

REPORT

Improving the Processability of Noble Metal Component Termination Finishes

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ABSTRACT

This project aimed to benchmark the processability of new lead-free plating chemistries. The project partners were National Physical Laboratory, leadframe plating chemistry suppliers and a component manufacturer. The project evaluated nine alternatives to tin/lead component finishes, bench-marked against one conventional tin/lead finish. The types of finish, all lead-free, were variants of palladium on nickel, gold on nickel and gold on palladium on nickel. The techniques used to compare the finishes included Auger electron spectroscopy, scanning electron microscopy, wire bond pull testing, solderability testing, moisture ingress measurements, process yield evaluation and solder joint shear testing.

None of the alternative finishes evaluated could be considered a direct 'drop-in' replacement for SnPb although some compared closely in a number of aspects. The majority of the finishes exhibited lower moisture ingress than the SnPb control and AuNi finishes showed comparable process yield results and as-received solderability results as the SnPb. Only one of the PdNi finishes had a process yield close to that of SnPb. The solderability of some of the finishes was adversely affected by cracking of the plating in the heel region. None of the finishes performed as well as SnPb in solderability testing after ageing for 16 days at 155°C.

The wirebond pull strengths of PdNi finishes were generally below those of Au-finished leadframes but still of acceptable values.

Solderability testing of aged samples was also undertaken with Pb-free alloys (SnAg, SnAgCu, SnAgCuSb). SnPb finished leadframes out-performed all the alternative leadframes with all the Pb-free alloys. The alternative leadframes also performed better with SnPb solder than with any of the Pb-free alloys.

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Approved on behalf of Managing Director, NPL, by Dr C Lea,
Head, Centre for Materials Measurement and Technology

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1 INTRODUCTION

An increasing number of component manufacturers are already using, or contemplating using, a new termination finish for their products ie palladium nickel (PdNi). The two main driving forces for this move is the possible ban on lead-containing finishes, and more cost effective component production. PdNi finishes are wire-bondable as well as solderable and therefore component manufacturers can use pre-plated leadframes in component manufacture, thus negating the requirement for complicated and costly tin/lead (SnPb) plating of leads after encapsulation. The microelectronics manufacturing industry, especially SMEs (small and medium sized enterprises), has little or no experience with this finish, or indeed the critical processing parameters involved.

Not surprisingly, therefore, this new finish has presented a number of assemblers with problems in obtaining satisfactory yield using their normal process, particularly when using reflow soldering. This is due to two effects: the low solubility of palladium at soldering temperatures around 220°C; and the possible oxidation of the underlying nickel. A recent project undertaken by NPL confirmed the lower process yields experienced when Pd-Ni finished components are utilised in existing assembly processes (Reference 1).

In this project the aim was to evaluate and identify different palladium on nickel finishes which may improve processability of components manufactured with these leadframes. The project partners were Centurion Speciality Chemicals (Lucent Technologies), Consumer Microcircuits Ltd., Enthone OMI (UK) Ltd., Handy & Harman, Lea Ronal Ltd., Matra BAe and Micro-metallic.

The component manufacturer partner supplied leadframes which were plated with varying finishes by the plating chemistry supplier partners. The component manufacturer partner then incorporated these leadframes into components. The resulting components were characterised using Auger spectroscopy, wire-bondability, solderability and for moisture ingress. Components were also assembled on to PCBs and process yield was measured by visual inspection.

Four plating chemistry suppliers participated in the project providing nine different alternative finishes. A conventional tin/lead (90Sn10Pb) finish was also included as a control.

2 AES DEPTH PROFILING ANALYSIS

This work aimed to characterise the palladium coatings on a number of leadframe samples, which were aged for 4 days at 155°C. The samples were analysed using Auger electron spectroscopy (AES) to identify the key elements present, and then using ion gun depth profiling to establish the elemental distribution in the near surface region.

2.1 EXPERIMENTAL PROCEDURE :

The samples were artificially aged in an oven for 4 days at 155°C. After ageing, they were mounted on an examination stub using a spot of silver-loaded Electrodag paint as adhesive to ensure electrical contact.

The instrument used was a Kratos XSAM800 XPS and AES spectrometer with argon ion bombardment (AIB) depth profiling capability. The ion etch rate was calibrated using a 100 nm tantalum pentoxide NPL reference film.

AES was performed using focused 6 kV, 10 nA electron beam rastered over an area of 10 x 15 μm . The depth profiling was carried out using a 7.5 kV, 50 nA ion beam at a magnification of x500, equivalent to a raster over an area 240 x 360 μm , and an etch rate of 0.18 nm/s on the tantalum pentoxide reference.

2.2 AES DEPTH PROFILING RESULTS

A summary of the analysis undertaken is given in Table 1, along with information of composition given by the plating chemistry suppliers. AES depth profiles are shown in Figures 1 to 9.

Table 1 : List of analysed samples

Sample No.	AES Profiling Results	Suppliers Information
1	Thick Au layer (>10nm) on Ni, no Pd	75nm Au on 1.5 μm Ni
2	Thick Au layer (>10nm) on Pd	25nm Au on 0.1 μm Pd on 1.5 μm Ni
3	Thick Pd layer (>10nm) on Ni substrate	75nm Pd on 50nm 70:30 PdNi on 1.5 μm Ni
4	Thick Pd layer (>10nm) on Ni substrate	Proprietary (not disclosed)
5	Thin Au layer (<3nm) on Pd	Proprietary (not disclosed)
6	Thick Au layer (>10nm) on Ni, no Pd	1.3 μm Au on 1.3 μm Ni
7	Thick Pd layer (>10nm) on Ni substrate	75nm Pd on 75nm PdNi on 1.5 μm of Ni
8	Sn/Pb - not analysed by AES	90Sn/10Pb
9	Thick Pd layer (>10nm) on Ni substrate	Proprietary (not disclosed)
10	Thick Pd layer (>10nm) on Ni substrate	Proprietary (not disclosed)

