NPL National Physical Laboratory

Measurement Note

DEPC-MN 038

Solderability Testing with Components Preheating

Summary

This note describes a new development of solderability testing with a component preheat which allows testing to be carried out using test temperatures and fluxes which reflect those in use in the reflow assembly industry. Worries about the relevance of the current testing are thus allayed. Previous work (1,2) established that components can be successfully heated to a controlled temperature prior to solder immersion, and that approach has been used as the basis for this work. The test procedure, parameters, and component preheat are detailed, together with recommendations for the preheating temperatures and profile for different solder alloys

The preheat test method worked well under the conditions studied, and is the preferred method. In the future it is expected that in some cases more challenging tests will be required, demanding greater discrimination, and the new pre-heat method is well placed to provide such discrimination. However, in the majority of cases, the new preheat method and the traditional method provided very similar results. This suggests that for many users the traditional method continuers to be capable of providing them with relevant and useful information.

A study of the correlation of process yield with solderability using both preheat and conventional solderability methods, is also included. It is shown that the solderability results using the preheat method do provide a good correlation with process yield.

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1 Introduction

Solderability testing is a well-established, and widely used tool for evaluating the solderability of components and PCB pads. A measurement of the time dependent wetting force as the solder meniscus spreads across the surface of interest can be quantified to provide a solderability index. A perceived limitation of existing solderability testing is that samples are evaluated at ambient temperatures, using an experimental set-up as shown in Figure 1. Here the molten solder wets the component termination directly while it is still close to room temperature. The component temperature profile is shown in Figure 2, and starts from the mid point B, and follows the profile B-C-D. This rapid increase in temperature is not typical of reflow and wave soldering, in which preheating is applied. In Figure 2 another profile is shown, which is more typical of manufacturing, and is the profile used in this work. It follows the profile A-C-D by the application of pre-heating using an external heat source.

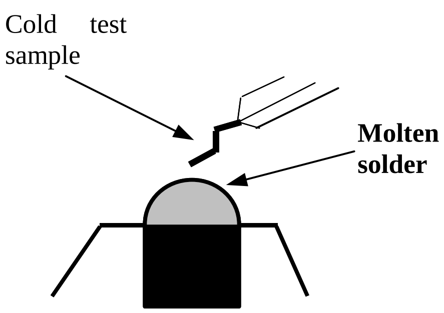


Figure 1: Solderability testing

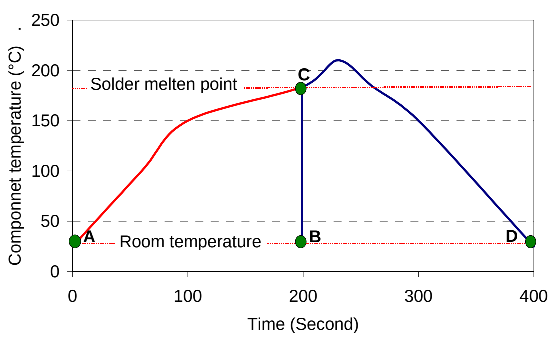


Figure 2: Component temperature profiles during solderability testing and reflow process

This Measurement Note describes a modified procedure for solderability testing that includes component preheating. It also details how the preheat temperature and the profile settings can be achieved for different components and PCB pads.

2 Solderability testing procedure with component preheat

2.1 Preheat setting

An infrared (IR) lamp has been developed for preheating the test components, and for mounting on a Concoat MUST II solderability tester. The IR beam is well defined, and controlled by a thermocouple, as shown in Figure 3. The temperature profile is controlled using additional routines running on the MUST instrument, and Figure 4 demonstrates the degree of temperature control. However, careful consideration must be given to the location of the thermocouple which provides the necessary feedback for the control of the IR system. Ideally the thermocouple should be on the component termination to be tested, so that the set temperature will be exactly the preheat temperature for the components. However, in most cases it is not possible to fix the thermocouple directly on the termination, as this would interfere with the wetting. Consequently, the thermocouple is fixed on the supporting clip, close to the test component termination, as shown in Figure 5.

