

REPORT

Developing a Stress Screening Regime for Isotropic Electrically Conductive Adhesives

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ABSTRACT

Recent renewed interest in isotropic conductive adhesives (ICAs) has been driven both by the impending restrictions on the use of lead in solders, and by the potentially increased recyclability of a range of products that use ICAs instead of solder for interconnection purposes. But wider use of these materials requires better understanding of the mechanisms of field failures, and an appropriate and agreed test method to assess both process quality and field reliability. In consequence, this work has been undertaken in order to review and investigate potential test regimes, and thereby to identify a representative accelerated ageing condition for assessing ICAs.

The study has involved examining joints on test boards produced from a matrix experiment using two ICA materials, a range of components, eight ageing regimes, and four assessment techniques (electrical conductivity, shear testing, drop testing and SIR). The results indicate that

- (a) the performances of the two ICA materials were broadly similar – the resistances of the bulk materials were stable over all the testing regimes
- (b) when used as component interconnect, the materials performed well, particularly when subjected to thermal cycling, exceeding the expectations of typical end-users
- (c) the parameters of an appropriate stress screening regime are :
unbiased joints, 85°C, 85%RH for 1000 hours
- (d) other potential screening regimes studied all exhibited significant drawbacks.
- (e) it is recommended that for future work on ICAs the 85/85 damp heat test be used: it provides a means to differentiate between assembly parameters, particularly for leaded SM components.

The second phase of this project will study the effect of bias on the ICA joints during testing. Moisture is expected to play an important role in the likely failure modes experienced by biased joints, underlining the suitability of the recommended test regime

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1 INTRODUCTION

The electronics production industry has used tin-lead solder for the manufacture of printed circuit assemblies for over 50 years. This situation is set to change with the impending removal of lead from electronic solders driven by legislation and market forces. The introduction of legislation in 2006 will force industry to change. The replacement lead-free solder alloys are generally of a higher melting point than the alloys which they replace, which 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 could 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 sequential soldering operations, i.e. when components are attached to a daughter board with a high temperature solder, and the daughter board is subsequently attached to the main assembly with a lower melting point solder, without the joints of the components on the daughter board re-melting. There are very few higher melting point alloys which do not contain lead. A possible solution is for conductive adhesives to be used for the lower fabrication temperatures with lead-free solders being used for the initial operations.

Additionally, pressure is being exerted on industry in general to improve the recyclability of a wide range of products. The current method of electronics assembly uses relatively high melting point solder alloys (180-235°C range), and this necessitates the use of thermoset epoxy resin systems as substrate materials, which can withstand these soldering temperatures. However, these epoxy materials, being thermosets, do not lend themselves to recycling. Currently it is estimated that around 25,000 tonnes of epoxy PCB materials are dumped to landfill annually in the UK alone. This equates to over 0.5 billion tonnes globally per annum. If electrically conductive adhesives could be introduced as a mainstream assembly technique, their lower assembly temperatures would allow the use of thermoplastic substrate materials, which are significantly more suited to recycling.

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 rising cost of assembly associated with the introduction of lead-free soldering, these materials have become more attractive and if sufficient field reliability can be proved, then these materials could find a more widespread market. But to achieve this, the industry needs to understand better the field failure mechanisms of these materials and to develop corresponding test methods to assess both field reliability and process quality. Additionally, this may allow UK industry to adopt fundamentally new, lower cost, flexible manufacturing systems.

The work reported here was undertaken to determine the most appropriate stress screening regime for isotropic electrically conductive adhesives (ICA).

2 METHODOLOGY

2.1 TEST VEHICLE DESIGN AND DETAILS

A test vehicle, incorporating different SM lead formats was designed and manufactured. A populated assembly is shown in Figure 1. The larger, left-hand portion of the assembly utilises daisy-chain components to enable electrical continuity to be measured through assembled components using the edge connector on the left. The lower right-hand portion of the design can be easily separated from the main board and was used for shear testing. The upper right-hand portion was not used in this study.

The PCB was manufactured from double-sided FR4 laminate 1.6mm thick. The surface finish used was immersion gold on electroless nickel (ENIG).

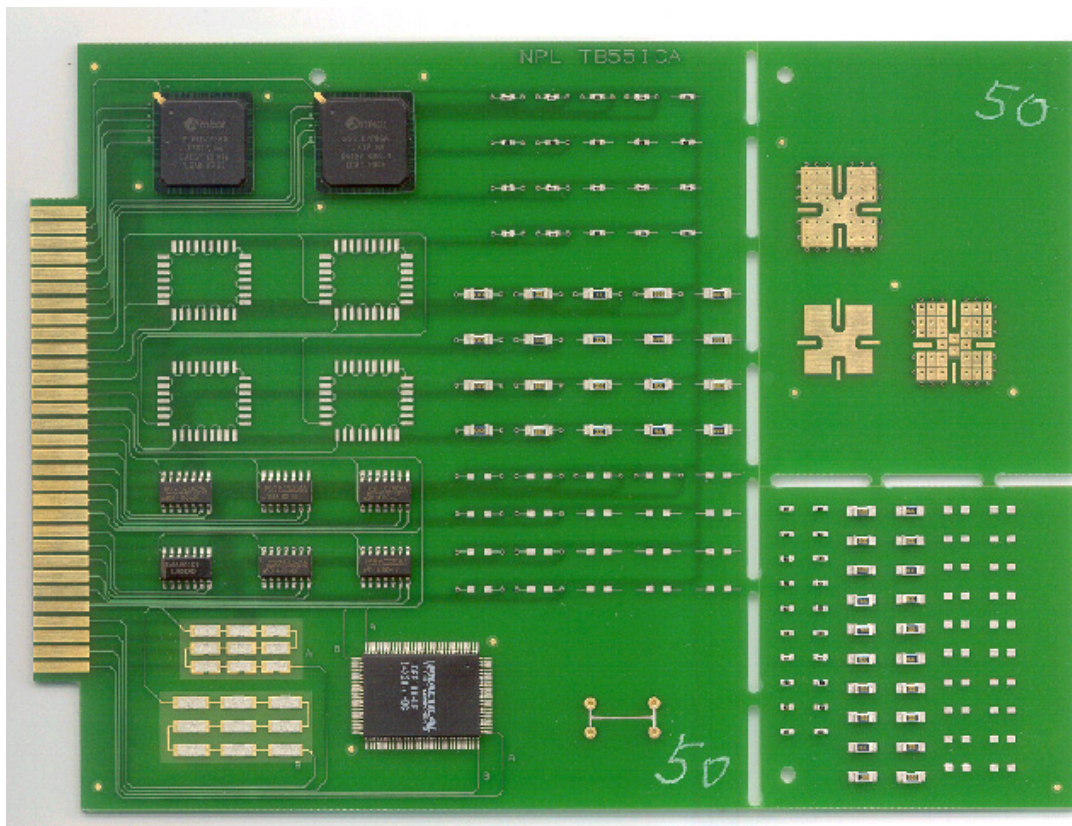


Figure 1 : Example of Populated Test Assembly

Each test assembly was populated with lead-free components as detailed in Table 1

Table 1 : Test Assembly Population

Component	Pitch	Finish	No. per assembly
PBGA256	1.0mm	SAC	2
LQFP100	0.65mm	SnCu	2
SOIC14	1.27mm	SnCu	5
R1206		Sn	40
R0603		Sn	40

In addition, the design incorporated a series of interconnect patterns designed to be used to monitor the performance of the ICA alone. These interconnect patterns are shown in Figure 2 and Figure 3 with the printed ICA in position. The pads for the interconnect pattern, shown in figure 3, were 2mm x 2mm with a 2mm gap between them. The stencil aperture size was 4.6mm by 1.8mm. A similar set of links were produced with the same pad size but with a smaller gap between (1.0mm), with an aperture size of 3.6mm x 1.8mm.

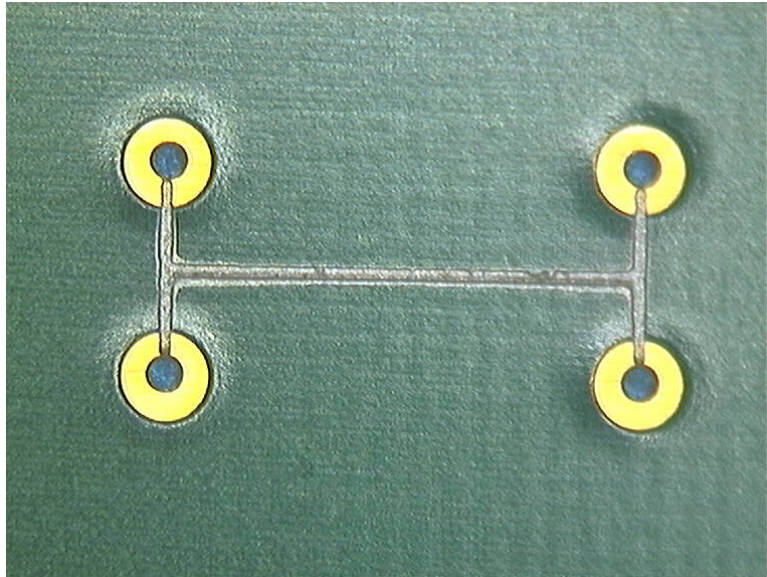


Figure 2: I-link Interconnect Pattern

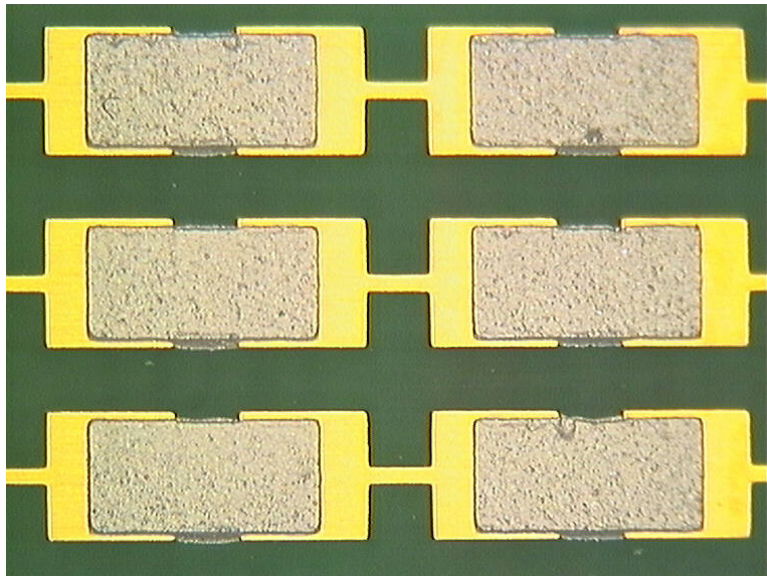


Figure 3: Jumper Interconnect Pattern

2.2 ISOTROPIC CONDUCTIVE ADHESIVE DETAILS

Experimental work was undertaken on two representative commercially available 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. The first of the materials was chosen as being suitable for curing in a reflow profile. The second material was chosen for its longer cure schedule. The manufacturers' quoted values for the two materials are given in Table 2

Table 2 : Comparison of Manufacturers Quoted Materials Data

	Material A	Material B
% Ag Fill	Not Quoted	74%
Glass Transition Temperature	120 to 180°C (cure dependent)	100°C
Volume Resistivity	$<1 \times 10^{-4} \text{ Ohm.cm}$	$7 \times 10^{-4} \text{ Ohm.cm}$
Storage Life	12 months@ -40°C	12 months@ -40°C
Pot Life	24 hours	3 days
Cure Schedules	200°C for 10 mins 180°C for 15 mins 150°C for 30 mins	150°C for 3 mins (reflow) 125°C for 5 mins (reflow) 150°C for 5 mins (convection)

2.3 TEST VEHICLE ASSEMBLY

The conductive adhesives were applied to the PCBs in the same fashion as solder paste, using stencil printing through a $75\mu\text{m}$ stainless steel laser-cut stencil. Normal 60° metal squeegees were utilised. After stencil printing, smaller components were placed using a Sanyo automatic placement system. Larger components were placed using a Finetech Fineplacer, with a split optics placement system. Cure of material A was undertaken in an air-circulation oven for 30 minutes at 150°C . Material B was cured in a 5-zone reflow oven using a modified SnPb reflow profile. The profiles of joint temperatures are shown in **Figure 4**. The assembly route followed standard SM assembly practices.

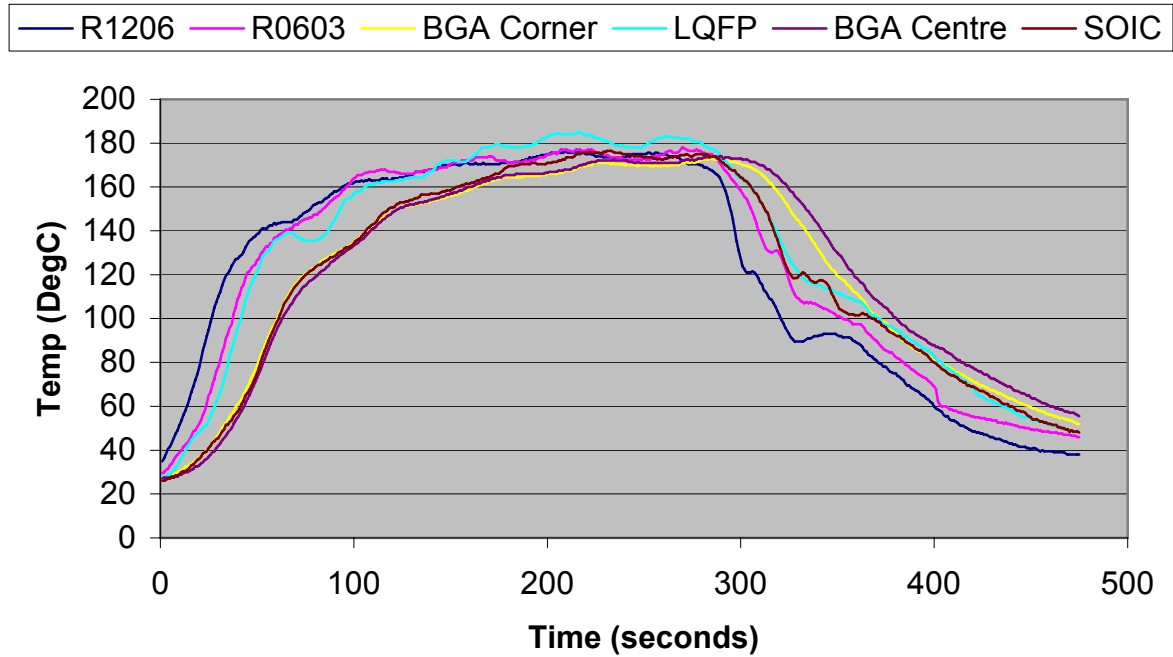


Figure 4: Cure Profile for Material B in Convection Reflow Oven

2.4 STRESS SCREENING REGIMES

After manufacture, groups of assemblies were subjected to three dry heat ageing regimes, three damp heat ageing regimes and two thermal cycle regimes. The details of these regimes are given in Table 3 and

Table 4. The dry heat ageing and damp heat ageing were undertaken for 1000 hours, and the two thermal cycle regimes for 1000 cycles. Dry heat and damp heat ageing have been incorporated in this work in order to determine their effect on ICA joint resistances, particularly the resistances of interfaces within the joints.

Table 3: Stress Screening Regime Parameters

Regime	Temperature	Humidity	Duration
Dry heat	40°C	Ambient	1000 hours
	85°C	Ambient	1000 hours
	125°C	Ambient	1000 hours
Damp heat	40°C	93%RH	1000 hours
	85°C	85%RH	1000 hours
	125°C	93%RH	1000 hours

Table 4: Thermal Cycle Regime Parameters

Upper Temperature	Lower Temperature	Dwell at extremes	Ramp Rate	No. of Cycles
125°C	-55°C	5 minutes	10 °C/min	1000
80°C	-20°C	5 minutes	10 °C/min	1000

2.5 ELECTRICAL CONTINUITY MONITORING

Five assemblies of each material were subjected to stress screening as detailed above for the full 1000 hours or cycles. Periodically during stress screening, the samples were tested at room temperature and the resistance of each circuit on the assembly logged via a PC, DVM and programmable switching system. The periodicity of the room temperature measurements is given in Table 5.

Table 5: Periodicity of Electrical Continuity and Shear Testing Measurements

Regime	Periodicity
Dry Heat 40°C, 85°C, 125°C	0, 30, 100, 300, 1000 hours
Damp Heat 40°C/93%RH, 85°C/85%RH, 125°C/93%RH	0, 30, 100, 300, 1000 hours
Thermal Cycling 125°C/-55°C, 80°C/-20°C	0, 15, 50, 150, 500, 1000 cycles

2.6 SHEAR TEST MEASUREMENT

Resistor components on the samples were subjected to shear testing, before and after stress screening, to determine if the stress screening regime had affected adhesion. The periodicity of these measurements is given in Table 5. Figure 5 illustrates a typical shear test. These tests were undertaken on a Dage Series-4000 modular multi-function bond-tester. The stand-off height of the tool was set equal to $h/2$ (typically 80 μm), between the bottom of the shear tool and board surface (h is the stand-off height between the component and the board surface). During each test, the shear tool was moved forward at a defined speed (200 $\mu\text{m/s}$) against the test component, and the applied force increased until the attachment was broken.

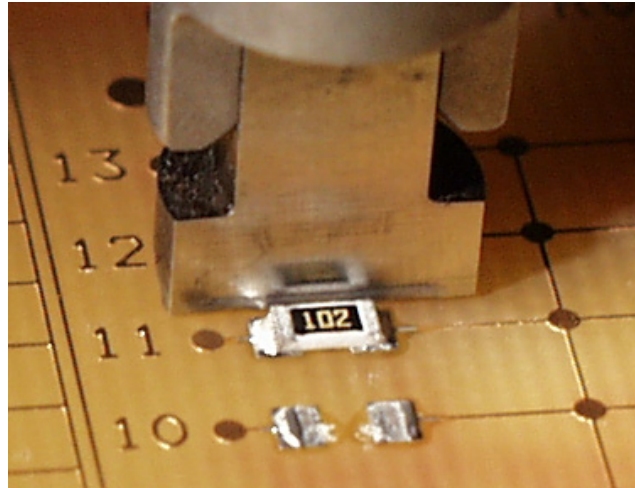


Figure 5: Shear Test Jig and Push-off Tool Before a Shear Test

2.7 DROP TESTING

Drop testing of samples was undertaken from a height of 1 metre onto a steel plate. A test rig of vertically orientated edge guides was used to ensure that the test assembly impacted on its lower edge. Only the left hand portion of the test assembly shown in Figure 1 was used in drop testing. The assembly was dropped onto the lower edge (Figure 1), closest to the QFP component, and the number and type of components detached after the drop were logged. After each drop, the assembly was electrically tested (as in Section 0 above) to ensure that components which appeared to be attached, were still electrically connected.

2.8 SURFACE INSULATION RESISTANCE TESTING

An NPL designed board with four identical SIR comb patterns (400/200 μm track/gap) was used for SIR measurement, as shown in Figure 1. The conductive adhesives were printed on the comb track, and cured.

The SIR measurements were performed under controlled temperature and humidity conditions, 85°C and 85% RH respectively. A bias voltage of 50V DC was applied during a test period of seven days. The SIR was measured every 15 minutes, using an Auto-SIR instrument, having a 10^6 ohm in-line resistor to protect any dendrites formed. This is the minimum resistance that can be measured.

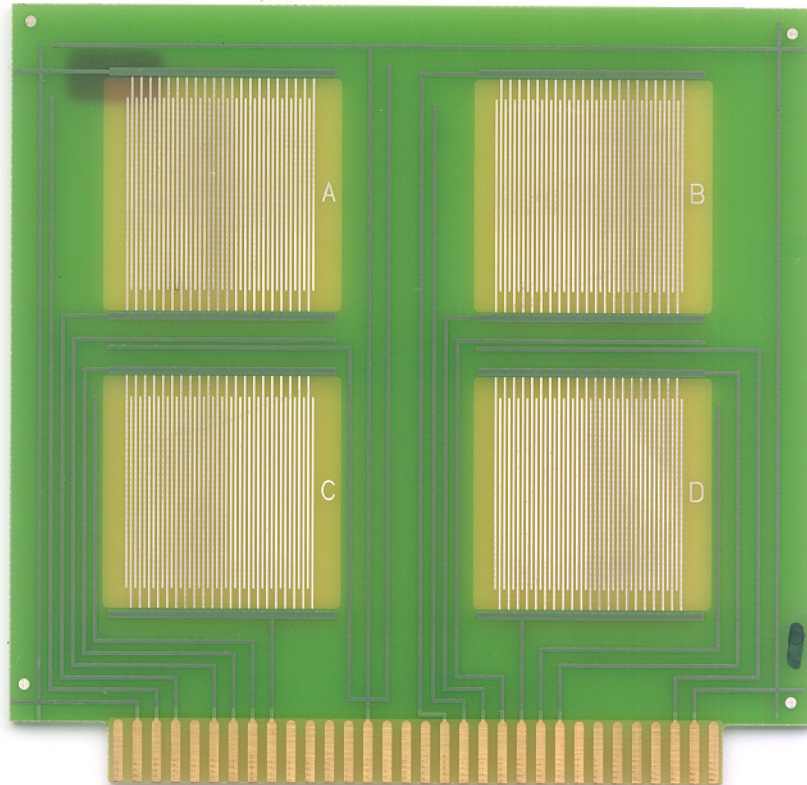


Figure 6: Surface Insulation Resistance Test Board

3 RESULTS

3.1 ELECTRICAL CONTINUITY RESULTS

3.1.1 I-Link Resistance Measurements

The measured resistances of the I-links of materials A and B for all the stress screening regimes are presented in Figures 7 to 12. These graphs represent the average of 10 measurements per ageing regime.

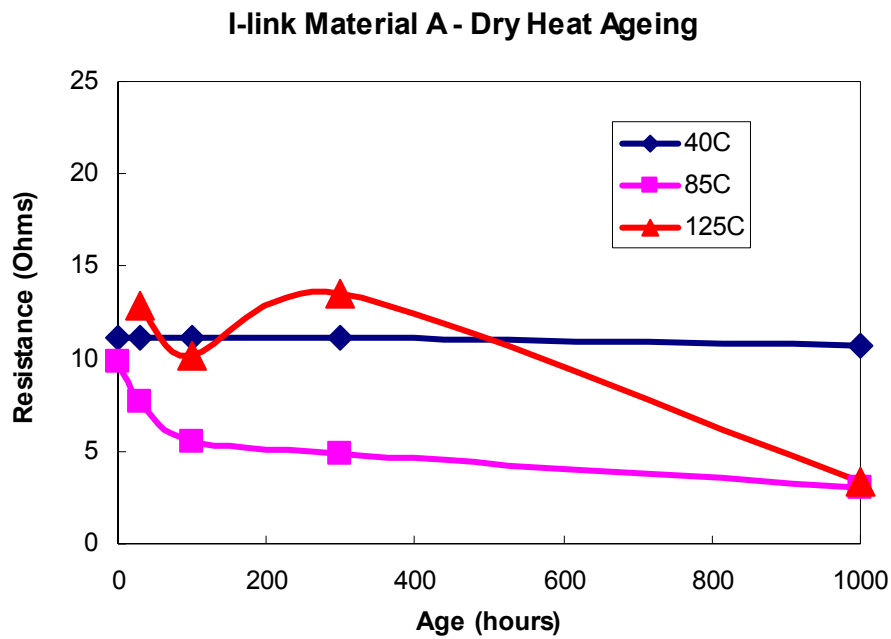


Figure 7: Variation of Average I-Link Resistance for Material A During Dry Heat Ageing

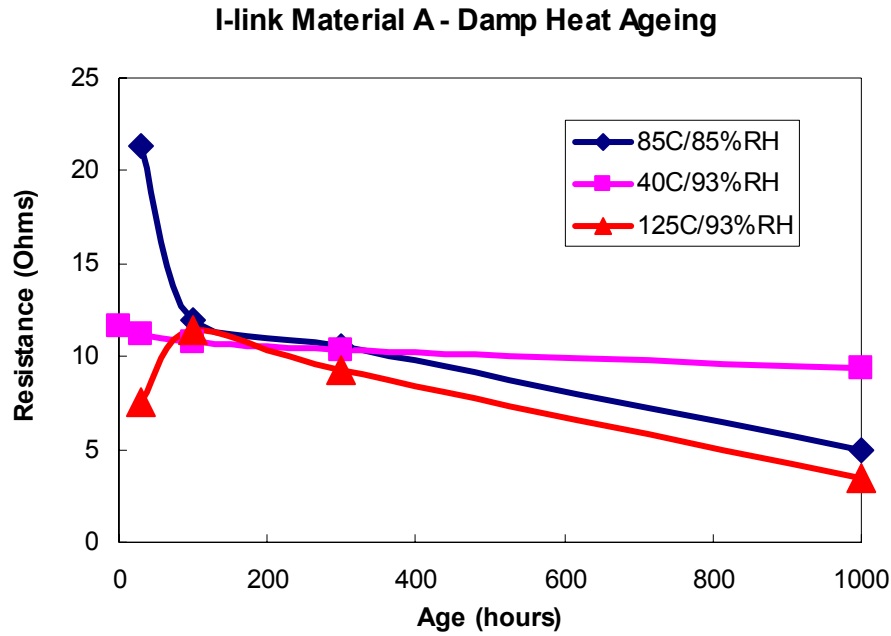


Figure 8: Variation of Average I-Link Resistance for Material A During Damp Heat Ageing

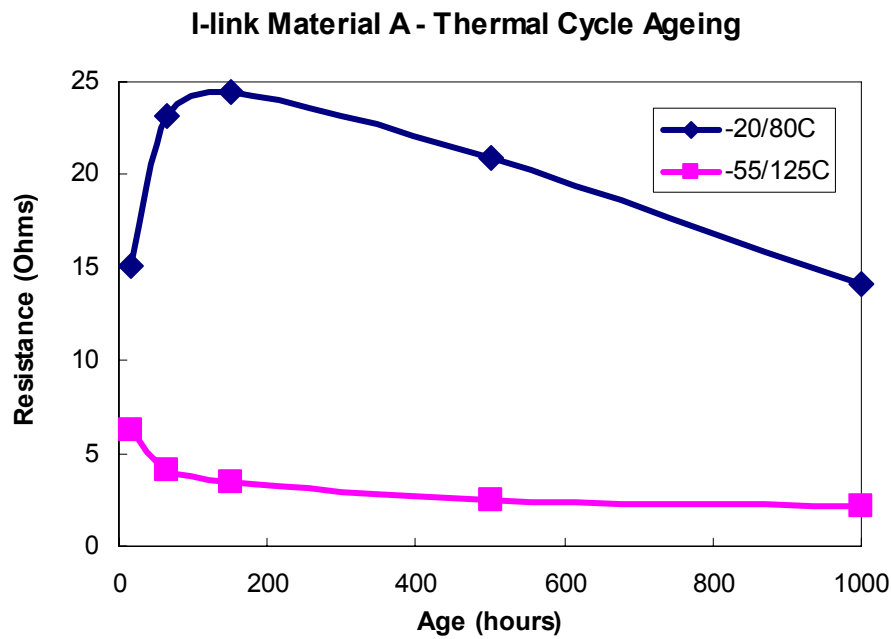


Figure 9: Variation of Average I-Link Resistance for Material A During Thermal Cycle Ageing