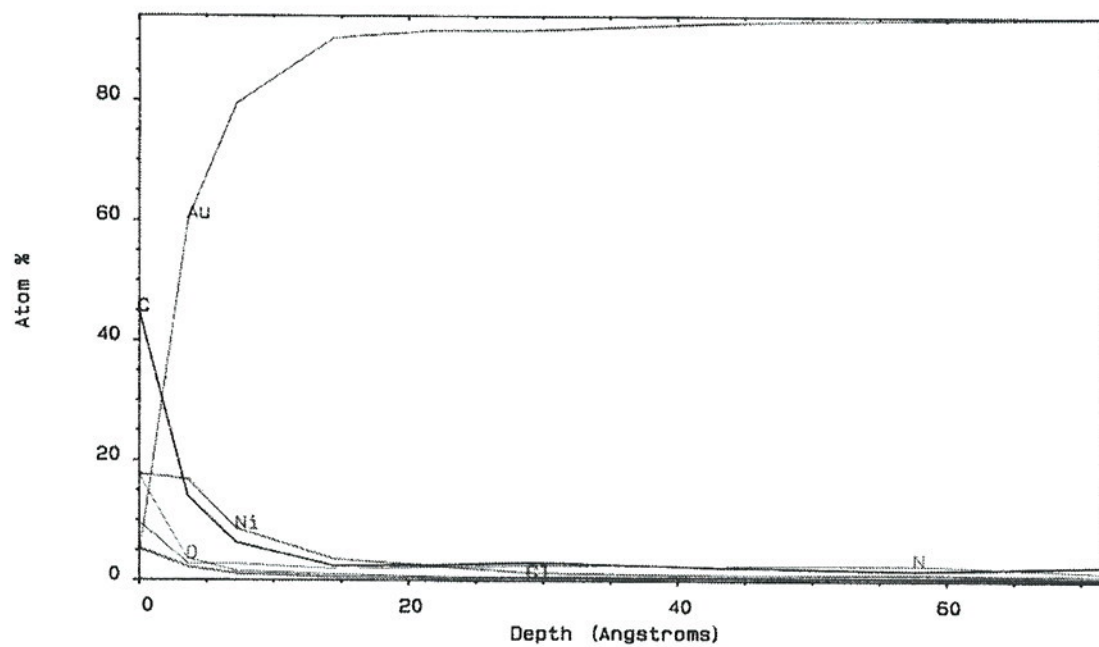


Figure 1 : AES depth profile of Sample 1

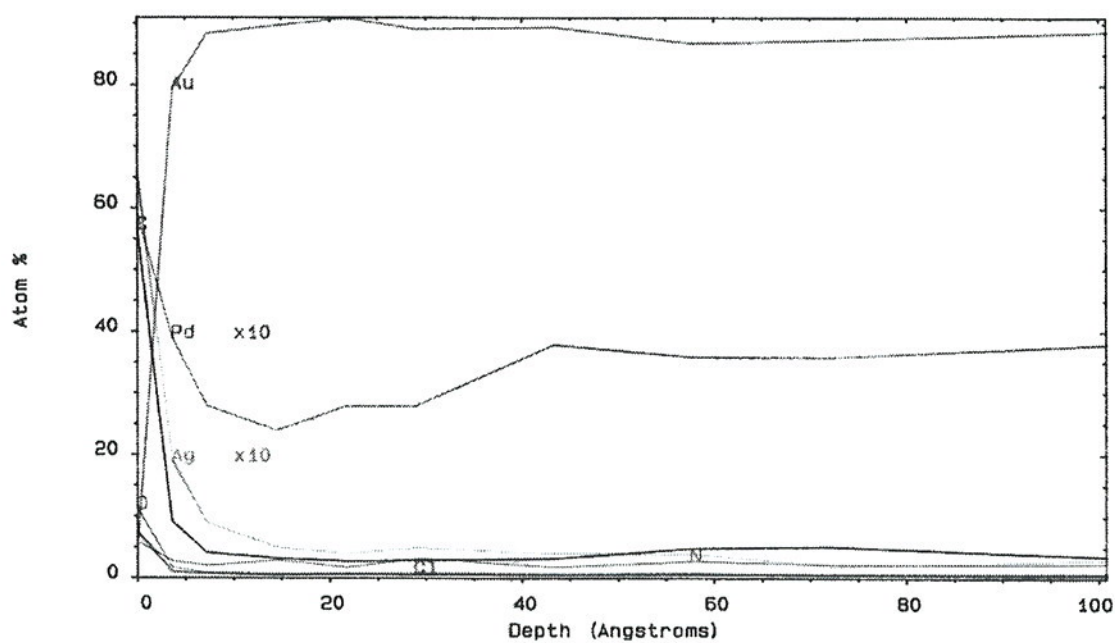


Figure 2 : AES depth profile of Sample 2

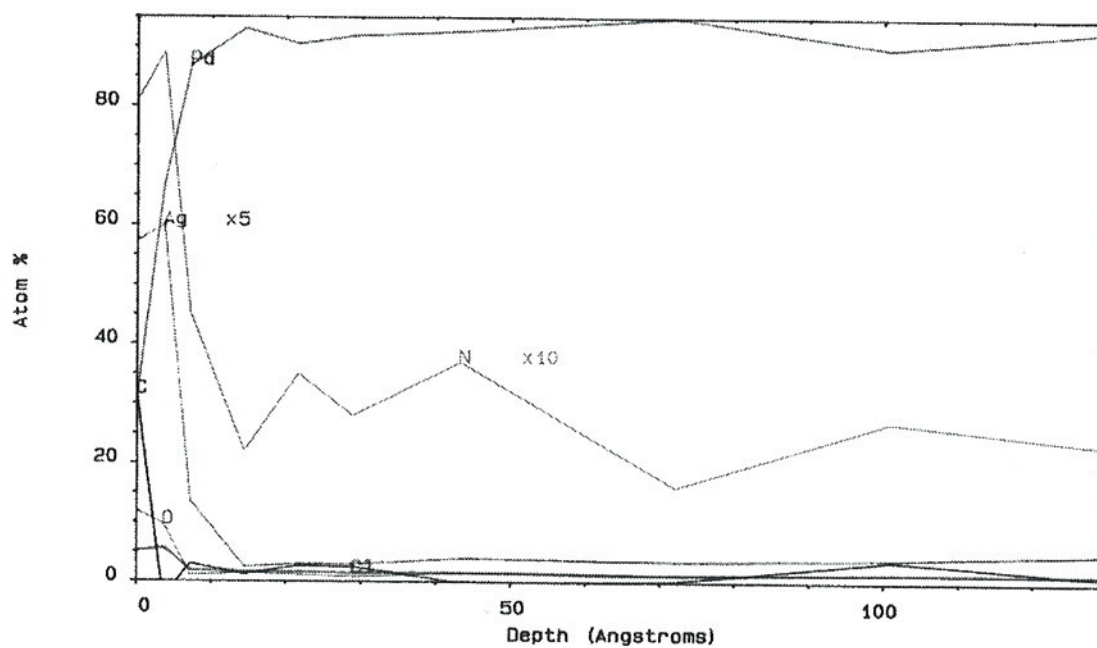


Figure 3 : AES depth profile of Sample 3

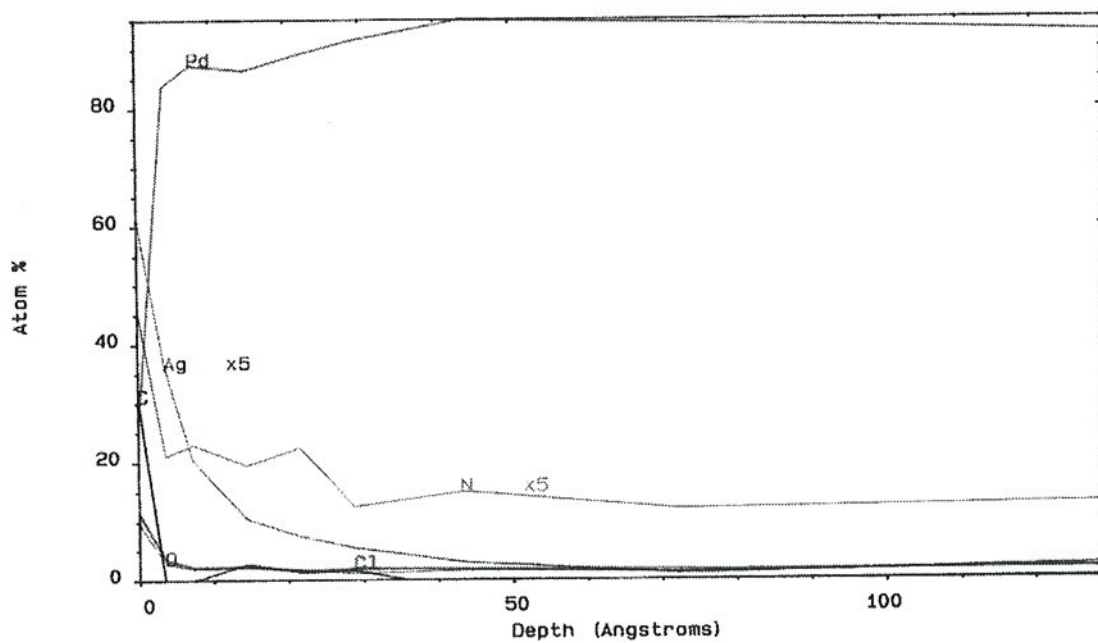


Figure 4 : AES depth profile of Sample 4

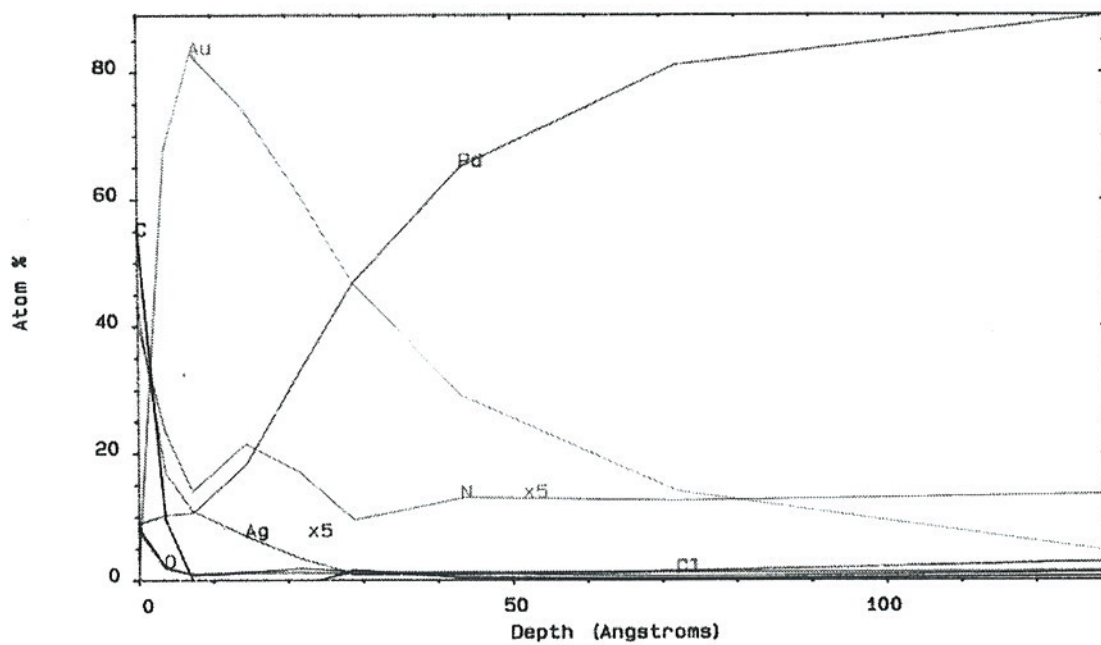


Figure 5 : AES depth profile of Sample 5

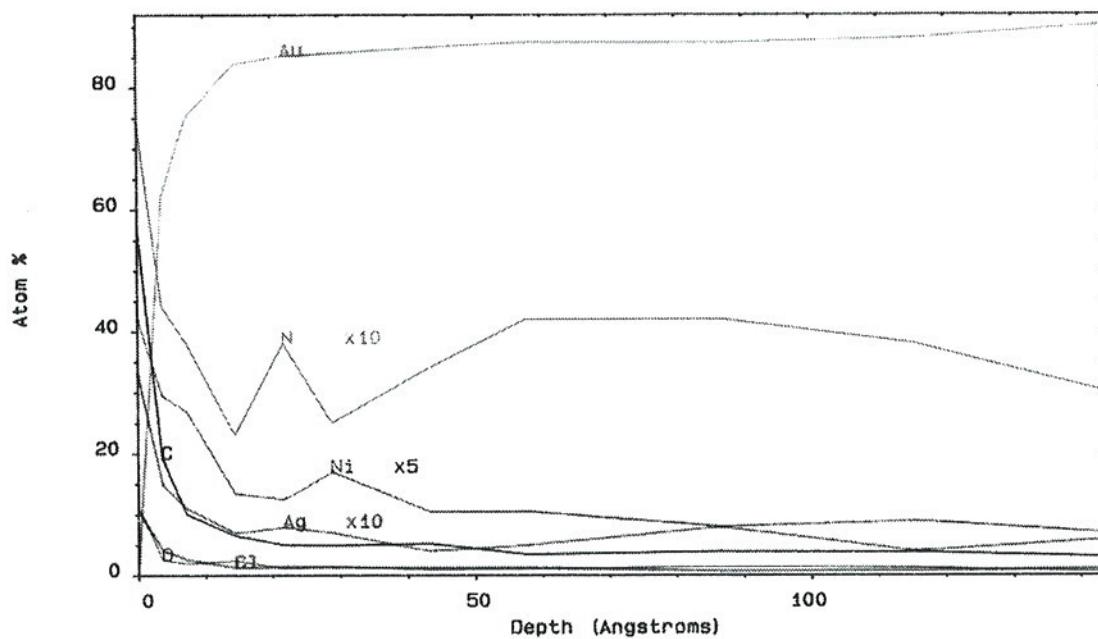


Figure 6 : AES depth profile of Sample 6

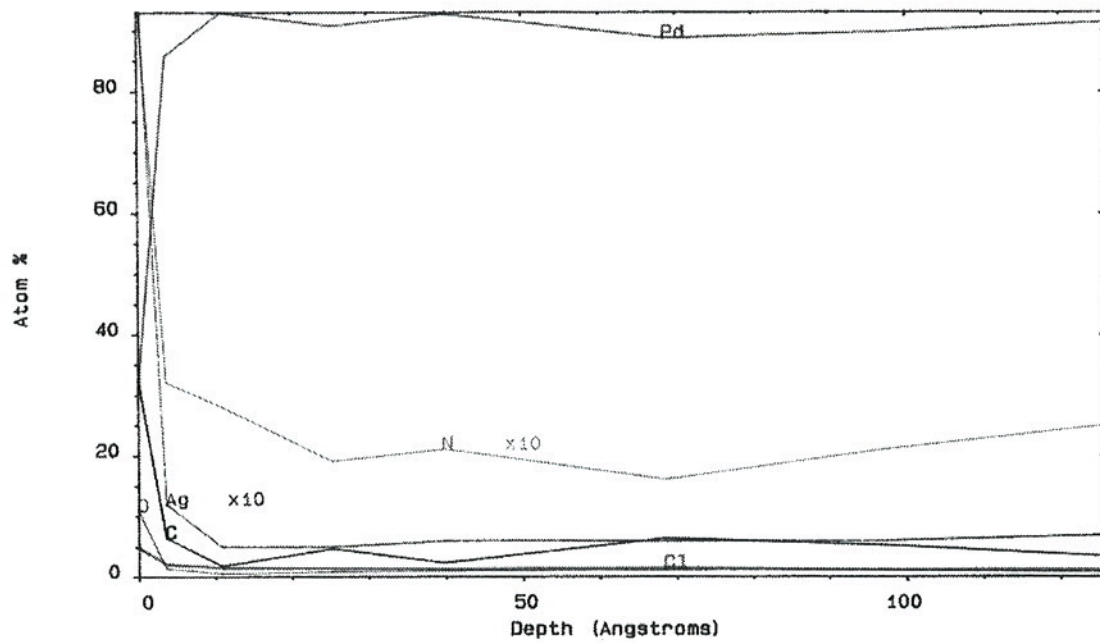


Figure 7 : AES depth profile of Sample 7

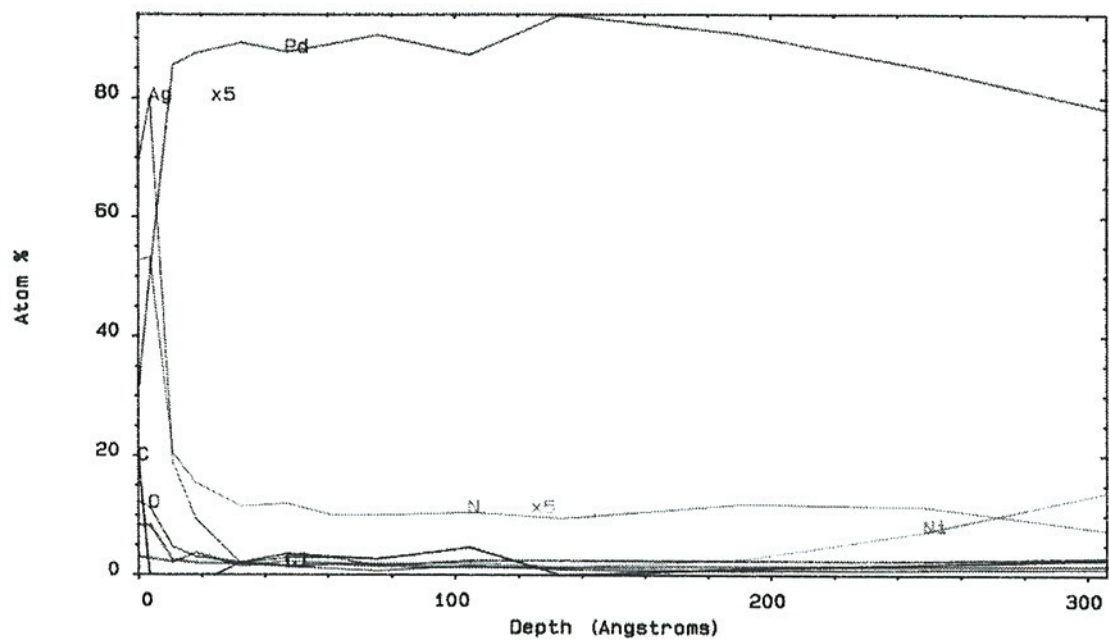


Figure 8 : AES depth profile of Sample 9

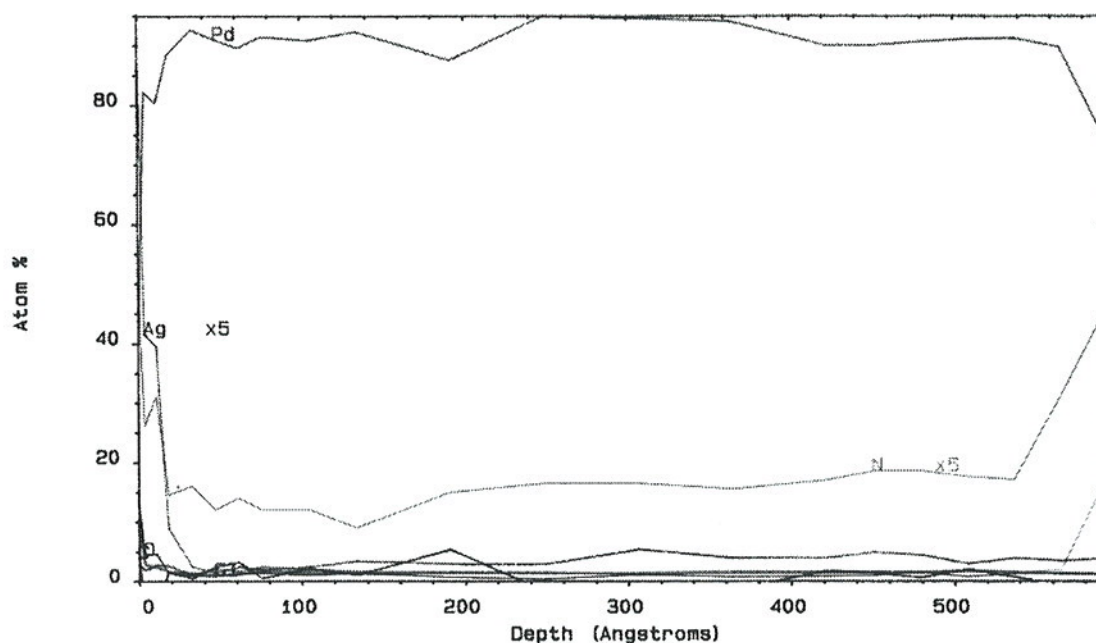


Figure 9 : AES depth profile of Sample 10

2.3 DISCUSSION OF AES DEPTH PROFILING RESULTS

All analysed samples had organic material, chlorine, silver, oxygen and nitrogen on their surfaces. In most cases the silver appeared to be associated with palladium. In general all these elements were superficial contamination which was removed by a very brief ion etch.

Sample 1 and 6 were both gold coloured and consisted of gold layers on a nickel substrate. There was no evidence for the presence of palladium on these samples but there was evidence for nickel diffusion through the gold.

Sample 2 consisted of a relatively thick gold layer (>10 nm) on a palladium layer. A low level of palladium was present throughout the gold layer, possibly diffused from the palladium layer beneath.

Sample 5 consisted of a thin (~3 nm) gold layer on a relatively thick palladium layer. Palladium was detectable throughout the gold layer.

Samples 3, 4, 7, 9 and 10 all consisted of relatively thick palladium layers (>10 nm). They are probably on the nickel substrate but the latter was only reached by extended depth profiling on samples 9 and 10. There was no gold on any of these samples.

The AES method analysed only shallow (max. 60 nm) layers of coating materials, which would be dissolved in a molten solder during the wetting balance measurement. If we consider temperatures between 235-270°C dissolution rates are: Pd - 0.015 - 0.05 $\mu\text{m/s}$,

Au 3 - 17 $\mu\text{m/s}$, Ni 0.25 - 6 nm/s. For example, 2 seconds wetting by molten SnPb solder would dissolve 6 μm of Au but only a 30 nm layer of Pd.

The AES results confirm the supplier description above given and show there are no other elements in the surface layer that might affect processability. The lower levels of Ni and Ag seen in the top one or two atom layers of the surface will not change the wetting properties of the surface.

3 SCANNING ELECTRON MICROSCOPY OF LEADFRAMES

3.1 EXPERIMENTAL PROCEDURE :

For the SEM micrographs, samples of the leads were taken from the fully assembled component, ie after the die had been encapsulated and the leads bent and cropped. From these assembled components three leads were taken from a single component representing each of the finishes. These samples were secured onto the specimen stub with a conductive ink and examined in a SEM. Photographs were taken of the bent area of the lead known as the heel, at two magnifications (150x and 1500x). EDX analysis was performed on the some of the finishes which exhibited cracking at the heel bend.

SEM micrographs of the heel bend region are shown in Figures 10 to 19.

