Solderability Measurements with Lead-Free Alloys

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ABSTRACT:

The wetting balance technique is used to measure the wetting of lead-free alloys on copper and electronic components. The results show that the wetting of the lead-free alloys broadly follows that of tin-lead solder if allowance is made for the melting point. Testing with electronic components proved to be more discriminating, revealing that the soldering temperature was more critical with thermal demand effects. Testing in an inert atmosphere revealed clear benefits for the lead-free alloys, restoring the solderability to tin-lead free levels.

CONTENTS

1. INTRODUCTION

Lead-free soldering has become a big issue in terms of environmental concerns. Lead-free soldering is technologically possible, but key implementation issues need to be addressed. The soldering properties between component terminations and solder alloys is a very important parameter for producing high quality electronic circuit boards. This project aims to characterise the soldering property between SnPb and lead-free solder alloys and the different component finishes using the wetting balance test method. A fundamental understanding of the solderability of the new lead-free solder alloys will help us to choose a suitable lead-free alloy to optimise the soldering profile, and hence produce high quality lead-free solder joints.

The wetting balance test is the most useful tool for investigating the soldering properties of a combination of solders, surfaces and fluxes. Since its development, it has been used extensively, not only for assessing the solderability of component finish, but also the solder alloy and flux. A typical wetting curve is shown in Figure 1. A very common solderability index is the wetting time T, the time passed until the force has reached two thirds of its maximum, measured from the buoyancy line. However, no specification is placed upon what that maximum force should be, and the use of T as an index implies a universal form to the wetting curve. In this project this index of wetting time is evaluated and used to asses the wetting property of different solder alloys with the different component finishes and fluxes.

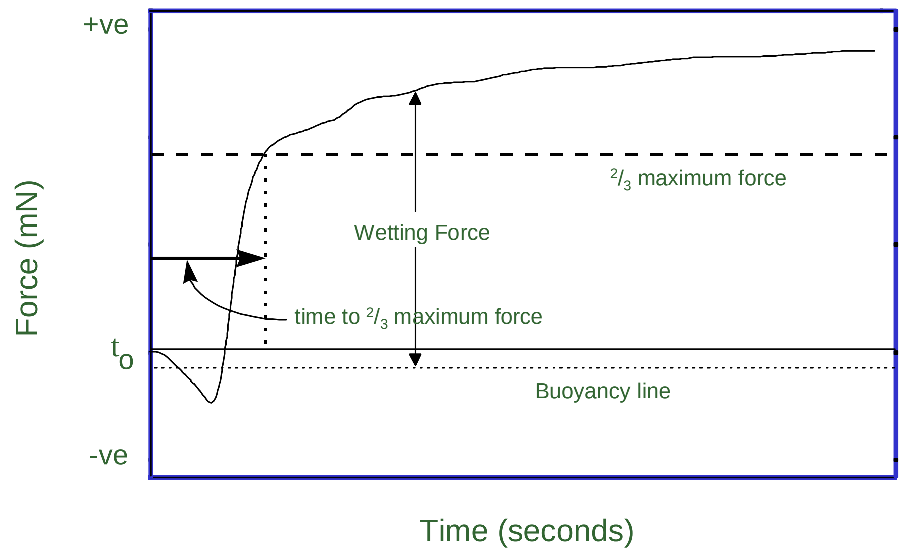

Figure 1 Wetting balance curve schematic with the wetting time defined.

2. EXPERIMENT

Three types of test sample, SOIC's, plain copper sheet, and chip capacitors were tested using four solder alloys, SnPb, SnAg, SnCu and SnAgCu. The SOIC components included two finishes, SnPb and PdNi. Copper sheet size was 25 x 12 x 0.1mm and the capacitors were 0603's The SOIC's and the Copper sheet were tested with two fluxes, 0.5% activated resin and pure rosin, in two test environments, atmosphere and nitrogen. The fluxes are a standard formulation according IEC 68-2-20. Two SOICs, three leads for each, and five copper sheets and five capacitors were tested for each condition. The test results are therefore an average value from the test samples.