There is a slight temperature difference between the thermocouples on the clip and on the component termination, since the IR intensity is not uniform due to a small angular dispersion (NB The mid position along the dotted line experienced the highest temperature). Therefore another thermocouple is fixed on the component termination to measure this temperature difference. Four examples are shown in Figure 6, with views of the whole clip and sample. The temperature difference between the two thermocouples for a C1206 component and clip is shown in Figure 7. It is evident that the component temperature closely follows the clip temperature, but with a stable offset. Subsequently, the temperature on the component can be measured and calibrated for each type component and PCB pad using just the clip temperature.

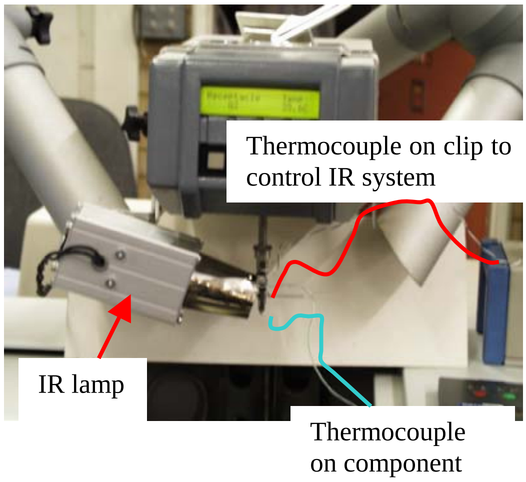
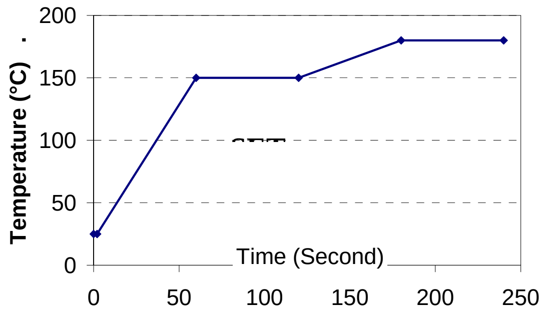