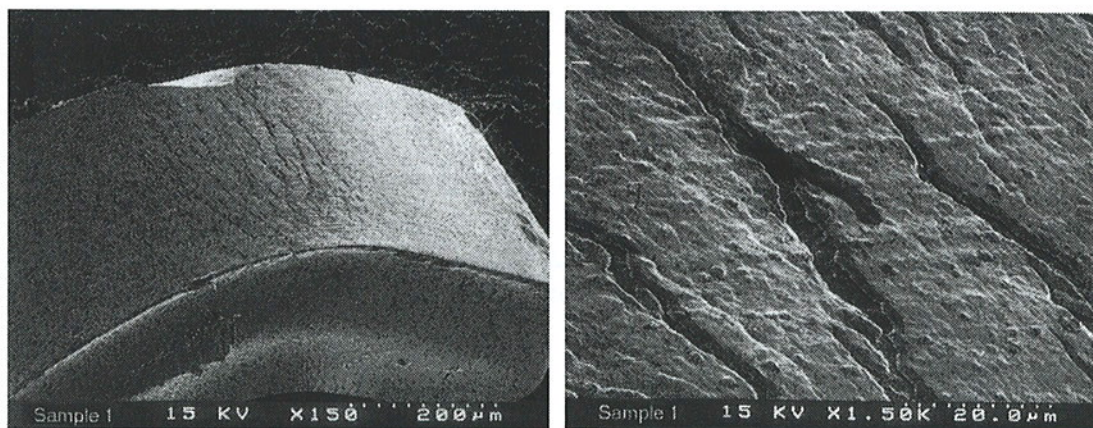


Figure 10 : SEM micrographs of finish 1 including detail

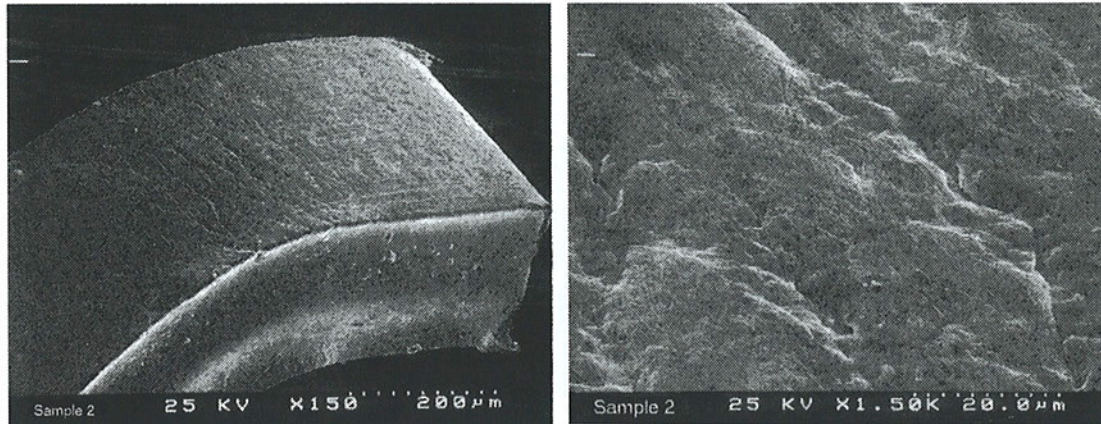


Figure 11 : SEM micrographs of finish 2 including detail

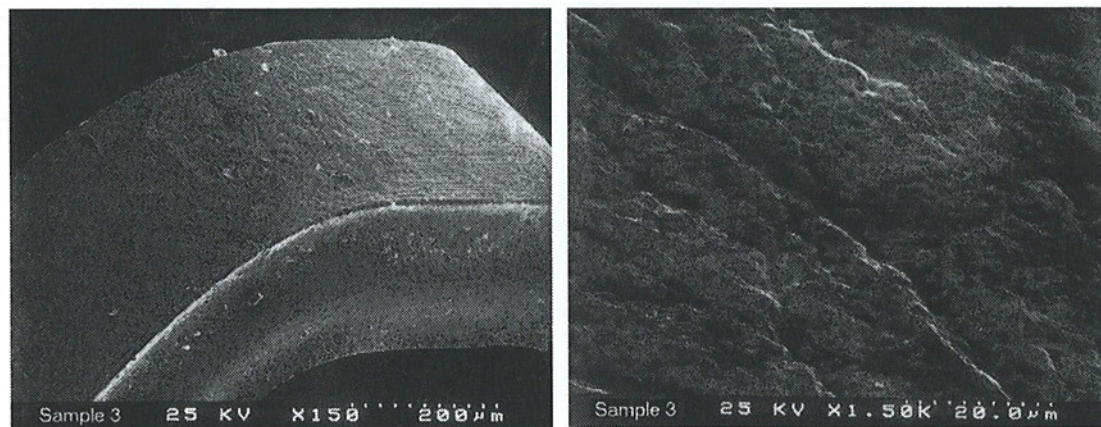


Figure 12 : SEM micrographs of finish 3 including detail

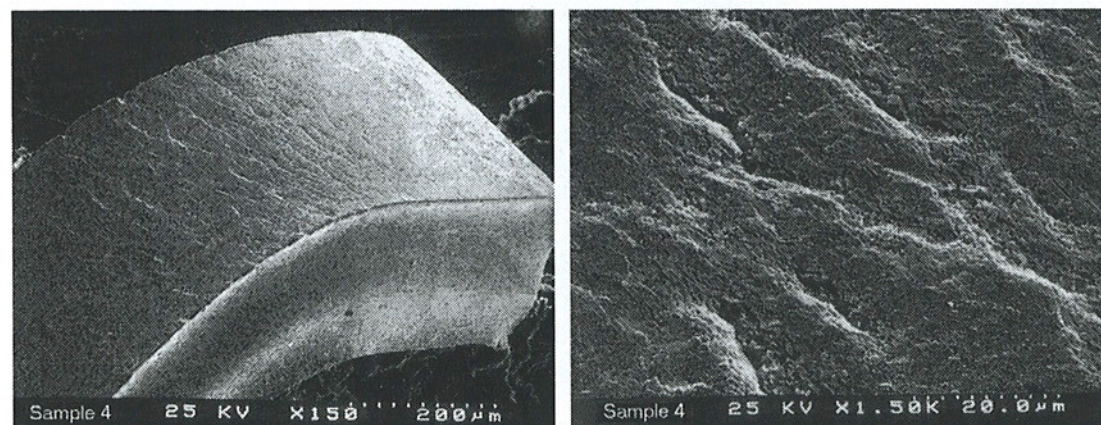


Figure 13 : SEM micrographs of finish 4 including detail

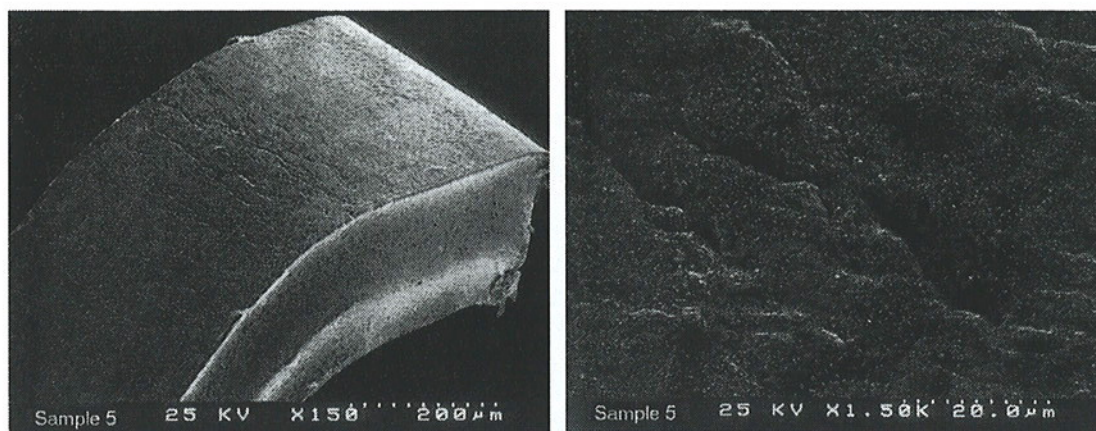


Figure 14 : SEM micrographs of finish 5 including detail

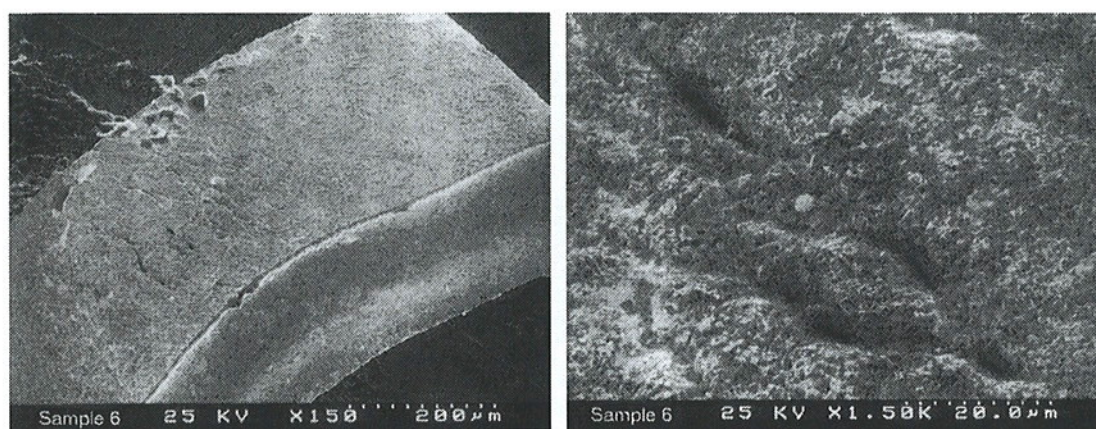


Figure 15 : SEM micrographs of finish 6 including detail

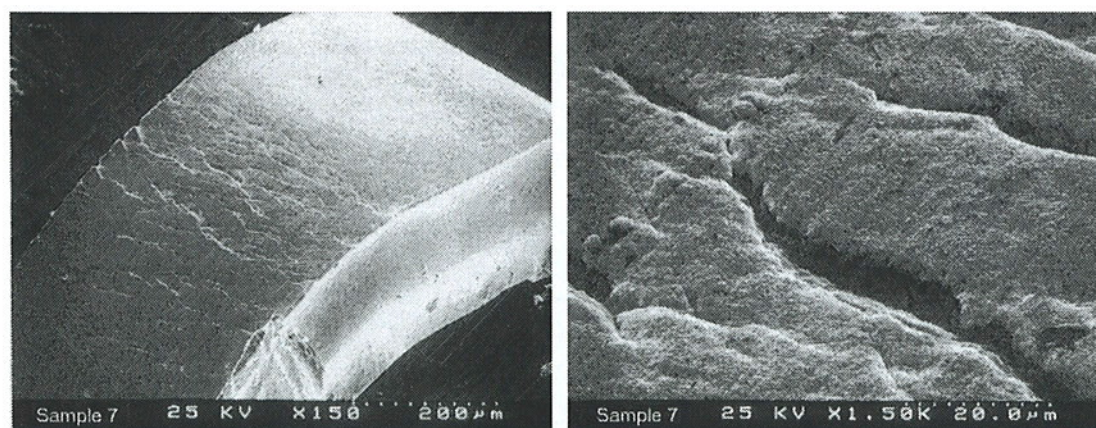


Figure 16 : SEM micrographs of finish 7 including detail

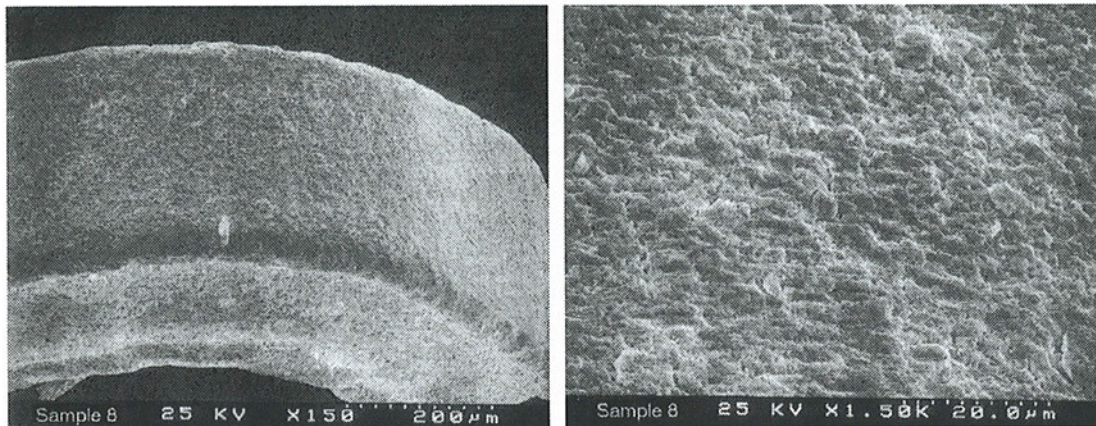


Figure 17 : SEM micrographs of finish 8 including detail

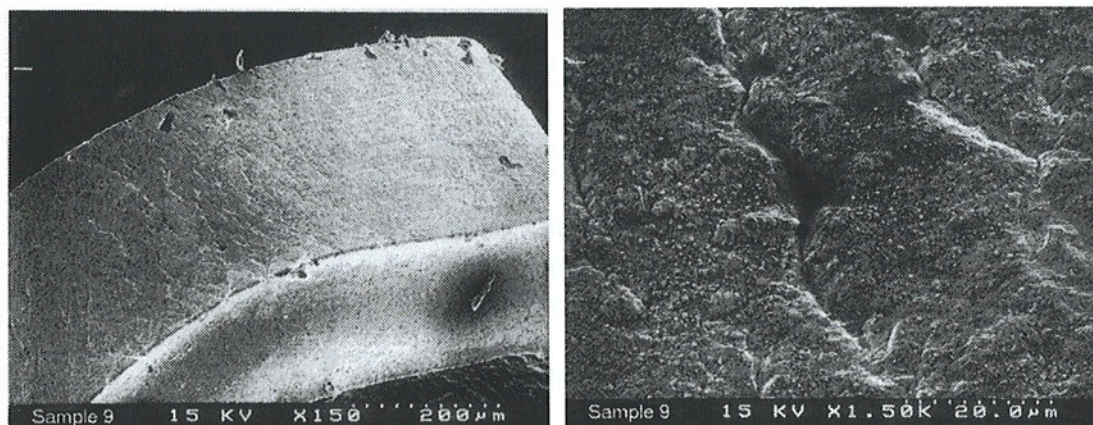


Figure 18 : SEM micrographs of finish 9 including detail

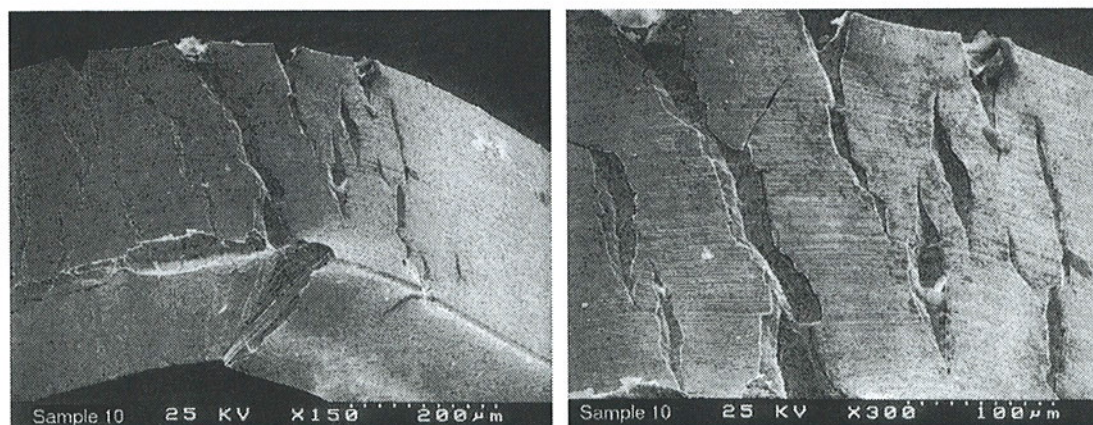


Figure 19 : SEM micrographs of finish 10 including detail

3.2 DISCUSSION OF SEM RESULTS

The results highlighted the varying degrees of cracking around the heel bend area. It was evident that many of the leads showed a degree of cracking that exposed the copper beneath the surface coating. Of the alternative finishes, finish 10 (PdNi) exhibited the deepest cracking, whilst the finish which seemed to be the least damaged in terms of cracking was finish 3 (also PdNi), closely followed by finish 6 (AuNi). The EDX analysis on finish 10 confirmed that the copper was exposed. The SnPb finish (finish 8) showed no evidence of surface cracking.

4 WIRE-BONDABILITY

The tensile strength of gold wire bonds between die and substrate for each of the 10 leadframe types was investigated.

4.1 EXPERIMENTAL PROCEDURE

Testing was undertaken with a Farco biaxial tensile testing machine. Each of the seventeen bond wires interconnecting a single die and leadframe were tensile stressed to failure in the vertical axis, thus producing a value for the ultimate tensile stress (UTS). This was repeated 5 times for each different finish. The final value for the UTS of a bond wire for a particular finish was determined by averaging these 85 values.

The average, and standard deviation of the ultimate tensile strengths for the 10 finishes are given in Figure 19.