3. RESULTS AND DISCUSSION

3.1 COPPER SAMPLES

First if we consider the solderability results for copper sheet. Wetting time with temperature for four solder alloys with activated rosin flux in atmosphere is plotted in Figure 2, and wetting time with superheat is shown in Figure 3. Superheat is defined as the temperature above the melting point. The inert effect on the solderability of different alloys are given in Figure 4-6. It is clear from Figure 2 that the wetting time is significantly affected by the test temperature for the three lead-free alloys, but is less significant for SnPb. The wetting was faster with increasing temperature for all alloys. Approximately an extra 50°C of temperature is required for the lead free alloy than SnPb to get the same wetting, this implies that a much higher soldering temperature will be needed for lead-free alloys.

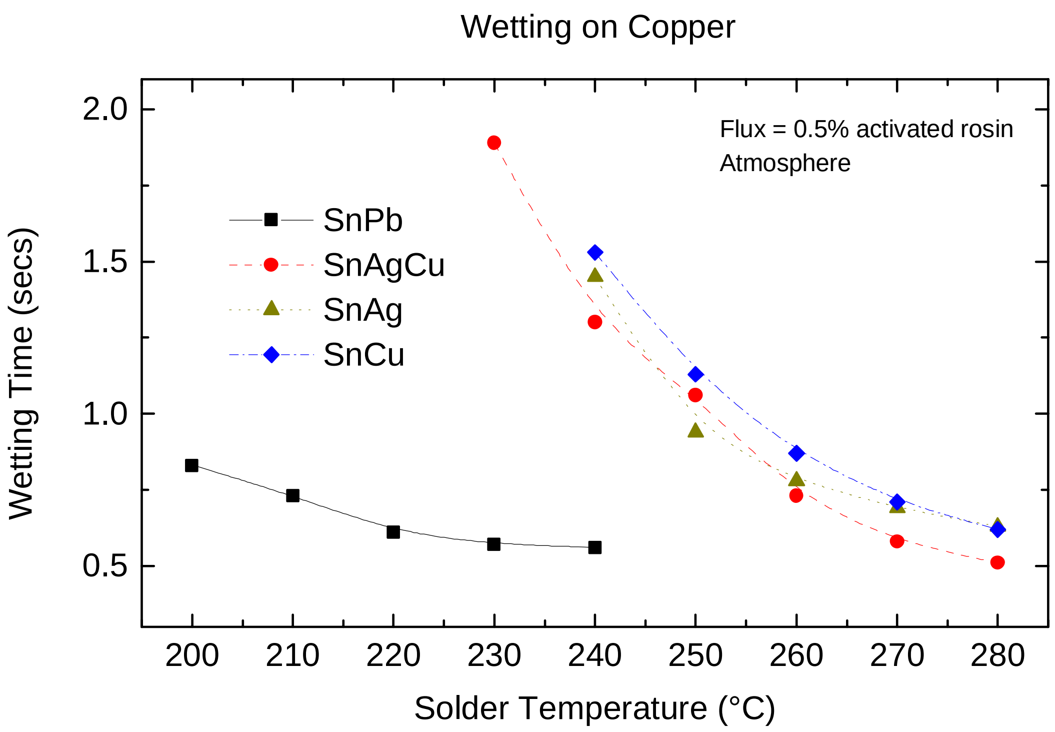

Figure 2 Wetting time with test temperature for four alloys
with activated rosin flux in atmosphere