Figure 3 Solderability testing with IR system



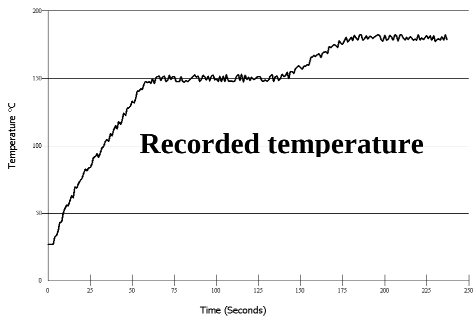


Figure 4 An example of set and recorded temperatures

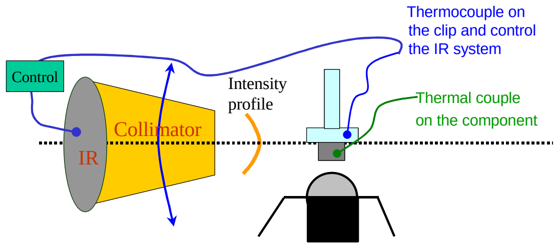


Figure 5 IR intensity profile

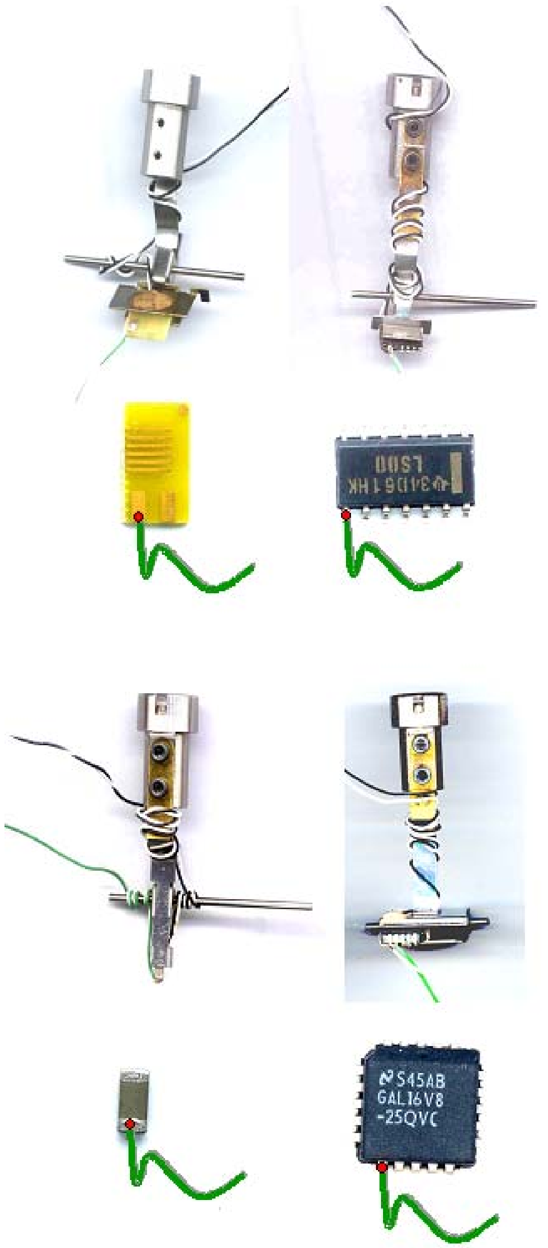


Figure 6 The positions of the thermocouples on clip and component

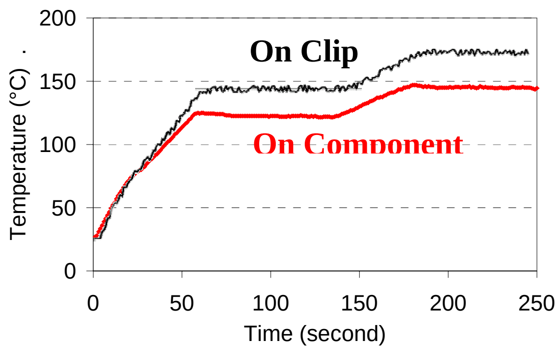


Figure 7 Temperature difference between two thermocouples for a C1206 component

2.2 Preheat temperature profile setting

The preheat profiles to achieve solderability testing at reflow temperatures were defined in previous work (1). It was shown that the optimum conditions were a 30 second ramp and a 30 second dwell. At the end of the dwell the sample is dipped in the solder. The target temperatures for the dwell are 130°C for SnPb and 160 °C for SnAgCu solder. Examples of the preheat temperature profile, as measured on the test components for SnPb and SnAgCu alloys, are presented in Figure 8. For each new component the procedure described in Section 2.1 needs to be applied.