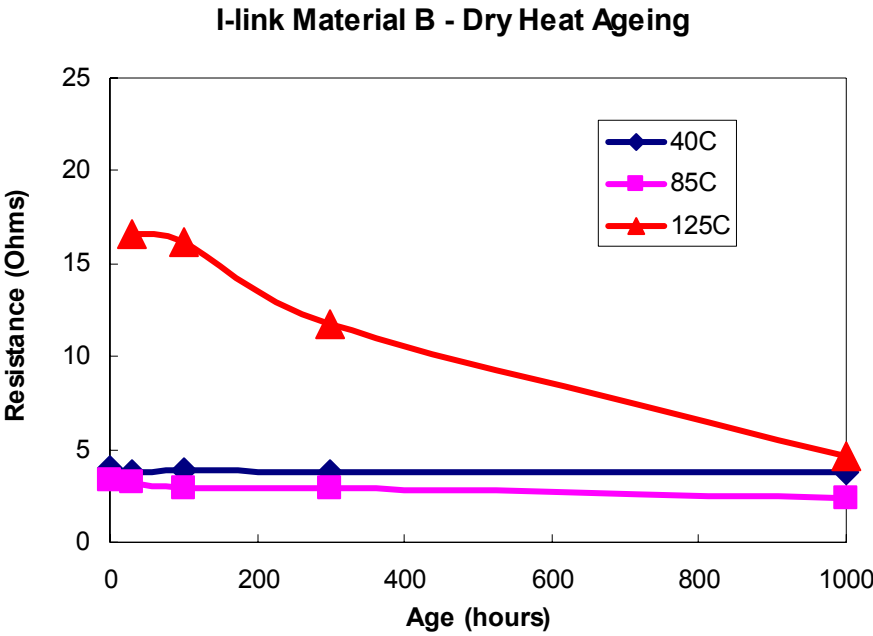


Figure 10: Variation of Average I-Link Resistance for Material B During Dry Heat Ageing

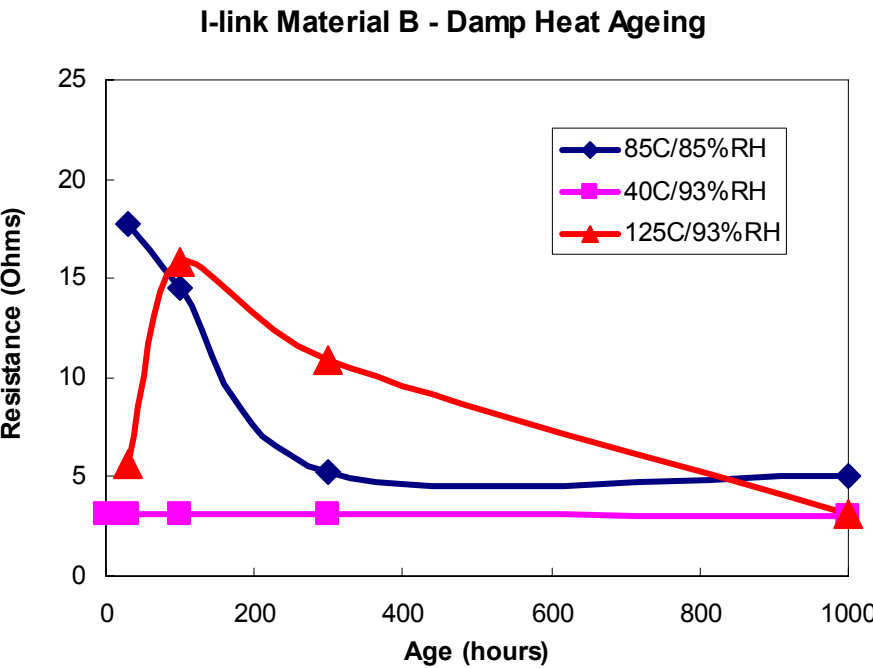


Figure 11: Variation of Average I-Link Resistance for Material B During Damp Heat Ageing

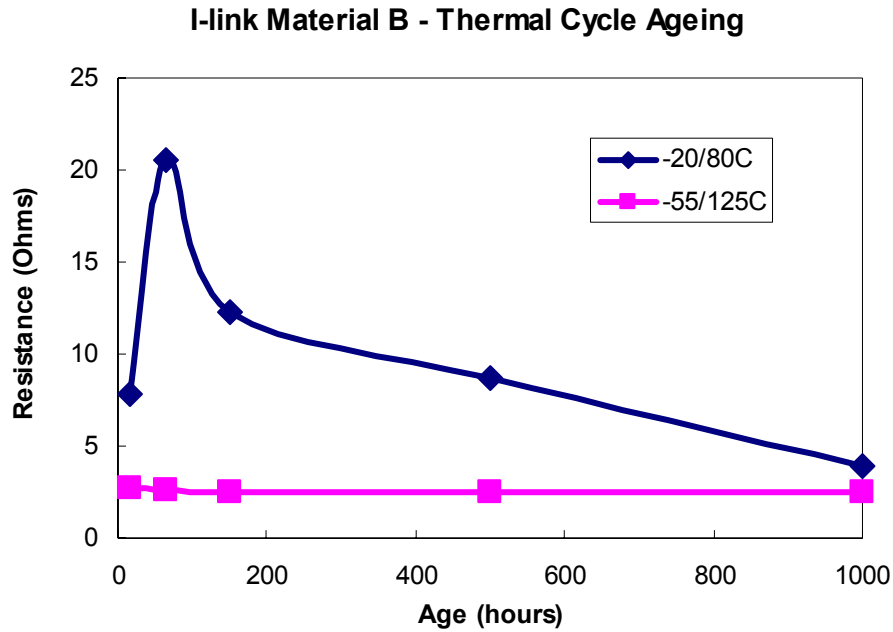


Figure 12: Variation of Average I-Link Resistance for Material A During Thermal Cycle Ageing

3.1.2 Jumper Resistance Measurements

The measured resistances of the jumpers of materials A and B for the four most stringent stress screening regimes are given in Figures 13 to 20. Results for only the four most stringent are shown as there was little difference with the lower temperature/humidity regimes. These graphs show the variation of each of 10 circuits of 9 jumpers in series.

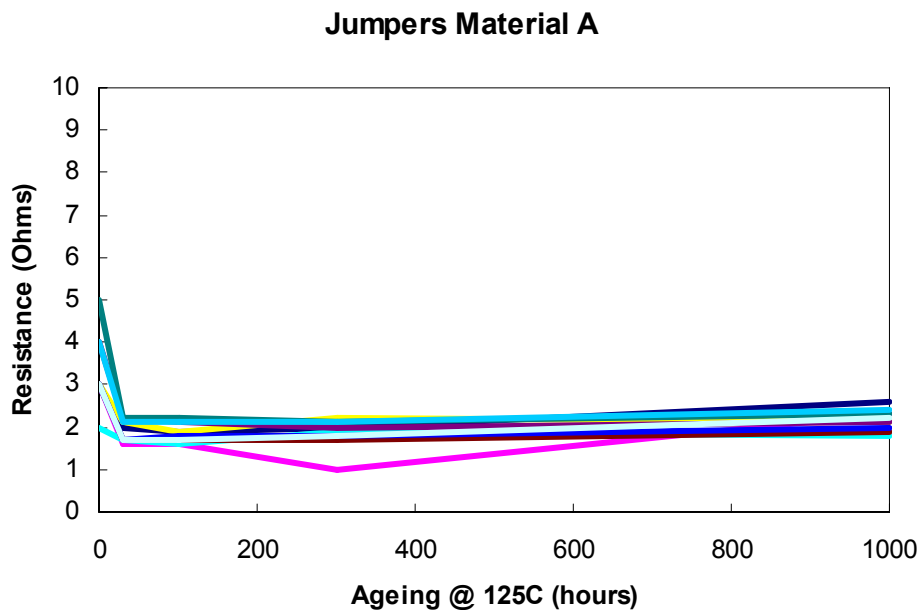


Figure 13: Variation of Jumper Resistance for Material A During Dry Heat Ageing at 125°C

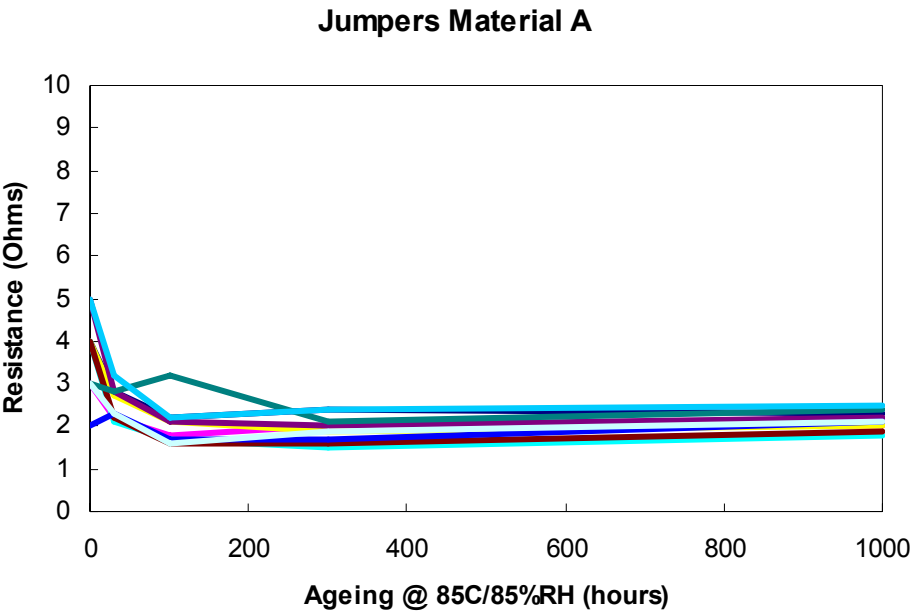


Figure 14: Variation of Jumper Resistance for Material A During Damp Heat Ageing at 85°C/85%RH

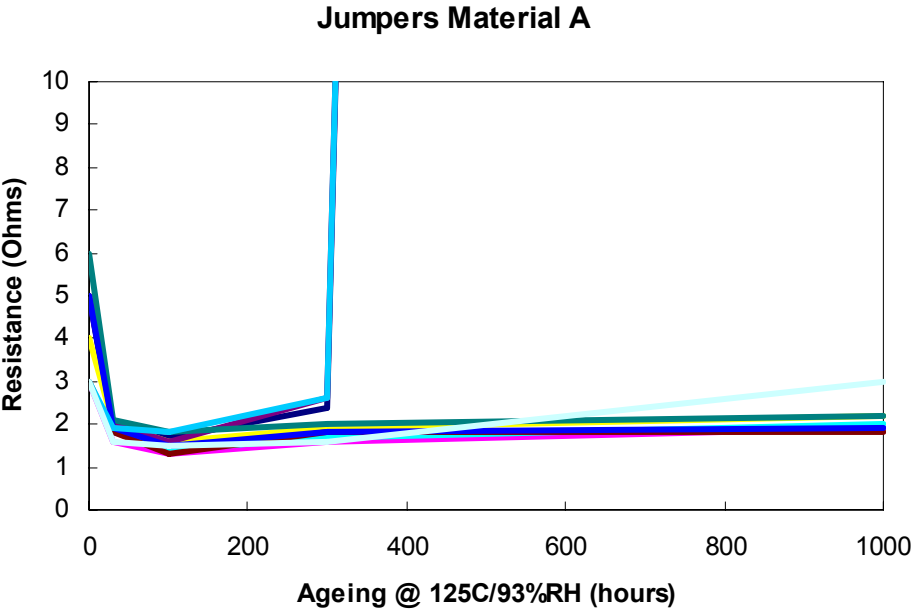


Figure 15: Variation of Jumper Resistance for Material A During Damp Heat Ageing at 125°C/93%RH

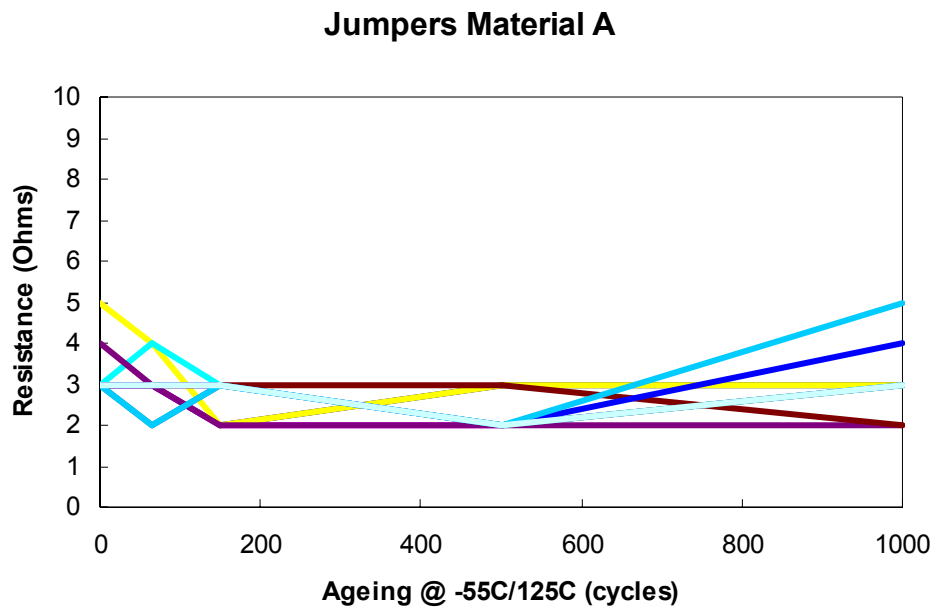


**Figure 16: Variation of Jumper Resistance for Material A
During Thermal Cycle Ageing at -55°C/125 °C**

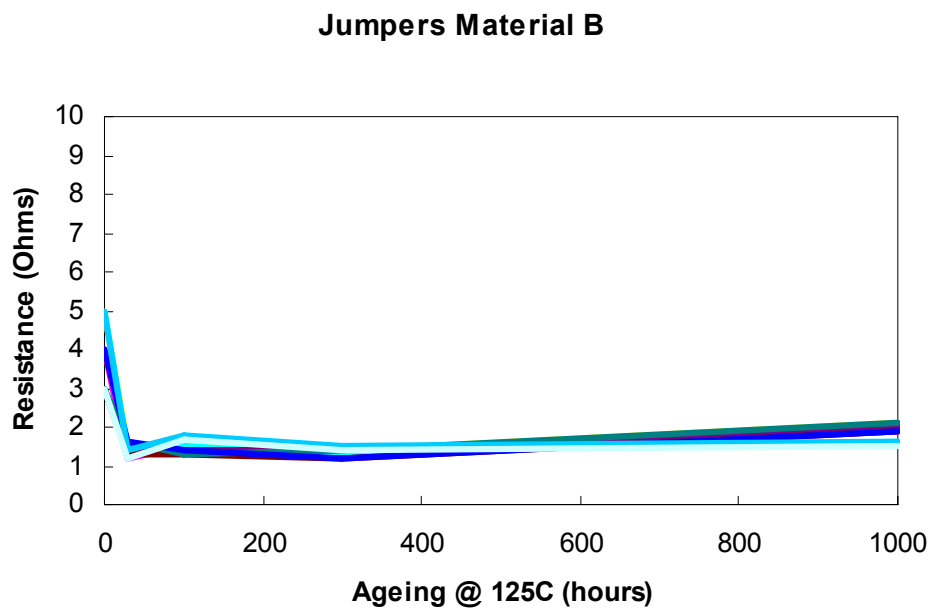


Figure 17: Variation of Jumper Resistance for Material B During Dry Heat Ageing at 125°C

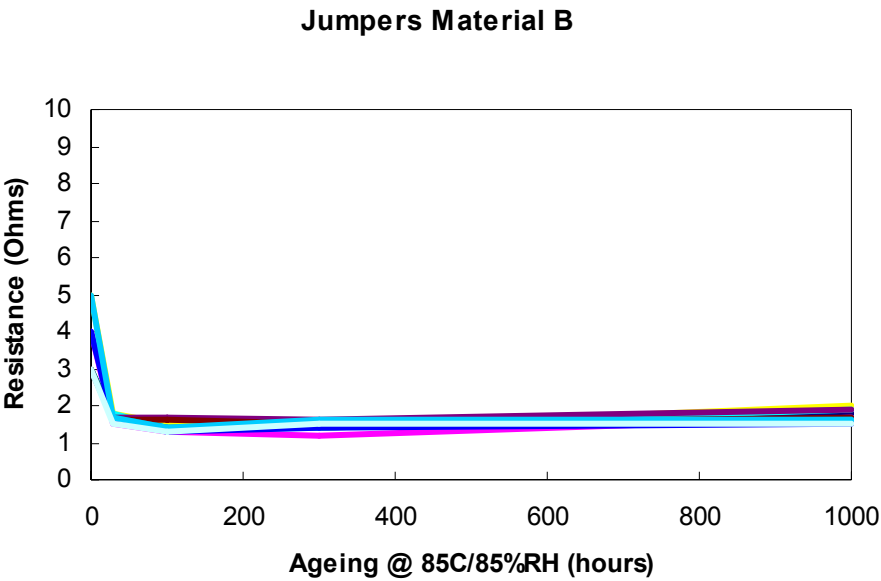


Figure 18: Variation of Jumper Resistance for Material B During Damp Heat Ageing at 85°C/85%RH

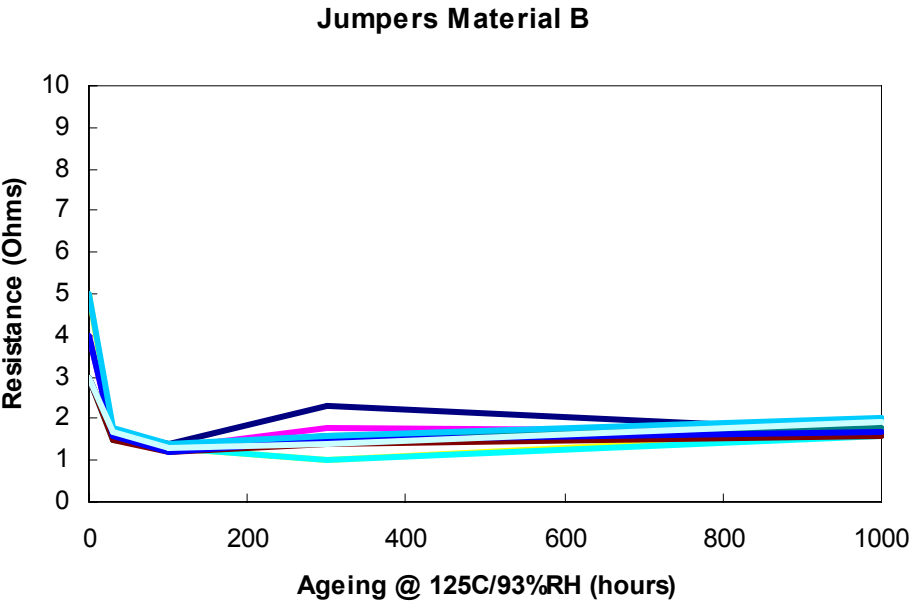


Figure 19: Variation of Jumper Resistance for Material B During Damp Heat Ageing at 125°C/93%RH

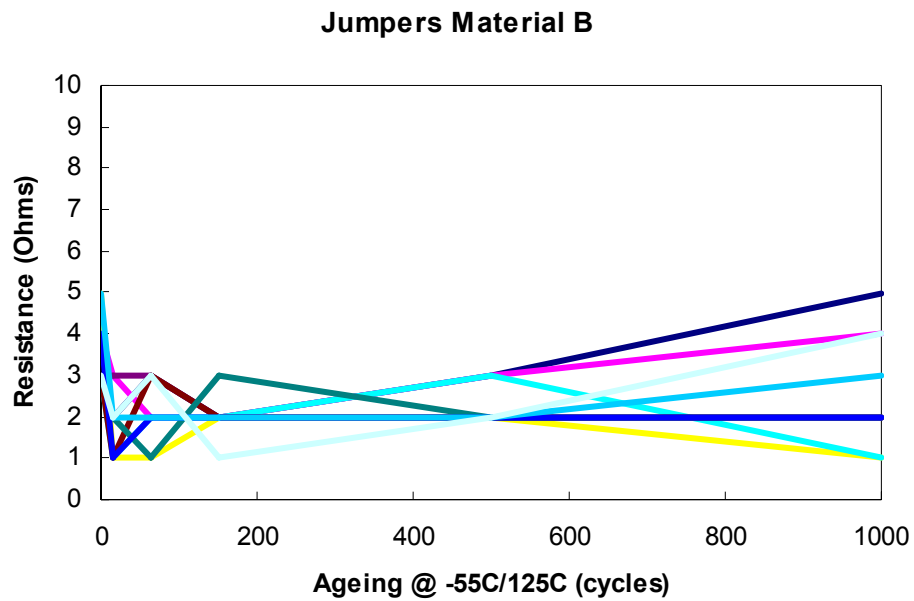


**Figure 20: Variation of Jumper Resistance for Material B
During Thermal Cycle Ageing at -55°C/125°C**

3.1.3 SOIC Resistance Measurements

The measured resistances of the joints of SOIC components (made from materials A and B) for the four most stringent stress screening regimes are given in Figures 21 to 28. These graphs show the variation of 30 individual circuits on 15 different daisy-chained SOIC components.

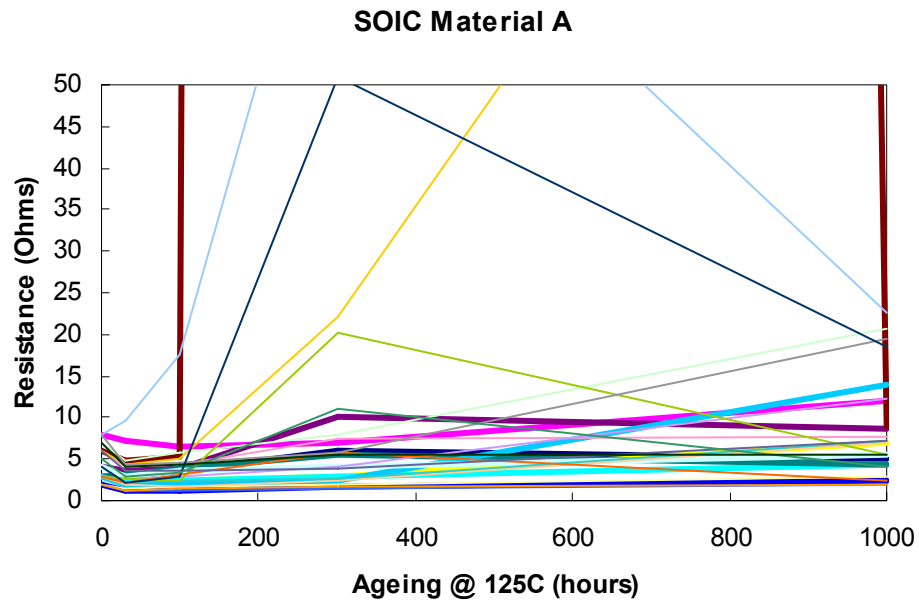


Figure 21: Variation of SOIC Resistance for Material A During Dry Heat Ageing at 125°C

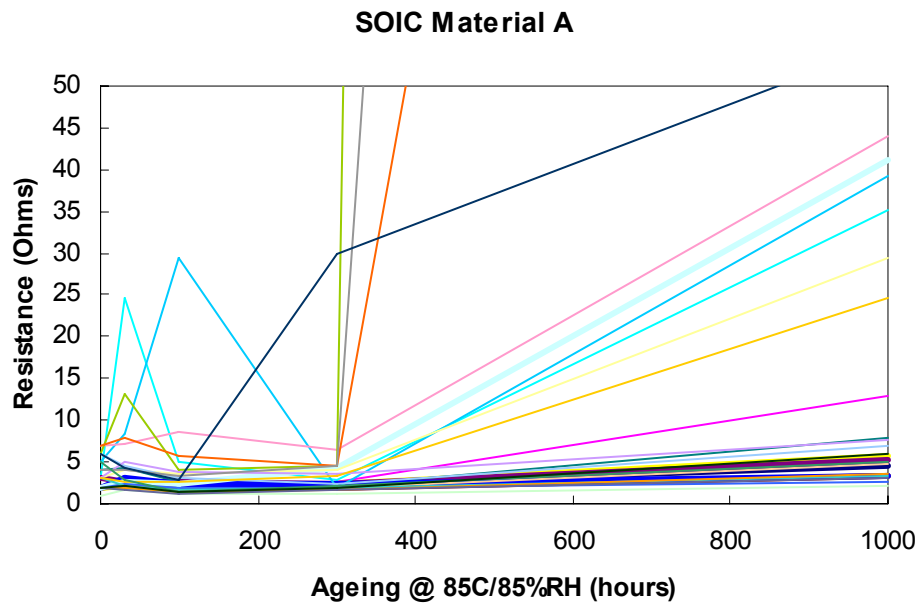


Figure 22: Variation of SOIC Resistance for Material A During Damp Heat Ageing at 85°C/85%RH

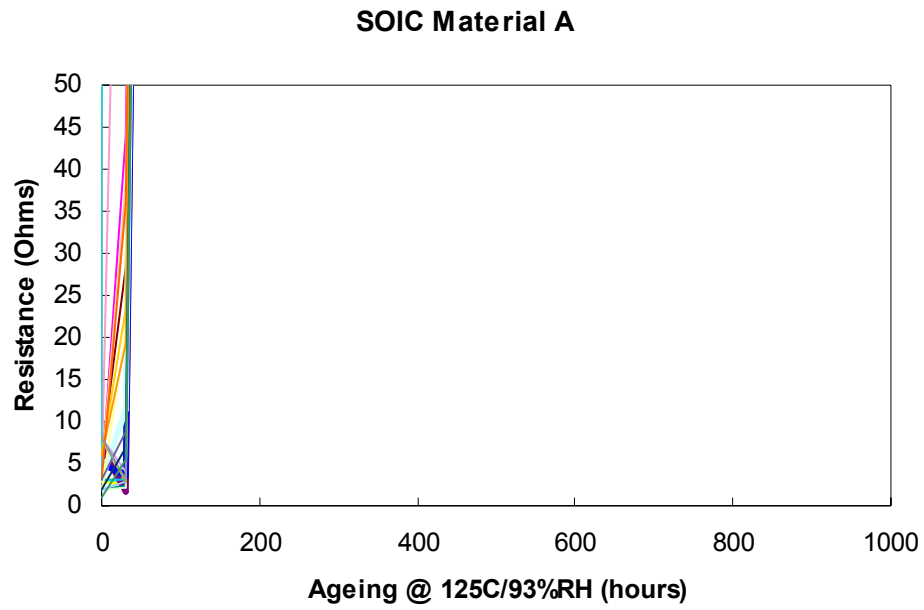


Figure 23: Variation of SOIC Resistance for Material A During Damp Heat Ageing at 125°C/93%RH

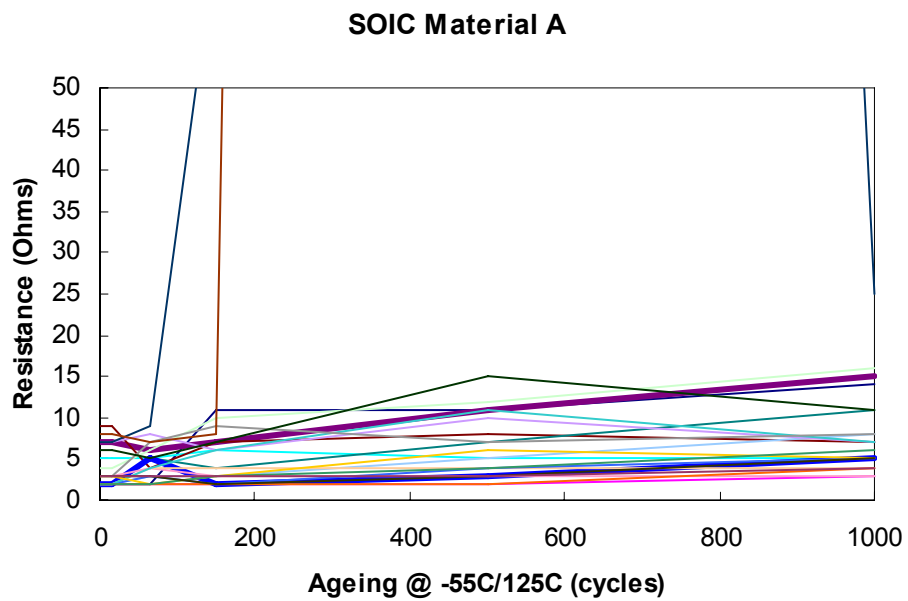


Figure 24: Variation of SOIC Resistance for Material A During Thermal Cycle Ageing at -55°C/125 °C