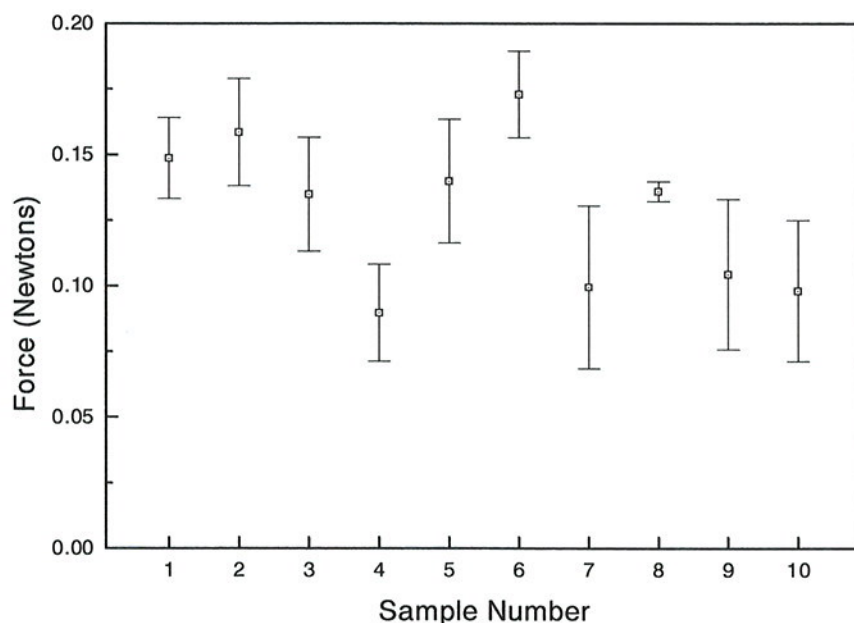


Figure 20 : Average UTS for Au Wire Bonds on 10 Different Finishes

4.2 DISCUSSION OF WIRE-BONDABILITY RESULTS

Results have shown a significant difference in strength between the various finishes with finish 2 (AuPdNi) having the highest value of 0.158 Newtons, and finish 1 (AuNi) having a similar level of performance. The poorest level of performance was indicated by the low values of 0.09 - 0.1 Newtons exhibited by finishes 4, 7, 9 & 10 (all PdNi). Those samples having a gold finish (finishes 1, 2, 5 & 6) clearly gave the highest performance. Finish 8, the SnPb control, showed a UTS comparable with the gold finishes. For the SnPb sample the bond was made to the base finish on the leadframe, which is typically Ag. All finishes showed UTS values in excess of normally permitted minimum values.

5 SOLDERABILITY MEASUREMENT

5.1 EXPERIMENTAL PROCEDURE

Again, fully moulded components in a SOIC16 package were used and all 10 finishes were tested. The components were aged at 155°C for 0, 4 and 16 days. The samples at three ages were tested with 3 fluxes for solderability. These were :

- A: Water based flux (passes Bellcore specification)
- B: High activity water based flux (passes J-STD-004)
- C: Low solid rosin flux

The solderability testing was carried out using a Multicore MUST II. The test conditions were in accordance with the IEC standard 68-2-69, and the instrument was used in the globule mode, using a 60/40 SnPb solder. The following conditions were used:

- 200mg solder pellet at a temperature of 235°C
- immersion speed = 1mm/s
- immersion depth = 0.2mm
- no pre-heat was used
- data were acquired over a 5 second period
- leads were dipped at an angle of 45°
- four leads from each of two components were tested for each finish.

The test results are therefore an average value from 8 leads.

The samples aged for 4 days were also tested with three lead-free alloys using flux A. These three alloys and their test temperature were :

- SnAg test temperature: 271°C
- SnAgCu test temperature: 267°C
- SnAgCuSb test temperature: 265°C

The solderability of samples with these three alloys was measured according to the same method as above, but using the different test temperatures. The measurement temperatures were chosen to be 50 °C above the melting point.

Wetting force and wetting time data for the 10 finishes at three ages are given in Figures 21 to 46 for the three fluxes, A, B and C as described above. Finish 8 is a control SnPb finish. Wetting force and wetting time data for the 10 finishes at four days age for three lead-free alloys and a SnPb alloy are given in Figures 47 & 48.

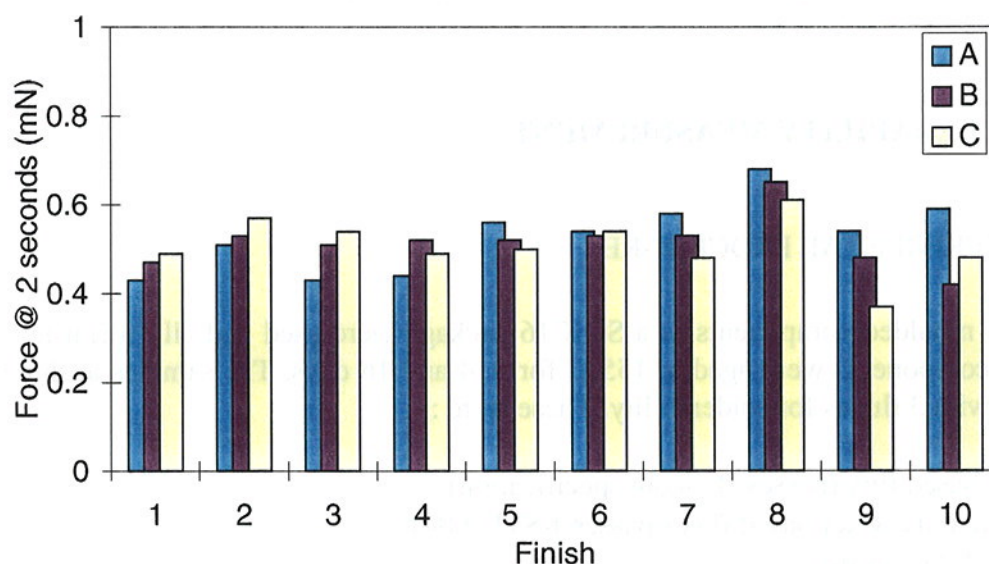


Figure 21 : Wetting forces for the 10 finishes in as-received condition for 3 fluxes

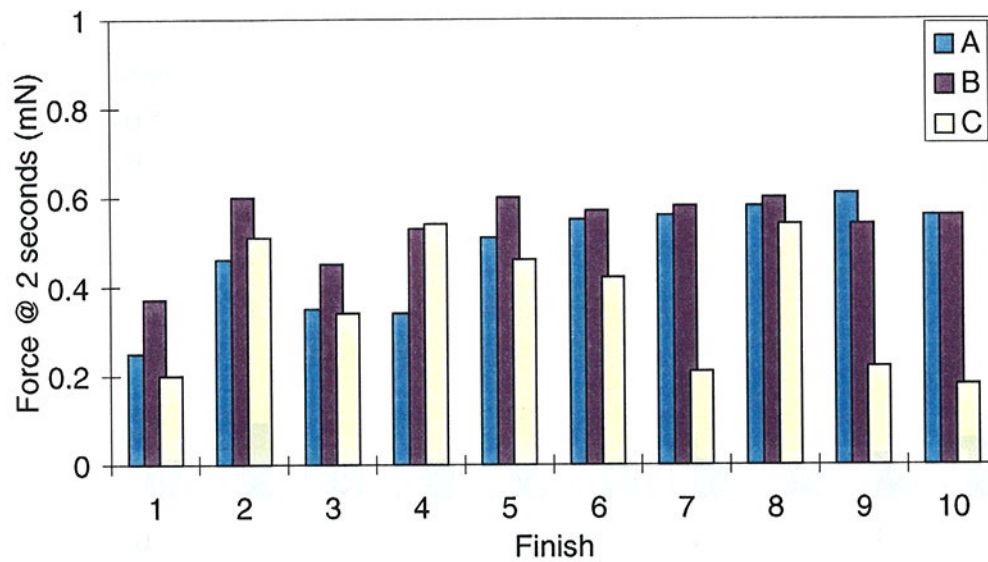


Figure 22 : Wetting forces for the 10 finishes after 4 days ageing for 3 fluxes

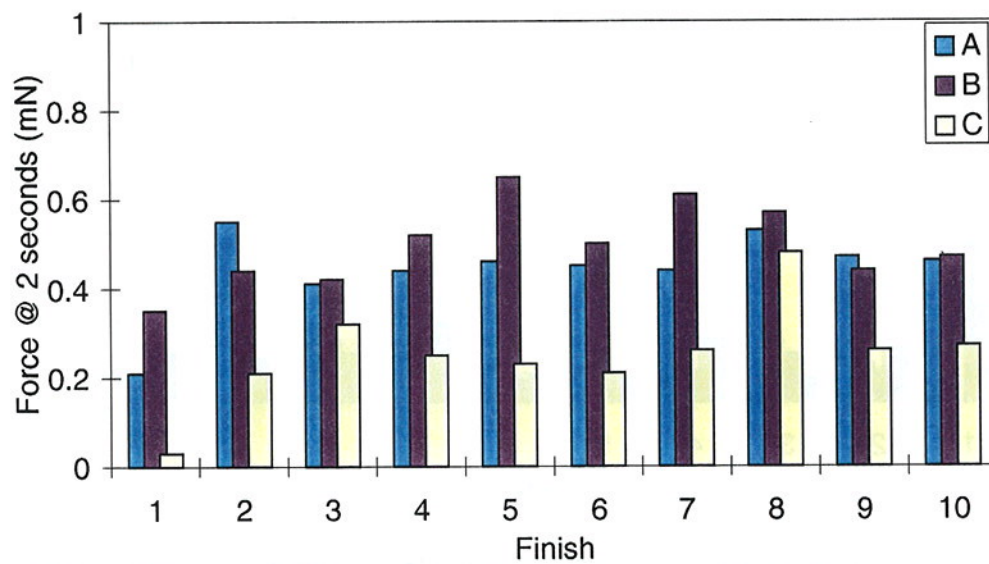


Figure 23 : Wetting forces for the 10 finishes after 16 days ageing for 3 fluxes

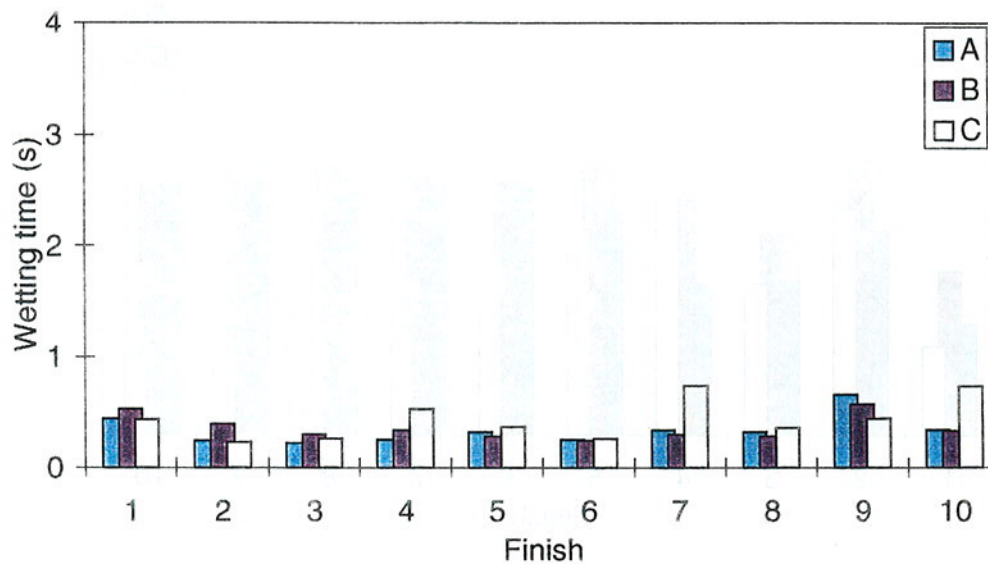


Figure 24 : Wetting times for the 10 finishes in as-received condition for 3 fluxes