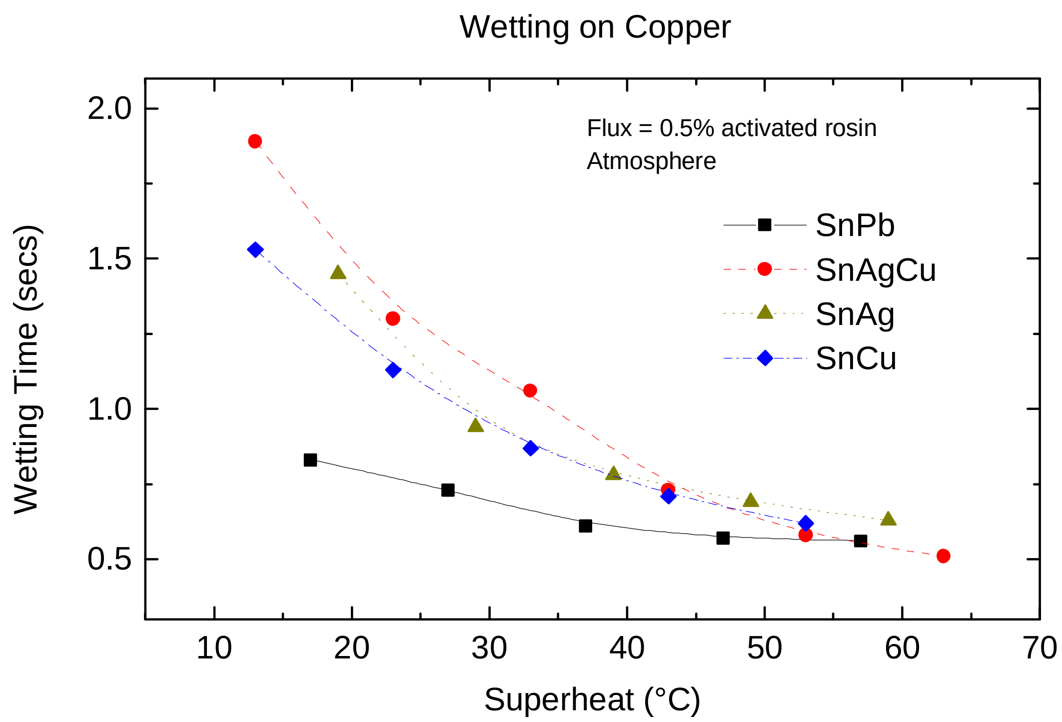

Figure 3 Wetting time with superheat for four alloys
with activated rosin flux in atmosphere

It can be seen from Figure 3 that there was a big difference in the wetting time between lead free alloys and SnPb at low superheat temperature, the wetting times were quite close when superheat was higher than 50°C. It is very likely that the high melting point alloys may need high superheat to get a good solderability. When lowering the superheat, the solderability dramatically degraded for lead-free alloys. SnPb solder alloy was more tolerant than lead-free alloy with temperature change. Therefore control of the soldering temperature will be crucial for lead-free soldering particularly for large, high density circuit boards.

Now we consider how an inert atmosphere will influence the solderability for the different solder alloys. The results in Figure 4-6 clearly show that the solderability was significantly improved by the inert test environment, particularly for lead-free alloys at the low superheat temperature. The wetting time was almost constant with decreasing superheat in nitrogen. Only 20°C superheat was needed in nitrogen to acheive the same solderability as 50°C superheat in atmosphere. This is probably because at the high test temperatures, the inert environment minimises the oxidation of the melting solder and the component surface, which consequently improves the solderability. The soldering temperature for lead-free alloys in nitrogen can be reduced to the soldering temperature for SnPb in atmosphere. Therefore soldering processes performed in nitrogen would be very beneficial for lead-free alloys.

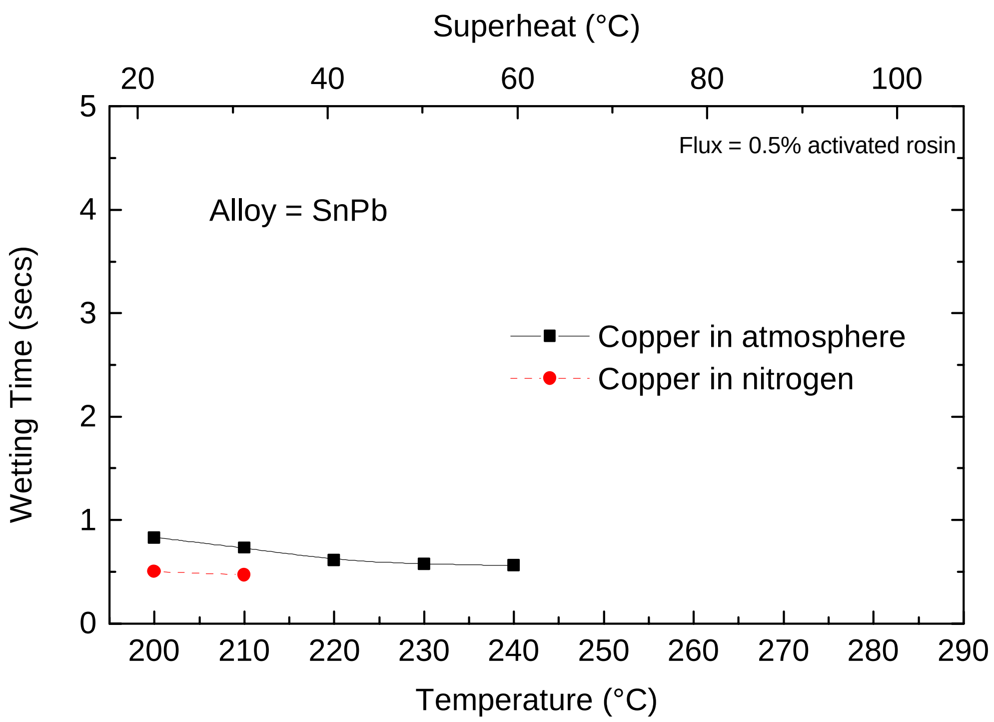

Figure 4 Wetting time with temperature and superheat for SnPb with activated rosin flux in atmosphere and nitrogen