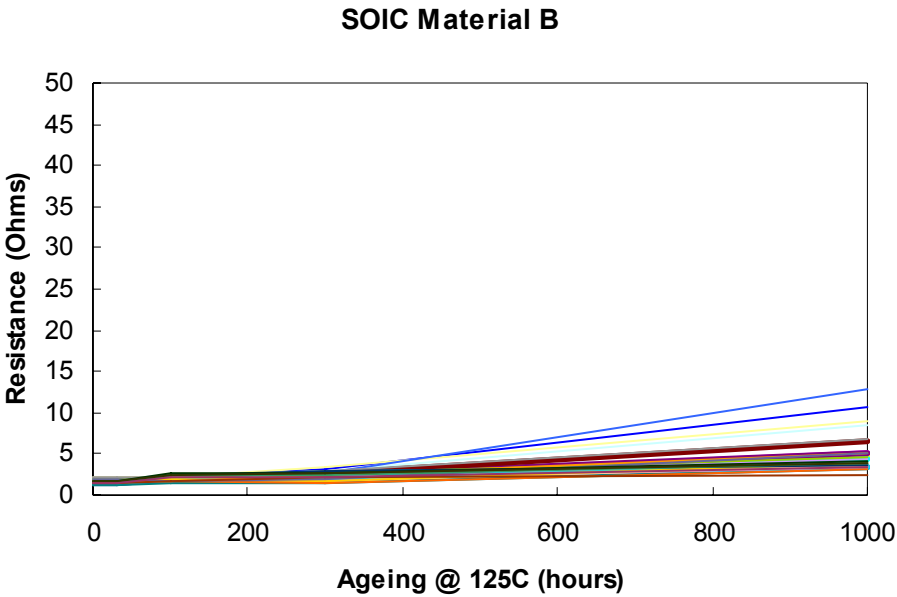


Figure 25: Variation of SOIC Resistance for Material B During Dry Heat Ageing at 125°C

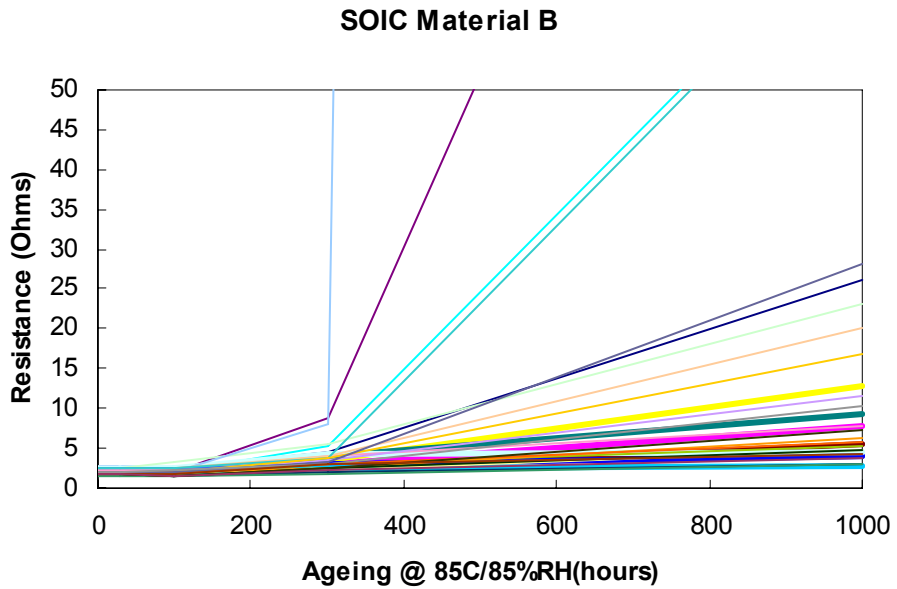


Figure 26: Variation of SOIC Resistance for Material B During Damp Heat Ageing at 85°C/85%RH

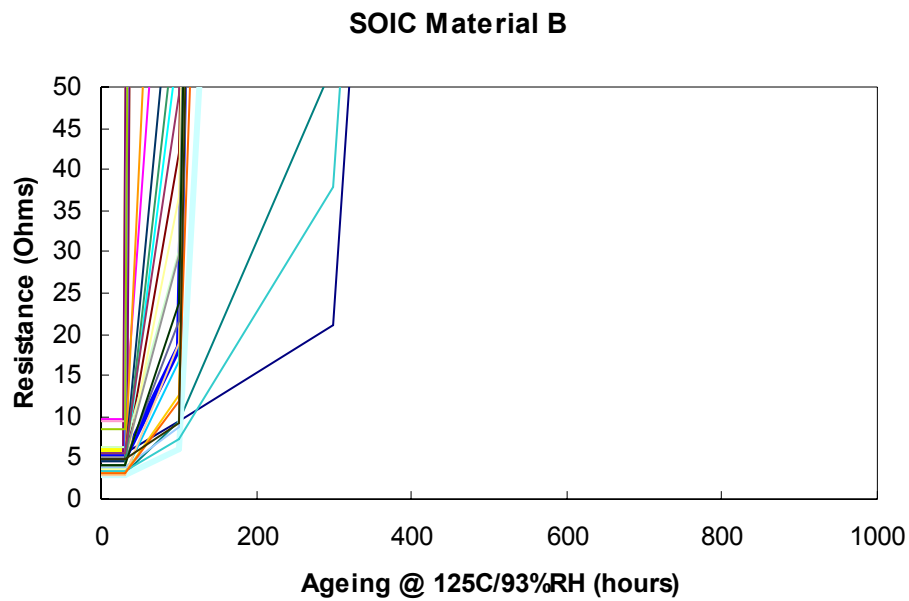


Figure 27: Variation of SOIC Resistance for Material B During Damp Heat Ageing at 125°C/93%RH

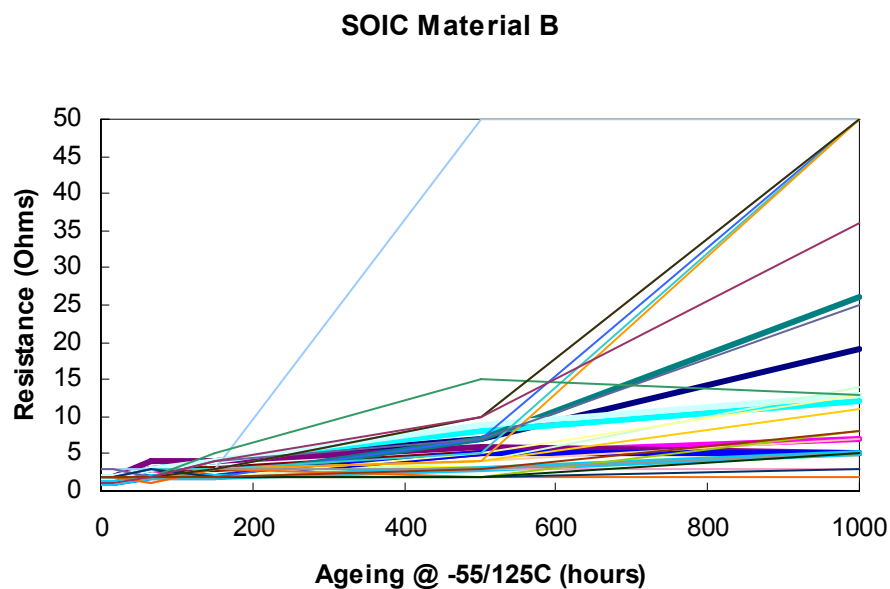


Figure 28: Variation of SOIC Resistance for Material B During Thermal Cycle Ageing at -55°C/125°C

3.1.4 R1206 Resistance Measurements

The measured resistances of the joints of 1206 type resistors (made from materials A and B) for the four most stringent stress screening regimes are presented in Figures 29 to 36. These graphs show the variation of 50 individual zero ohm resistor components.

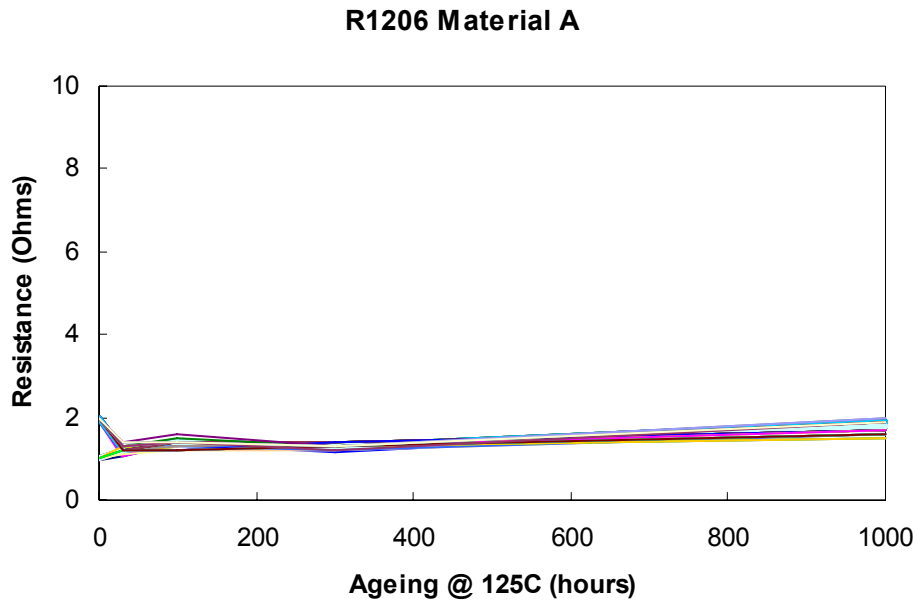


Figure 29: Variation of R1206 Resistance for Material A During Dry Heat Ageing at 125°C

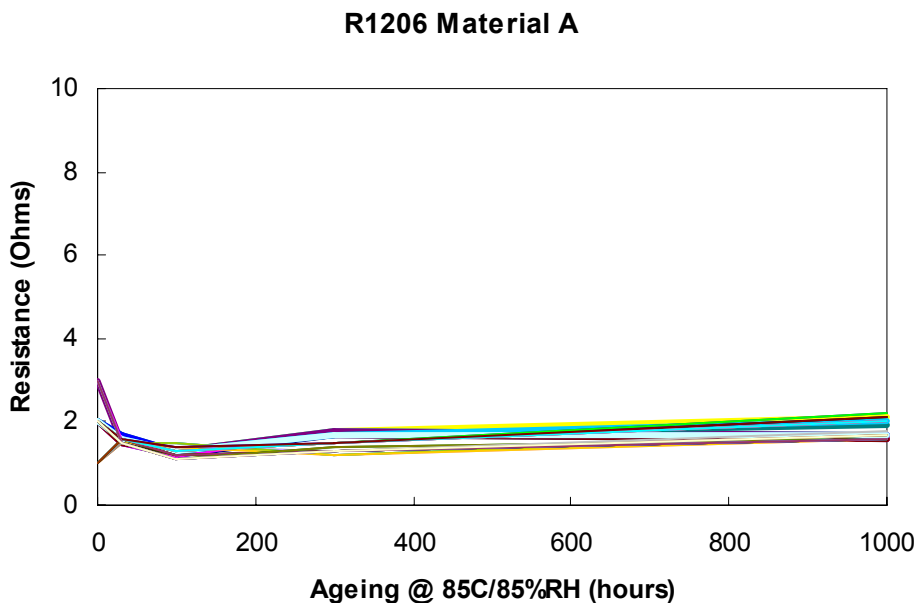


Figure 30: Variation of R1206 Resistance for Material A During Damp Heat Ageing at 85°C/85%RH

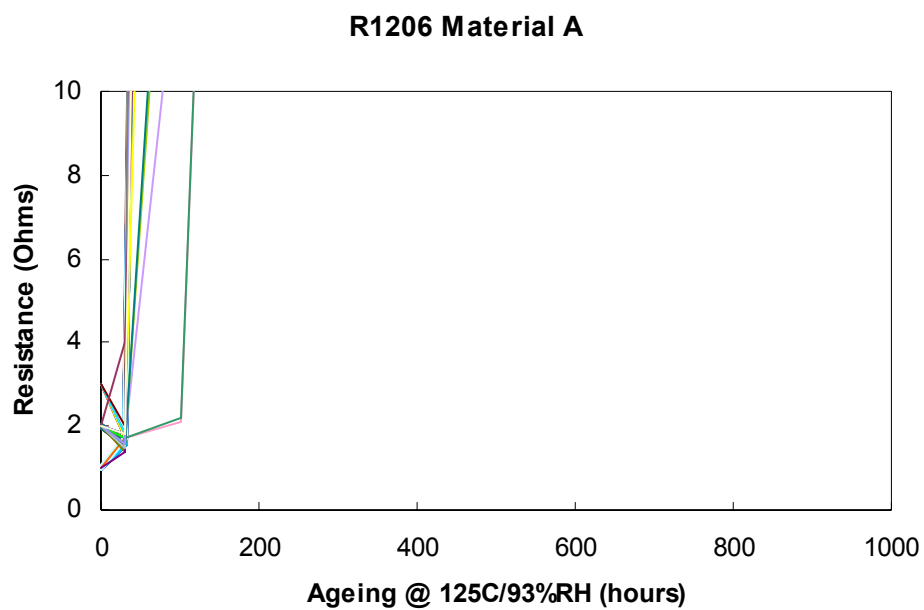


Figure 31: Variation of R1206 Resistance for Material A During Damp Heat Ageing at 125°C/93%RH

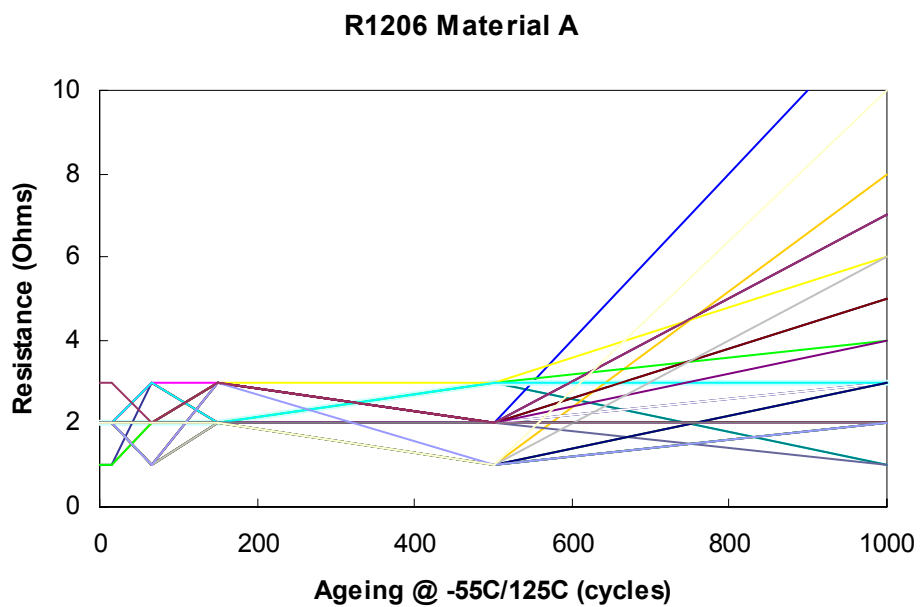


Figure 32: Variation of R1206 Resistance for Material A During Thermal Cycle Ageing at -55°C/125 °C

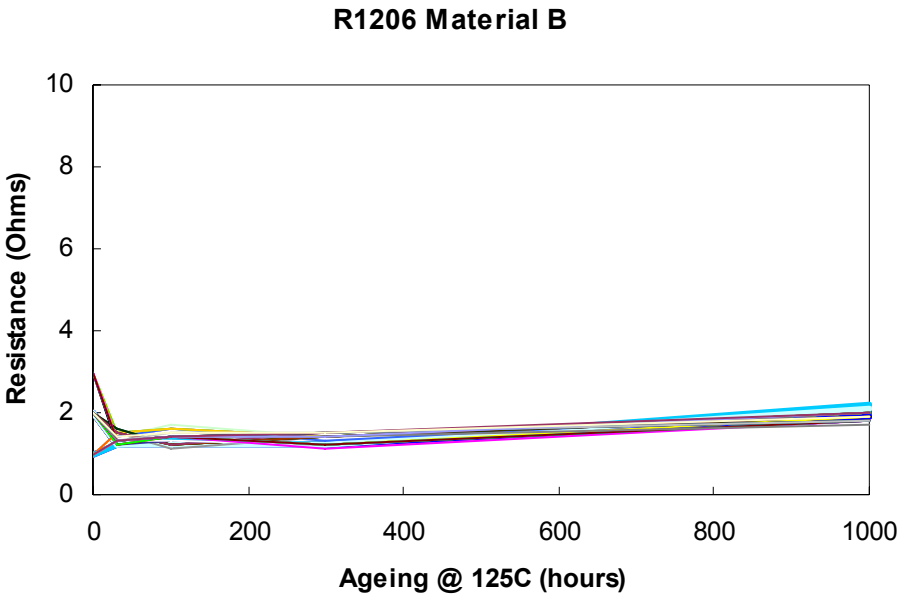


Figure 33: Variation of R1206 Resistance for Material B During Dry Heat Ageing at 125°C

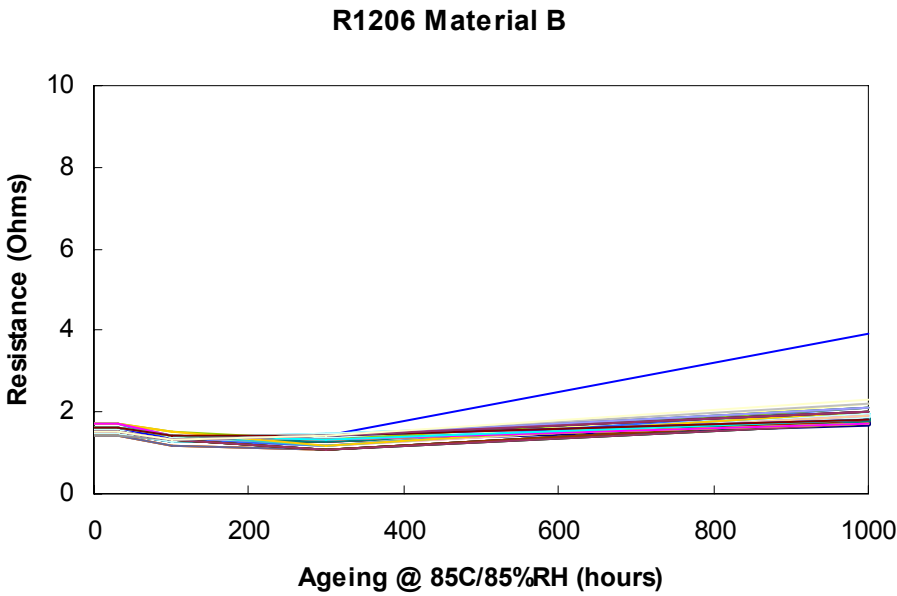


Figure 34: Variation of R1206 Resistance for Material B During Damp Heat Ageing at 85°C/85%RH

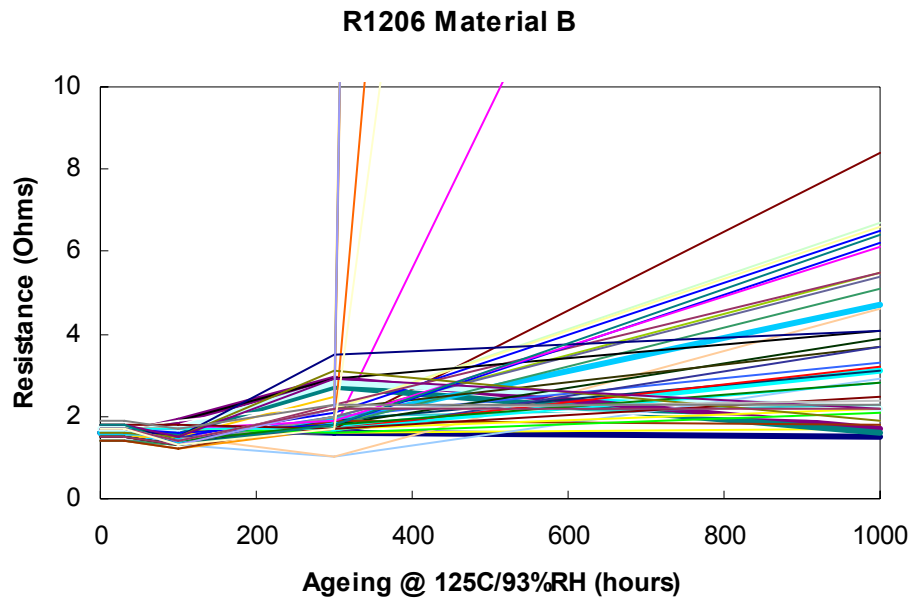


Figure 35: Variation of R1206 Resistance for Material B During Damp Heat Ageing at 125°C/93%RH

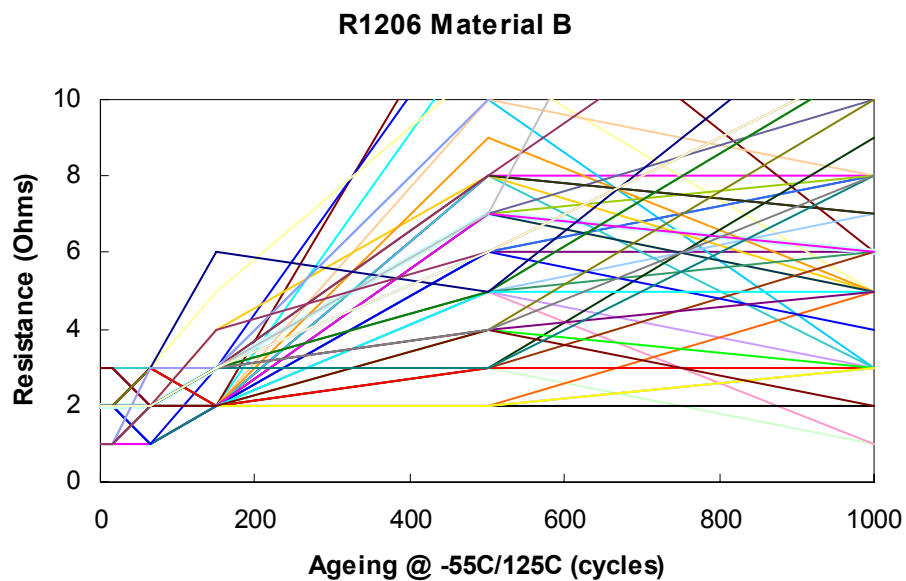


Figure 36: Variation of R1206 Resistance for Material B During Thermal Cycle Ageing at -55°C/125°C

3.1.5 R0603 Resistance Measurements

The measured resistances of the joints of 0603 type resistors of (made from materials A and B) for the four most stringent ageing regimes are given in Figures 37 to 44. These results are corrected for the resistor value (39ohms subtracted from measured values). These graphs show the variation of 50 individual resistor components.

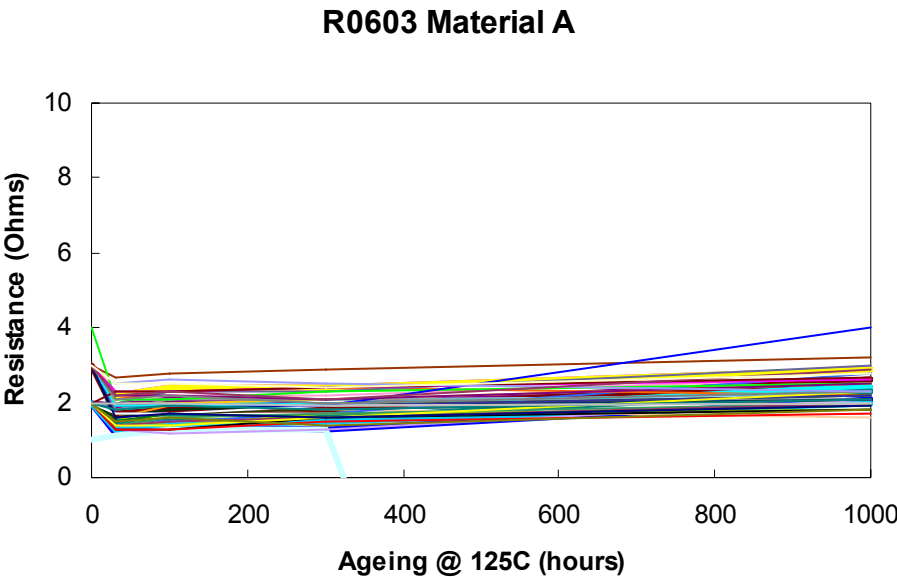


Figure 37: Variation of R0603 Resistance for Material A During Dry Heat Ageing at 125°C

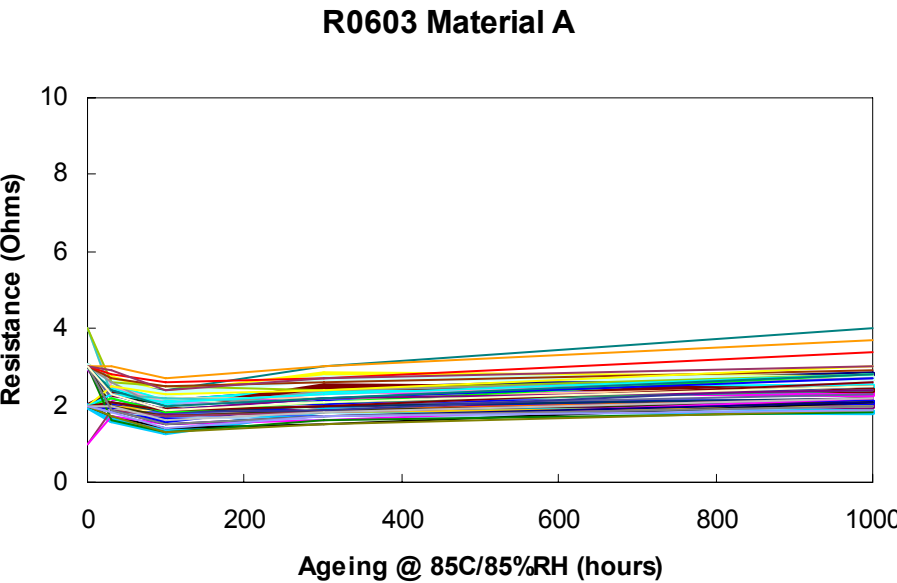


Figure 38: Variation of R0603 Resistance for Material A During Damp Heat Ageing at 85°C/85%RH

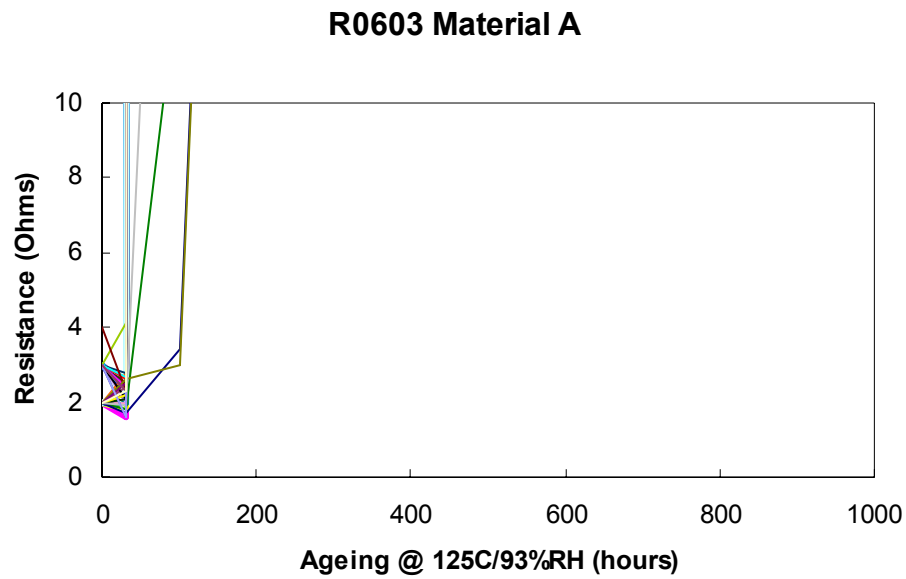


Figure 39: Variation of R0603 Resistance for Material A During Damp Heat Ageing at 125°C/93%RH