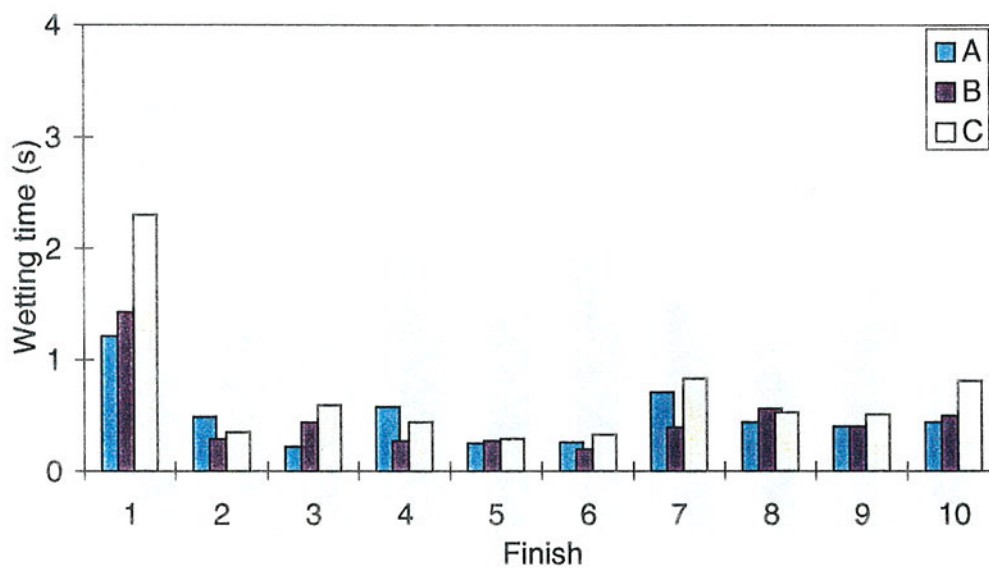


Figure 25 : Wetting times for the 10 finishes after 4 days ageing for 3 fluxes

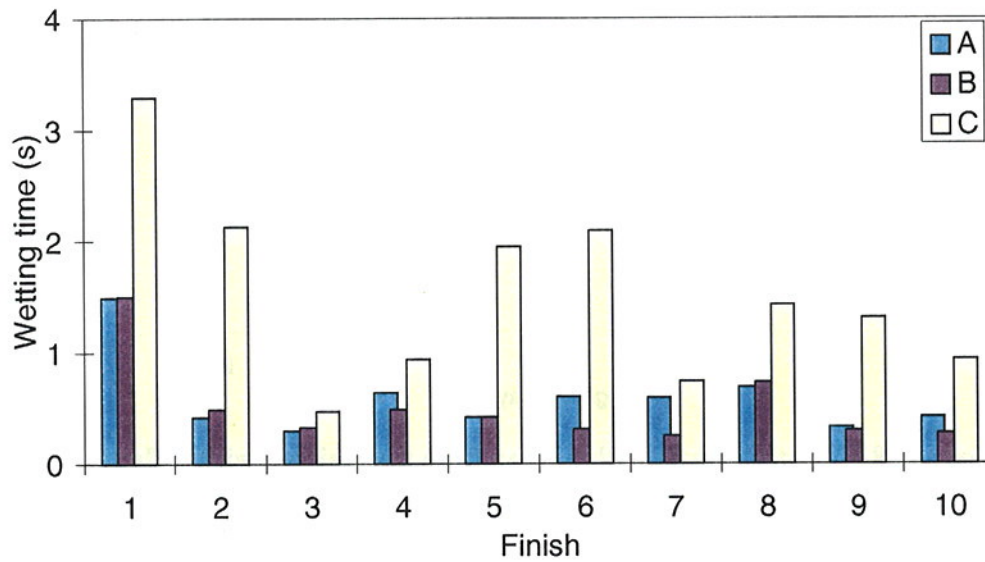


Figure 26 : Wetting times for the 10 finishes after 16 days ageing for 3 fluxes

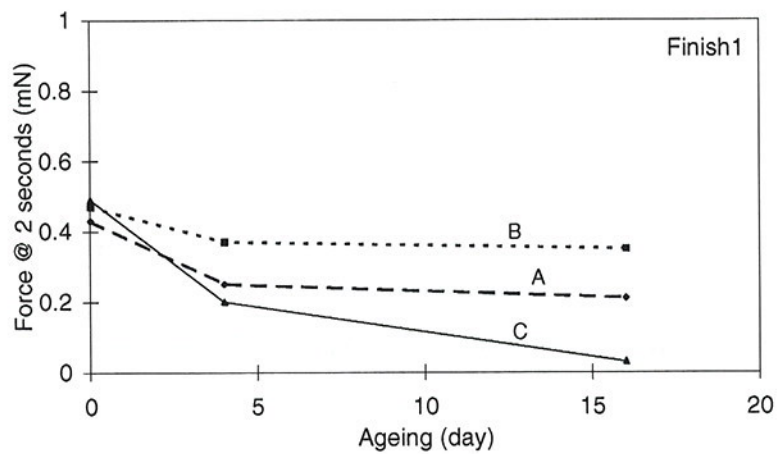


Figure 27 : Wetting force with ageing time for finish 1 with 3 fluxes

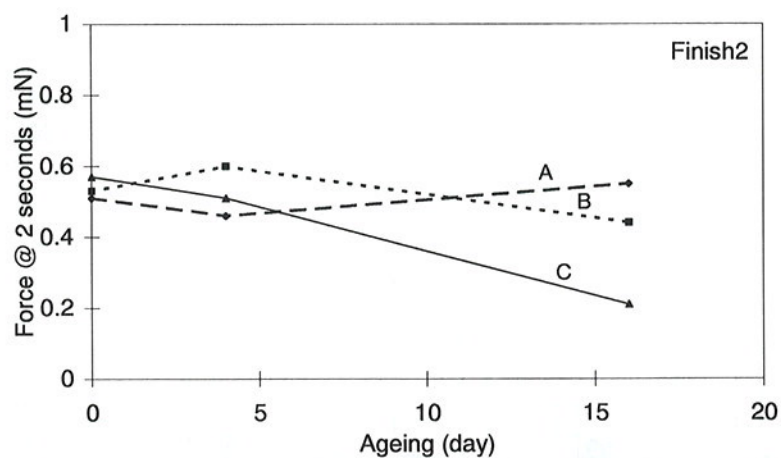


Figure 28 : Wetting force with ageing time for finish 2 with 3 fluxes

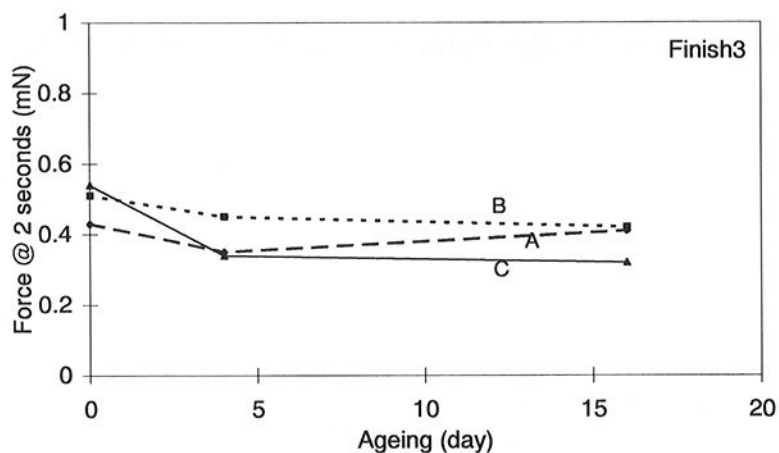


Figure 29 : Wetting force with ageing time for finish 3 with 3 fluxes

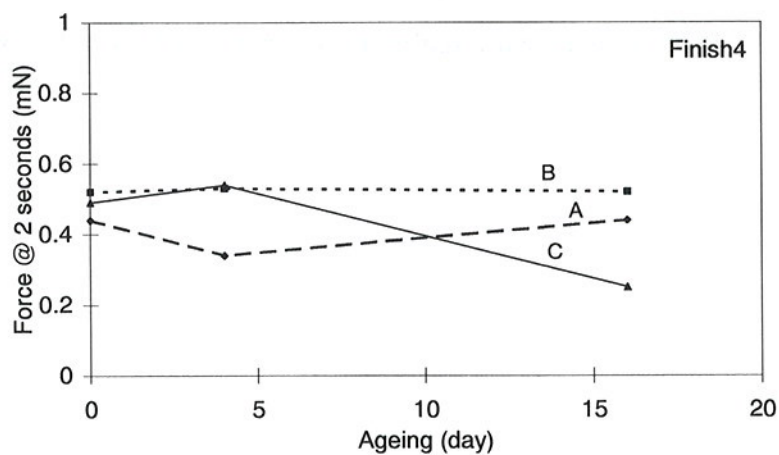


Figure 30 : Wetting force with ageing time for finish 4 with 3 fluxes

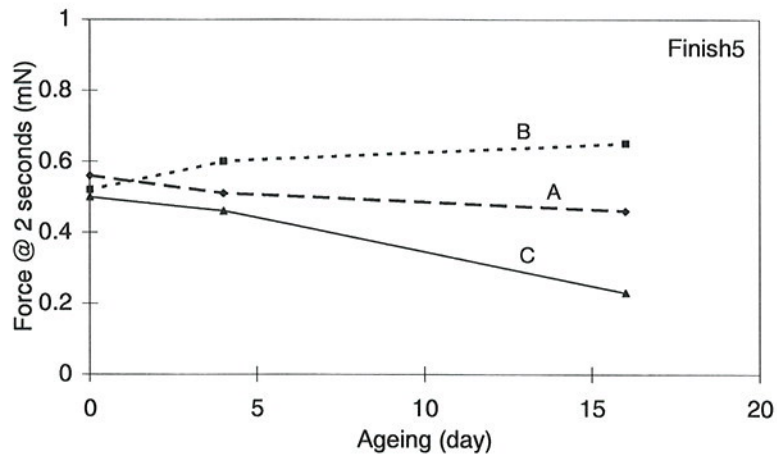


Figure 31 : Wetting force with ageing time for finish 5 with 3 fluxes

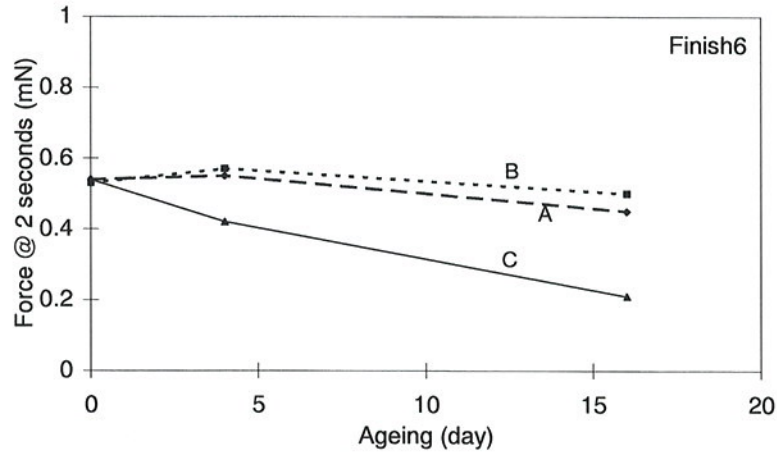


Figure 32 : Wetting force with ageing time for finish 6 with 3 fluxes

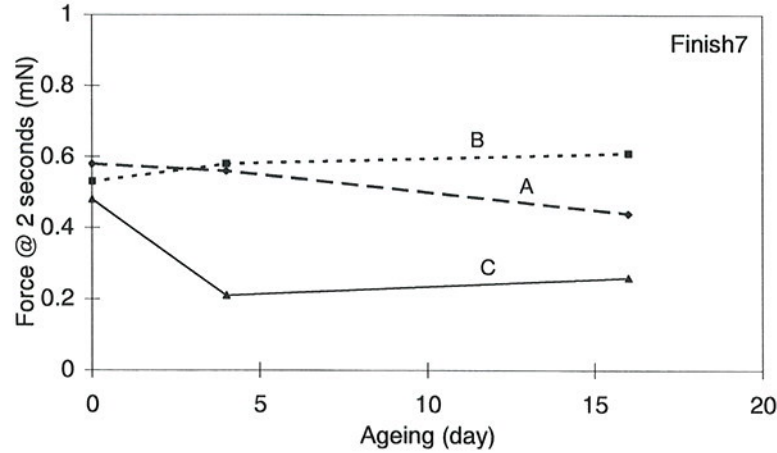


Figure 33 : Wetting force with ageing time for finish 7 with 3 fluxes

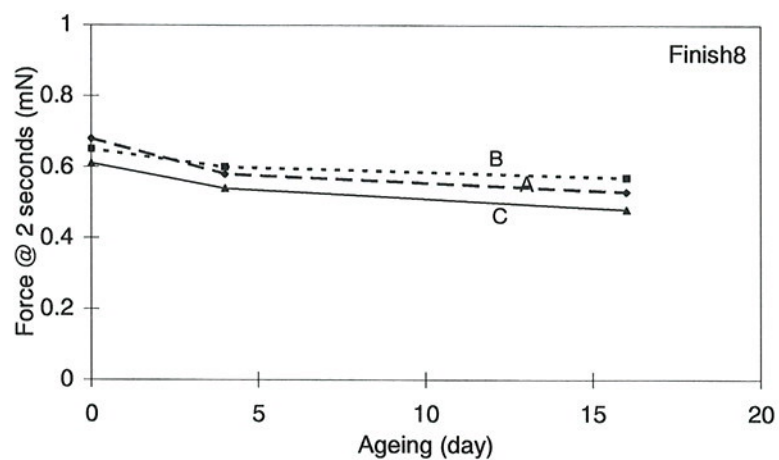


Figure 34 : Wetting force with ageing time for finish 8 with 3 fluxes

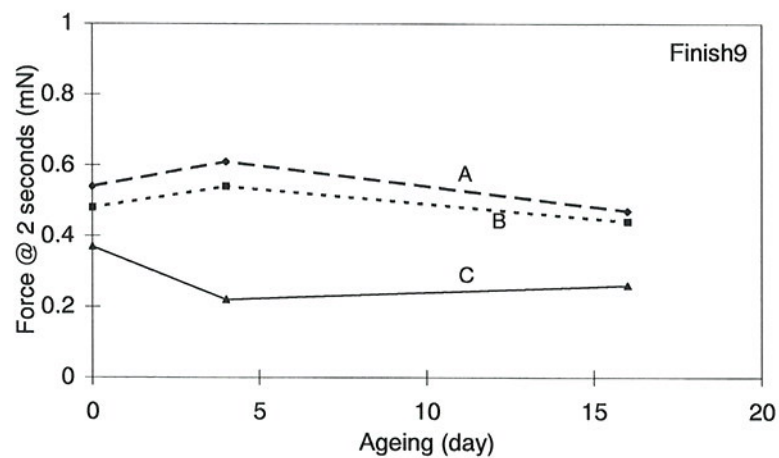


Figure 35 : Wetting force with ageing time for finish 9 with 3 fluxes

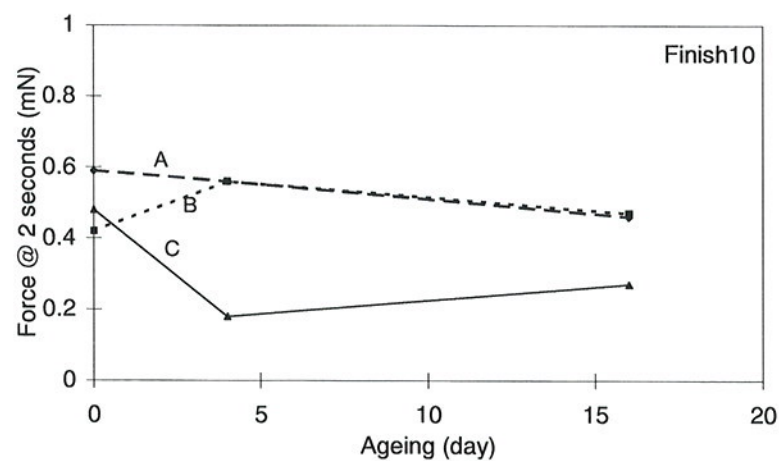


Figure 36 : Wetting force with ageing time for finish 10 with 3 fluxes

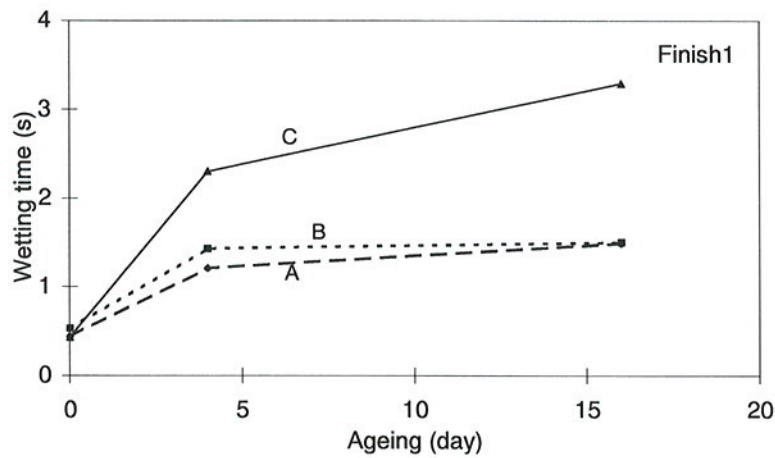


Figure 37 : Wetting time with ageing time for finish 1 with 3 fluxes

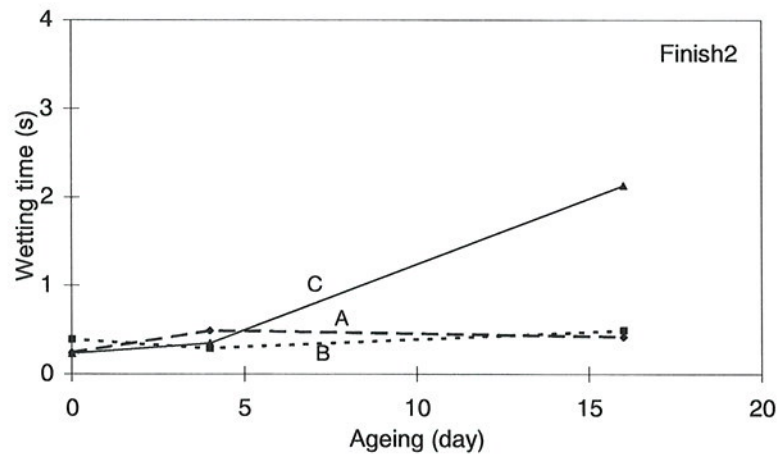


Figure 38 : Wetting time with ageing time for finish 2 with 3 fluxes

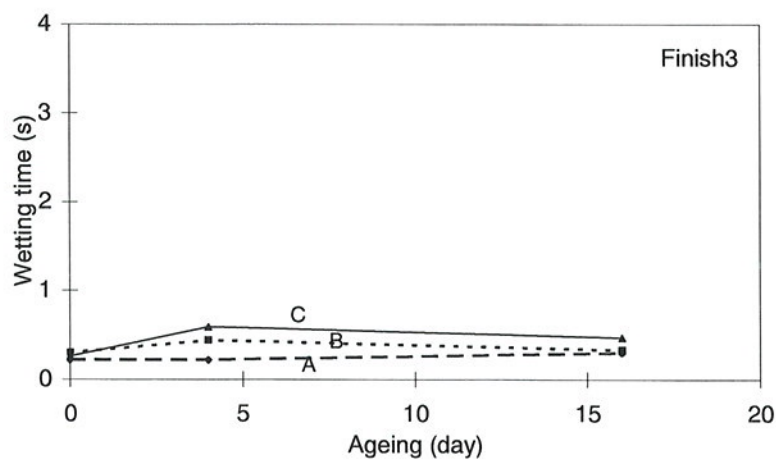


Figure 39 : Wetting time with ageing time for finish 3 with 3 fluxes

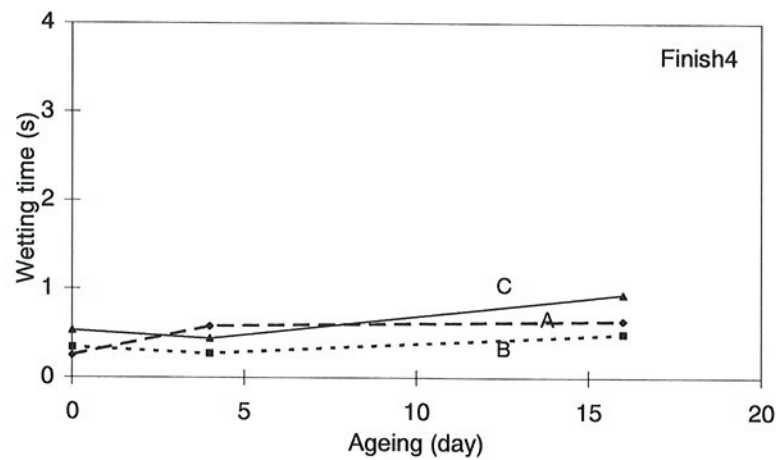


Figure 40 : Wetting time with ageing time for finish 4 with 3 fluxes

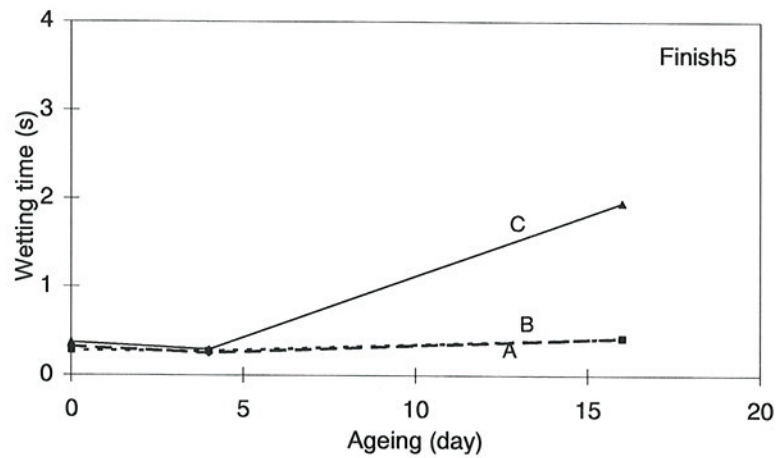


Figure 41 : Wetting time with ageing time for finish 5 with 3 fluxes

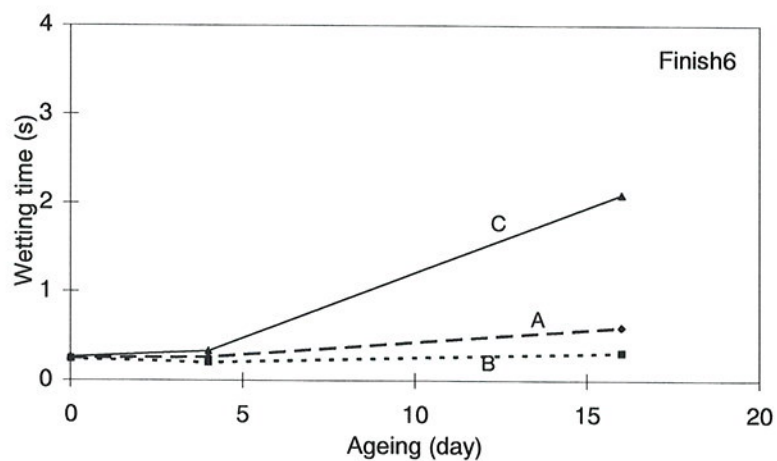


Figure 42 : Wetting time with ageing time for finish 6 with 3 fluxes

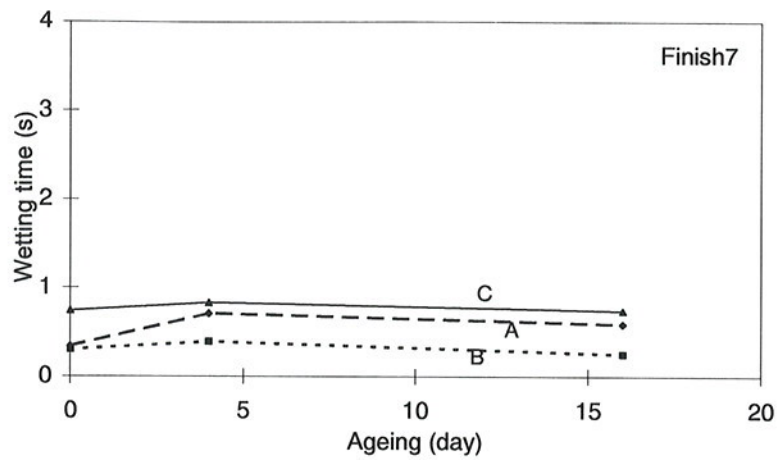


Figure 43 : Wetting time with ageing time for finish 7 with 3 fluxes

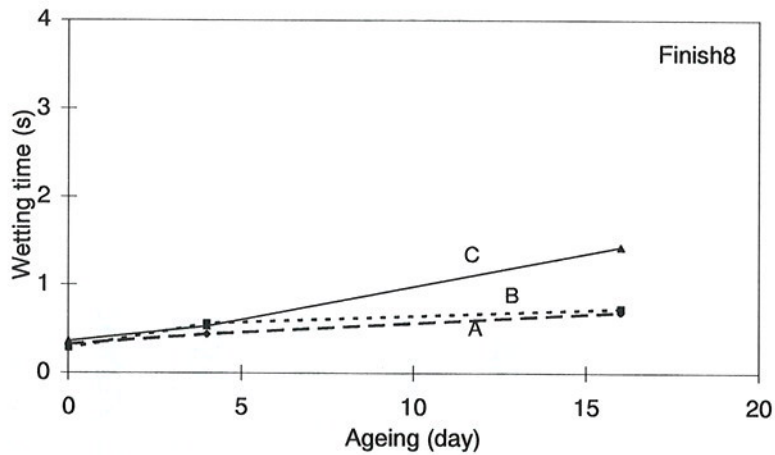


Figure 44 : Wetting time with ageing time for finish 8 with 3 fluxes

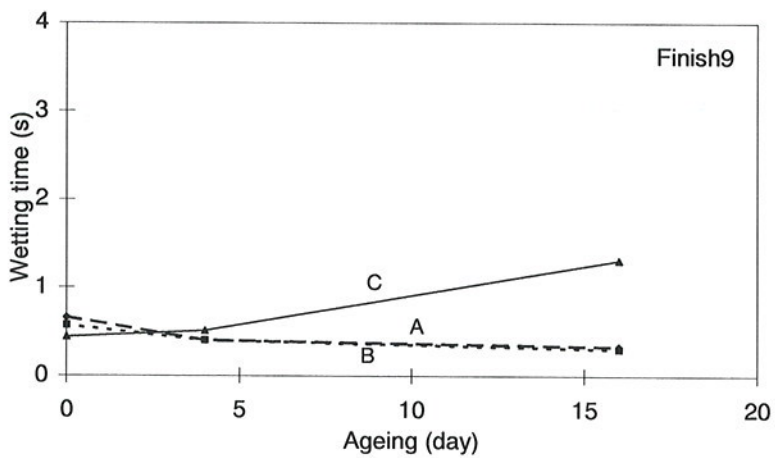


Figure 45 : Wetting time with ageing time for finish 9 with 3 fluxes

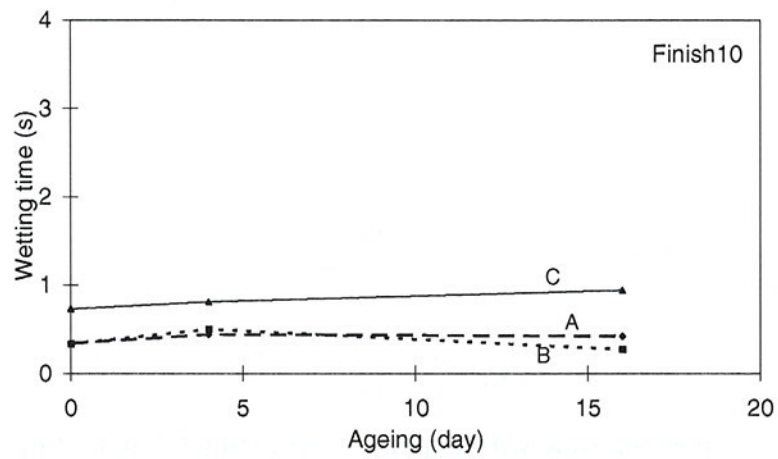


Figure 46 : Wetting time with ageing time for finish 10 with 3 fluxes

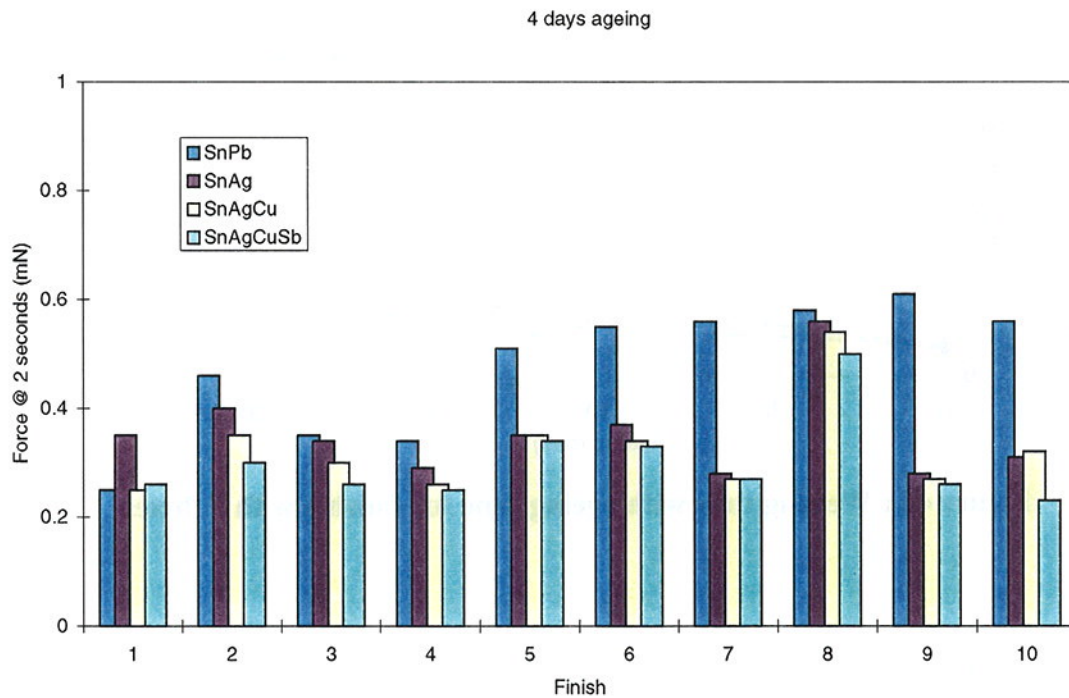


Figure 47 : Wetting force from 10 finishes at 4 days age for 3 lead-free alloys and the SnPb alloy

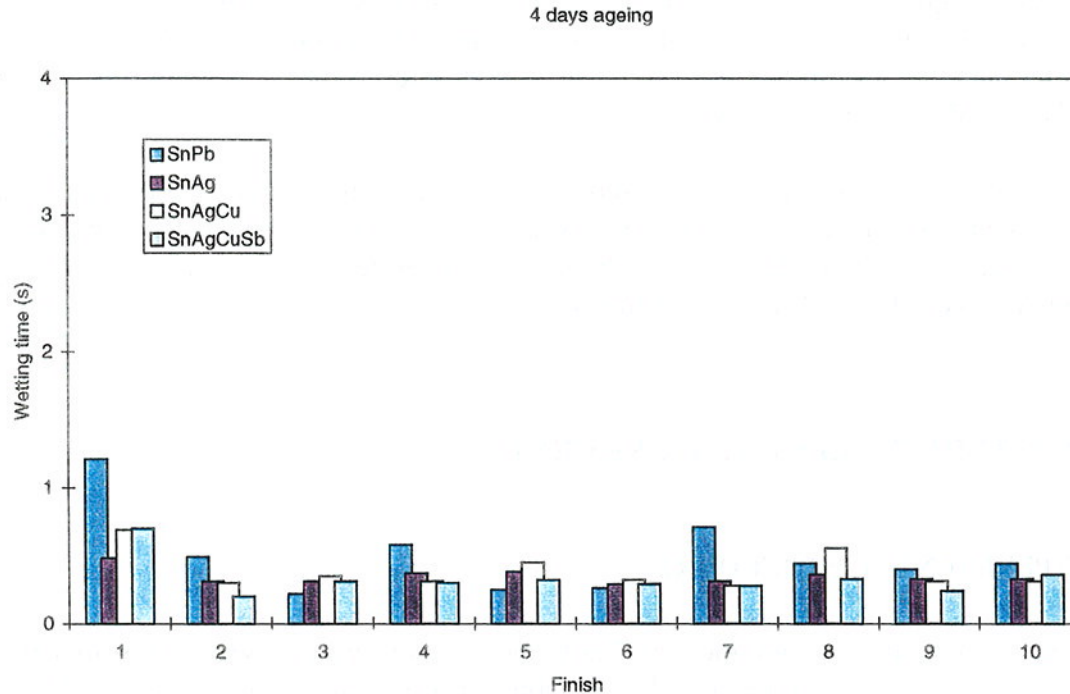


**Figure 48 : Wetting time from 10 finishes at 4 days age for 3 lead-free alloys
and the SnPb alloy**

5.2 DISCUSSION OF SOLDERABILITY RESULTS