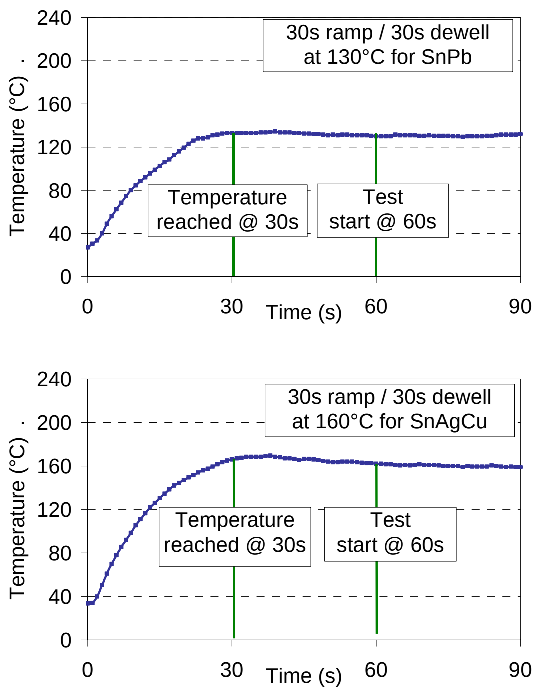


Figure 8 Preheat temperature profile for SnPb and SnAgCu alloy

2.3 Solderability testing

2.3.1 Solderability testing parameters

Solderability testing can be carried out on any suitable wetting balance equipped to preheat the sample. The work described here assumes an instrument configuration operating in the solder globule mode. Test parameters should be set as given in the Measurement Good Practice Guide (2), *Solderability Testing of Surface Mount Components and PCB Pads.* However, the test temperatures are now modified. The test components are preheated to a controlled temperature prior to immersion, as given in Section 2.2. The solder test temperature is reduced to typical soldering temperatures. Hence, the solderability testing parameters are modified as per the following:

- New test method
  - Test temperature:
    - 215 °C for SnPb
    - 240 °C for SnAgCu
  - Component preheat temperature:
    - 130 °C for SnPb
    - 160 °C for SnAgCu
  - Preheat method
    - Infrared lamp
  - Preheat time
    - 30 seconds ramp and 30 seconds dwell

2.3.2 Solderability test procedure

- Solder thermocouple to component termination, and attach a thermocouple to sample clip with adhesive.
- Set the preheat temperature profile according to the solder alloy as given in Section 2.3.1.
- Adjust the instrument preheat control system to establish a calibrated preheat temperature profile using two thermocouples.
- Initiate IR lamp preheat sequence and ensure solderability test starts (component termination being immersed into the solder) 60 seconds after the preheat sequence starts.
- Ensure other test procedures associated with the wetting balance test are still completed, i.e. preparation of the solder, fluxing of the component.

Appendix A: Correlating solderability and process yield

Verification of the method was undertaken in the form of an experiment in which the solderability measurements were correlated with process yield measurements. Five component types were selected and artificially aged to produce three levels of solderability.

The five selected component types were aged at 155 °C for two periods of time. This variation in ageing time represents differences in plating thickness and quality. Hence components having three levels of ageing were available for testing, and subsequently, 80 components for each type and each ageing condition were prepared. The component type, finish, and ageing time are listed in Table A1. The ageing time was varied to give approximately the same level of solderability degradation for each component type.

Table A1
Components and ageing conditions

Component	Finish	Age 1	Age 2
		Ageing time (hours @ 155 °C)	
PLCC20	SnPb	504	1000
SOIC14	PdNi	48	680
LED	AuNi	96	384
SOT23	Sn	16	282
R0603	SnPb	288	388

Each ageing level of each component set was divided into two groups, 1 and 2, with 120 samples for each group. Hence, there were 40 in each ageing group. Group 1 was used for solderability testing, and Group 2 for assembly build.

Solderability testing

The components from Group 1 were solderability tested using SnPb solder alloy and four test methods, as listed in Table A2. Test Method A is the standard method in international standard IEC 60068-2-69. The LED components from Age 1 were only tested using Method A. Ten components were tested for each method, and the average result tabulated.

Table A2
Solderability test parameters

Method	Test Temperature (°C)	Flux	Preheat Temperature (°C)
A	235	Actiec5	RT*
B	215	Actiec5	130
C	215	AOA	130
D	215	WOA	130

*RT: Room Temperature

Actiec5 is pure rosin with 0.5% halide, in accordance with IEC 60068-2-20. AOA and WOA are alcohol- and water-based carboxylic acid fluxes, developed for solderability testing in a previous project (3). The compositions for these two fluxes are listed below, and defined in terms of percentage by mass:

AOA flux:

94% Propan-2-ol
1.5% Adipic acid
1.5% Succinic acid
1.5% Glutaric acid
1.5% Rosin

WOA flux:

95.1% De-ionised water
5% Co-solvent (Glycol ester)
0.1% Alcohol ethoxylate surfactant
1.6% Adipic acid
1.6% Succinic acid
1.6% Glutaric acid

Solderability results

The solderability results, wetting force at 2 seconds and the time to 2/3 of the maximum force, from the four test methods for three ageing components are listed in Tables A3 to A5.