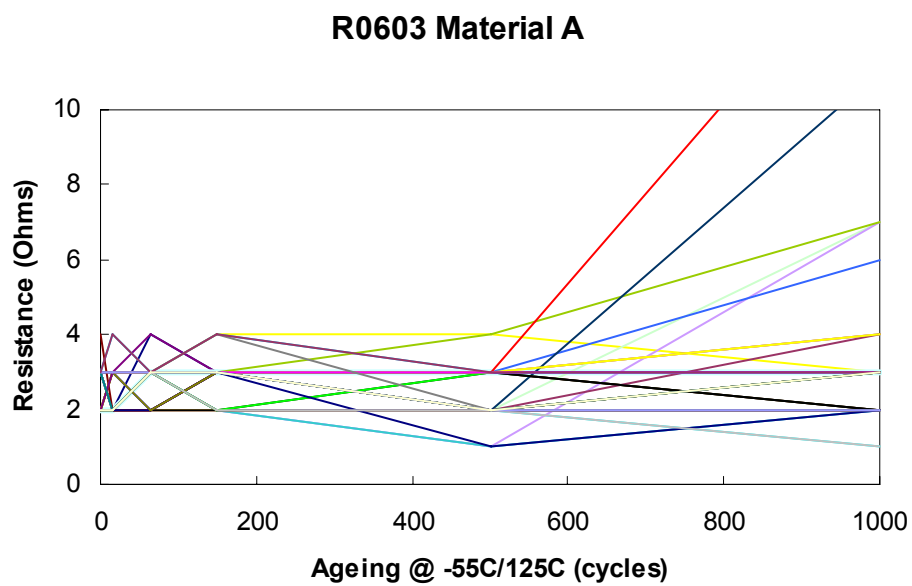


Figure 40: Variation of R0603 Resistance for Material A During Thermal Cycle Ageing at -55°C/125 °C

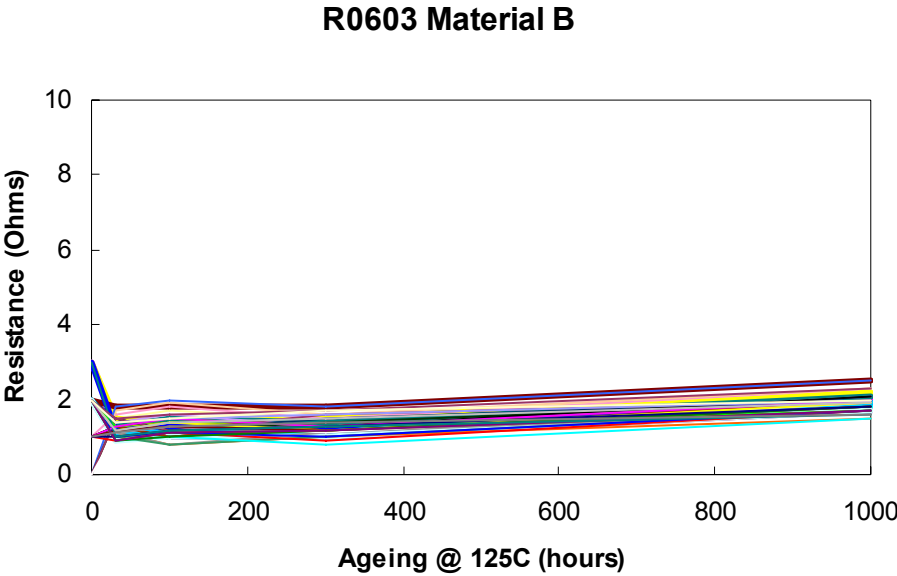


Figure 41: Variation of R0603 Resistance for Material B During Dry Heat Ageing at 125°C

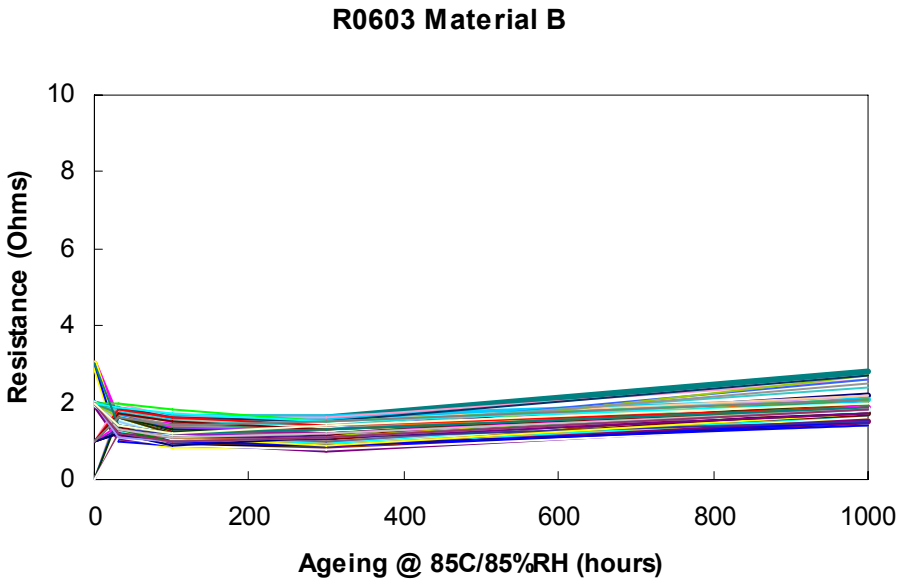


Figure 42: Variation of R0603 Resistance for Material B During Damp Heat Ageing at 85°C/85%RH

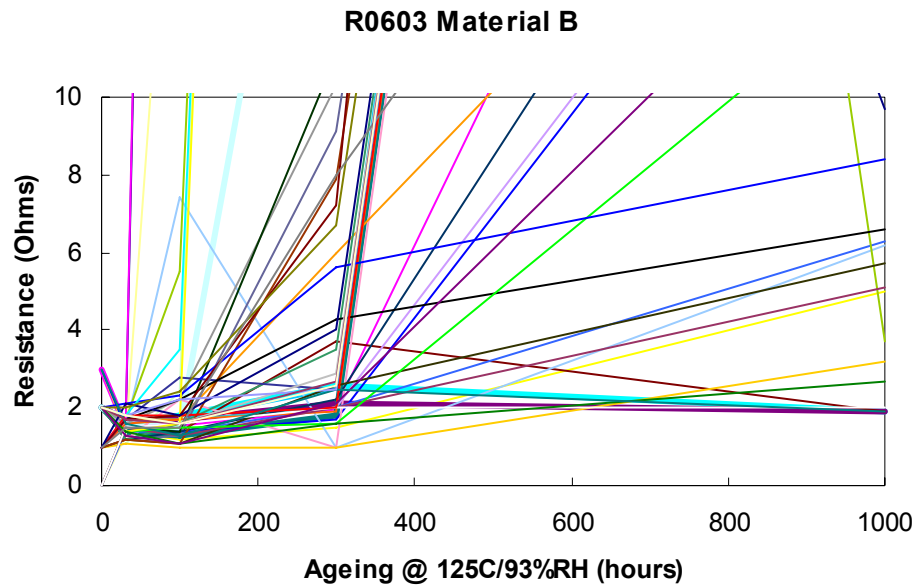


Figure 43: Variation of R0603 Resistance for Material B During Damp Heat Ageing at 125°C/93%RH

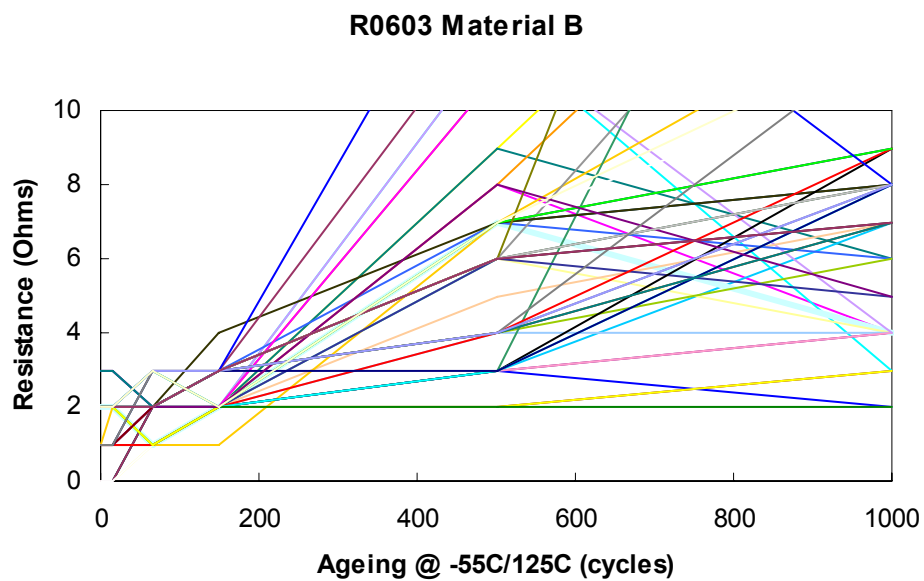


Figure 44: Variation of R0603 Resistance for Material B During Thermal Cycle Ageing at -55°C/125°C

3.1.6 BGA Resistance Measurement

The measured resistances of the joints to BGA components (made using materials A and B) for the four most stringent ageing regimes are given in Figures 45 to 52. These graphs show the variation of 40 individual circuits on 10 different daisy-chained BGA components.

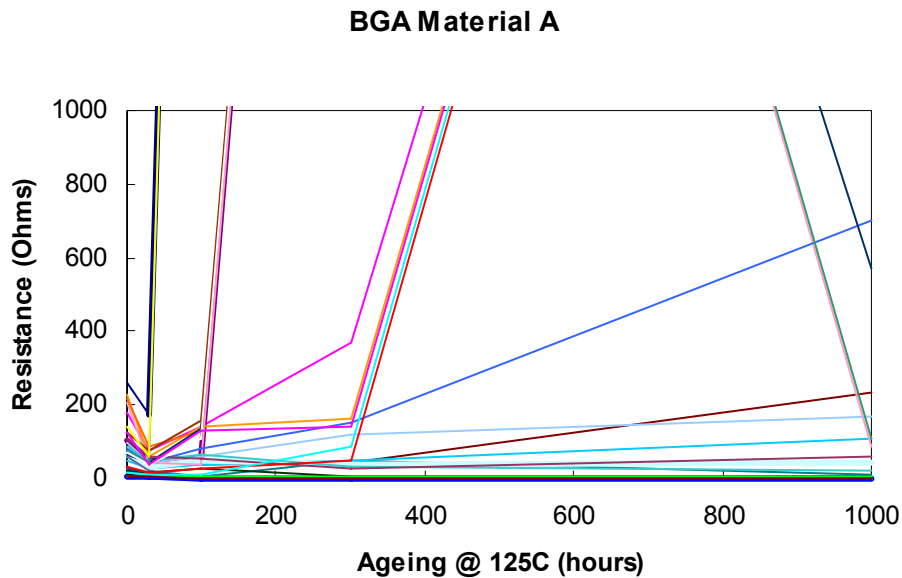


Figure 45: Variation of BGA Resistance for Material A During Dry Heat Ageing at 125°C

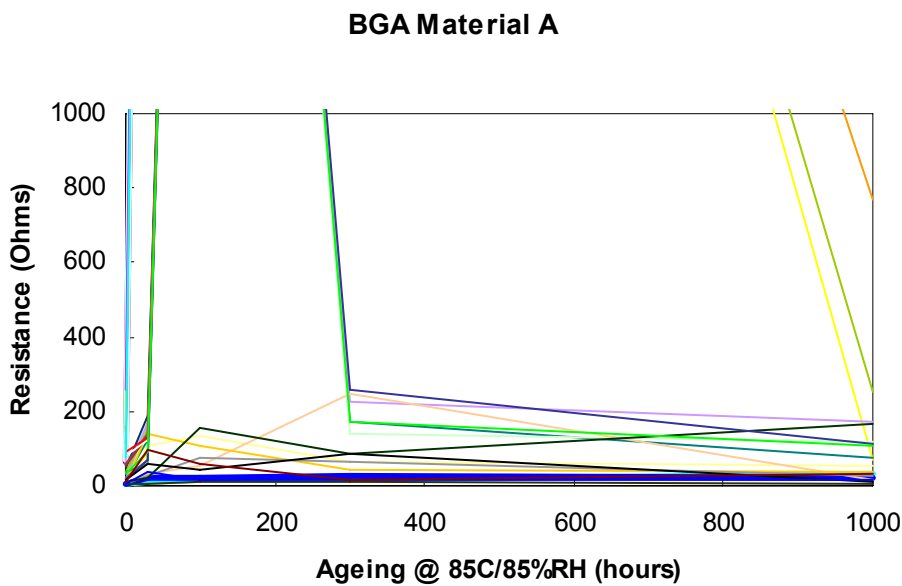


Figure 46: Variation of BGA Resistance for Material A During Damp Heat Ageing at 85°C/85%RH

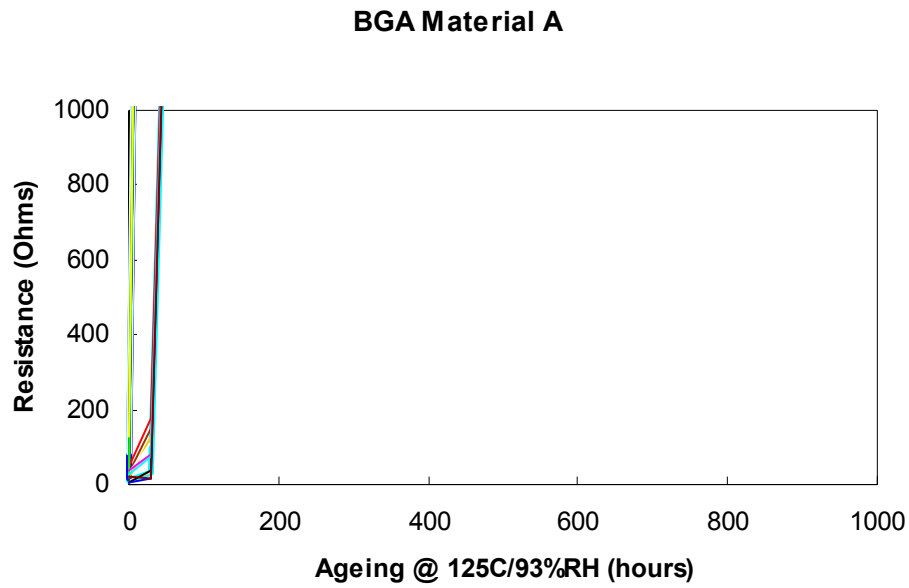


Figure 47: Variation of BGA Resistance for Material A During Damp Heat Ageing at 125°C/93%RH

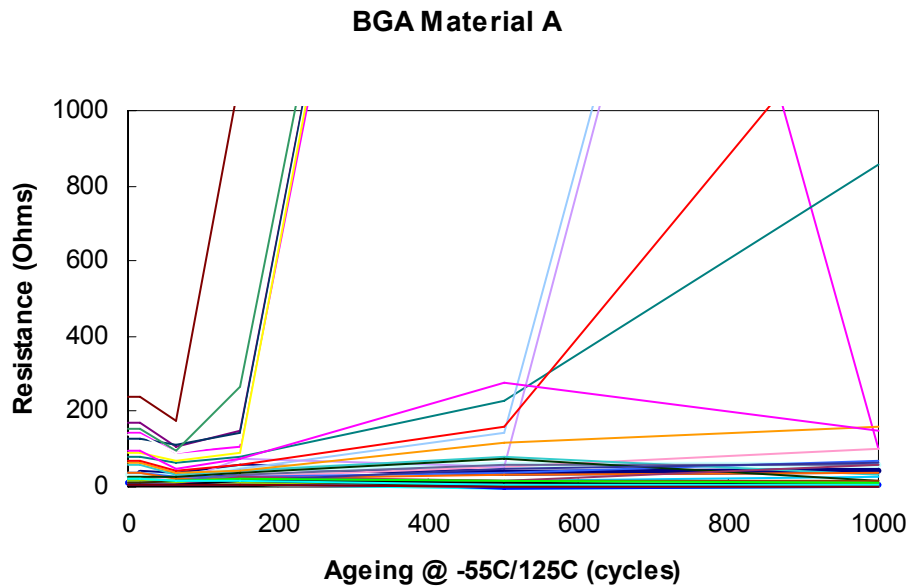


Figure 48: Variation of BGA Resistance for Material A During Thermal Cycle Ageing at -55°C/125 °C

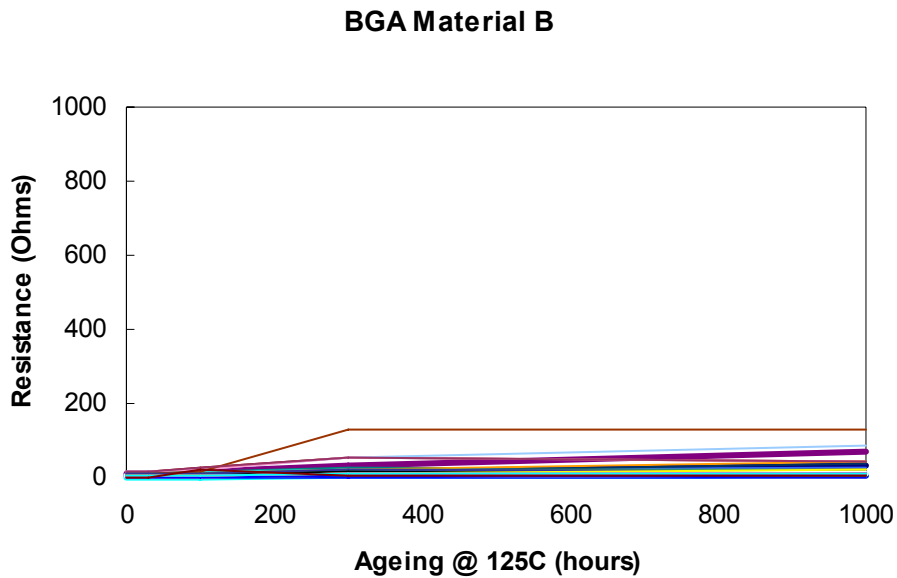


Figure 49: Variation of BGA Resistance for Material B During Dry Heat Ageing at 125°C

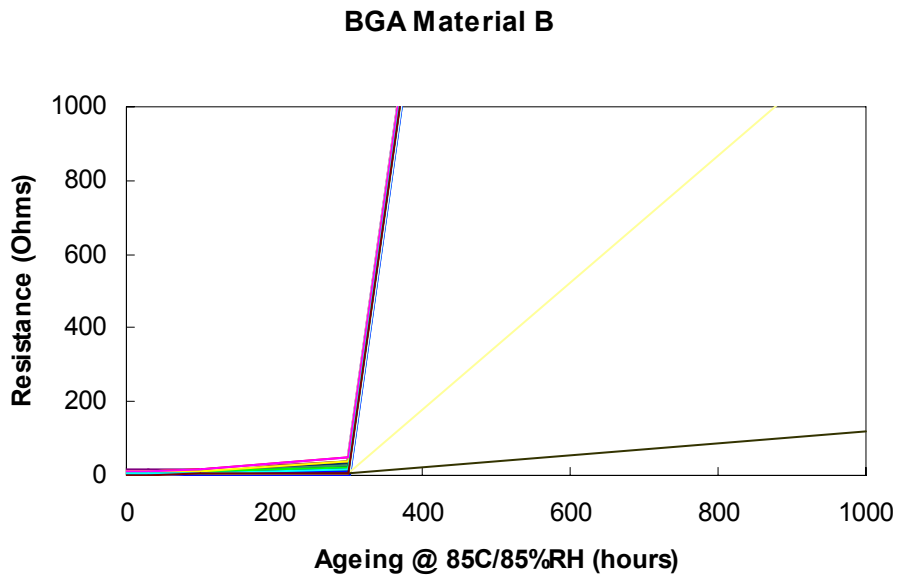


Figure 50: Variation of BGA Resistance for Material B During Damp Heat Ageing at 85°C/85%RH

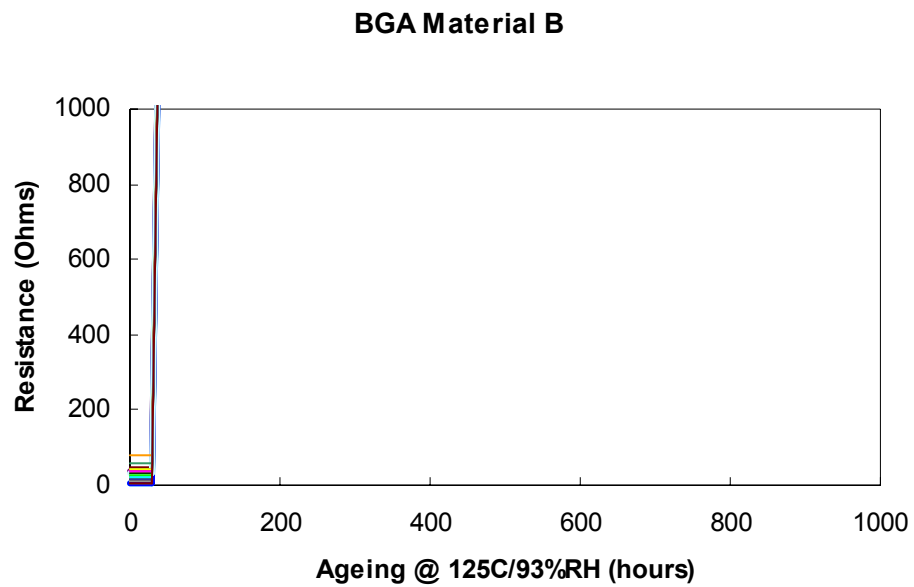


Figure 51: Variation of BGA Resistance for Material B During Damp Heat Ageing at 125°C/93%RH

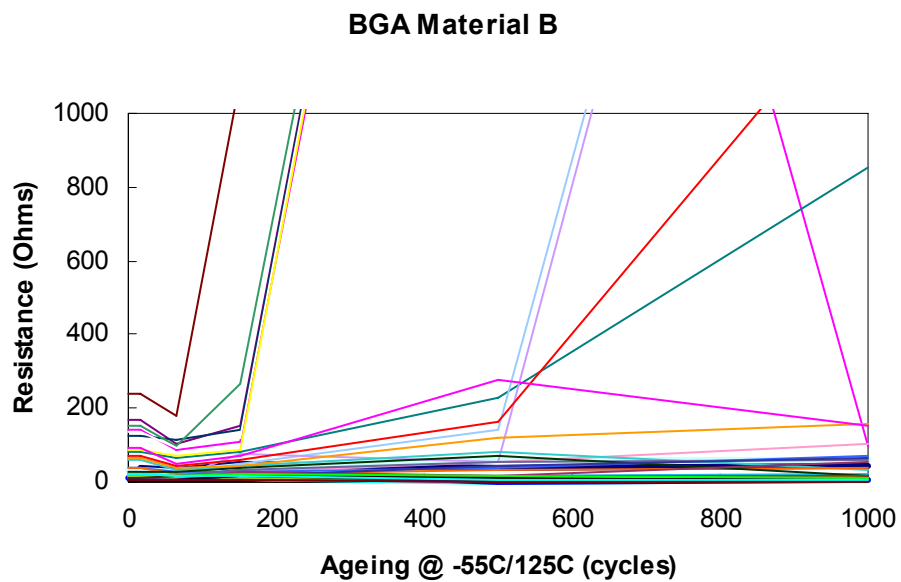


Figure 52: Variation of BGA Resistance for Material B During Thermal Cycle Ageing at -55°C/125°C

3.1.7 QFP Resistance Measurement

The measured resistances of the joints to QFP components (made using materials A and B) for the four most stringent ageing regimes are given in Figures 53 to 59. These graphs present the variation of 10 individual circuits on 5 different daisy-chained QFP components.

No results are presented for 125°C/93%RH material A as only one circuit survived the second electrical measurement after 30 hours of ageing.