It can be seen from Figures 21 to 24 that for both the force at 2 seconds and the time to 2/3 maximum force, there was little difference among the alternative finishes with the three fluxes for the as-received components with the SnPb globule. Finish 8 (SnPb leadframe) had a slightly higher wetting force than all the alternative finishes. However there was a significant difference among three fluxes for aged components particularly at 16 days (Figures 23 and 26). Flux C was the least aggressive of the fluxes and appeared to be unable to remove the oxide layer of aged components. The highest activity flux B provided the best solderability.

The results in Figures 27 to 46 demonstrate that increased ageing time significantly reduces the solderability of finishes with flux C, particularly the wetting time. Significantly, ageing does not affect the wetting force for finish 8 (SnPb leadframe) with flux C (Figure 34). The solderability of finish 1 is dramatically decreased with ageing time for all fluxes (Figures 27 and 37). Apart from finish 1 all finishes were relatively unaffected by the ageing process when using the two water-based fluxes, A and B.

Figure 47 clearly shows that there was little difference with wetting forces among the 10 finishes after four days of ageing for the three lead-free alloys, except finish 8. The wetting forces of ten finishes were very similar among three lead-free alloys, and were higher than that for SnPb alloy except finish 1. This may be because the higher test temperature with the

lead-free alloys improves the solderability for aged finish 1. This is confirmed by the wetting time in Figure 48, which shows the wetting times of finish 1 for three lead-free alloys were much shorter than that for SnPb alloy. There was little difference for the wetting time among the 10 finishes and three lead-free alloys.

The solderability of all finishes aged for 4 days shows very similar results among three lead free alloys when using flux A. All finishes (except finish 1) performed better with SnPb solder than with any of the Pb-free solders (Figure 47). High test temperatures for lead free alloys improved the solderability for aged finish 1.

6 MOISTURE INGRESS MEASUREMENTS

6.2 EXPERIMENTAL PROCEDURE

Components manufactured from the ten leadframe finishes were assessed for moisture ingress by weight gain measurements. The components were dried at 125°C for 24 hours, and weighed. The dried components were placed in 40°C/93% humidity chamber for 24 hours, and weighed again.

The weight gain and standard deviation data for components having the ten finishes are presented in Figure 49. This clearly shows that the finish 1 (AuNi) and the control SnPb finish components had a higher weight gain than the remaining 8 finishes, which all showed very similar weight gains. The difference is nearly 50% between finish 1 and the other finishes.