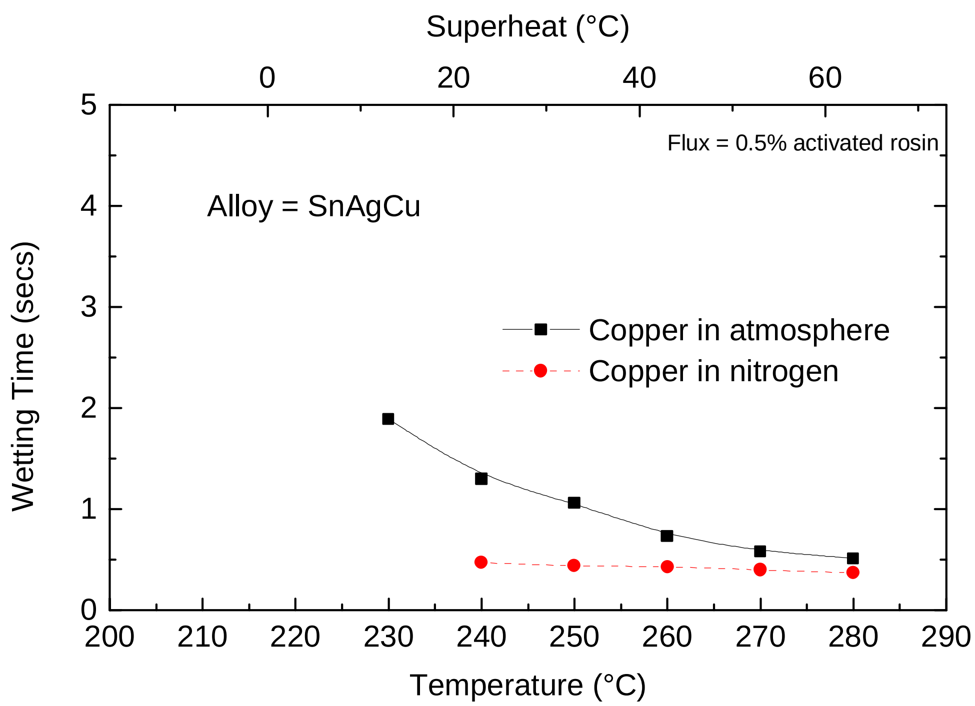

Figure 5 Wetting time with temperature and superheat for SnAgCu with activated rosin flux in atmosphere and nitrogen