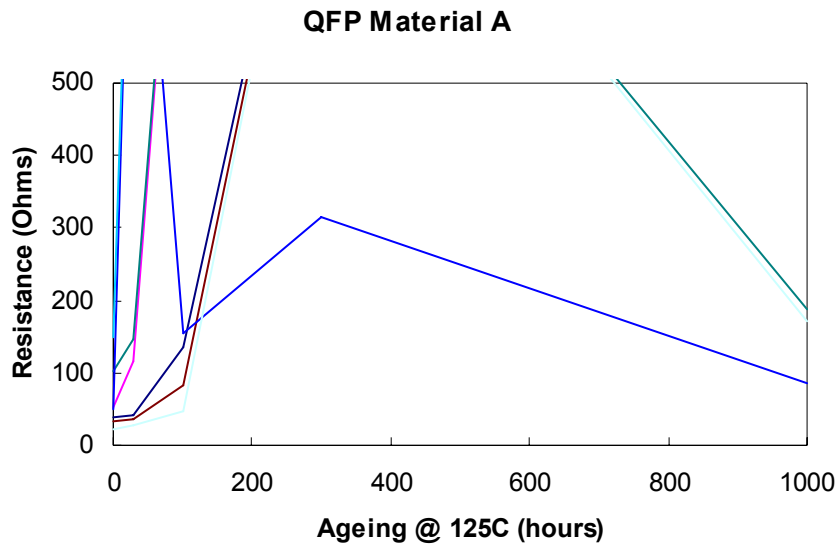


Figure 53: Variation of QFP Resistance for Material A During Dry Heat Ageing at 125°C

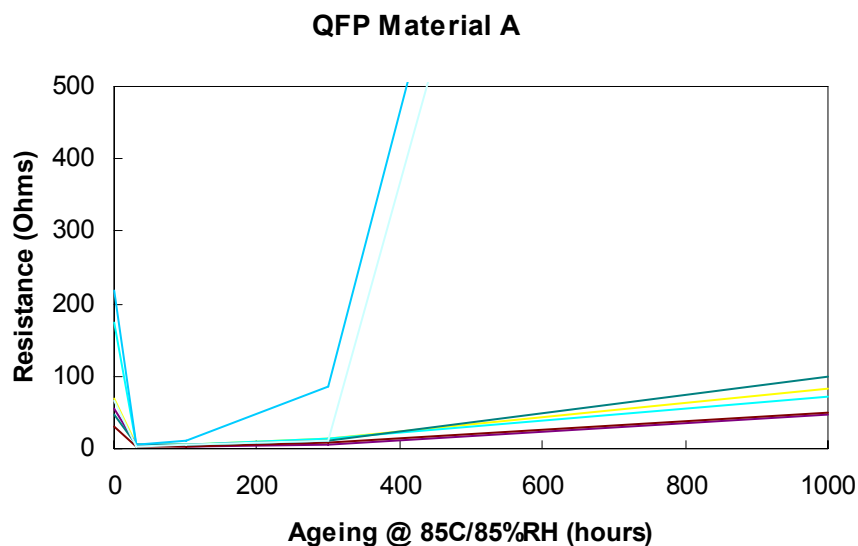


Figure 54: Variation of QFP Resistance for Material A During Damp Heat Ageing at 85°C/85%RH

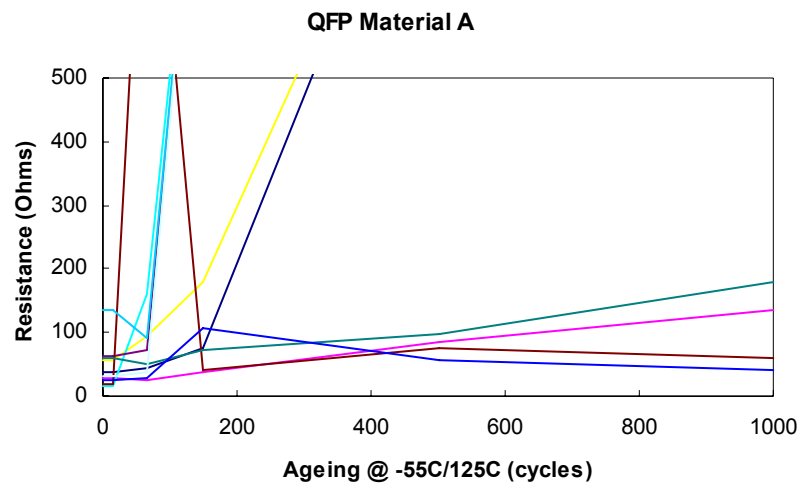


Figure 55: Variation of QFP Resistance for Material A During Thermal Cycle Ageing at -55°C/125°C

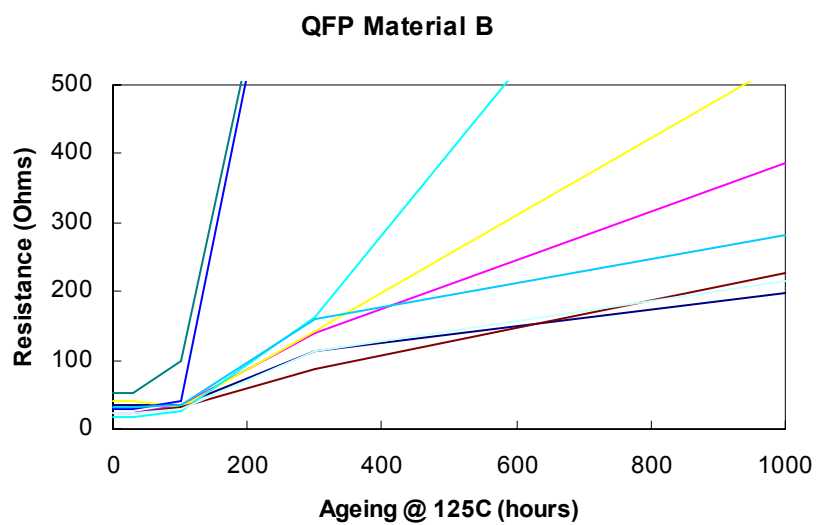


Figure 56: Variation of QFP Resistance for Material B During Dry Heat Ageing at 125°C

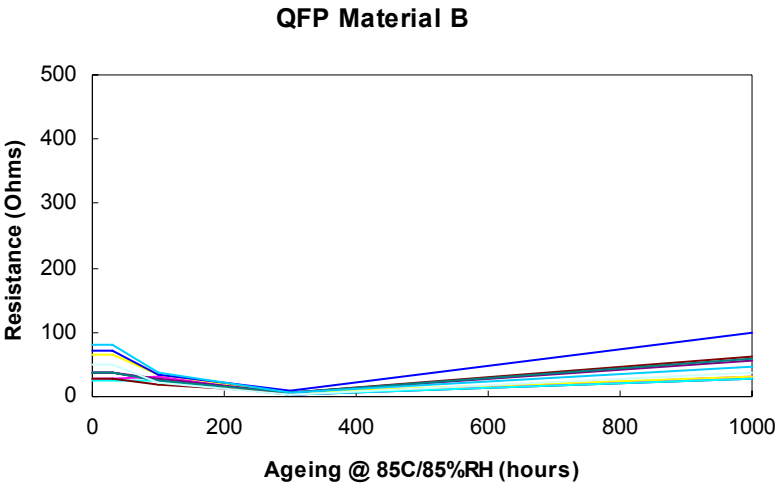


Figure 57: Variation of QFP Resistance for Material B During Damp Heat Ageing at 85°C/85%RH

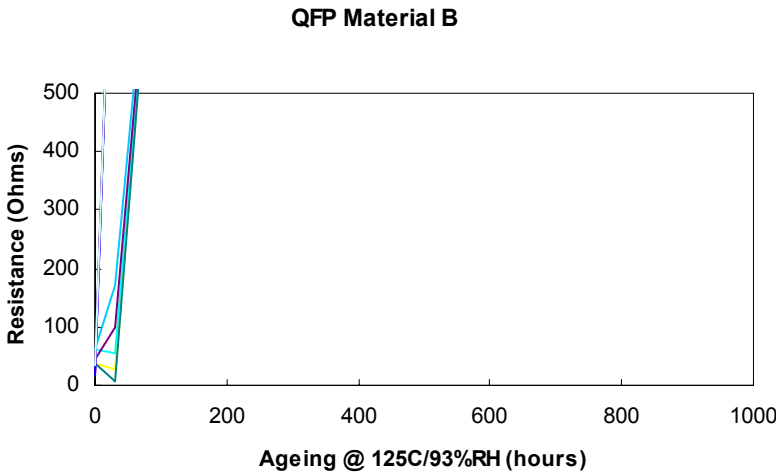


Figure 58: Variation of QFP Resistance for Material B During Damp Heat Ageing at 125°C/93%RH

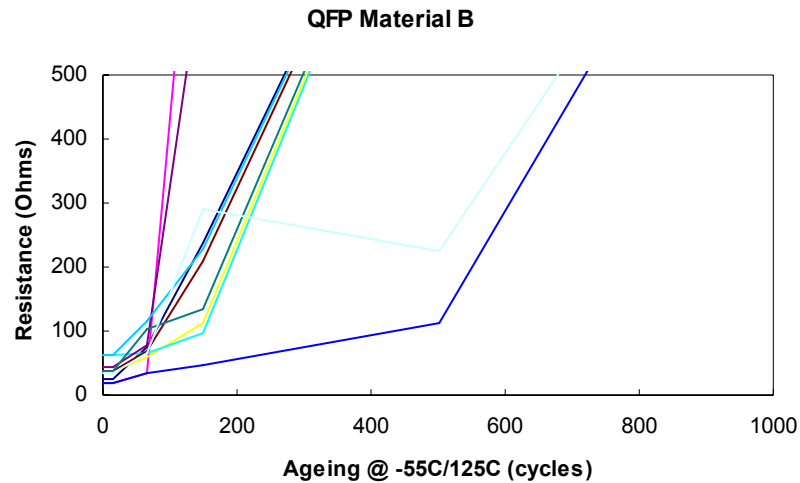


**Figure 59: Variation of QFP Resistance for Material B
During Thermal Cycle Ageing at -55°C/125 °C**

3.2 SHEAR TEST MEASUREMENT RESULTS

The ultimate shear strengths of the chip resistor (R0603 and R1206) components as a function of ageing time for all stress screening regimes are given in Figures 60 to 63 for both materials A and B. These graphs present the average values of 20 shear test measurements at each age.

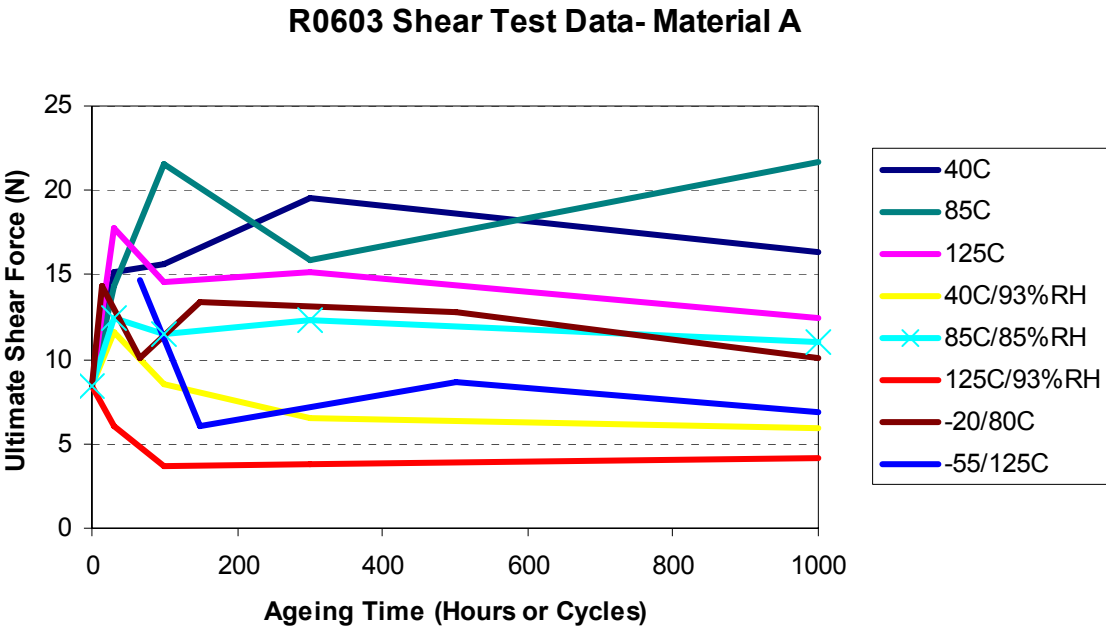


Figure 60: Variation of Average Ultimate Shear Force for R0603 Components With Material A With Ageing Time for All Ageing Regimes

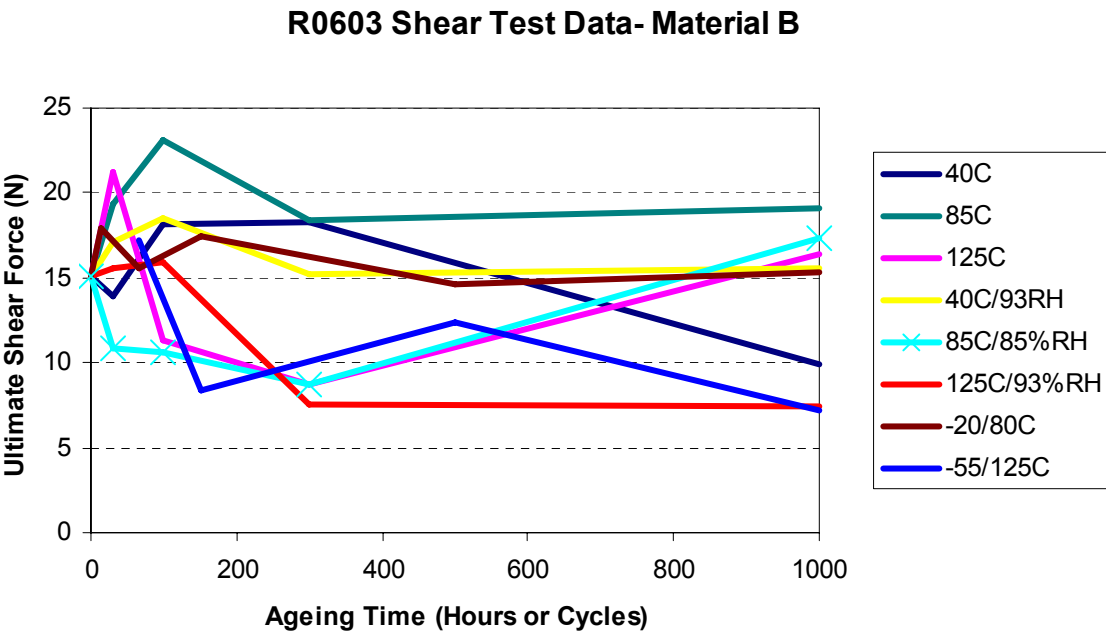


Figure 61: Variation of Average Ultimate Shear Force for R0603 Components With Material B With Ageing Time for All Ageing Regimes

R1206 Shear Test Data- Material A

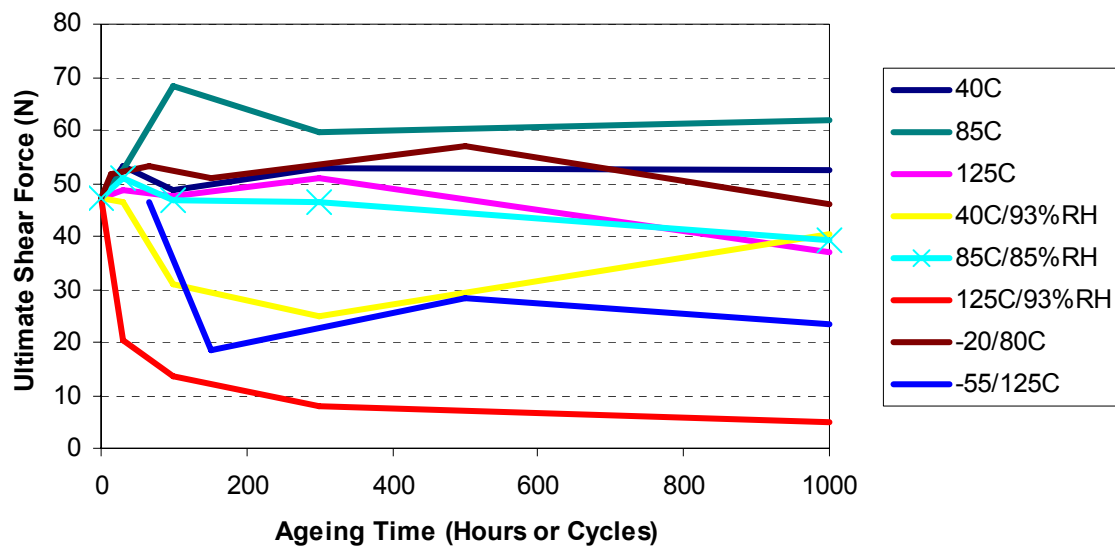


Figure 62: Variation of Average Ultimate Shear Force for R1206 Components With Material A With Ageing Time for All Ageing Regimes

R1206 Shear Test Data- Material B

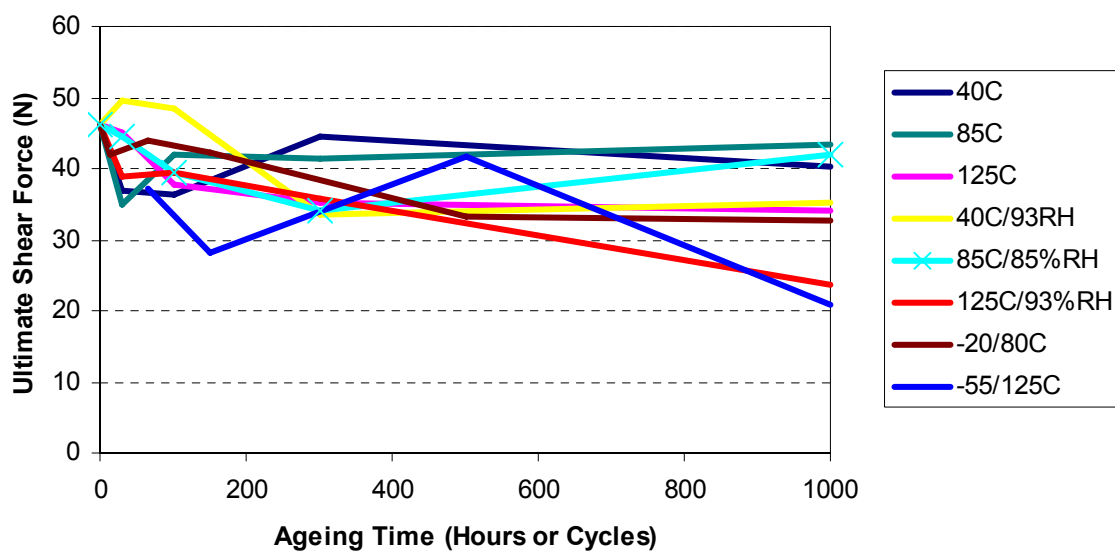


Figure 63: Variation of Average Ultimate Shear Force for R1206 Components With Material B With Ageing Time for All Ageing Regimes

3.3 DROP TESTING RESULTS

These results presented in Figures 64 to 69, refer to one assembly per material. This means that for each component type, the results are an average of the following number of components: BGAs x 2, QFP x 2, SOICs x 4, and R0603 and R1206 x 20.

All resistor components survived 20 drops after ageing for 1000 hours at all regimes.

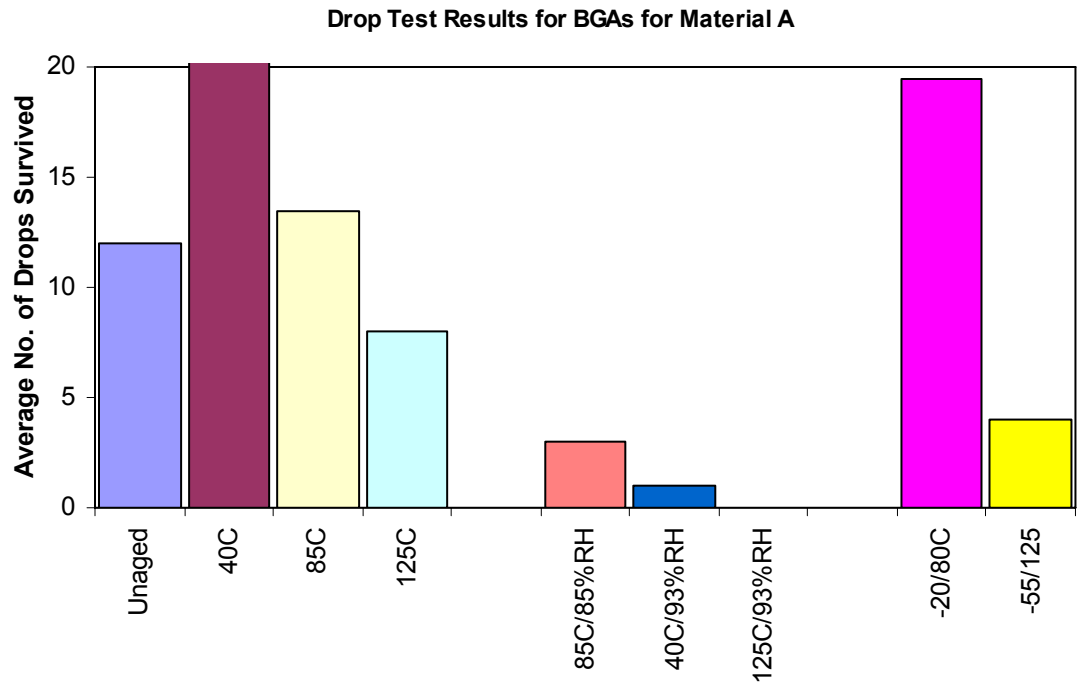


Figure 64: Drop Testing Results for BGA Components for Material A After 1000 Hours or Cycles Ageing At All Regimes

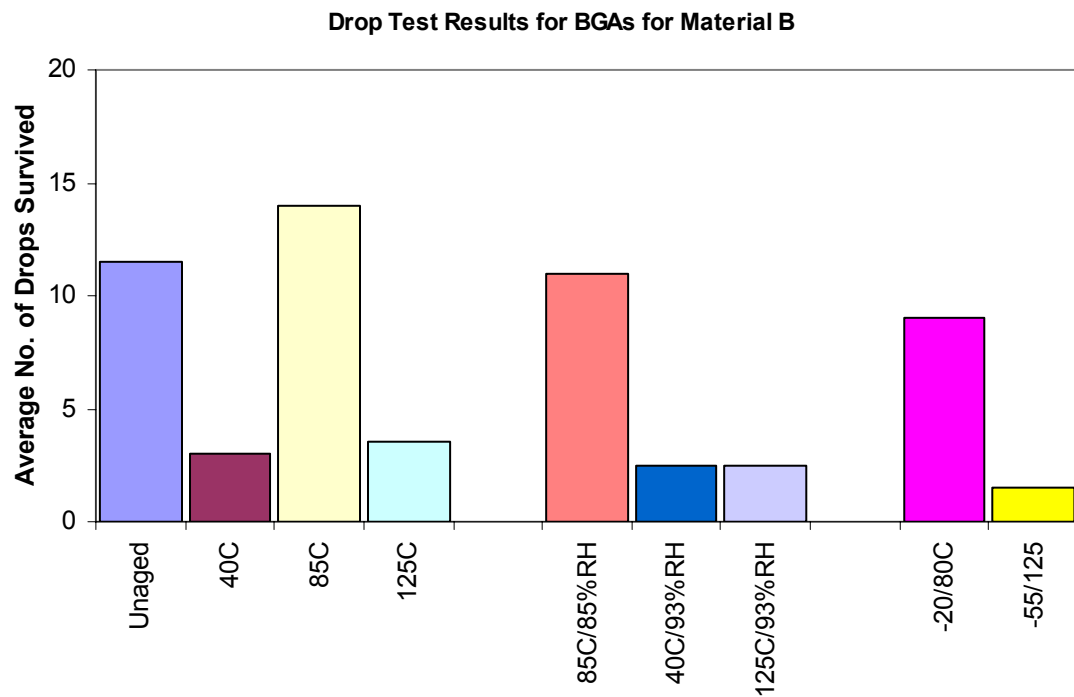


Figure 65: Drop Testing Results for BGA Components for Material B After 1000 Hours or Cycles Ageing At All Regimes

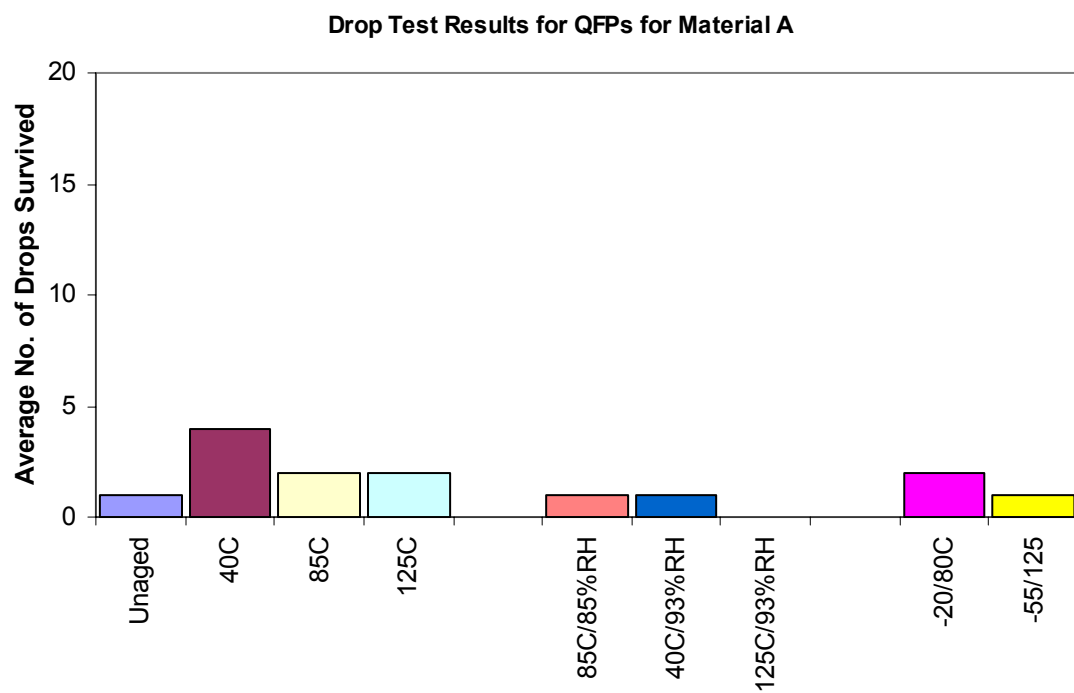


Figure 66: Drop Testing Results for QFP Components for Material A After 1000 Hours or Cycles Ageing At All Regimes

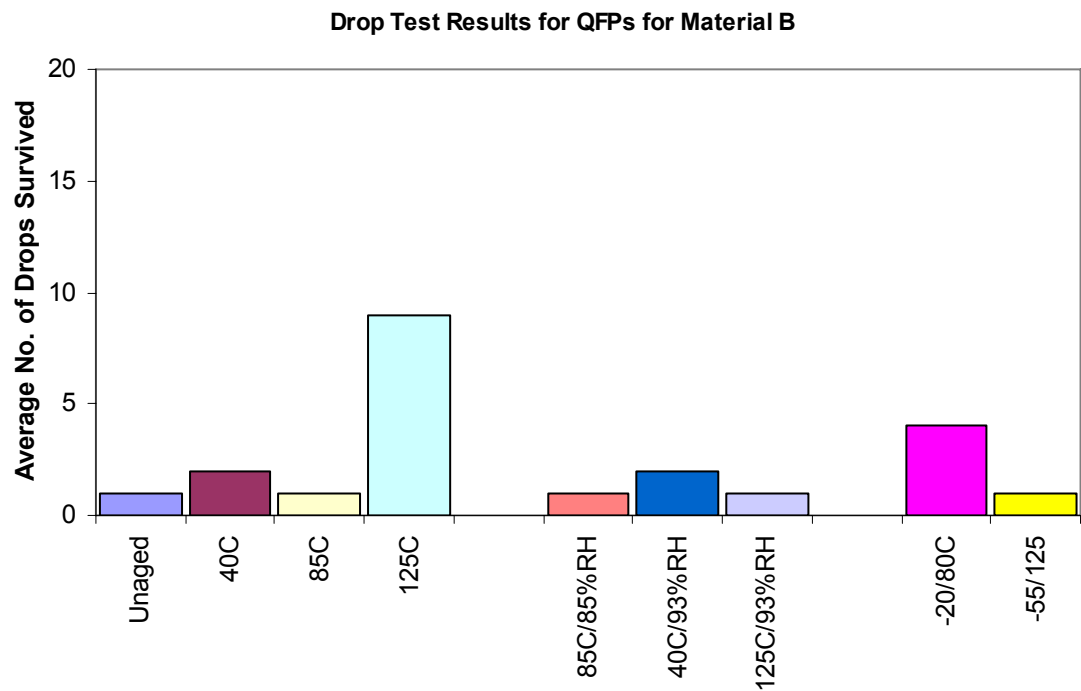


Figure 67: Drop Testing Results for QFP Components for Material B After 1000 Hours or Cycles Ageing At All Regimes

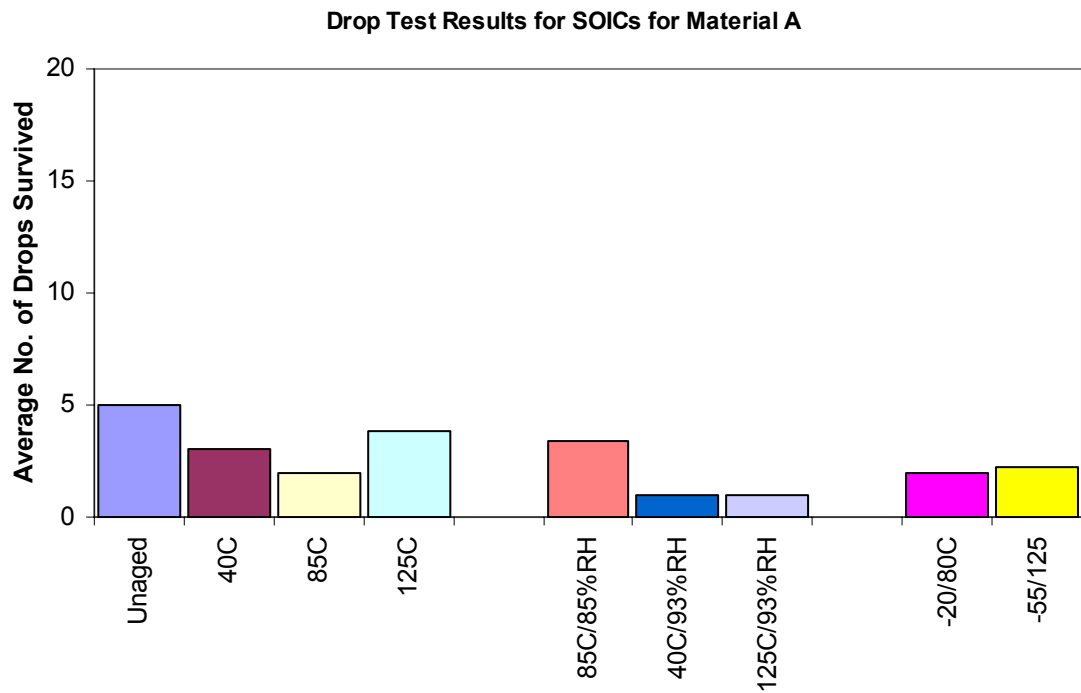


Figure 68: Drop Testing Results for SOIC Components for Material A After 1000 Hours or Cycles Ageing At All Regimes

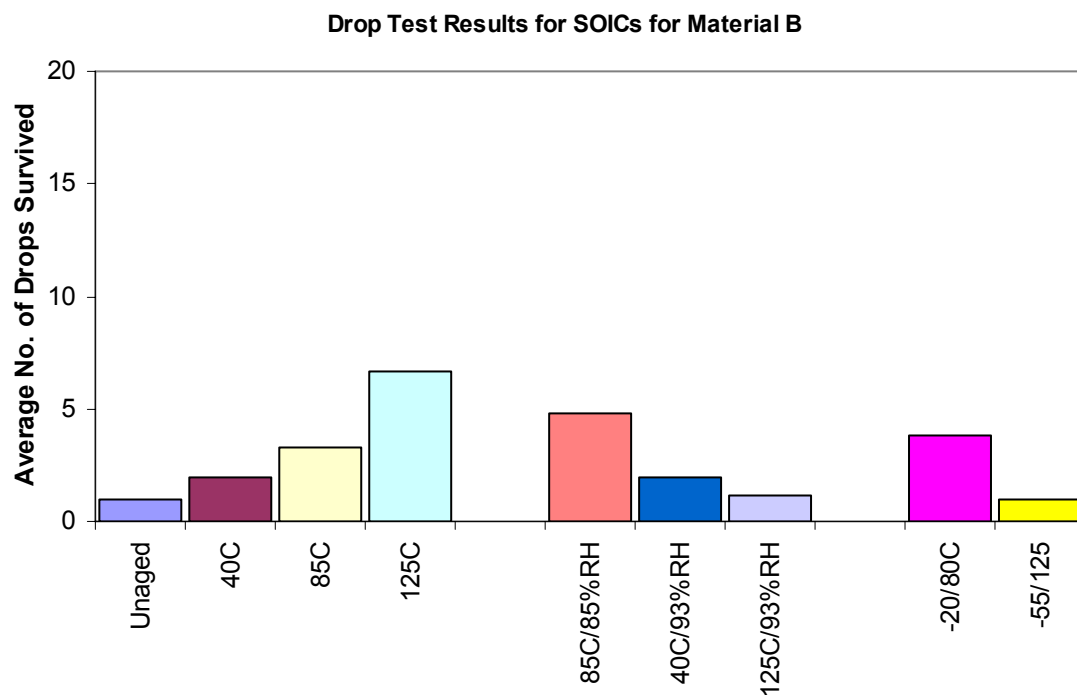


Figure 69: Drop Testing Results for SOIC Components for Material B After 1000 Hours or Cycles Ageing At All Regimes

3.4 SURFACE INSULATION RESISTANCE MEASUREMENT RESULTS

The variation of surface insulation resistance with time for the four test patterns for both materials is shown in Figure 70 and Figure 71. The results for a control board without printed conductive adhesive are given in Figure 72.