Table A3
Solderability results for as-received components

Components	Method	Wetting force (mN)	Wetting time (s)
PLCC20	A	0.98 ± 0.06	0.60 ± 0.17
	B	0.97 ± 0.04	0.21 ± 0.07
	C	0.80 ± 0.03	0.17 ± 0.04
	D	0.90 ± 0.09	0.15 ± 0.01
SOIC14	A	0.43 ± 0.01	0.14 ± 0.03
	B	0.45 ± 0.04	0.25 ± 0.06
	C	0.43 ± 0.05	0.22 ± 0.09
	D	0.49 ± 0.02	0.23 ± 0.06
LED	A	0.24 ± 0.04	1.53 ± 0.33
SOT23	A	0.39 ± 0.01	0.14 ± 0.03
	B	0.39 ± 0.02	0.21 ± 0.07
	C	0.39 ± 0.04	0.41 ± 0.07
	D	0.41 ± 0.02	0.22 ± 0.06
R0603	A	0.32 ± 0.03	0.69 ± 0.10
	B	0.32 ± 0.01	0.29 ± 0.05
	C	0.31 ± 0.02	0.34 ± 0.06
	D	0.33 ± 0.03	0.32 ± 0.03

The results for the wetting force at 2 seconds for the SOIC14 components using the different test methods are compared in Figure A1, and clearly demonstrate there is little difference between the different solderability test methods. Encouragingly the preheat method and synthetic fluxes gave very similar results to the conventional test method, the differences being within the standard deviation. In Figures A2 to A6 the wetting force with ageing time for different components tested with Method A are plotted. The results demonstrate that the solderability dramatically decreased with ageing time for all components. This loss of solderability can be expected to cause defects in assembly.

Table A4
Solderability results for Age 1 components

Components	Method	Wetting force (mN)	Wetting time (s)
PLCC20	A	0.87 ± 0.11	0.60 ± 0.12
SOIC14		0.32 ± 0.05	1.12 ± 0.75
LED		0.24 ± 0.04	1.53 ± 0.33
SOT23		0.28 ± 0.13	2.01 ± 1.21
R0603		0.23 ± 0.11	1.22 ± 0.50

Table A5
Solderability results for Age 2 components

Components	Method	Wetting force (mN)	Wetting time (s)
PLCC20	A	0.40 ± 0.14	1.61 ± 0.67
	B	0.36 ± 0.22	2.02 ± 1.72
	C	0.61 ± 0.18	0.84 ± 0.61
	D	0.63 ± 0.19	1.07 ± 0.45
SOIC14	A	0.09 ± 0.04	2.78 ± 0.88
	B	0.12 ± 0.08	2.17 ± 0.88
	C	0.08 ± 0.04	1.54 ± 1.43
	D	0.24 ± 0.16	1.54 ± 1.45
LED	A	0.01 ± 0.16	3.08 ± 0.84
SOT23	A	0.05 ± 0.05	2.40 ± 0.93
	B	0.04 ± 0.06	2.84 ± 1.48
	C	0.03 ± 0.05	2.97 ± 1.46
	D	0.04 ± 0.05	2.68 ± 1.54
R0603	A	-0.05 ± 0.15	2.78 ± 1.56
	B	0.03 ± 0.12	1.75 ± 1.46
	C	-0.02 ± 0.17	2.79 ± 1.68
	D	0.05 ± 0.17	3.01 ± 1.67

