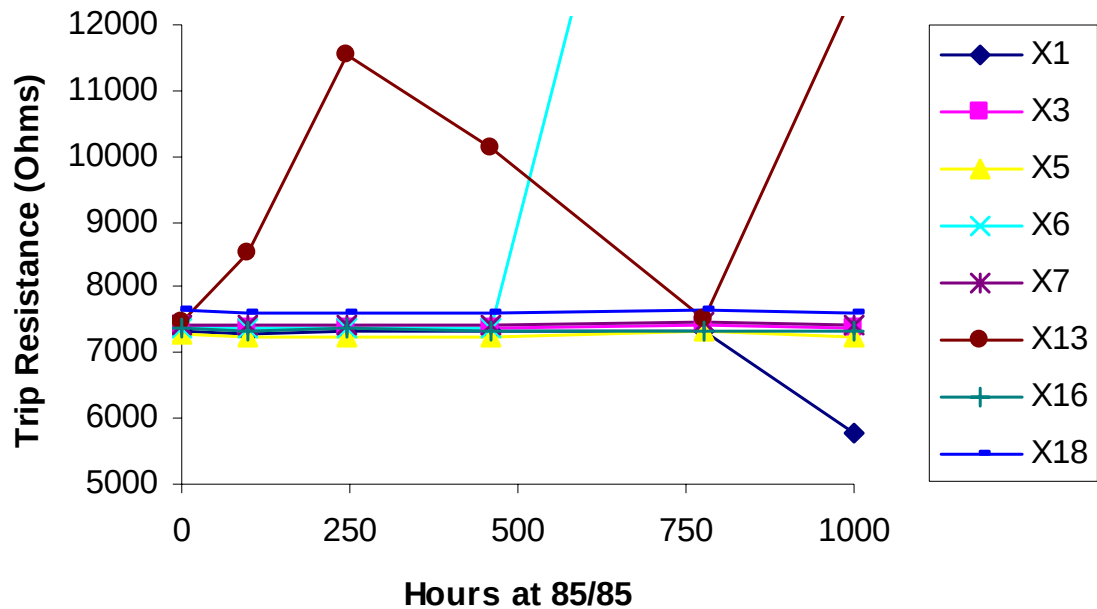


Figure 5: Trip resistance performance for material X after ageing at 85°C/85%RH

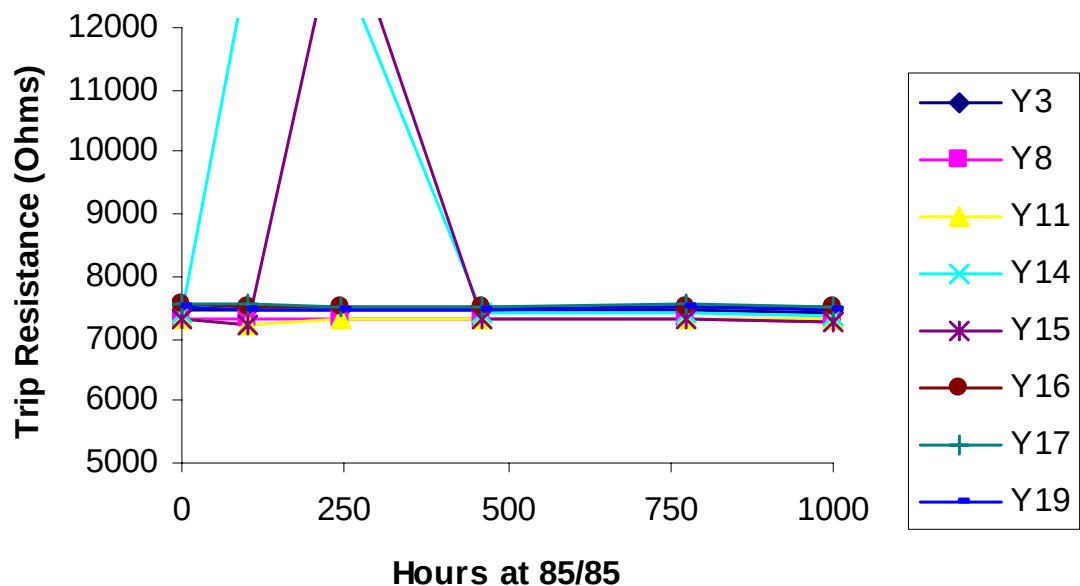


Figure 6: Trip resistance performance for material Y after ageing at 85°C/85%RH

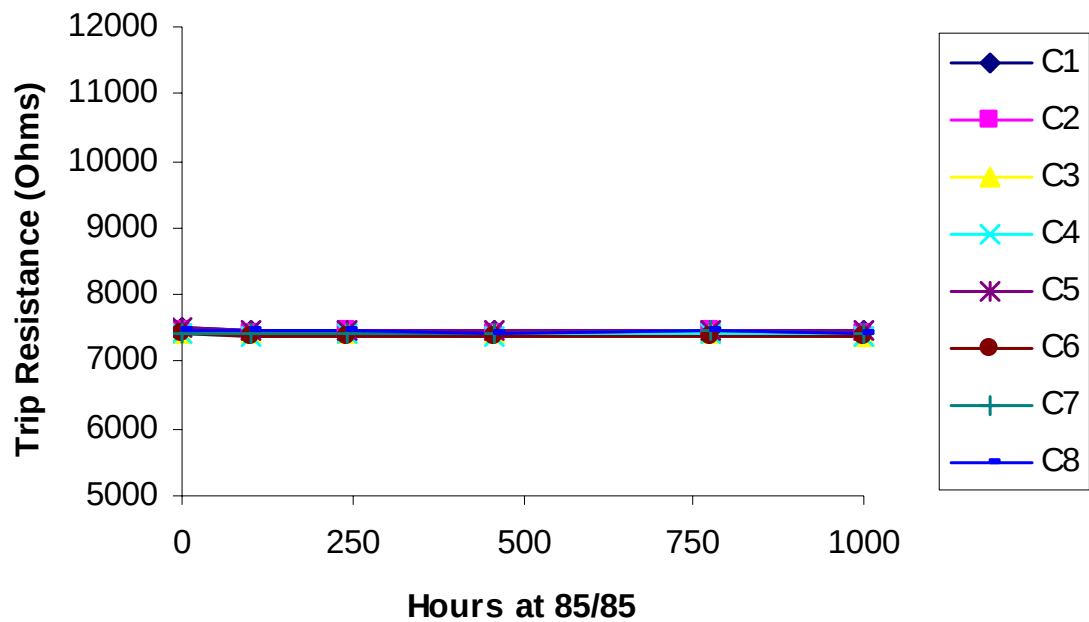


Figure 7: Trip resistance performance for SnPb assemblies after ageing at 85°C/85%RH

4 DISCUSSION

4.1 MANUFACTURING YIELD

90% of the failures using material X, and 50% of the failures using material Y, were due to shorts under the R0603 components – see Figure 8. However, since all these shorts were confined to one component type and to only 3 specific component positions (see Figure 9), it is felt that the yield could be significantly improved by better control of the print process. Also, the use of lower placement pressures might have a beneficial effect.

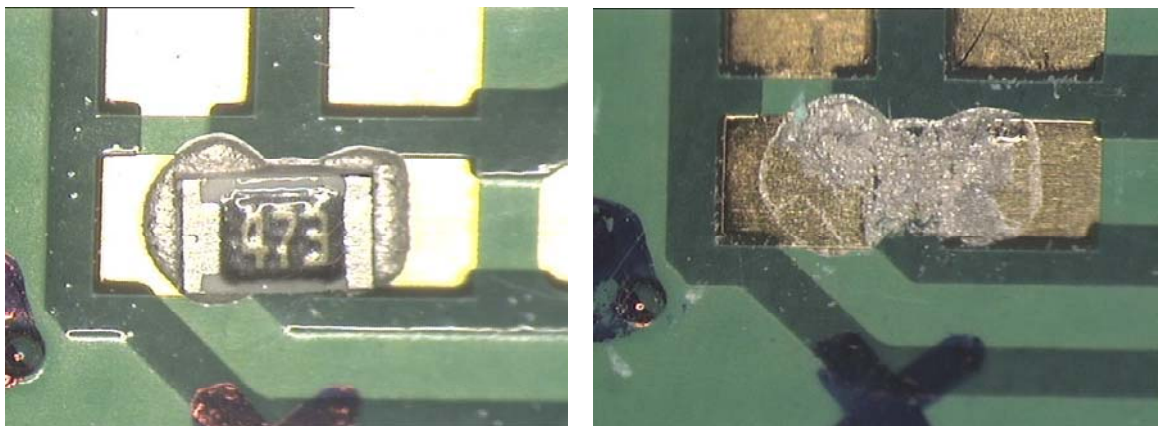


Figure 8. Example of short under R0603 component (before and after component removal)

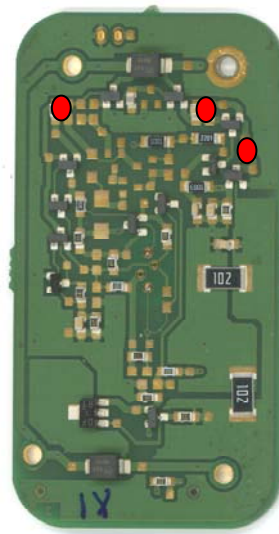


Figure 9. Location of R0603 shorts indicated by red dots

4.2 ELECTRICAL TEST RESULTS

After ageing for 1000 hours at 85%RH/85°C, 62% of the circuits built using material X were functioning within tolerance. Of the remaining, 25% of the circuits were still functioning but the trip resistance had risen above or fallen below the permitted 10% tolerance limit. One circuit was no longer functional after 750 hours of ageing.

For material Y, 75% of circuits were functioning within tolerance after 1000 hours at 85%RH/85°C. Of the remaining, 25% of the circuits failed mechanically due to SOT23 components becoming detached during handling, a problem associated with the small adhesive contact area. The small number and limited size of leads on a SOT23 component can result in poor mechanical strength when attaching to the PCB. In this case, the latter was insufficient to withstand even mild handling. In fact, some SOT23 components could be removed with minimal finger pressure. Typical SOT23 lead bond areas are shown in Figure 10. For production assemblies these components would need additional mechanical bonding such as that provided by an over-adhesive or encapsulation. After repair of the three SOT23 devices, these circuits functioned normally for the remainder of the ageing. Thus 100% of circuits manufactured with material Y were working within tolerance after 1000 hours of ageing.