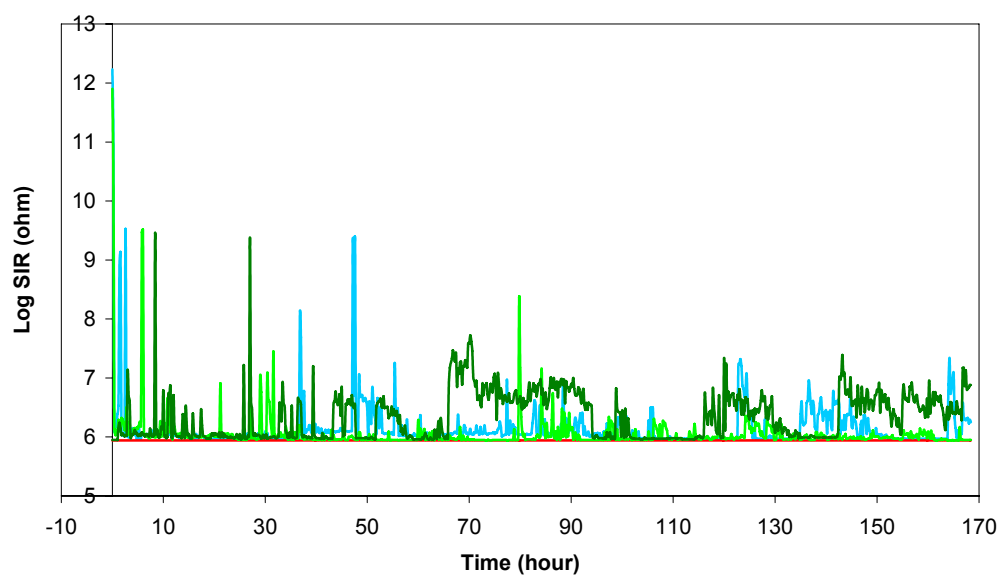


Figure 70: Surface Insulation Measurements for Test Patterns with Material A

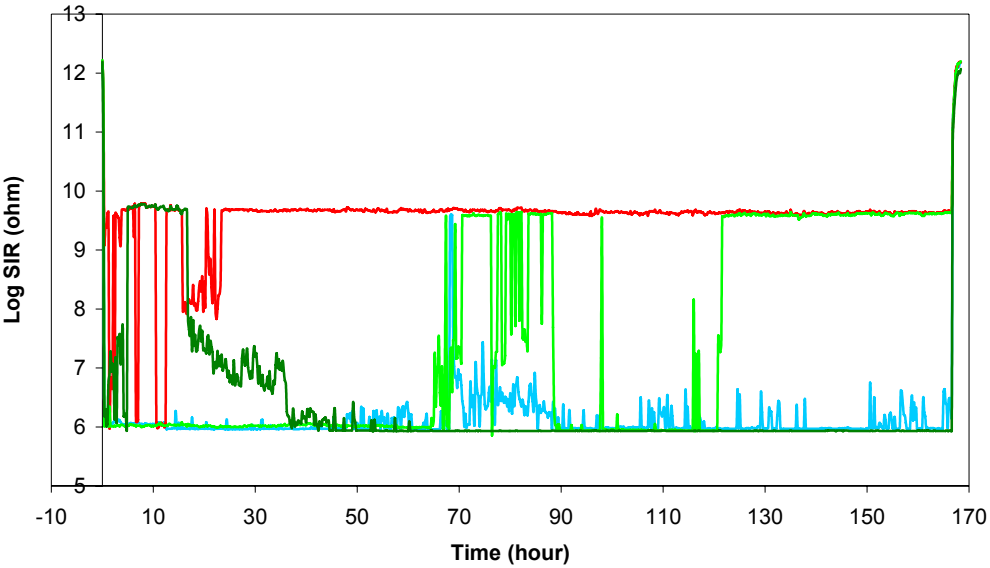


Figure 71: Surface Insulation Measurements for Test Patterns with Material B

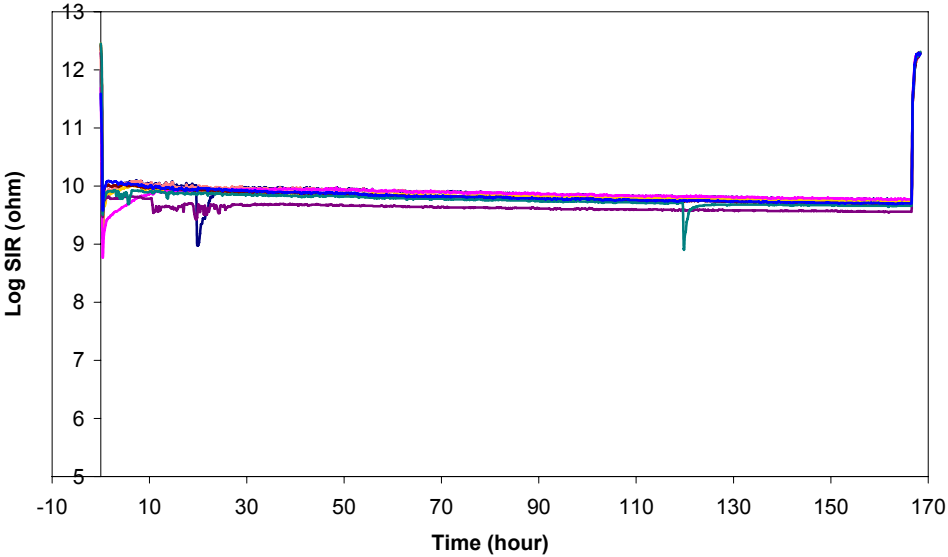


Figure 72: Surface Insulation Measurements for Control Test Patterns

4 DISCUSSION

4.1 ISOTROPIC CONDUCTIVE ADHESIVE FAILURE MODES

Due to the inherent flexibility associated with epoxy adhesives, stress screening of these materials must be viewed differently than for soldered joints. With soldered joints, the main failure mechanism is generally associated with cracking and ultimate joint failure within the bulk solder due to low cycle fatigue. This fatigue is normally generated by regular thermal excursions and a difference in the thermal coefficient of expansion (TCE) between the component, solder and PCB. The inherent conductivity of the solder, or its interface to components or PCBs, is unaffected by dry heat, damp heat or thermal cycling. Indeed, joint resistances generally rise little until immediately prior to full crack propagation through the joint.

Conductive adhesives may, however, be prone to all three of the above types of stress screening. The adhesive bond at the interface to the PCB or the component, may be subject to weakening and failure both mechanically, due to adhesion failure, and electrically, due to surface oxidation. The surfaces of the component and the PCB may oxidise and thereby increase in resistance if the oxide formed is not electrically conducting (as is the case with tin). Swelling of the polymer matrix due to moisture ingress may increase interface resistance by increasing the spacing between filler particles and the component or PCB termination surface, reducing electrical contact.

Similar failure modes may be present internally within the adhesive. Oxidation of the conductive particles may increase joint resistance although silver is generally chosen as an ICA filler material because silver oxide is electrically conducting. Polymer swelling may move filler particles further apart, increasing bulk resistance. Failure of the resin to filler interface may also result in increased resistance.

These failure modes may be promoted by any of the three types of stress screening chosen for this evaluation. Dry heat ageing may increase surface oxidation of materials. Damp heat ageing may promote surface oxidation, polymer swelling or adhesion failure (Reference 1). Thermal cycling may promote interfacial or bulk material failure and to a lesser extent, promote surface oxidation due to the high temperature dwells.

4.2 I-LINK RESISTANCE

The I-links were tracks of conductive adhesive printed on top of the PCB resist connecting ENIG plated PTHs. They had only a relatively small interface between the adhesive and the PTH land, making measurements of their resistance a good indication of the bulk material behaviour of the ICA.

Both A and B materials behaved well, with no electrical failures during any of the stress-screening regimes. Generally electrical resistance decreased over the 1000 hours or cycles of ageing. This was probably due to further curing of the resin matrix due to the elevated temperatures of testing, leading to resin shrinkage reducing the spacing and improving contact between filler particles. No evidence of detrimental effects of polymer swelling

during damp heat testing were noted, not even at the lower temperature/high humidity combination (40°C/93%RH).

As the interface between the tracks and the lands of the PTHs is relatively small compared to the length of the tracks, one can have some confidence that any resistance increases noted with other joint configurations with different termination materials or increased interface areas, are not due to bulk material changes.

4.3 JUMPER RESISTANCE

The jumpers shown in Figure 3 perform a similar measurement function to the I-links, but have an increased interface area between the ENIG pad and the ICA material. However, this increase appears to have had little effect on the results with both materials performing in a similar fashion to their I-links. In the majority of regimes, resistance of the jumper circuits decreases initially and then remains constant for the 1000 hours or cycles of ageing. The initial resistance decrease was probably due to further curing of the resin matrix at the elevated temperatures of testing. Resin shrinkage may also have occurred, reducing the spacing between filler particles and improving electrical contact.

With both A and B materials, a small trend of increasing resistance can be seen when ageing at -55°/125°C. This change may be due to the difference in TCE between the ICA and the pad causing a weakening of the interface, as no such resistance changes were observed after dry heat ageing at 125°C, which represents a considerably longer dwell at 125°C than the thermal cycling.

Material A also exhibited two continuity failures after damp heat ageing at 125°C/93%RH for 1000 hours, although the other eighteen samples aged with this regime showed little resistance change over the 1000 hours. No cause for these two failures was identified.

4.4 SOIC RESISTANCE

Comparisons of failure rates at 1000 hours or cycles for SOIC components for both materials are given in Figure 73 and Figure 75. A failure is considered to have occurred when the continuity circuit resistance increases by more than 100% from the as-manufactured value. The development of the failures for the four most stringent regimes, are given in Figure 74 and Figure 76 for materials A and B respectively.

The two materials performed similarly. Failures (greater than 100% resistance increase) occurred with all the ageing regimes, with higher temperatures and higher humidity giving the greater numbers of failures. Failures were generally low for dry heat ageing with the exception of material B at 125°C, where close to 100% failures occurred. Damp heat testing gave greater failures than with the dry heat ageing at similar temperatures, indicating that moisture plays a significant part in the ageing process. Ageing at 125°C/93%RH caused 100% failures in less than 100 hours of ageing and must be considered too stringent as an ageing regime designed to differentiate between experimental parameters.

Thermal cycling was generally less severe than damp heat ageing, but more stringent than dry heat ageing, indicating that TCE mismatch may play a part in accelerating failure modes. The rate of failure development for damp heat 85°C/85%RH, dry heat 125°C and thermal cycling -55°C/+125°C can be seen to be very similar.

Figure 77 illustrates a typical joint after 1000 hours damp heat ageing. A separation of the ICA from the underside of the SOIC lead can clearly be seen.

The SOIC components used in this study were plated with SnCu. The main failure mode would therefore appear to be associated with interfacial failure between the component and the adhesive. Oxidation of the SOIC termination may have a lesser effect on resistance.

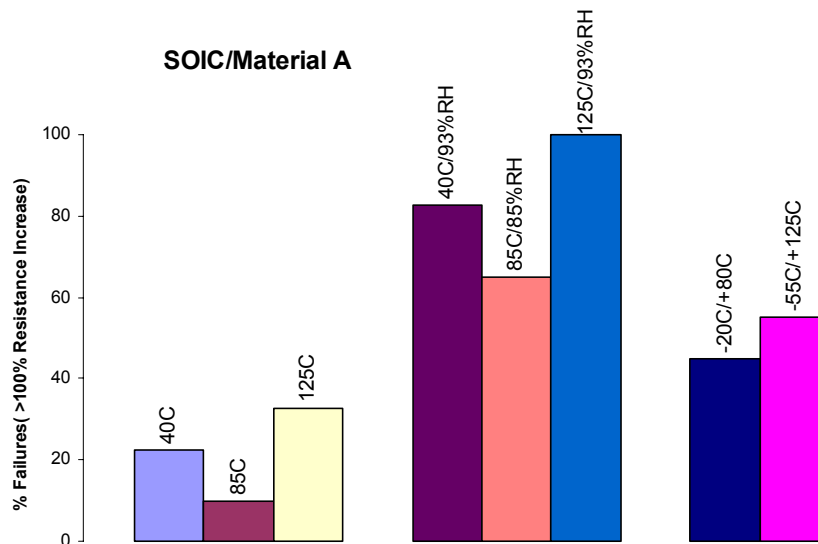


Figure 73: Comparison of Failure Rates (>100% Resistance Increase) for SOIC Components with Material A After 1000 Hours or Cycles For All Ageing Regimes

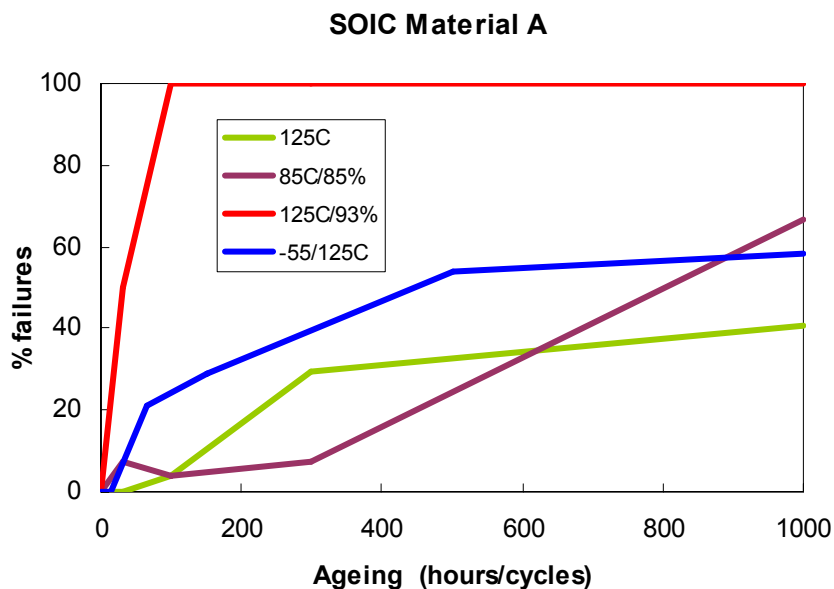


Figure 74: Cumulative % Failures for Material A with SOIC Components

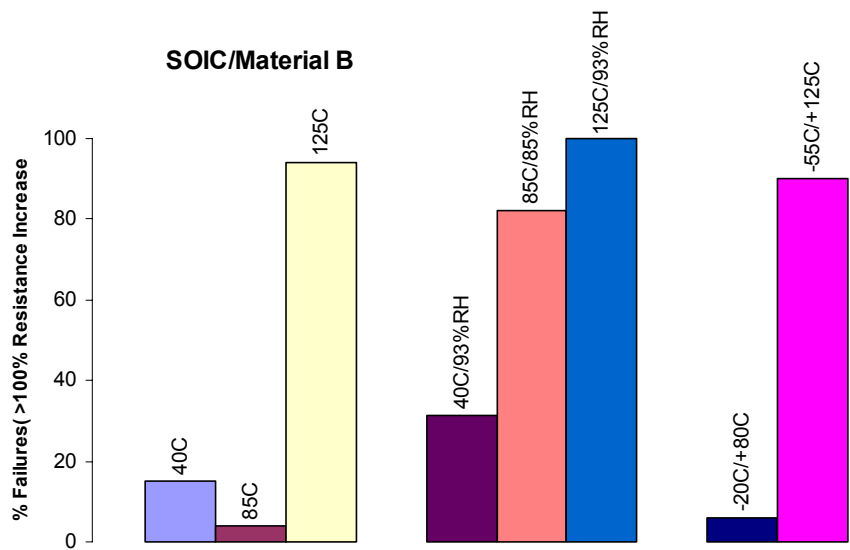


Figure 75: Comparison of Failure Rates (>100% Resistance Increase) for SOIC Components with Material B After 1000 Hours or Cycles For All Ageing Regimes

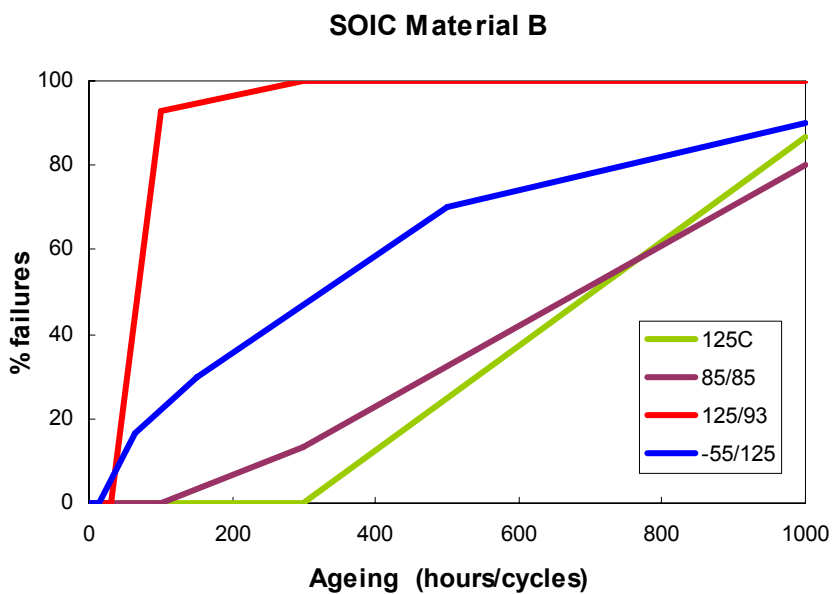


Figure 76: Cumulative % Failures for Material B with SOIC Components

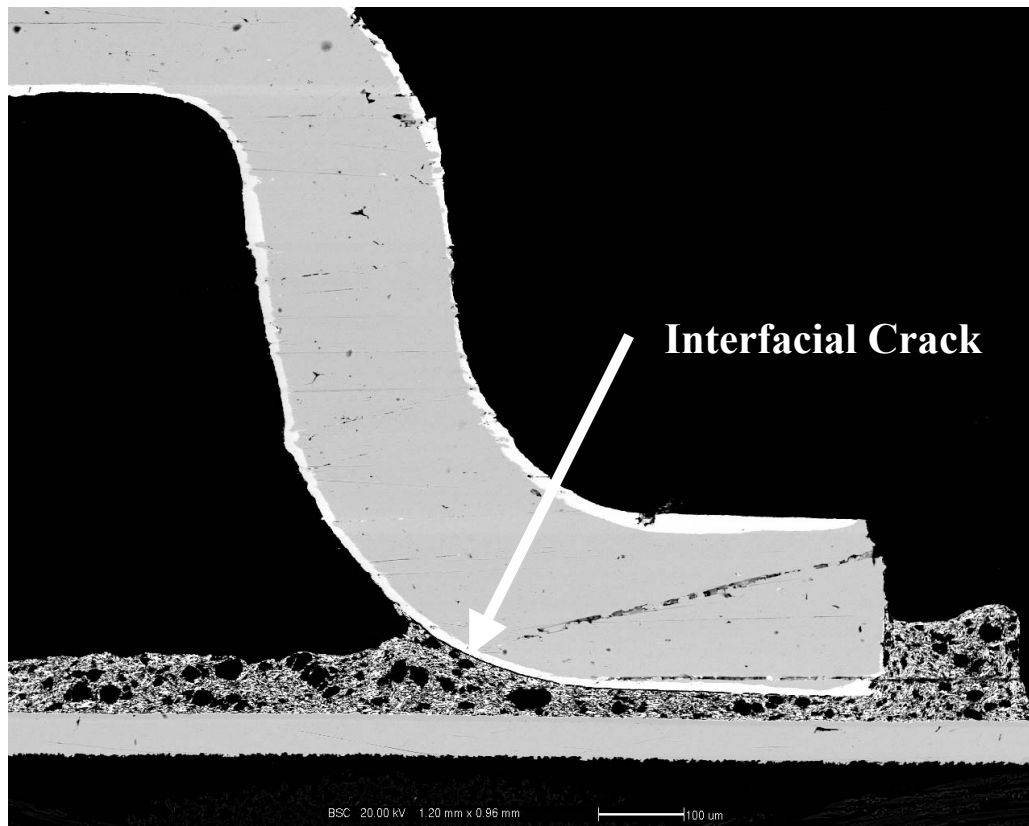


Figure 77: SEM Image of SOIC Conductive Adhesive Joint of Material B after 1000 Hours of 85°C/86%RH Showing Partial Crack at the Interface Between the Component (top) and Adhesive

4.5 R1206 RESISTANCE

Comparisons of failure rates at 1000 hours or cycles for R1206 components for materials A and B are given in Figure 78 and Figure 80 respectively. As before a failure is considered to have occurred when the continuity circuit resistance for the component increases by more than 100%. The development of the failures for the two most stringent regimes is shown for materials A and B respectively in Figure 79 and Figure 81. No significant failures were noted for the other stress screening regimes.

The two materials performed similarly with significant failures (greater than 100% resistance increase) occurring only with ageing at damp heat 125°C/93%RH and thermal cycling –55°C/+125°C regimes. Material A performed better for thermal cycling than for the damp heat ageing, but this trend was reversed for material B. Ageing at 125°C/93%RH causes 96% failures within 100 hours of ageing for material A and must be considered too stringent as an ageing regime.

The R1206 components used in this study were plated with tin. As no failures were noted for ageing at 125°C, heat alone was not significant in the generation of the failure mode for this component type. These components are ceramic based and failures associated with thermal cycling may be due to TCE mismatch between the component and the adhesive or the substrate material, causing a breakdown of the interface between the component and the adhesive.

Further evidence for this interfacial breakdown could be seen in microsections.

Figure 82 shows a section of an R1206 joint with material B after thermal cycling for 1000 cycles at $-55^{\circ}\text{C}/+125^{\circ}\text{C}$. Cracking at the interface is visible to the left and right of the indicating arrow. Damp heat testing may have begun to cause oxidation at the interface between the component and the adhesive. There is also evidence to suggest that the more severe damp heat testing $125^{\circ}\text{C}/93\%\text{RH}$, caused adhesion failure between the component and the adhesive. This can clearly be seen in

Figure 83. Similar adhesion failures were not noted in micro-sections of samples after less severe damp heat testing (see Figure 84). Also these cracks were not present in the micro-sections of joints of material A after severe damp heat testing $125^{\circ}\text{C}/93\%\text{RH}$. However, increases in resistance were still noted for material B so it is likely that an oxidation effect increasing resistance was at work here.