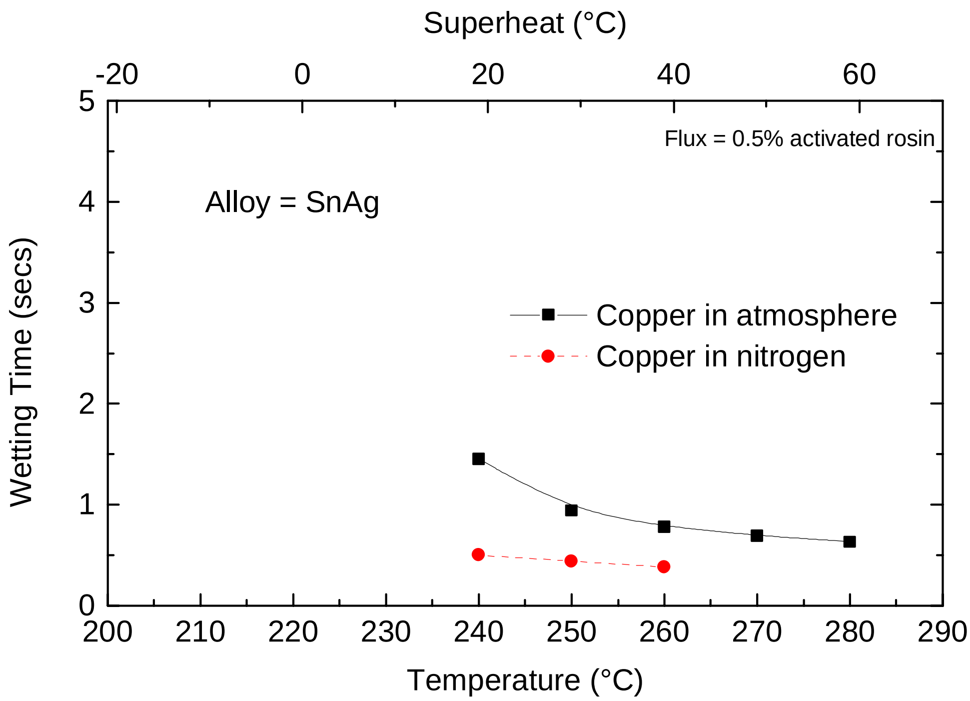

Figure 6 Wetting time with temperature and superheat for SnAg with activated rosin flux in atmosphere and nitrogen

3.2 SOIC SAMPLES

We now consider the solderability results for SOIC's different finishes. The wetting time with temperature and superheat with SnPb and PdNi finishes for SnPb alloy with activated rosin flux in atmosphere and nitrogen are plotted in Figure 7, and with pure rosin flux in Figure 8. Similarly the wetting results for SnAg alloy are presented in Figure 9 and 10. The wetting time with superheat for PdNi finish using the different alloys with activated rosin is shown in Figure 11.

It is immediately clear from Figure 7 and 8 that the solderability was dramatically improved in nitrogen for both finishes of SOIC at the low superheat temperature. Only 20°C superheat will be needed to acheive the acceptable solderability in nitrogen, whereas 60°C superheat was required to achieve this same level in atmosphere. There was no difference in solderability for both finishes in atmosphere, but the wetting time of the SnPb finish was slightly quicker than the PdNi finish in nitrogen. The PdNi finish was more dependent on flux strength particularly at the low superheat temperature as shown in Figure 8. Hence the wetting for PdNi was clearly quicker with the stronger flux.

The wetting results for SnAg alloy are presented in Figure 9 and 10, and showing that there is a marked difference with wetting time for both finishes in atmosphere and nitrogen. The wetting was more sensitive to the flux strength and component finish. The strong flux gave a greater improvement in performance to SnAg solder alloy, than to SnPb solder alloy. The inert atmosphere again showed a significant beneficial effect on the solderability when using SnAg alloy.

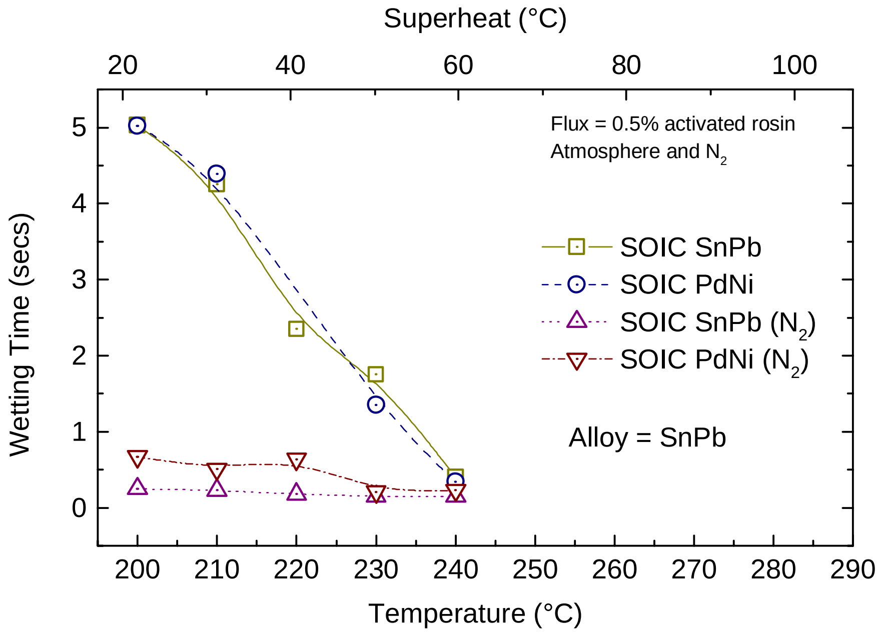

Figure 7 The wetting time with temperature and superheat for SnPb and PdNi finishes of SOIC using SnPb alloy with activated rosin flux in atmosphere and nitrogen