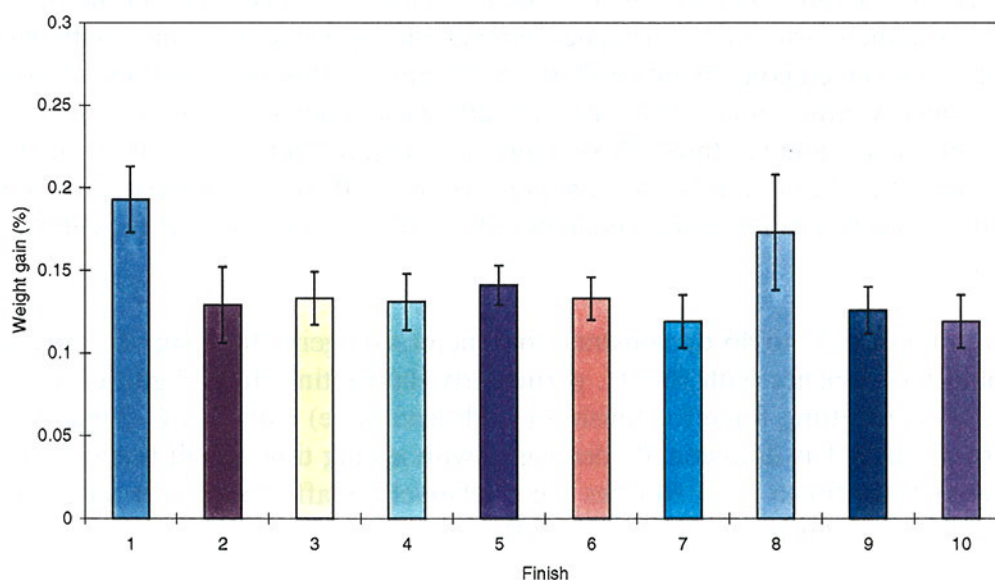


Figure 49 : Weight gain and standard deviation for ten finishes components

6.2 DISCUSSION OF MOISTURE INGRESSION RESULTS

Finish 1 and the control SnPb finish may be more prone to package delamination during reflow, giving rise to the so called “pop-corning” effect.

7 PROCESS YIELD MEASUREMENT

7.2 EXPERIMENTAL PROCEDURE

Test samples were manufactured by Matra BAe using their normal single sided surface mount (SM) assembly process. The test assembly utilised a simple single sided FR4, 80mm x 80mm printed circuit board (PCB) with a hot air solder levelled finish and without solder resist. This is shown in Figure 50. Each assembly contained 25 components of a single leadframe finish, and twenty assemblies were manufactured for each leadframe finish.

The manufacturing process utilised a Sn62 RMA solder paste printed through a 150 micron chemically etched stainless steel stencil. The components were autoplaced and reflowed through the same profile in an air atmosphere. The maximum reflow temperature was 215°C and the maximum molten solder time was 65 secs.

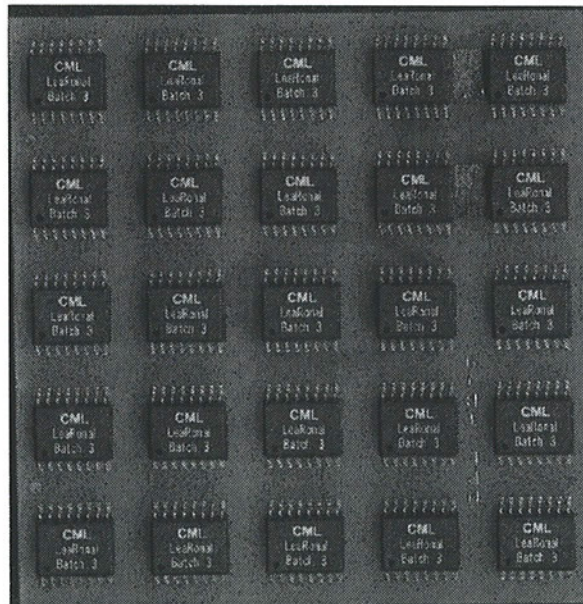


Figure 50 : Process yield test assembly

After assembly, the resulting solder joints were visually inspected by a single operator using a binocular zoom microscope at 15X magnification. Illumination was provided by a fibre optic fed ring illuminator. The four corner joints of each device were inspected and scored based on the scoring system shown in Figure 51. Using the IPC visual inspection guidelines (reference 2), a joint failure would be scored 2 or below on this scoring system.

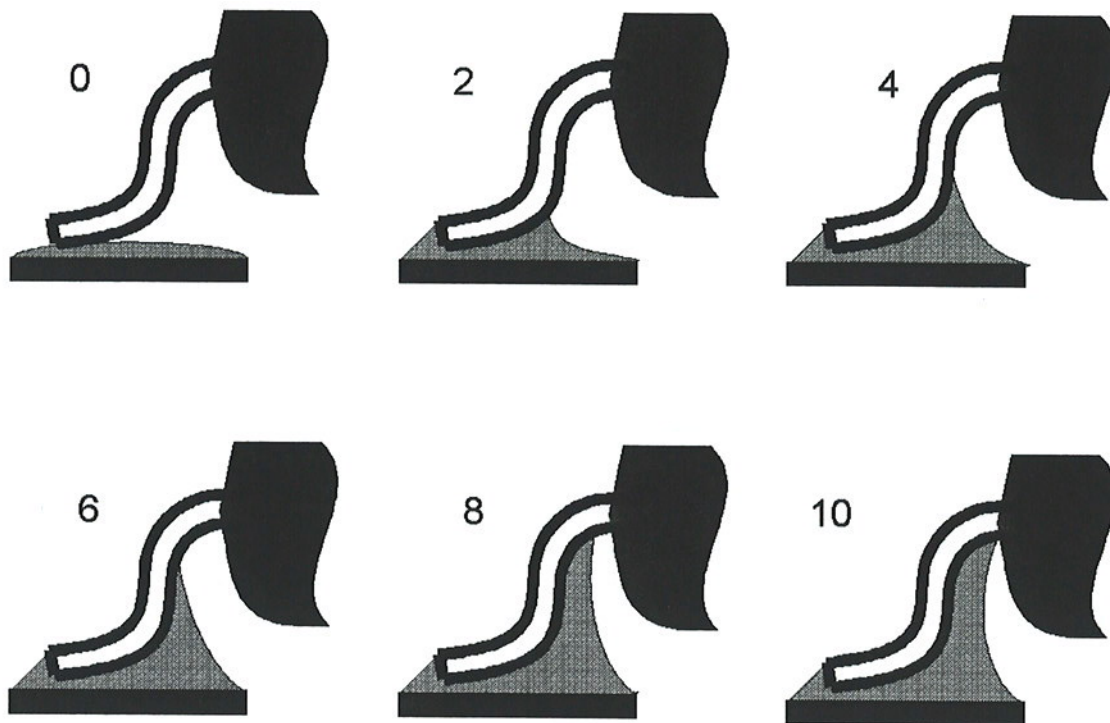


**Figure 51 : Schematic representation of solder joint scores used
in visual inspection**

The range of joint scores recorded is shown in Figures 52 to 62.