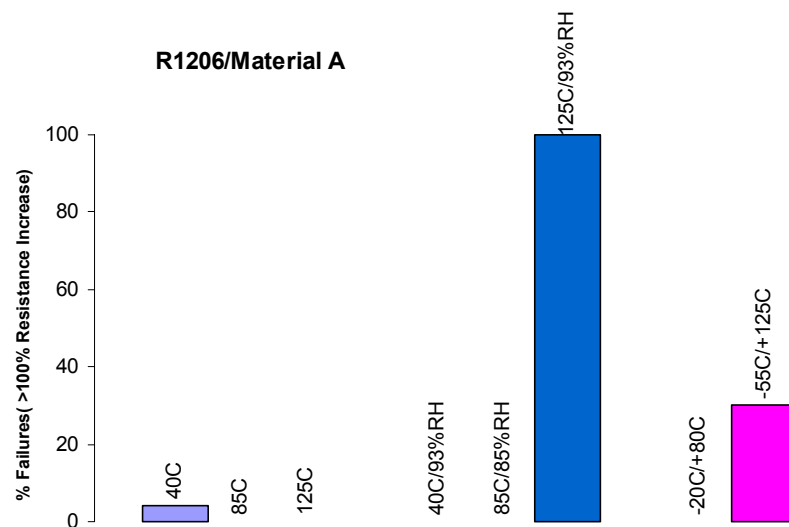


Figure 78: Comparison of Failure Rates (>100% Resistance Increase) for R1206 Components with Material A After 1000 Hours or Cycles for All Ageing Regimes

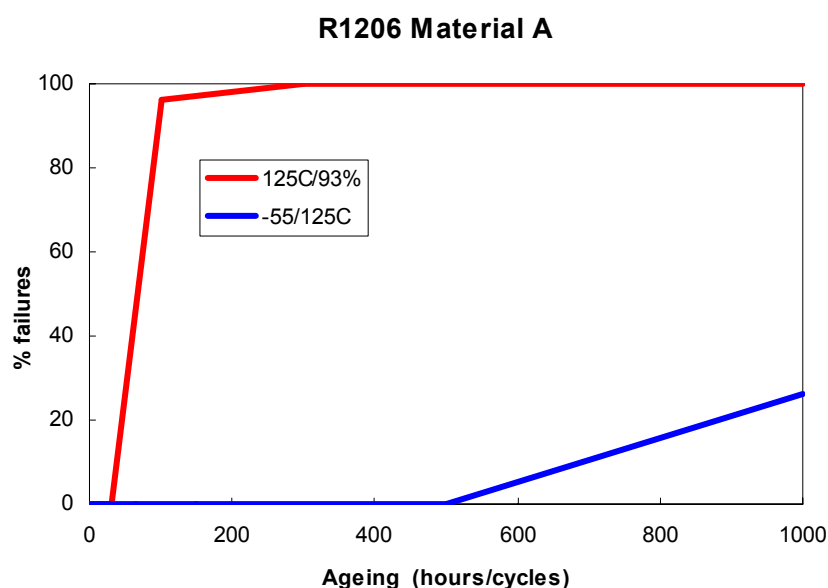


Figure 79: Cumulative % Failures for Material A with R1206 Components

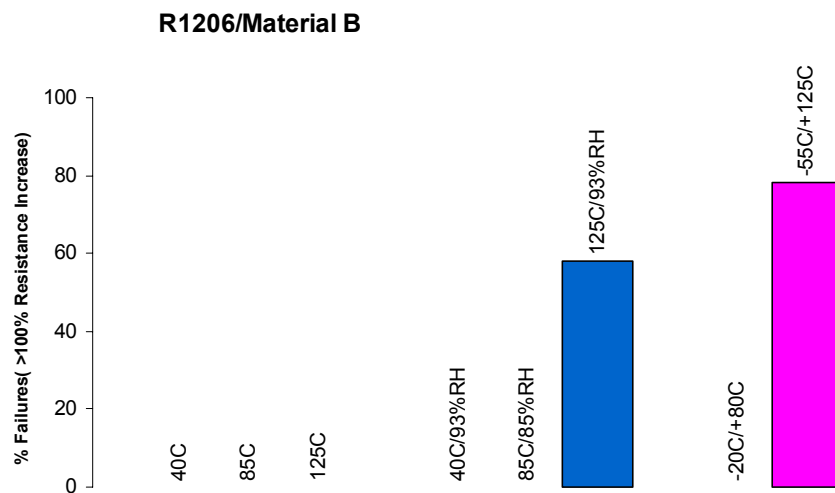


Figure 80: Comparison of Failure Rates (>100% Resistance Increase) for R1206 Components with Material B After 1000 Hours or Cycles For All Ageing Regimes

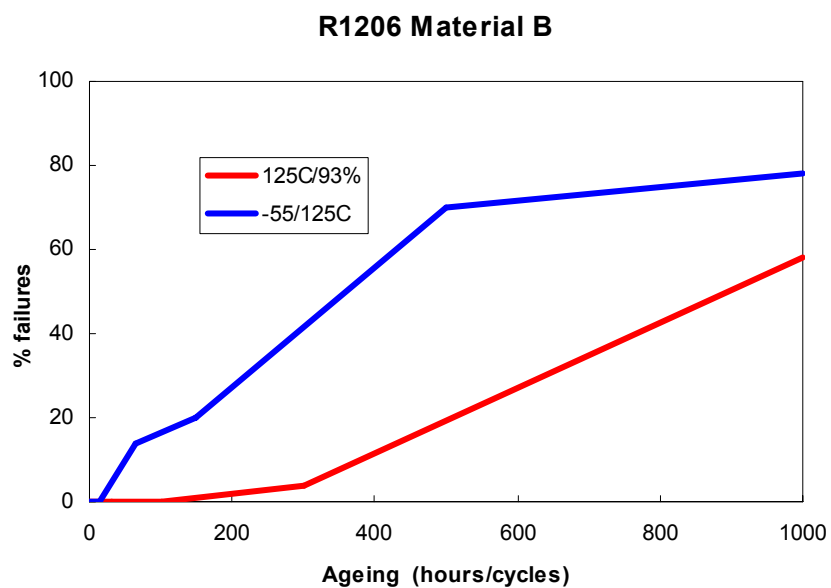


Figure 81: Cumulative % Failures for Material B with R1206 Components

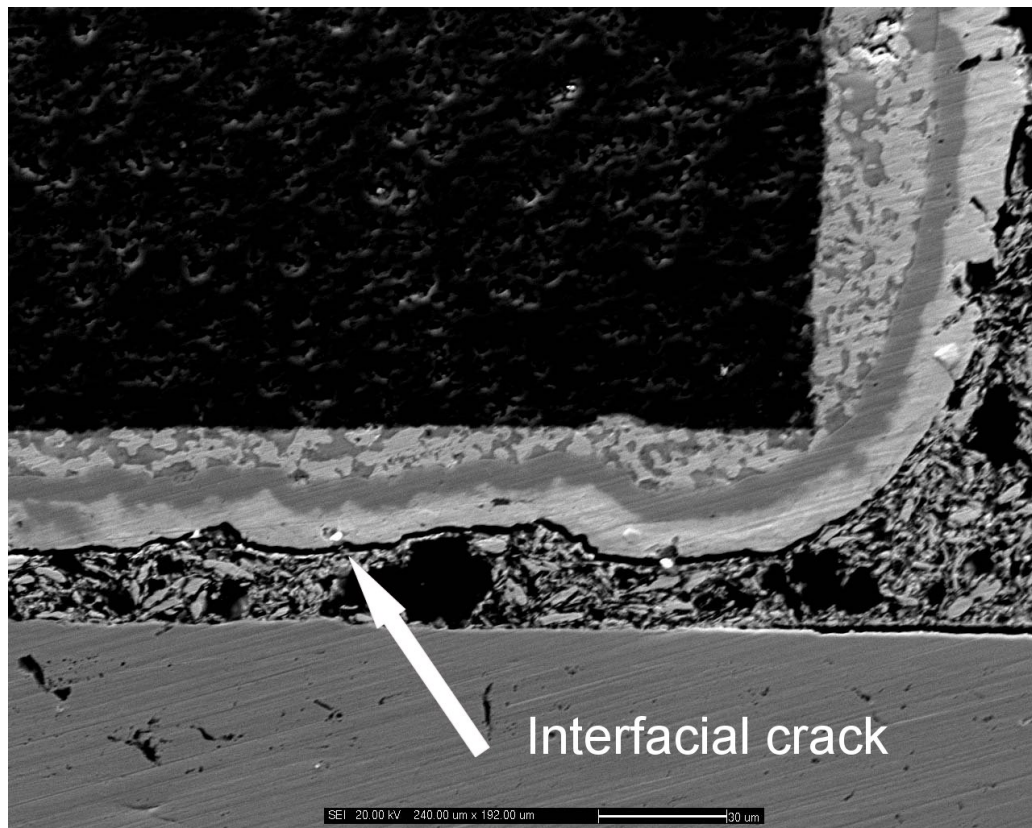


Figure 82: SEM Image of R1206 Conductive Adhesive Joint of Material B after 1000 cycles of -55°C/+125°C Showing Partial Crack at the Interface Between the Component (top) and Adhesive

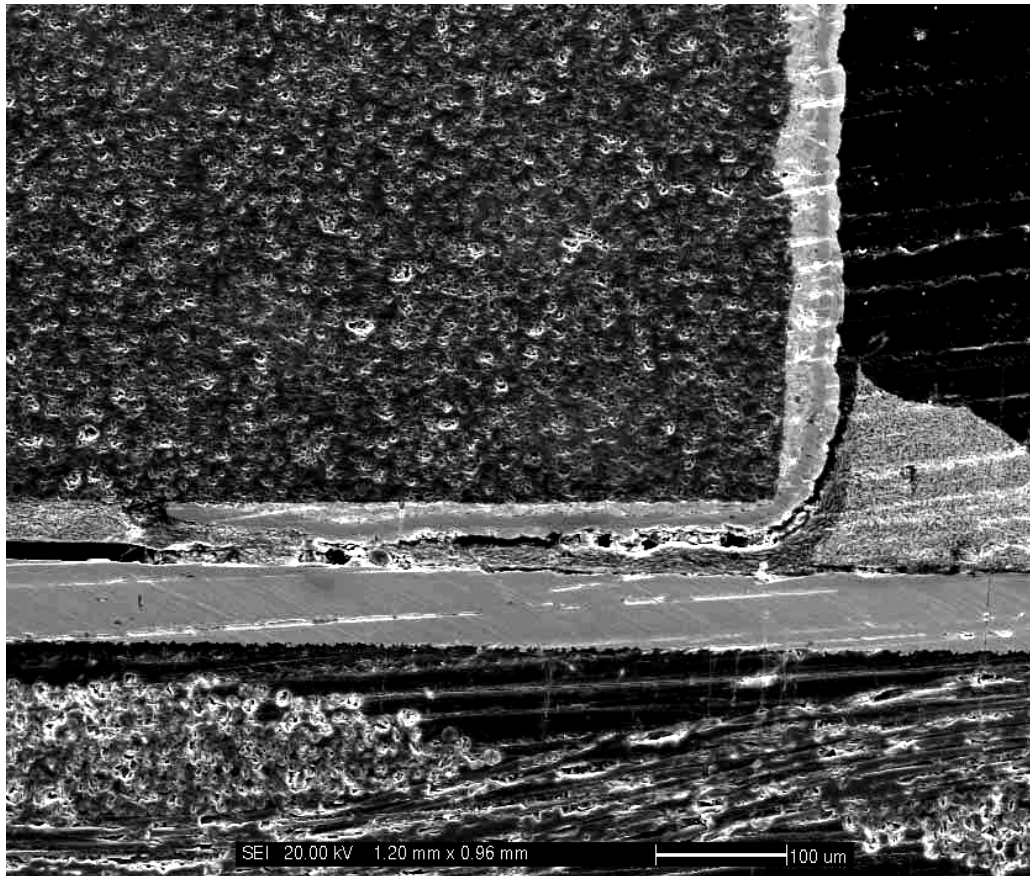


Figure 83: SEM Image of R1206 Conductive Adhesive Joint of Material A after 1000 Hours of 125°C/93%RH Showing Adhesion Failure at the Interface Between the Component (top) and Adhesive

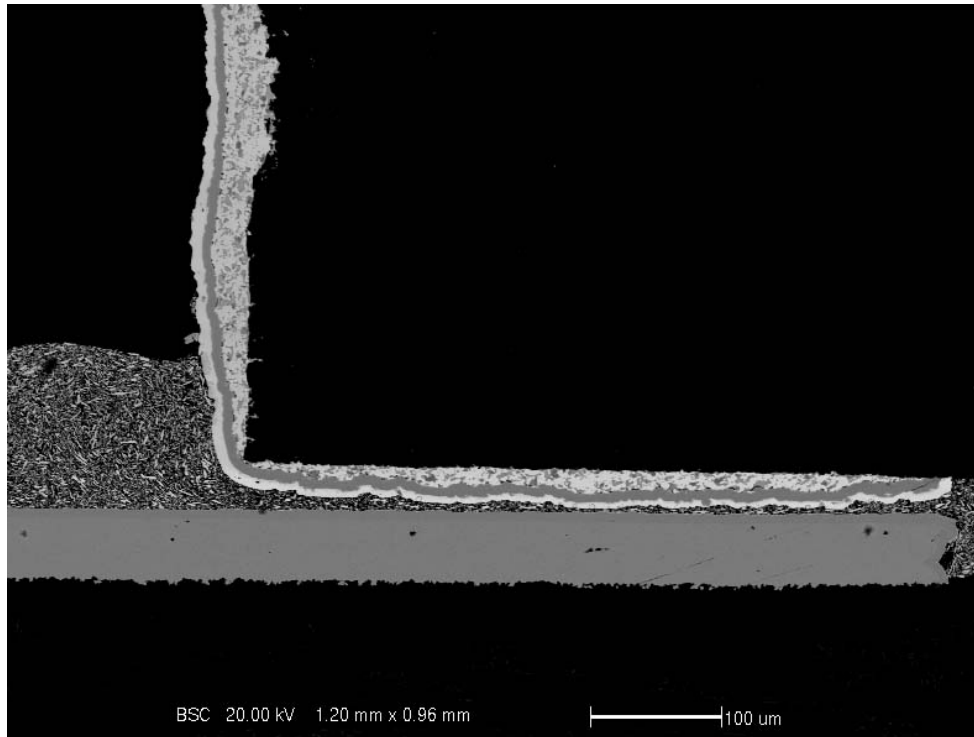


Figure 84: SEM Image of R1206 Conductive Adhesive Joint of Material A after 1000 hours of 85°C/85%RH Showing No Evidence of Adhesion Failure at the Interface Between the Component (top) and Adhesive

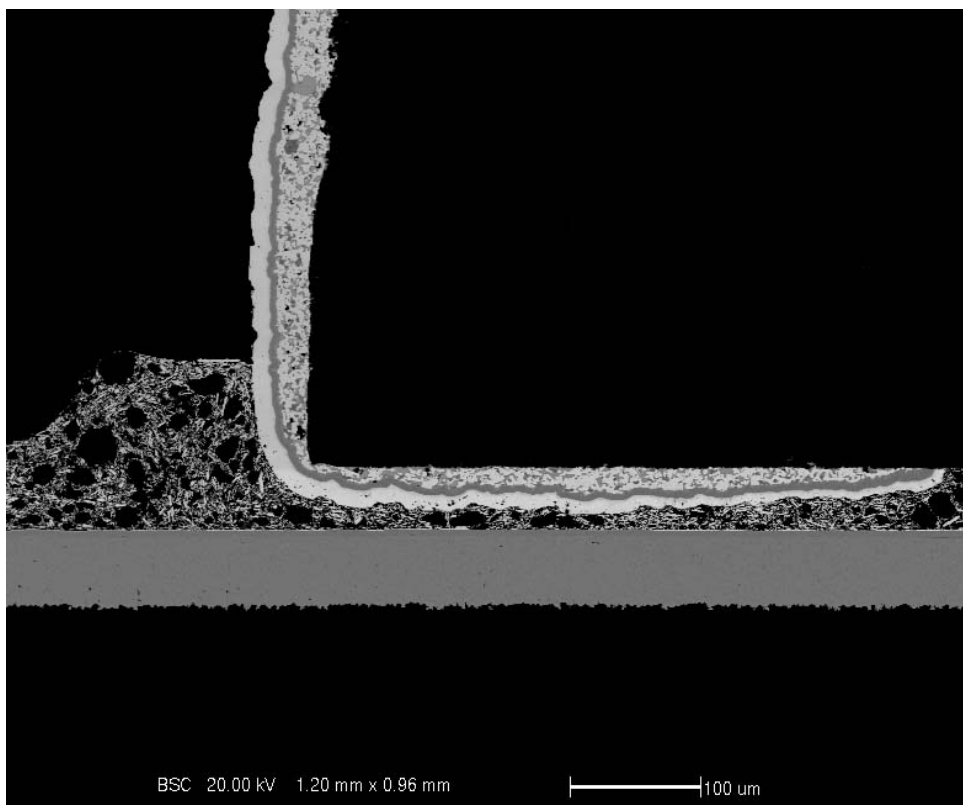


Figure 85: SEM Image of R1206 Conductive Adhesive Joint of Material B after 1000 hours of 125°C/93%RH Showing No Apparent Adhesion Failure

4.6 R0603 RESISTANCE

Significant failures of R0603 components occurred only for the damp heat 125°C/93%RH regime. Comparisons of failure rates at 1000 hours or cycles for both materials are given in Figure 86. As before a failure is considered to have occurred when the continuity circuit resistance for the component increases by more than 100%. The development of the failures for both materials for the 125°C/93%RH regime is given in Figure 87.

Material B performed better for ageing at 125°C/93%RH, with failures developing at a slower rate. The failure rate for material A was at 96% within 1000 hours of ageing and therefore 125°C/93%RH must be considered too stringent as an ageing regime.

The R0603 components used in this study were plated with tin. Unlike their R1206 counterparts, no failures were noted for thermal cycling. This is because R0603 components are smaller than R1206 components and therefore the strain on the adhesive is less. Failures may occur if thermal cycling were extended beyond 1000 cycles.

Heat or moisture alone were not significant in the generation of the failures for this component. Damp heat testing at 125°C/93%RH may have initiated oxidation at the interface between the component and the adhesive.

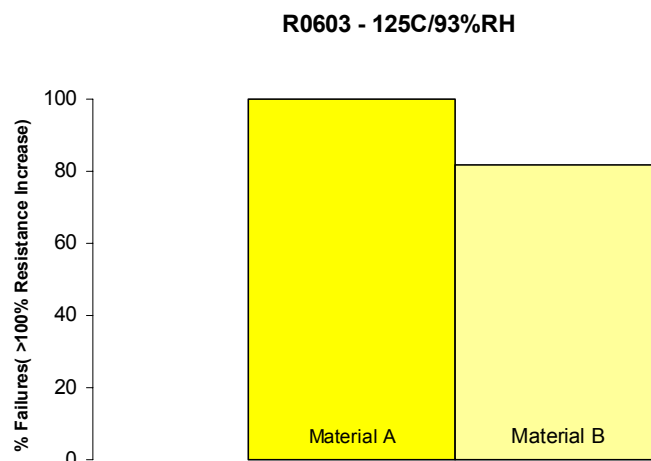


Figure 86: Comparison of Failure Rates (>100% Resistance Increase) for R0603 Components with Materials A & B After 1000 Hours at 125°C/93%RH

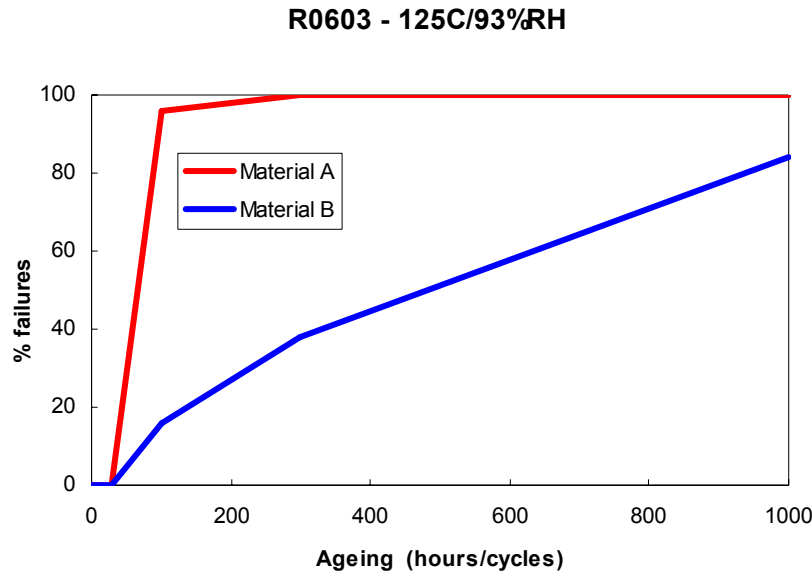


Figure 87: Cumulative % Failures for Materials A & B with R0603 Components at 125°C/93%RH

4.7 BGA RESISTANCE

Comparisons of failure rates at 1000 hours or cycles for BGA components for materials A and B are given in Figure 88 and Figure 90 respectively. As before a failure is considered to have occurred when the continuity circuit resistance for the component increases by more than 100%. The development of the failures for the four most stringent regimes is given in Figure 89 and Figure 91 for materials A and B respectively.

The two materials performed similarly. Significant failures (greater than 100% resistance increase) occurred with most of the ageing regimes, the exceptions being dry heat ageing at 40°C and 85°C, with higher temperatures and higher humidity giving the greater number of failures. Failures for dry heat ageing at 125°C were lower than for the same temperature when humidity was included, indicating that moisture plays a significant part in the ageing process. Ageing at 125°C/93%RH caused 100% failures in less than 100 hours of ageing and must be considered too stringent as an ageing regime. Similar failure rates were noted for components assembled with material A and tested using 85°C/85%RH.

Figure 92 shows a section of a BGA joint after 1000 hours at 125°C/93%RH. Adhesion failure at the interface between the component and the adhesive can clearly be seen.

Thermal cycling is generally less severe than similar temperature damp heat ageing, but more stringent than dry heat ageing, indicating that TCE mismatch may play a part in accelerating failure modes. The rate of failure development for dry heat 125°C and thermal cycling –55°C/+125°C can be seen to be very similar for material A, whilst failure development rates for damp heat 85°C/85%RH, dry heat 125°C and thermal cycling –55°C/+125°C are similar for material B.

Figure 93 shows a section of a BGA joint after 1000 cycles at –55°C/+125°C. Adhesion failure at the interface between the component and the adhesive can clearly be seen.

The balls of the BGA components used in this study were manufactured from SnAgCu alloy. The micro-sections indicated that adhesion failure was the primary failure mode with the possibility that oxidation of the BGA termination was also a contributing factor to resistance increases.

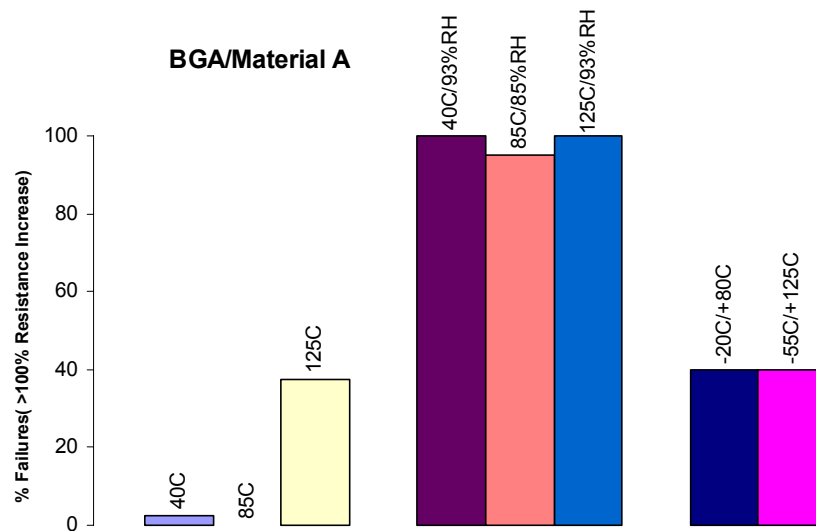


Figure 88: Comparison of Failure Rates (>100% Resistance Increase) for BGA Components with Material A After 1000 Hours or Cycles For All Ageing Regimes

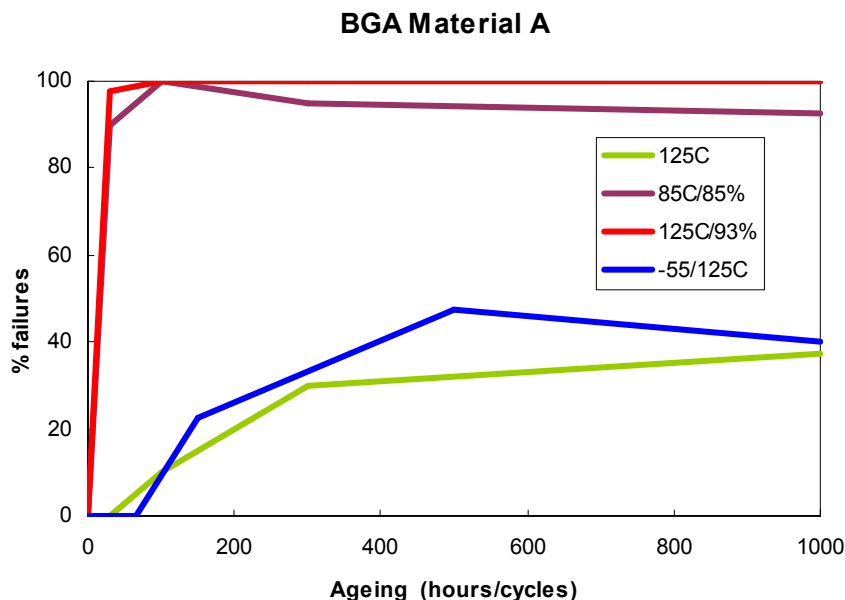


Figure 89: Cumulative % Failures for Material A with BGA Components

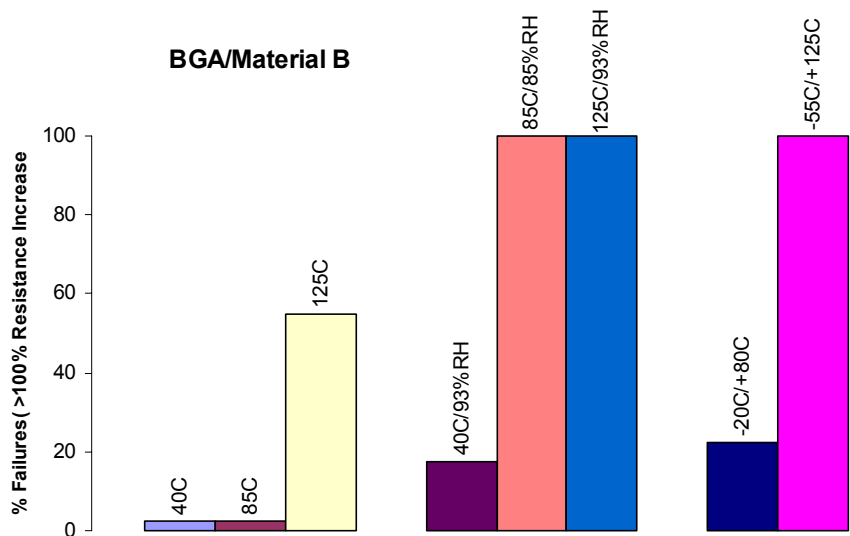


Figure 90: Comparison of Failure Rates (>100% Resistance Increase) for BGA Components with Material B After 1000 Hours or Cycles For All Ageing Regimes