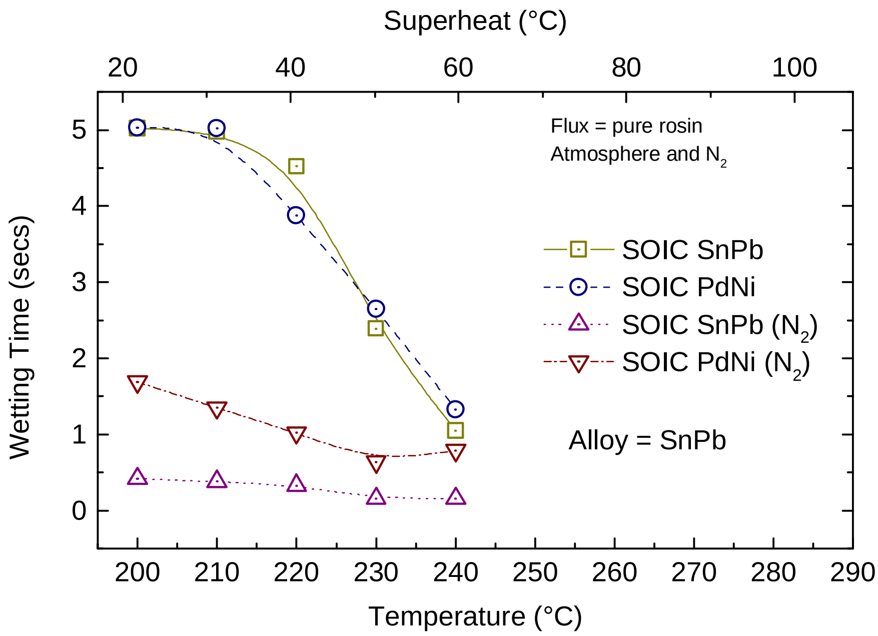

Figure 8 The wetting time with temperature and superheat for SnPb and PdNi finishes of SOIC using SnPb alloy with pure rosin flux in atmosphere and nitrogen

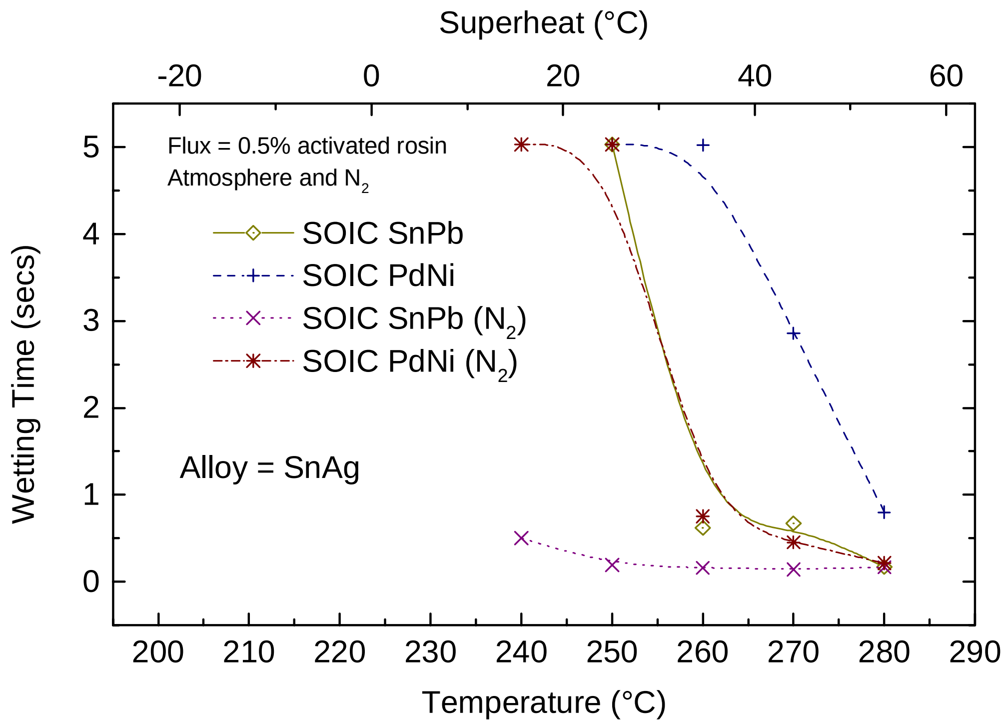

Figure 9 The wetting time with temperature and superheat for SnPb and PdNi finishes of SOIC using SnAg alloy with activated rosin flux in atmosphere and nitrogen