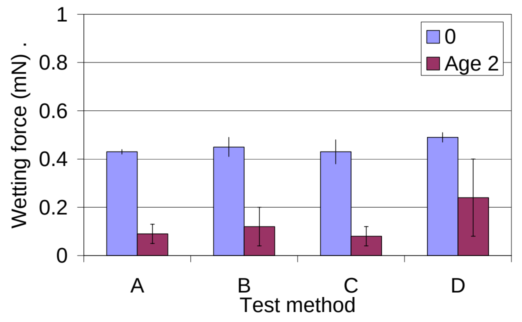


Figure A1 Wetting force from different methods for SOIC14

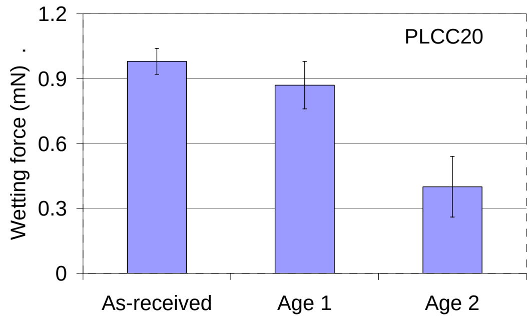


Figure A2 Wetting force with ageing time for PLCC20

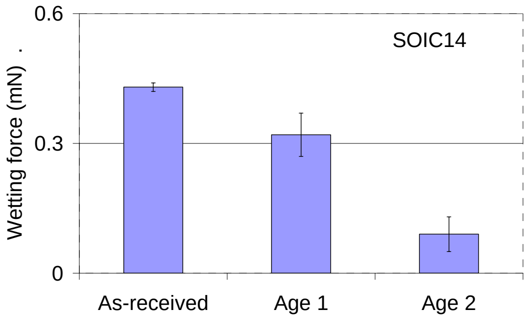


Figure A3 Wetting force with ageing time for SOIC14

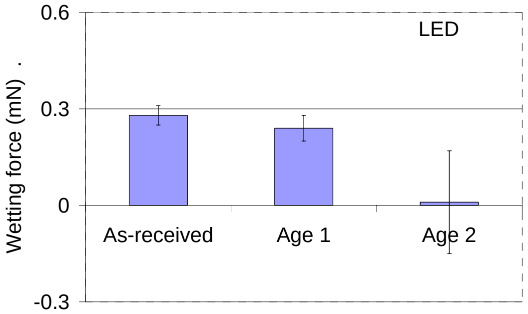


Figure A4 Wetting force with ageing time for LED

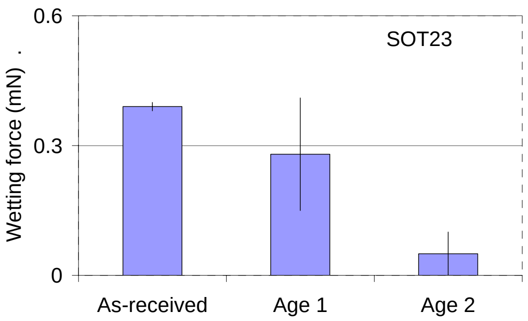


Figure A5: Wetting force with ageing time for SOT23

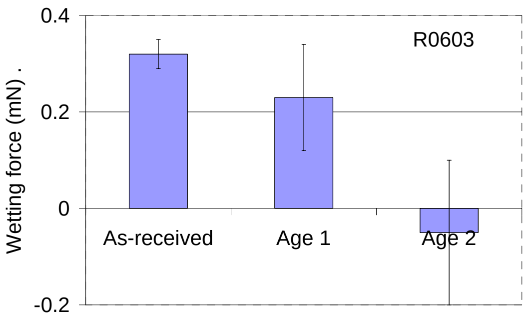


Figure A6 Wetting force with ageing time for R0603

Printed board assembly

The board and stencil used on this work are illustrated in Figure A7.

Figure A7 Board and stencil used for assembly

Twenty boards were printed with solder paste using a 150µm laser cut stencil and a metal squeegee blade. After printing, each board was inspected for a satisfactory paste deposit. The solder paste used was a low residue no-clean product with a metal content of Sn 62 /Ag 2 / Pb 36. The boards were also inspected during component placement. All components were hand placed prior to reflow due to the fact that not all the components were in their original packaging. Ageing at 155ºC required the components to be removed from their original packaging, so preventing automatic placement. One board assembly was used for profiling the reflow oven. Initially this was carried out to achieve complete reflow on the assembly, but further profiles were taken to achieve the lowest reflow temperature for the board assembly. The aim of this was to increase the apparent differences between the aged and non-aged terminations and give a greater spread of inspection results.