NB. 100% of the control SnPb-soldered assemblies were functioning within tolerance after ageing for 1000 hours at 85%RH/85°C.

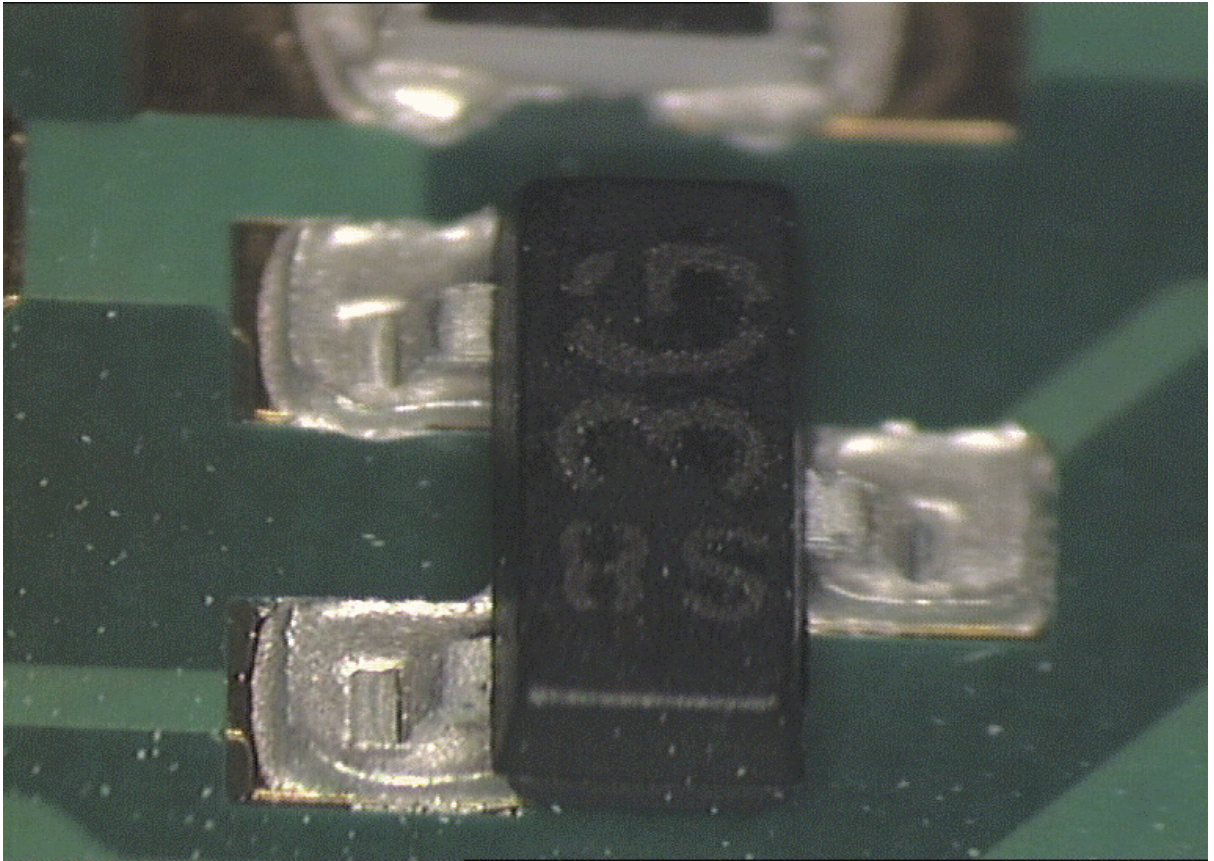


Figure 10: Typical SOT23 lead bond areas.

5 CONCLUSIONS

The salient conclusions are:

- Whilst the reliability of the circuits assembled using the two ICA materials did not mirror that of the soldered circuits, their performance was encouraging, and certainly warrants further study. With minor processing adjustments the CAs could find viable applications as a lead-free solder replacement for component attachment.
- One ICA material produced joints the reliability of which was close to that of the soldered joints. For this material (Y) all the assemblies survived 1000 hours at 85%RH/85°C, although two circuits required reworking of SOT23 components.
- As with any new attachment technology, there is a learning curve involving materials choice, process development and attachment assessment.
- Components with few leads and small bond areas (e.g. SOT23) would benefit from additional mechanical support to improve their tolerance of mechanical handling.

- Processing yield issues were experienced using the two ICA materials, associated with the formation of shorts under some R0603 components. However, the fact that these were restricted to one component type and three specific locations, strongly suggests that they could be eliminated by normal process optimisation techniques.
- The work has confirmed the suitability of using damp heat testing as a tool for assessing the reliability of joints made using ICA materials.

6 ACKNOWLEDGEMENTS

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Apollo Fire Detectors

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