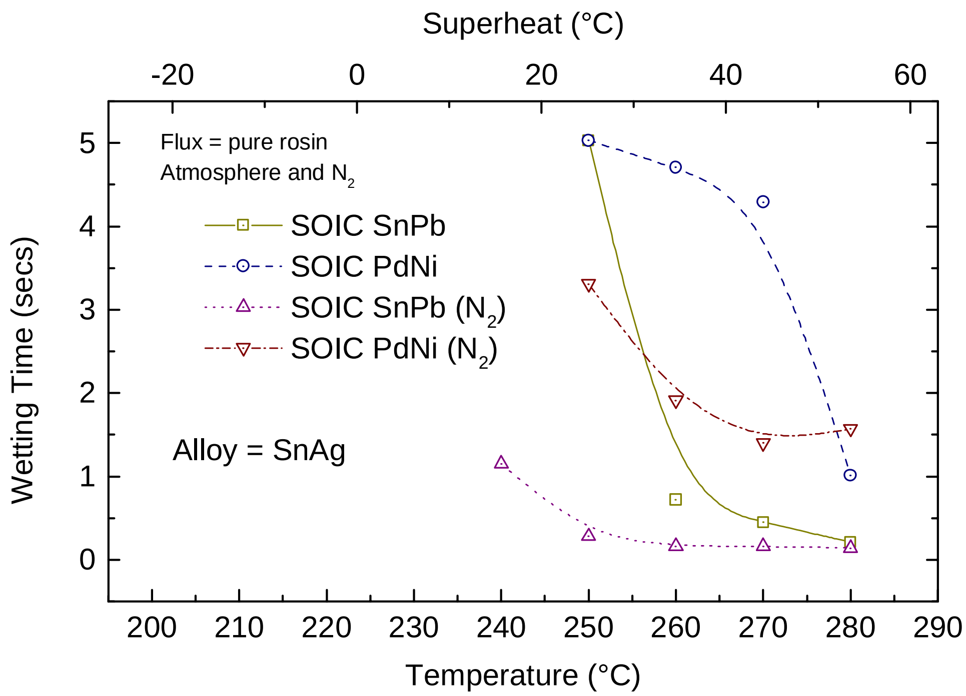

Figure 10 The wetting time with temperature and superheat for SnPb and PdNi finishes of SOIC using SnPb alloy with pure rosin flux in atmosphere and in nitrogen.

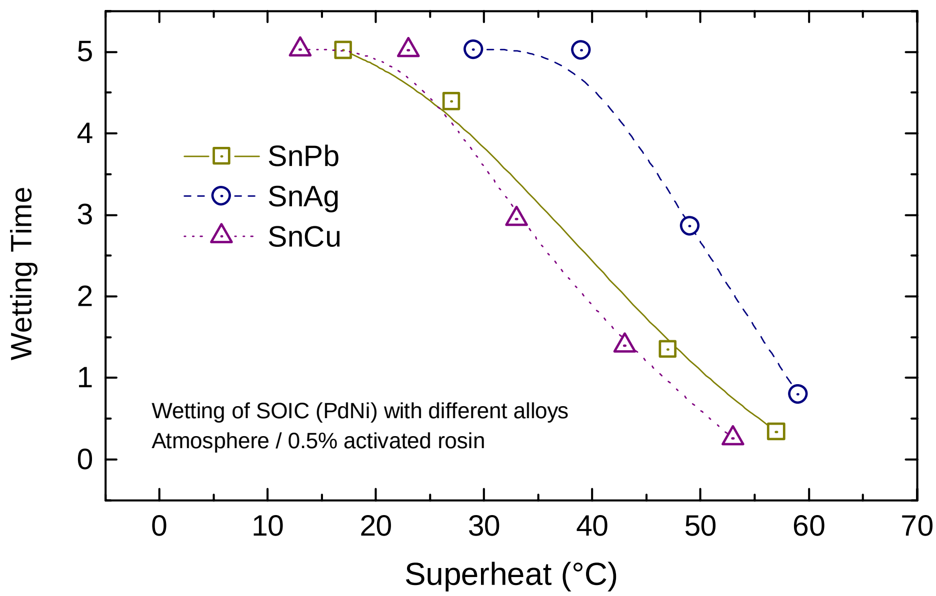

Figure 11 The wetting time with superheat for PdNi finish for the different alloys with activated rosin.