Process yield and visual inspection

Solder joints were visually inspected and assessed for solder wetting and solder rise based on the scoring system shown schematically in Figure A8. In addition, they were assessed photographically using a micro-scope at 10-20× magnification. Examples of these are also shown in Figure A8.

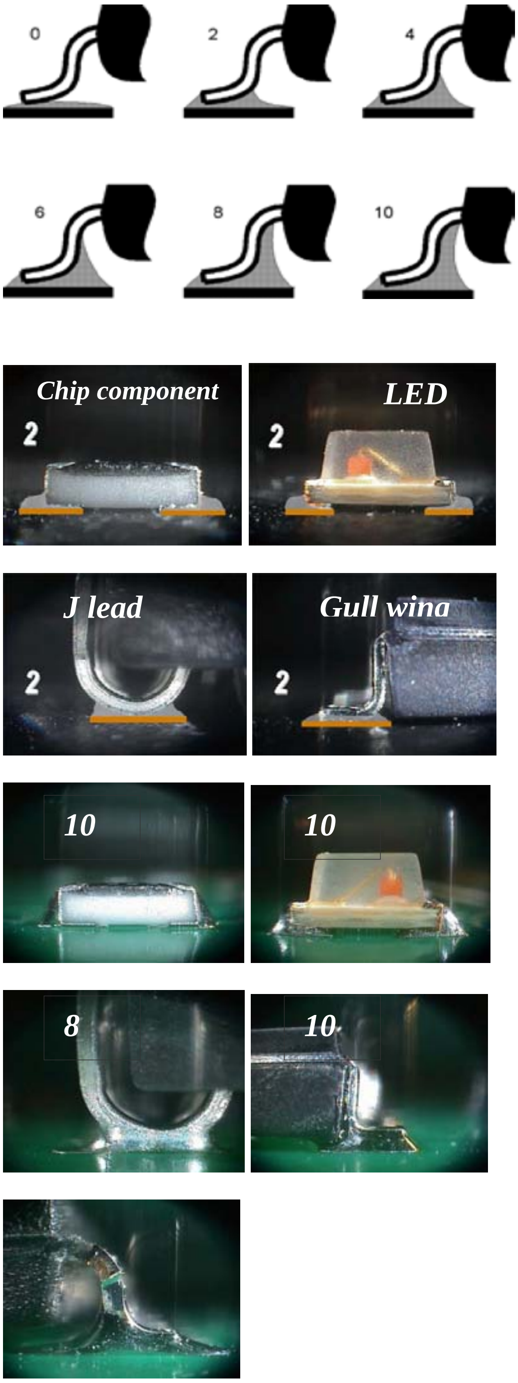


Figure A8 Solder joint scores used in visual inspection

Assessment results

The average scores from each set of 40 components with ageing time for different types of component are plotted in Figure A9 to A13. The Figures clearly highlight that the joint score decreases as ageing time increases. This confirms that ageing components does produce various defect levels.