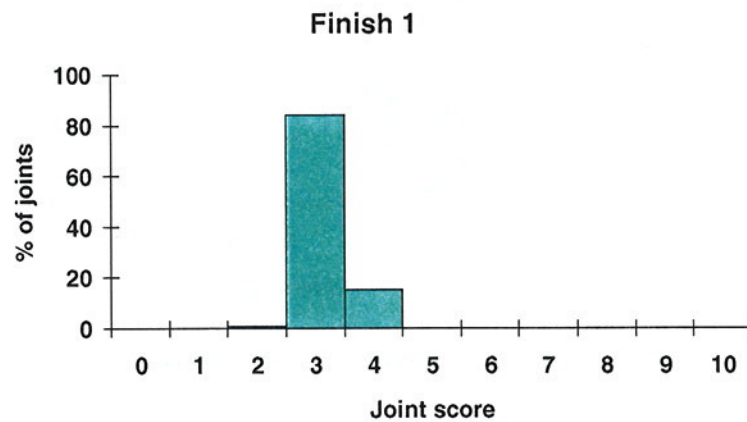


Figure 52 : Joint scores for finish 1

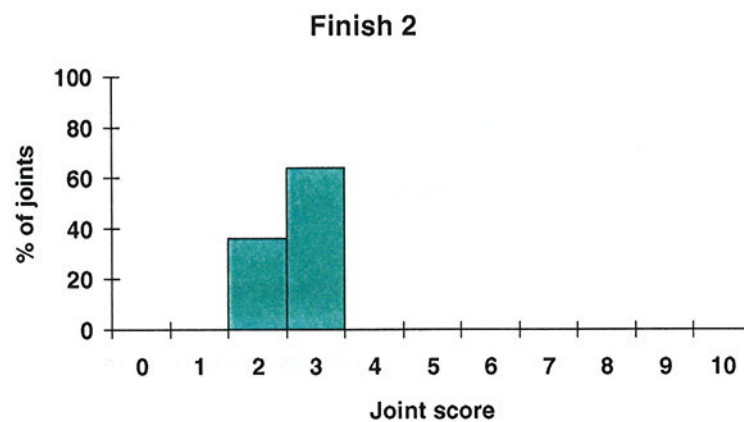


Figure 53 : Joint scores for finish 2

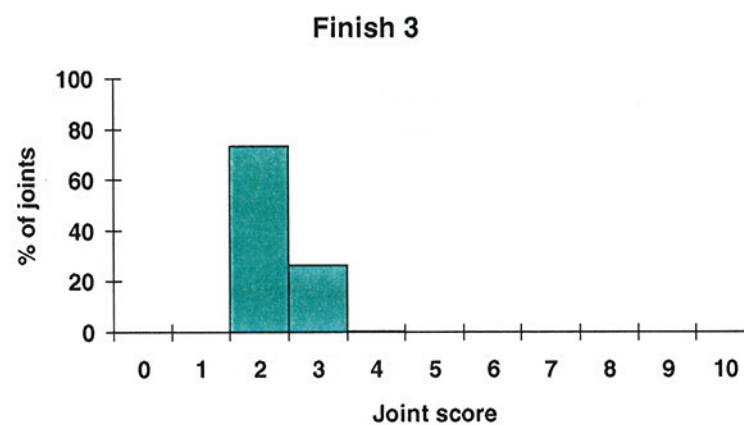


Figure 54 : Joint scores for finish 3

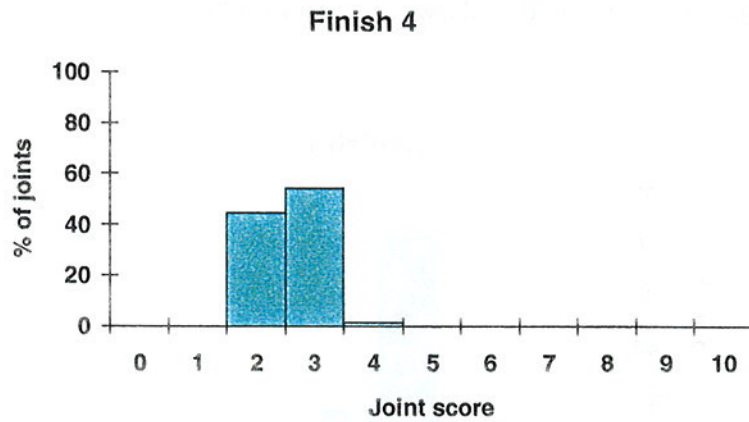


Figure 55 : Joint scores for finish 4

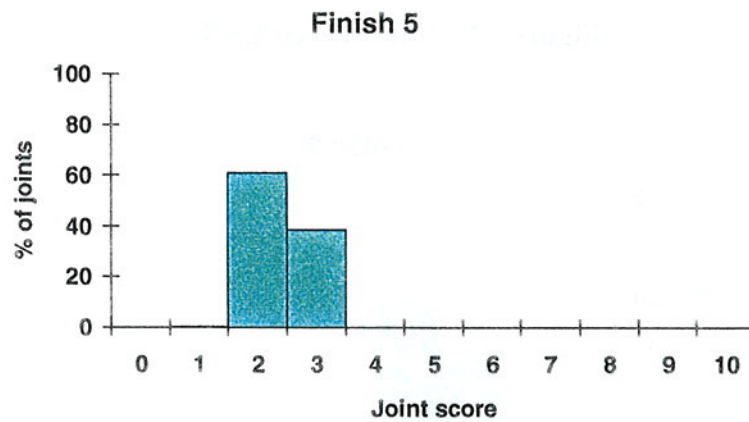


Figure 56 : Joint scores for finish 5

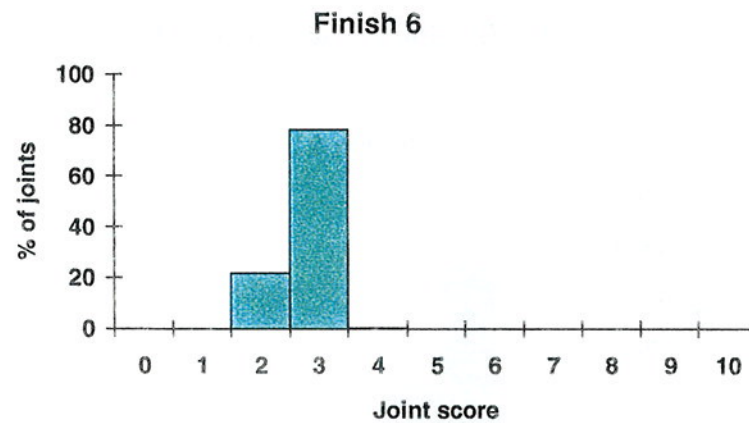


Figure 57 : Joint scores for finish 6

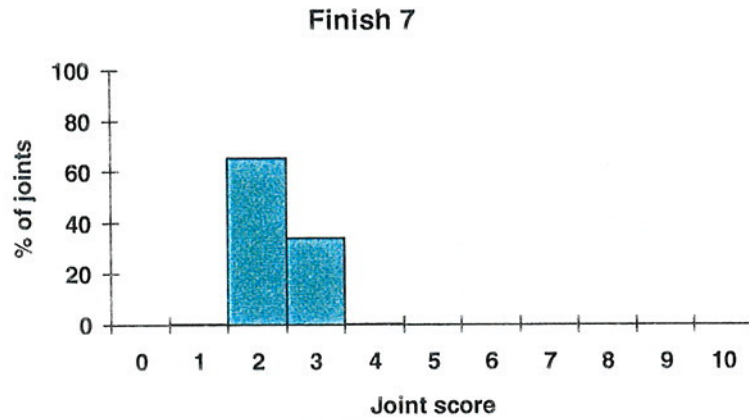


Figure 58 : Joint scores for finish 7

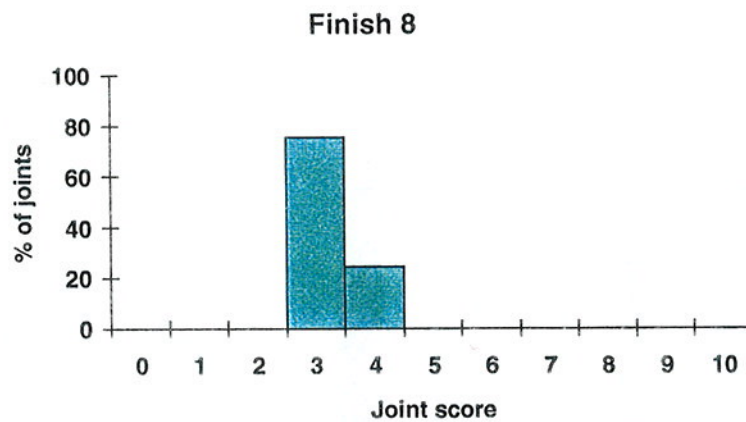


Figure 59 : Joint scores for finish 8

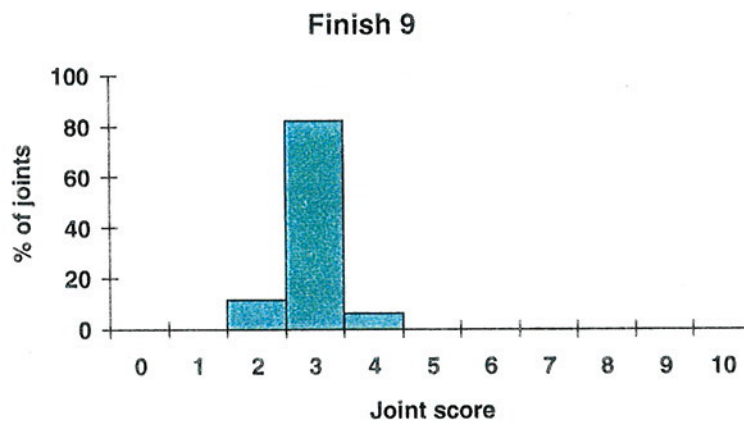


Figure 60 : Joint scores for finish 9

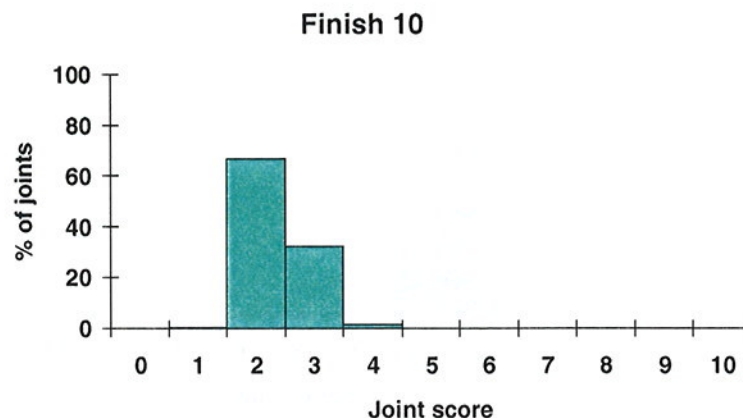


Figure 61 : Joint scores for finish 10

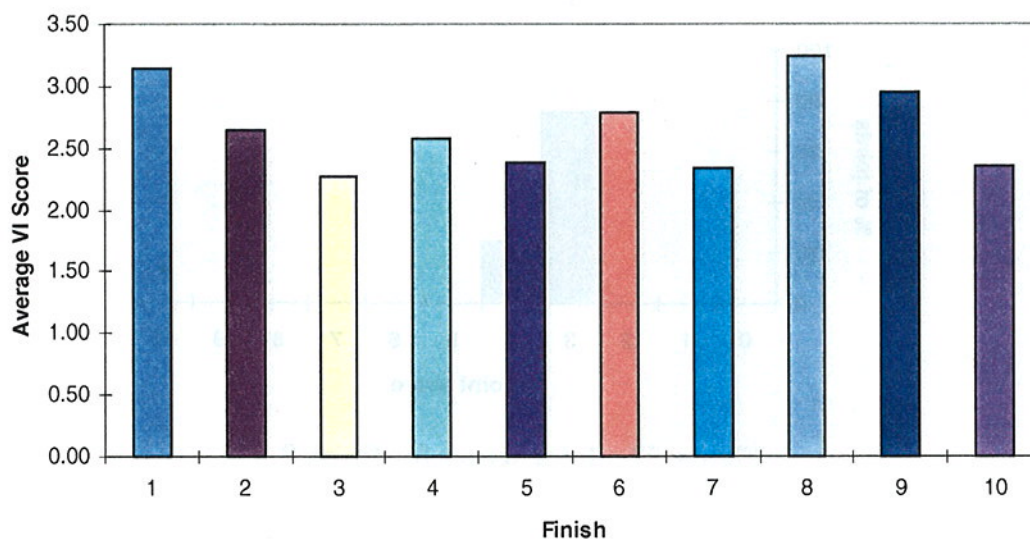


Figure 62 : Comparison of average visual inspection scores for all finishes

7.1 DISCUSSION OF PROCESS YIELD RESULTS :

In total, only four joints failed out of 5000 inspected. This low incidence of failures makes meaningful calculations of parts-per-million defect rates impossible. All finishes provided acceptable process yield with this assembly process, although four finishes (3, 5, 7 and 10) are only just above minimum acceptable score. No finish had a better VI score than SnPb control although finishes 1 and 9 come close. The surface texture of finish 6 was much rougher than the other finishes, probably due to the relatively thick gold finish.

8 SOLDER JOINT SHEAR TESTING OF ASSEMBLED COMPONENTS

After visual inspection, samples of each leadframe finish were tested for shear strength.

The encapsulated portions of the devices were detached from the leads using a diamond tipped saw, leaving solder joints fully intact. These joints were then stressed to failure from the rear of the heel using a Farco biaxial tensile testing machine. This machine records the ultimate shear stress (USS) applied to the joint to cause fracture. This test was performed on five leads from three components for each different termination finish. An average of the USS for the fifteen leads per finish was used for comparisons.

The average, and standard deviation of USS values are shown in Figure 63.

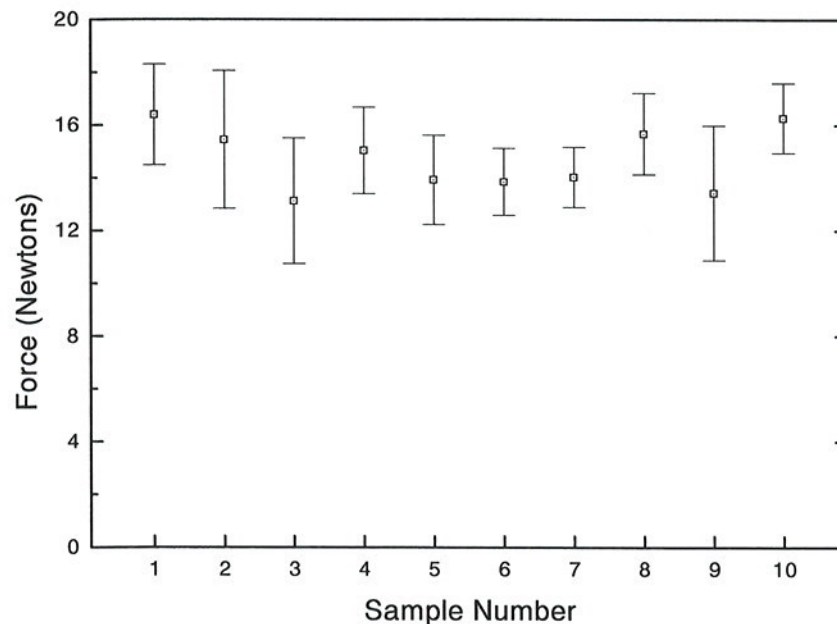


Figure 63 : The average ultimate shear stress values for the soldered joints of the ten finishes

There was very little difference of the Ultimate Shear Stress between the different finishes in the experiment, and the visual inspection revealed very similar solder joint fillets for the different finishes. It is therefore not surprising that there is little difference between the different finishes.

9 DISCUSSION

Table 2 shows a comparison of visual inspection (VI) scores and solderability results. The percentage scores calculated have been based on 100% for the highest VI score and shortest time to 2/3 maximum force. The order of the results has been arranged in order to have similar finishes grouped together.

Table 2 : Comparison of visual inspection scores and solderability measurements

Finish	3	4	7	9	10	2	5	1	6	8
Visual Inspection	70%	80%	70%	90%	70%	80%	70%	100%	90%	100%
Solderability as-received	90%	80%	80%	60%	80%	90%	80%	80%	90%	100%
Solderability after 16 days	70%	50%	50%	50%	60%	40%	50%	10%	40%	100%
Finish Type	Pd/ Ni	Pd/ Ni	Pd/ Ni	Pd/ Ni	Pd/ Ni	Au/ Pd	Au/ Pd	Au/ Ni	Au/ Ni	Sn Pb

With regard to the visual inspection scores, Au/Ni & SnPb finishes generally gave better results (90 to 100%) than the Pd/Ni or Au/Pd finishes. The exception was Pd/Ni finish 9 which had a score close to that of the SnPb score. The surface of the solder joints formed using finish 6 was much rougher than the other finishes. This is explained by the information given by the finish suppliers given in Table 1. Finish 6 has a much thicker gold coating than the other gold finishes, causing a higher level of SnAu intermetallics which cause the surface roughening. However, this level of intermetallics did not affect the joint shear strength.

The solderability results show that in the as-received condition, the SnPb finish performed better than the alternatives although the performance of some alternatives was close exhibited by Sn/Pb. Finish 9 exhibited particularly poor solderability. The solderability results for samples after 16 days ageing show that the SnPb finish performed significantly better than the alternatives. The Pd/Ni finishes showed a lower level of solderability reduction than the other alternative finishes.

There is no apparent correlation between the visual inspection scores and the as-received solderability scores. Such a correlation was noted in the previous project undertaken by the authors (1). The lack of a correlation may be explained by the surface finish in the bend or heel area, the latter being critical during joint formation in reflow soldering. To form a good joint, the solder must rise up the heel of the lead to a height greater than the lead thickness. If the plating in the heel region of the lead is cracked (during the forming of the leads in the component manufacturing operation) this may inhibit solder wetting up the heel. This is

component manufacturing operation) this may inhibit solder wetting up the heel. This is particularly important if the plating is completely ruptured and the copper underneath has oxidised. The cracking of this plating in the heel region would not affect solderability testing as the lead is immersed in the solder at an angle of 45 degrees. The solder globule wets up the base of the lead, rarely rising as far as the heel. This is illustrated in Figure 64.

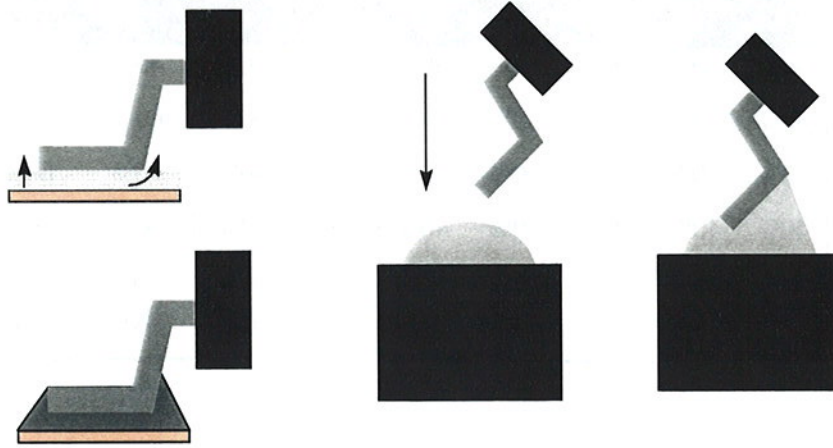


Figure 64 : Diagram showing the differences between reflow soldering (left) and solderability testing (right) with respect to the heel area of the lead

Figure 19 shows the surface finish at the bend area of a lead of finish 10, and extensive cracking can be seen, exposing the copper underneath. Finish 10 shows a relatively poor visual inspection score but average solderability, illustrating the lack of correlation. The results for finish 7 (Figure 16) are also similar but with less pronounced cracking of the plating.

Table 3 : Comparison of wirebondability results and moisture ingress results as a percentage of greatest value

Finish	3	4	7	9	10	2	5	1	6	8
Wirebond	80%	60%	60%	70%	60%	100%	90%	90%	90%	90%
Moisture	100%	100%	100%	100%	100%	100%	90%	70%	100%	70%
Finish Type	Pd/ Ni	Pd/ Ni	Pd/ Ni	Pd/ Ni	Pd/ Ni	Au/ Pd	Au/ Pd	Au/ Ni	Au/ Ni	Sn/ Pb

Table 3 shows the results for wire-bondability and moisture ingress converted to percentages based on the best result being 100%. As discussed previously a significant difference in wirebond strength can be seen between the various finishes. Finish 2 had the highest value with the other Au finishes (1, 5 and 6) having a similar level of performance. The wirebond strength of finish 8 (SnPb with Ag spot plating in the wirebond area) also had a similar value. The poorest level of performance was exhibited by finishes 4, 7, 9 & 10, i.e. all PdNi finishes. PdNi finish 3 was the best of the PdNi finishes with a wirebond strength close to that of the gold finishes.

The moisture ingress results show very little difference between the finishes. All the PdNi, AuPd and one of the AuNi (finish 6) were superior to the control SnPb finish (finish 8). Finish 1 (AuNi) showed similar moisture take-up to the control. These two finishes may be more prone to package delamination during reflow.

Table 4 : Comparison of solderability of Pb-free alloys

Finish	3	4	7	9	10	2	5	1	6	8
SnPb	60%	60%	90%	100%	90%	80%	80%	40%	90%	100%
SnAg	60%	50%	50%	50%	50%	70%	60%	60%	60%	90%
SnAgCu	50%	40%	40%	40%	50%	60%	60%	40%	60%	90%
SnAgCuSb	40%	40%	40%	40%	40%	50%	60%	40%	50%	80%
Finish	Pd/ Ni	Pd/ Ni	Pd/ Ni	Pd/ Ni	Pd/ Ni	Au/ Pd	Au/ Pd	Au/ Ni	Au/ Ni	Sn Pb

Table 4 shows a comparison of the solderability of the leadframes with SnPb and Pb-free alloys. The comparison is based on the force at 2 seconds with the highest value taken as 100%. As previously discussed, this Table shows that there is little difference between the solderability of the alternative finishes and that of the lead-free alloys. Better solderability is exhibited when using SnPb as an alloy (exceptions being finishes 1, 3 and 4 which perform much the same with all alloys) or using Pb-free alloys with SnPb leadframes. These results indicate that moving to a total Pb-free soldering system (Pb-free components and solder) may result in a significantly reduced soldering yield. Thus if a lead-free alloy is used with SnPb finished components, better wetting, and hence better process yield, will be achieved than with a totally lead free system.

10 CONCLUSIONS

- The solderability of the as-received PdNi finish was not as good as the SnPb, although visual inspection scores of two lead-free finishes were similar to those of the SnPb control. The Au flash on the PdNi finish improved the solderability compared to other lead-free finishes.
- The solderability of the PdNi finishes did not generally withstand the accelerated ageing at 155°C as well as the SnPb finish over a 16 day period.
- The mechanical forming process did reveal significant differences between the finishes, with evidence of severe cracking on some finishes, revealing the underlying copper leadframe. This is an area for further study. Solderability testing, using the standard test, was not sensitive to this defect.
- The wire-bondability of the finishes was dependent on finish, with the Au finishes better than the PdNi finish. The Au finish was better than the control SnPb.
- All the lead-free finishes had less moisture ingress than the SnPb finish.
- The solderability of the lead-free *finishes* was superior when used with a SnPb alloy as compared to lead-free alloys. The solderability of the lead-free *alloys* was optimum with

the SnPb finish. The poorest performance was with the lead-free *finish* and the lead-free *alloy*.

- None of the lead-free finishes could be considered a drop in replacement for a SnPb finish, although some came close. The typical joint fillet formed when using a lead-free finish is different to the current SnPb finish and hence could be rejected by over-jealous inspectors. However, the components with lead-free finishes all pass IPC-A-610B visual inspection guidelines and no reliability issues are anticipated, although the soldering process window may be smaller.

11 ACKNOWLEDGEMENTS

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 Consumer Microcircuits Ltd.
 Enthone OMI (UK) Ltd.
 Handy & Harman
 Shipley Ltd.
 Matra-BAe
 Micro-metallic

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- (2) IPC-A-610B, 'Acceptability of Electronic Assemblies', Revision B, December 1994.