The wetting behaviour among the different alloys is now compared. The results presented in Figure 11 clearly show that the different alloys behave similarly regarding the degree of superheat, although SnAg is slightly poorer.

The wetting property of copper sheet and SOIC results for SnPb, as shown in Figure 4 and 7, appeared to exhibit different dependencies. The copper sheet still wet well until superheat was reduced by 20°C in both atmosphere and nitrogen. The SOIC did not wet at all when superheat was reduced by 40°C in atmosphere, but wetted well under this condition in nitrogen. Therefore the inert atmosphere has a greater effect on SOICs than on copper sheet. The results are very similar for SnAg as well. Lowing the soldering temperature had a more adverse effect with SOICs. This means thermal demand and high temperatures in profiling are going to be an issue with lead-free alloys when using less superheat.

3.3 CAPACITORS

Figure 12 shows a marked change in the comparison between the lead free alloys and SnPb. The relative performance of tin lead has degraded significantly so that the wetting times are comparable with the lead free alloys. This may be due to the high thermal demand of the component. Hence the greater absolute temperature is beneficial, especially in terms of flux activation.

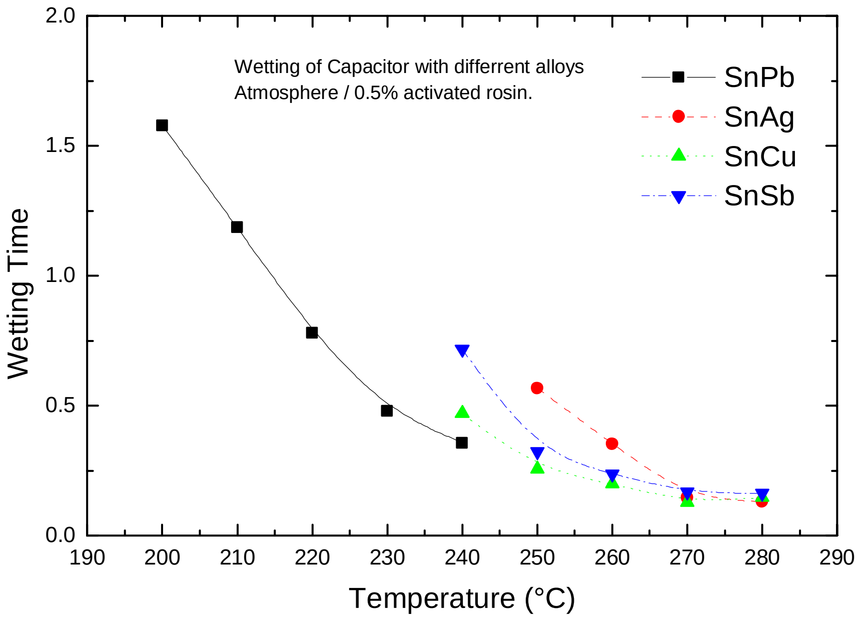

Figure 12 The wetting time with temperature of capacitors using different alloys with activated rosin.

4. CONCLUSION

An increase of about 50°C to the soldering temperature may be needed for lead-free solder alloys to maintain identical wetting to SnPb. When using lower soldering temperatures, the wetting property dramatically degrades for lead-free alloys. Sufficient superheat is very important for lead free soldering.

An inert soldering environment will be very beneficial for lead free soldering. The soldering temperature for lead-free alloys in nitrogen can be reduced to the same soldering temperature as SnPb in atmosphere. This appears to reflect thermal demand effects seen with real components

The wetting property of a lead-free solder alloy is more sensitive to the strength of the flux and the component finish. There is no marked difference between the two component finishes for SnPb solder alloy, but the wetting is faster for a SnPb finish than that for a PdNi finish for lead-free alloy. Hence the lead free alloys wet better to a SnPb finish than to a lead free finish. Therefore, if we consider real process issues for boards with high ΔT's then nitrogen could well prove beneficial.

5. ACKNOWLEDGEMENTS

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