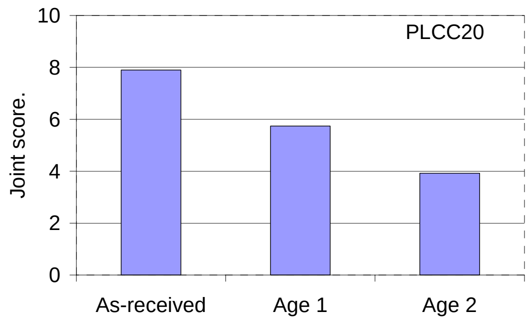


Figure A9 Joint score with ageing time for PLCC20

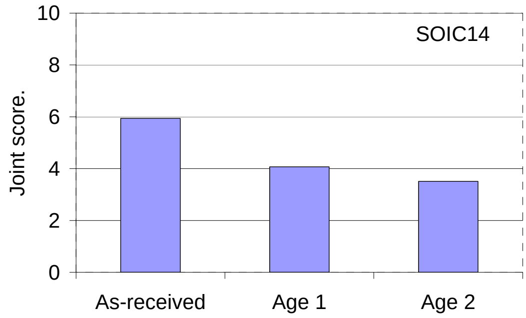


Figure A10 Joint score with ageing time for SOIC14

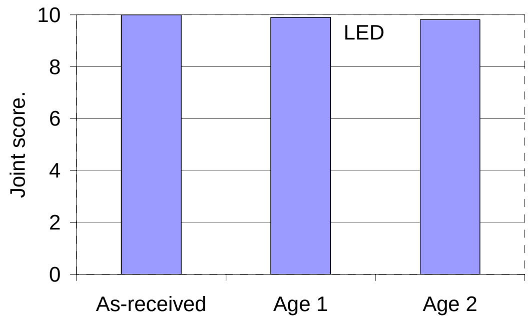


Figure A11 Joint score with ageing time for LED

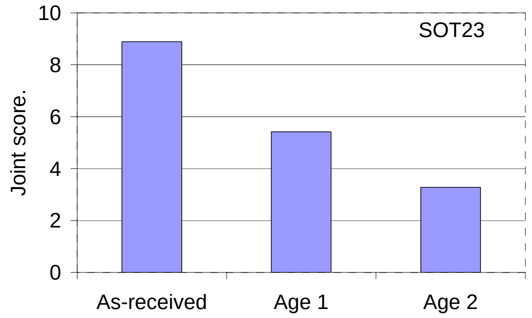


Figure A12 Joint score with ageing time for SOT23

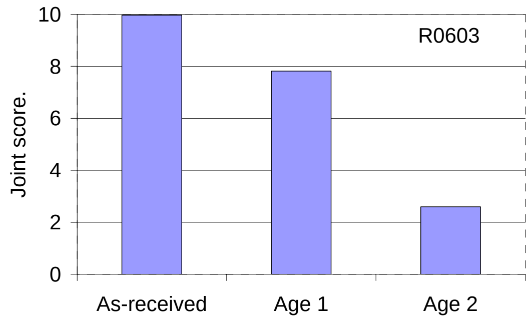


Figure A13 Joint score with ageing time for R0603

The correlation between solderability results and assembly inspection score

The accelerated ageing reduced solderability and increased defect levels during assembly. In Figure A14 the wetting force results from Method A are presented as a function of wetting score. It is apparent that there is a very good correlation between solderability results and assembly joint score for all components. Similar results were obtained from all four methods.

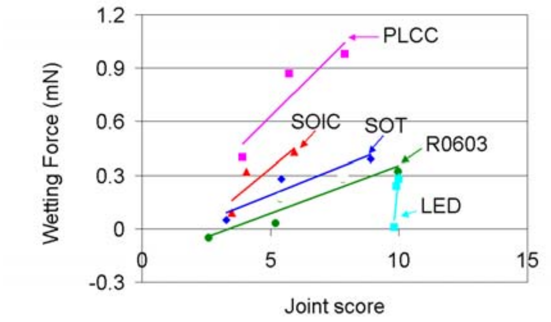


Figure A14 Correlation of solderability and joint score

Conclusions

- The preheat solderability test method allows test temperatures and flux families to be used which reflect those of current assembly processes, thereby allaying the worries about the relevance of the testing parameters.
- The preheat test method has worked well under the conditions studied, and is the test method recommended. In the future it is expected that in some cases more challenging tests will be required, demanding greater discrimination, and the new pre-heat method is well placed to provide such discrimination.
- However, in the majority of cases, the new preheat method and the traditional method provided very similar results. This suggests that for many users the traditional method is capable of providing them with relevant and useful information.
- Variations in the solderability of artificially aged components are readily detected using solderability testing.
- There is a good correlation between solderability testing results and defect levels

Acknowledgements

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References

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2. Ling Zou, Deborah Lea, Christopher Hunt, *Solderability testing of surface mount components and PCB Pads,* September 2004, NPL Measurement Good Practice Guide No. 66, Issue 2.
3. Alan Brewin, Ling Zou, Christopher Hunt, *Development of new solderability test fluxes*, September 2002, NPL Report MATC(A)122.

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