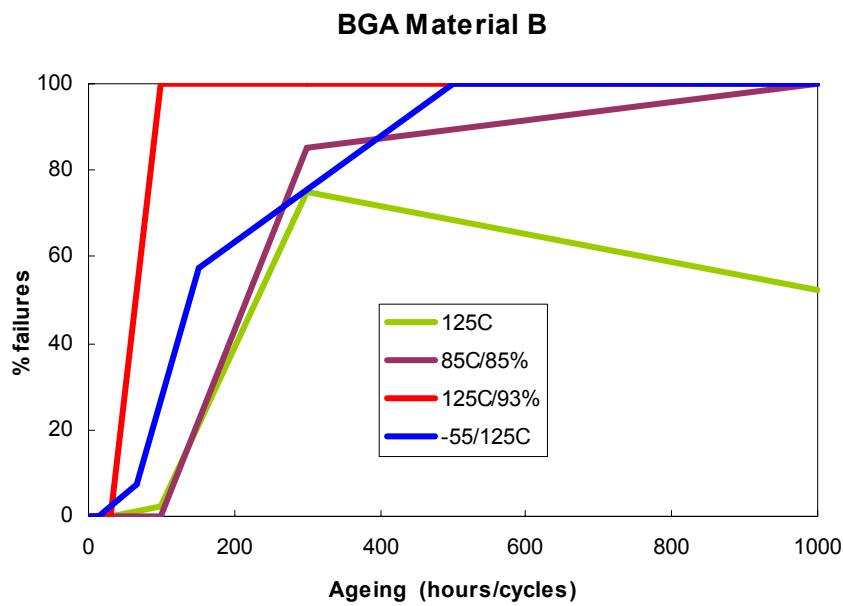


Figure 91: Cumulative % Failures for Material B with BGA Components

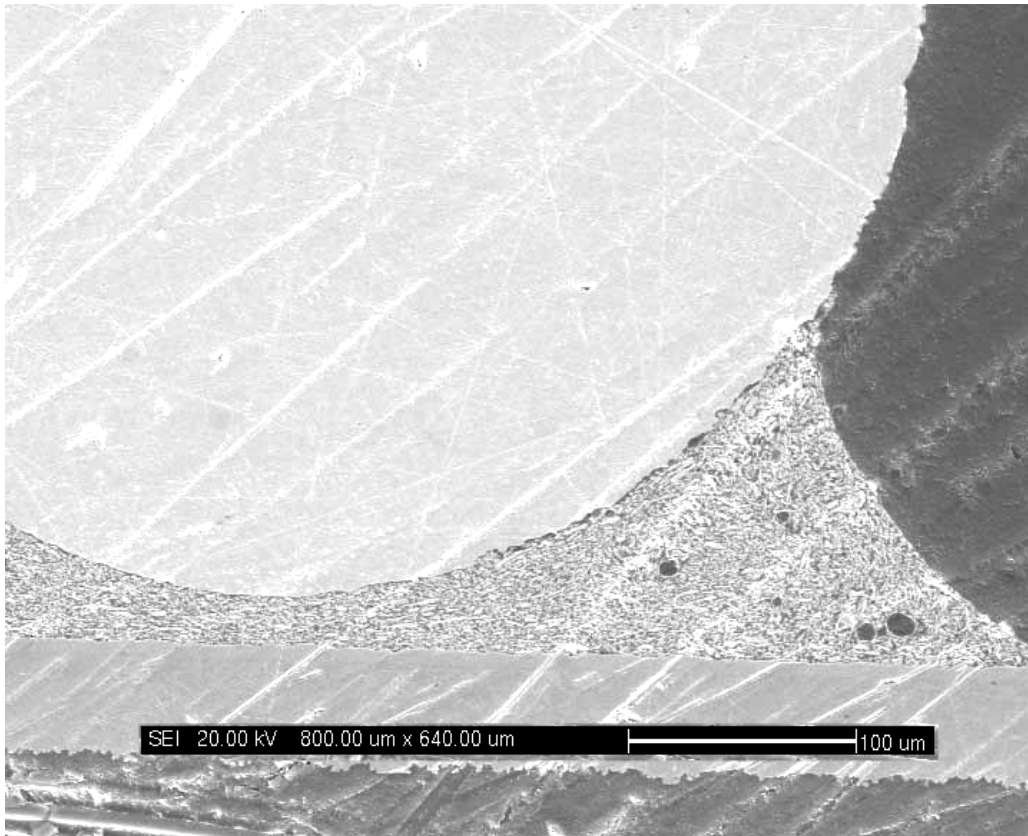


Figure 92: SEM Image of BGA Conductive Adhesive Joint of Material A after 1000 cycles of 55°C/+125°C Showing Partial Crack at the Interface Between the Component (top) and Adhesive

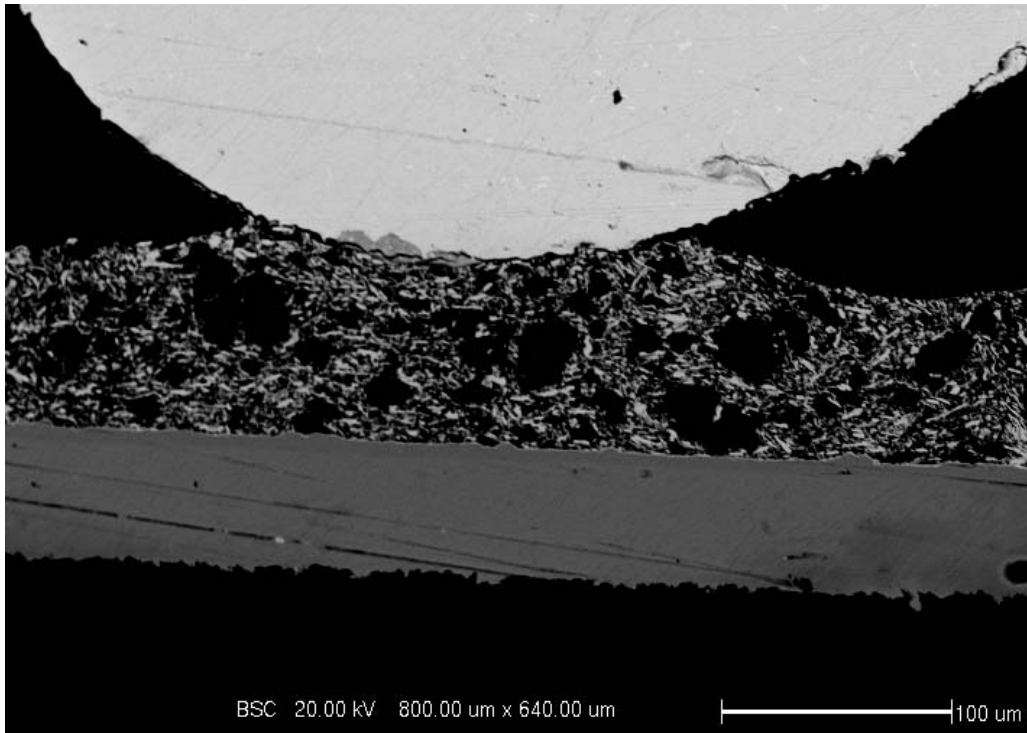


Figure 93: SEM Image of BGA Conductive Adhesive Joint of Material B after 1000 hours of 125°C/93%RH Showing Adhesion Failure at the Interface Between the Component (top) and Adhesive

4.8 QFP RESISTANCE

Comparisons of failure rates at 1000 hours or cycles for QFP components for materials A and B are given in Figure 94 and Figure 96 respectively. A failure is considered to have occurred when the continuity circuit resistance for the component increases by more than 100% from the as-manufactured value. The development rates of the failures for the four most stringent regimes are given in Figure 95 and Figure 97 for materials A and B respectively. It should be noted that these results are based on only 10 components per condition.

The two materials performed similarly. Failures (greater than 100% resistance increase) did not occur with all the ageing regimes; higher temperatures and higher humidity gave more failures. Failures were generally low for dry heat ageing with the exception of ageing at 125°C, where significant failures occurred for both materials. Damp heat testing gave more failures than with the corresponding dry heat ageing for material A, but responses for material B were similar. Generally, when components did fail during any regime, they failed within a few hundred hours or cycles of testing. Material B did not exhibit any failures for ageing at 85°C/85%RH.

For material A, thermal cycling proved as severe as similar temperature damp heat ageing, but more stringent than dry heat ageing, indicating that TCE mismatch may play a part in accelerating failure modes.

The QFP components used in this study were plated with SnCu. As with other components, interfacial adhesion failure is considered to be the primary failure mode.

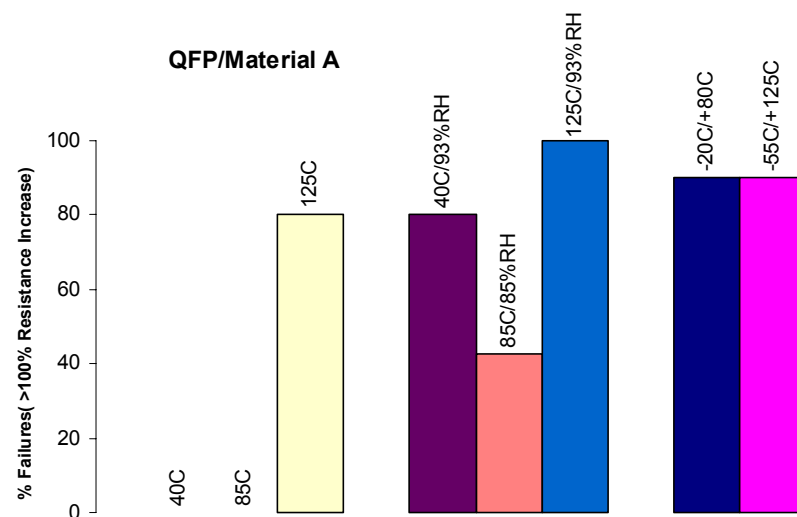


Figure 94: Comparison of Failure Rates (>100% Resistance Increase) for QFP Components with Material A After 1000 Hours or Cycles For All Ageing Regimes

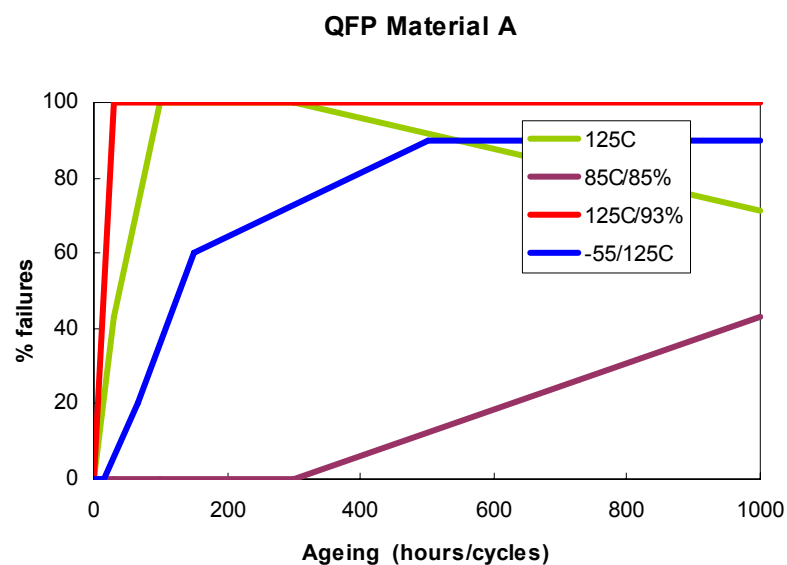


Figure 95: Cumulative % Failures for Material A with QFP Components

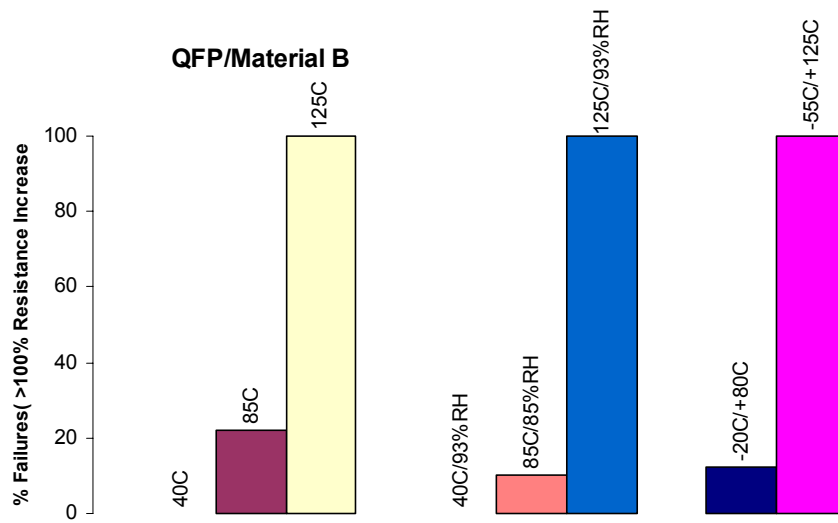


Figure 96: Comparison of Failure Rates (>100% Resistance Increase) for QFP Components with Material B After 1000 Hours or Cycles For All Ageing Regimes

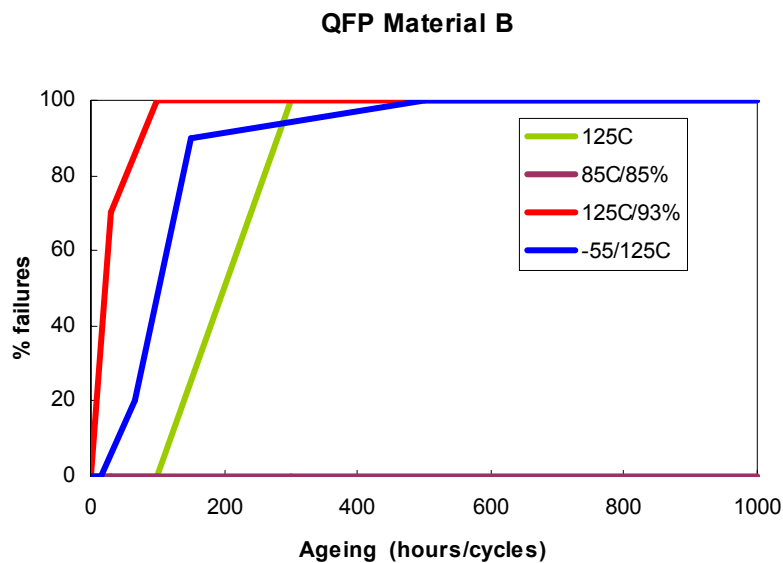


Figure 97: Cumulative % Failures for Material B with QFP Components

4.9 SHEAR TESTING

4.9.1 R0603 Components

Shear testing of R0603 components gave similar responses for both materials. Shear strengths generally improved during dry heat ageing. This was probably due to further curing of the resin matrix due to the elevated temperatures of testing. The more stringent thermal cycling

regime, $-55^{\circ}\text{C}/+125^{\circ}\text{C}$, gave an improvement in shear strength initially, with a reduction as the thermal cycling was extended to 1000 hours (see figures 60 and 61). This reduction is probably due to weakening of the component/adhesive or adhesive/PCB interfaces due to the TCE mismatch between the ceramic component and the PCB. Thermal cycling at $-20^{\circ}\text{C}/+80^{\circ}\text{C}$ had little effect on shear strength as the strain placed on the joints due to TCE mismatch was lower than for $-55^{\circ}\text{C}/+125^{\circ}\text{C}$. For damp heat testing, the higher heat, higher humidity ageing regime ($125^{\circ}\text{C}/93\%\text{RH}$) gave a greater reduction in shear strength than $40^{\circ}\text{C}/93\%\text{RH}$ or $85^{\circ}\text{C}/85\%\text{RH}$. The harshest regimes ($125^{\circ}\text{C}/93\%\text{RH}$ and $-55^{\circ}\text{C}/+125^{\circ}\text{C}$) gave similar reduction in shear strength for both materials. Reduction in shear strengths for these components is likely to be due to the interfacial failures observed earlier. However, these reductions were not as significant in circuit functionality terms as the increases in electrical resistance as discussed above.

Figure 98 shows a typical adhesion failure in an R0603 component. The typical failure mode is a combination of adhesion failure at the component/adhesive and at the PCB/adhesive interfaces. No evidence of failure within the bulk adhesive was found. No trends in changes in failure mode with ageing were noted. Material A was generally prone to more failures at the PCB interface than material B.

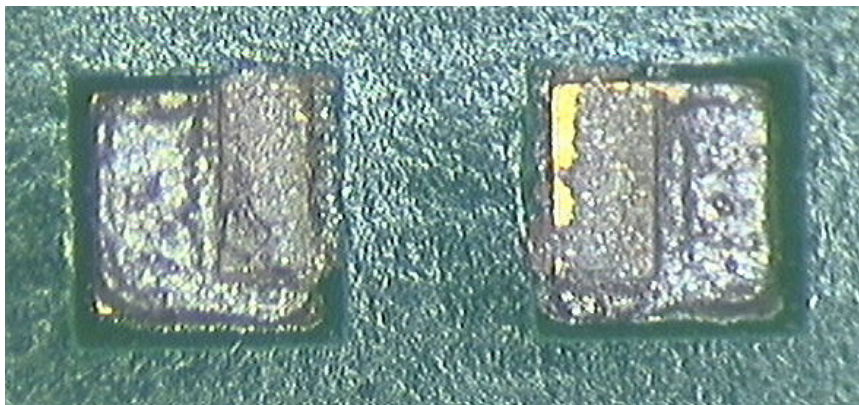


Figure 98: Typical Shear Test Failure in R0603 Component

4.9.2 R1206 Components

Shear testing of R1206 components highlighted different responses for the two materials. For material B (Figure 63), there was little reduction in shear strength for the ageing regimes over 1000 hours or cycles. However, the greatest reduction was again with the more stringent regimes of $125^{\circ}\text{C}/93\%\text{RH}$ and $-55^{\circ}\text{C}/+125^{\circ}\text{C}$, but again these shear strength reductions were not as significant as the increases in electrical resistance as discussed above.

The results for material A (Figure 67) are very similar to those for the R0603 components. Shear strengths generally improved during dry heat ageing as before. The more stringent thermal cycling regime, $-55^{\circ}\text{C}/+125^{\circ}\text{C}$, gave an improvement in shear strength initially, with a reduction as the thermal cycling was extended to 1000 hours. Thermal cycling at $-20^{\circ}\text{C}/+80^{\circ}\text{C}$ had little effect on shear strength. For damp heat testing, the higher heat, higher humidity ageing regime ($125^{\circ}\text{C}/93\%\text{RH}$) gave a greater reduction in shear strength than

either the 40°C/93%RH or 85°C/85%RH regimes. The harshest regimes in shear strength reduction were 125°C/93%RH and -55°C/+125°C. Reduction in shear strengths for these components is likely to be due to the interfacial failures observed earlier. However, these reductions were not as significant in functionality as the increases in electrical resistance as discussed above.

Figure 99 shows a typical adhesion failure in a R1206 component. The results are similar to those for the R0603 components with the typical failure mode being a combination of adhesion failure at the component/adhesive and at the PCB/adhesive interfaces. Again, no clear evidence of failure within the adhesive was found and no trends in changes in failure mode with ageing were noted. Material A was again prone to more failures at the PCB interface than material B.

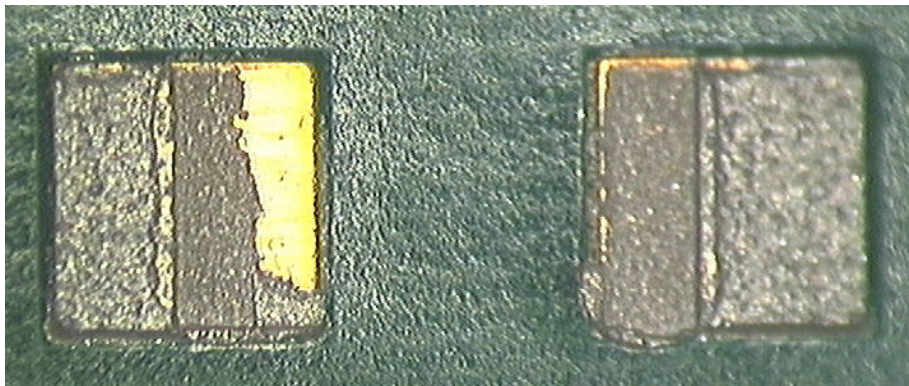


Figure 99: Typical Shear Test Failure in R1206 Component

These results correlate well with the micro-sections of these components shown in Figure 83 (1000 hours, 125°C/93%RH, material A) and Figure 85 (1000 hours, 125°C/93%RH material B). Material A exhibited significant failure of the component/adhesive interface and a low ultimate shear strength (Figure 62), whilst material B had little evidence of interfacial failure and maintained the shear strength after testing (Figure 63).

Shear testing did not show the clear trends in material degradation highlighted by resistance measurements and therefore this latter method will be favoured for future work as the primary means of discriminating between process variables.

4.10 DROP TESTING

The drop testing of these assemblies represented a severe test for these conductive adhesives. Indeed, the larger components, particularly the gull-wing terminated components, did not perform well.

With the QFP components (Figure 66 and Figure 67), few components survived the initial drop. Because of this it is impossible to determine if the ageing regimes had any effect, positive or negative, on the ability of the components to survive the drop testing.

SOIC components fared little better, although with these results (Figure 68 and Figure 69) there is some evidence, particularly with material B, that dry heat ageing improves drop testing performance. This was probably due to further curing of the resin matrix due to the elevated temperatures of testing. However, few examples of any regime, survived more than 5 drops.

BGA components did perform better, probably because of the greater ratio of joint area to mass for these components, with both materials, unaged components surviving over 10 drops on average. With material A, drop performance was improved (Figure 64) by low temperature dry heat or by $-20^{\circ}\text{C}/+80^{\circ}\text{C}$ thermal cycle ageing. However, damp heat ageing and thermal cycle ageing at $-55^{\circ}\text{C}/+125^{\circ}\text{C}$, significantly reduced drop performance. For material B, most ageing regimes reduced drop performance (see Figure 65).

For both resistor components (R0603 and R1206), all components survived 20 drops, for all ageing regimes.

The drop performance of the larger components was significantly improved by use of a supplementary adhesive.

Figure 100 illustrates how normal wave soldering adhesive was added around the outside of the components after the normal manufacturing operation (red areas) and then cured. This operation would best be incorporated into the manufacturing process prior to component placement. During subsequent drop testing, all the components survived 20 drops.

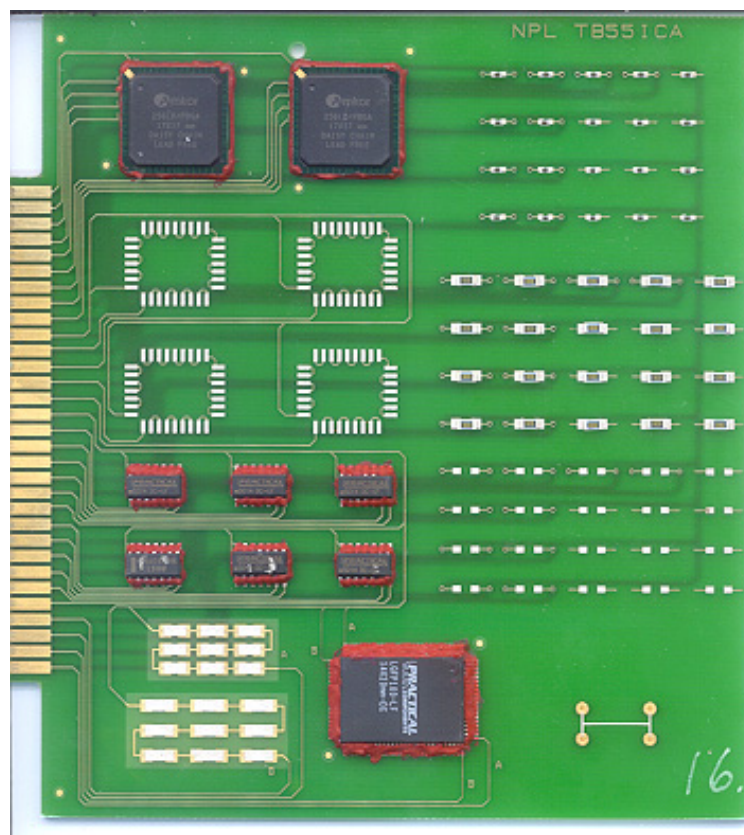


Figure 100: Test PCB With Supplementary Adhesive Around Larger Components

4.11 SURFACE INSULATION RESISTANCE TESTING

The surface insulation resistance measurements for materials A and B are presented in Figure 70 and Figure 71 with the results from a control assembly without conductive adhesive being shown in Figure 72. They demonstrate relatively poor performance for both materials compared to no-clean soldering fluxes, which would normally be better than 10^8 ohms. The SIR of both ICA materials dropped to 10^6 ohms, with material B performing slightly the better of the two. 10^6 ohms is the lowest measurable value for the system used due to a current limiting resistor that is employed.

These results suggest that ionic species are present after curing of the adhesives, which lead to the reduction in resistance. It is unclear which species are present but future work is planned to address this point. This poor performance of these materials would represent a major obstacle to their use in production of many higher reliability applications.

5 CONCLUSIONS

Recent renewed interest in isotropic conductive adhesives (ICAs) has been driven both by the impending restrictions on the use of lead in solders, and by the increased recyclability of a range of products that use ICAs instead of solder for interconnection purposes. But wider use of these materials requires a better understanding of the mechanisms of field failures, and an appropriate and agreed test method to assess both process quality and field reliability. In consequence, this work has been undertaken in order to review and investigate potential test regimes, and thereby to identify a representative accelerated ageing condition for future assessment of ICAs.

The study has involved examining joints on test boards produced from a matrix experiment using two ICA materials, a range of components, eight ageing regimes, and four assessment techniques (electrical conductivity, shear testing, drop testing and SIR). The salient results are summarised below.

5.1 ELECTRICAL RESISTANCE

The performances of the two bulk ICAs were broadly similar. The resistances of the materials were stable over all the testing regimes. The observed tendency for the resistance to decrease has been attributed to further curing of the resin matrix at the elevated temperatures of the ageing regimes.

When used to connect components to PCBs, the materials performed well, particularly when subjected to thermal cycling, perhaps better than typical end-users might suspect. Chip resistors of both sizes (R0603 and R1206) survived 1000 hours (or 1000 cycles) of all the regimes studied except damp heat testing at 125°C/93%RH and thermal cycling between -55°C and +125°C. The smaller R0603 components, having less strain on adhesive joints than their larger R1206 counterparts, survived the thermal cycling without failures. Heat alone was not sufficient for the generation of failures in these chip components. They are ceramic based and hence failures might be expected after thermal cycling, due to TCE mismatch between the component and the adhesive, or the substrate material, causing a breakdown of the interface between the component and the adhesive. Indeed failures were observed after damp heat testing.

The performances of the leaded devices (SOICs, QFPs and BGAs) were generally similar. Damp heat testing, particularly at the higher temperatures, gave rise to significant numbers of failures with all component types. Joints made with material B generally out-performed those made of material A. The significantly better results for the I-links and jumpers, indicated that the resistance increase experienced with these regimes was not due to a change in bulk material properties. Failures were generated after thermal cycling but not at the same level as those after damp heat testing. In this case the increases in resistance were again due to interfacial failure.

5.2 SHEAR TESTING

Shear testing of resistor components did provide early indications of interfacial failure in the joints of material A, but those of material B did not show a similar deterioration. However,

the latter did exhibit significant electrical failures after severe damp heat testing. It is pertinent that clearer trends were observed by monitoring electrical resistance, suggesting that method as a more appropriate means of assessing the performance of ICAs.

5.3 DROP TESTING

The results of drop testing generally fell into one of two groups: larger components tended to fail (become detached) after a very limited number of drops, whilst smaller components survived 20 drops. The drop performances of joints made using the two materials are of concern, and methods of improving them will be explored in later phases of this project. However, the test did not provide a means of differentiating between the various stress screening regimes and will not be used as such in later phases of this project.

5.4 SURFACE INSULATION RESISTANCE TESTING

The SIR test results for both the ICA materials used in this project were poor, and considerably inferior to those from product assembled using traditional solder pastes.

6 RECOMMENDATIONS ON STRESS SCREENING REGIME FOR ISOTROPIC ADHESIVES

The results suggest that the parameters of an appropriate stress screening regime are :

unbiased joints, 85°C, 85%RH for 1000 hours

Significant joint resistance increases were observed with a range of components within 1000 hours of testing, and the regime was useful for leaded components and for both the ICA materials explored. Moreover, damp heat chambers are already widely available within the electronics assembly industry. The second phase of this project will study the effect of bias on the ICA joints during testing. Moisture (in this case provide by the 85%RH) is expected to play an important role in the likely failure modes experienced by biased joints.

Damp heat screening at 125°C/93% RH is considered too severe a regime with many failures in less than 100 hours making discrimination between process variables difficult. In addition, the regime causes severe darkening of the PCB laminate, and requires specialist test equipment not widely available in the industry.

Thermal cycling between -55°C and +125°C did give significant increases in joint resistance within 1000 cycles, particularly with ceramic components. But this regime was much less effective for leaded components such as SOICs. It should be remembered that the next phase of the project will involve investigating the effects of component and PCB surface finishes on the reliability of ICA-based joints. With SOICs expected to provide the widest range of finishes, this regime is inappropriate for this next stage of the project. Moreover, thermal cycling equipment is perhaps not as widely available with the industry as damp heat chambers.

7 ACKNOWLEDGEMENTS

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Emerson & Cuming
Promatech & EpoTek

8 REFERENCES

1. Overview of display conductive adhesive interconnection technologies; Kristiansen & Liu: Conductive Adhesives for Electronic Packaging p 395