Improving Joint Quality with Nitrogen

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Abstract
Nitrogen inerting has been widely reported to reduce defects in lead-free reflow soldering. However, many solder pastes available claim that they either do not need nitrogen or work equally well in air. While some of these pastes can produce an acceptable joint quality, they are very susceptible to any narrowing of the process window and some cannot produce high quality joints even under the most advantageous conditions.

At a leading consumer electronics manufacturer in Asia, three pastes from major producers were compared. Commercial boards were reflowed in air, and in nitrogen at two purity levels. The boards were then visually inspected for joint quality using the manufacturer's standards. The results showed that even the joint quality produced by the best paste could be improved using nitrogen and the highest nitrogen purity tested could bring the worst paste up to the standard of the best.

Introduction
It has been widely reported that nitrogen inerting reduces defects in lead-free reflow soldering, particularly those that can be attributed to poor wetting [1]. However, many current solder pastes that claim that they either do not need nitrogen or work equally well in air [2, 3]. This is mainly attributed to the advanced fluxing systems used. Paste users must consider if a more active, higher residue, possibly more expensive, fluxing system is appropriate for their product [4]. While some of these pastes can produce an acceptable joint quality, they often operate very close to the boundaries of solderability. They are therefore very susceptible to any narrowing of the process window and some cannot produce high quality joints even under the most advantageous conditions.

A BOC customer in Asia decided to conduct trials to find out if a paste that performed poorly in air could be brought up to the performance of the best performing paste in air by using nitrogen inerting. Previous experience with nitrogen suggested that very low oxygen levels could give rise to defects associated with excessive wetting, therefore the minimum oxygen level considered was 2000 ppm.

Experimental
The experimental work was carried out on a production SMT line. A local BOC company supplied the nitrogen in a portable cryogenic container and the reflow oven (the Koki seven heating zone (APSR-257-VII-N2) with TORAY RF-30 zirconium oxygen analyser and automatic nitrogen flow control shown in Figure 1) was tuned by its manufacturer.

Reflow temperature settings (from the data collected using a temperature profiler, after the oven is heated):
Preheat 150ºC – 190ºC 80 seconds;
Reflow above 220ºC 37 – 40 seconds
Peak Temp 235ºC

Oven zone settings:
1st side: 160ºC / 170ºC / 180ºC / 180ºC / 185ºC / 255ºC / 233ºC
Speed: 0.92 m/min
2nd side: 160ºC / 170ºC / 180ºC / 185ºC / 185ºC / 257ºC / 233ºC
Speed: 0.88 m/min

The slight differences in settings between the first and second side reflow were to allow for the additional components present when the second side was reflowed.

Figure 1 - Koki soldering oven

All pastes are lead-free Sn96.5/Ag3.0/Cu0.5 (SAC305) and had been qualified for use by the board manufacturer's parent company. The pastes had previously been used for different products manufactured on the site.

Paste A 11.5% flux	powder size: 20-30 micron
Paste B 11% flux	powder size: 25-36 micron
Paste C 11.4% flux	powder size: 25-38 micron
Paste D 12% flux	powder size: 10-28 micron

The trial ran for four days, one for each type of paste. Unfortunately, there were several problems on the first day, which made the results from Paste A erratic. The results for Paste A were therefore discarded and are not reported in this paper.

The board tested, shown in Figure 2, was the main board from a consumer electronics product. Components on this board included 1608/0603 resistors and capacitors, 0.5mm QFP, 0.4mm QFP and 0.5mm BGA. Each frame consisted of two identical sections (boards) with different sides facing upwards and downwards. Thus, each board needed to be reflowed twice. Although this board was used as the test board, it had been running in mass production for some time, using Paste D and occasionally Paste A.

Figure 2 - Test board - 1st side, immediately before reflow

As the experiment involved four different pastes at three different oxygen levels (air (210000 ppm), 4000 ppm and 2000 ppm) there was a total of twelve conditions. For each condition, five frames (each consisting of two boards joined together (see Figure 2) were reflowed on the first side and then again on the second side. When the frames were broken apart, there were ten boards, reflowed on both sides, for each condition.

Visual Inspection
The quality of the soldering was assessed by visual inspection of selected points on the board, as set out in Table 1 and illustrated in Figure 3. Some examples of how the inspection criteria were applied are shown in Figures 4 to 6.

Table 1 - Scoring criteria

Inspection point	Scoring criteria
1. Chip with five leads	Out of three of the leads on the right in Figure 4, how many were covered by solder (0-3)
2. Test pad	0.2 mm diameter solder dot on copper pad. 0=missing, 1=not melted, 2=partially melted, 3=melted and round
3. Wire pad #1	How many of the wires had shorts? 3=zero shorts, 2=1 short, 1=2 shorts and 0=3 shorts Wires were 0.4 mm diameter with separation distances of 0.3, 0.2 and 0.15 mm
4. IC 3009	Solder joint condition and fillet height (1=poor to 3=excellent)
5. Capacitor & resistors 1608/0603	Solder joint condition and height (1=poor to 3=excellent)
6. 0.5mm QFP lead	Solder joint condition and fillet height (1=poor to 3=excellent)

Figure 3 - Selected inspection sites

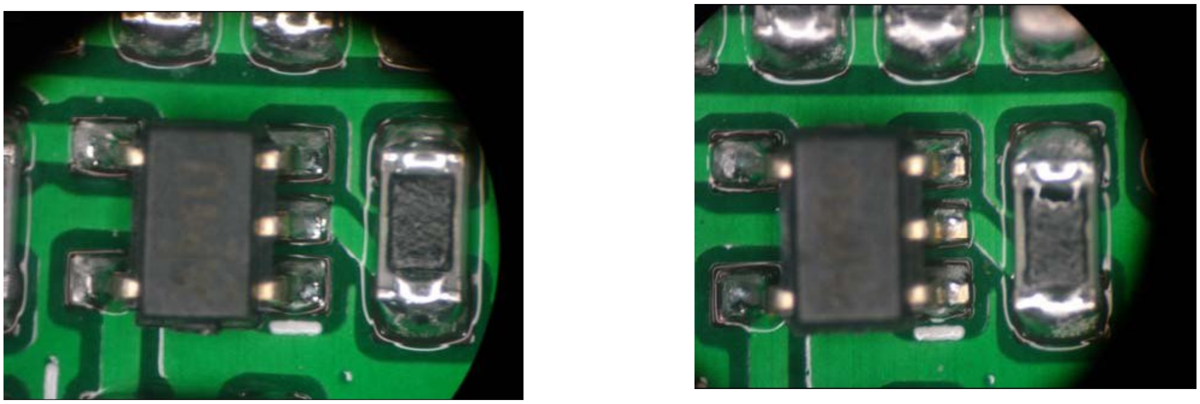

Figure 4 - Inspection point 1: Left - Reasonable cover of the leads (n=3); Right - Poor cover of the leads (n=1.25)

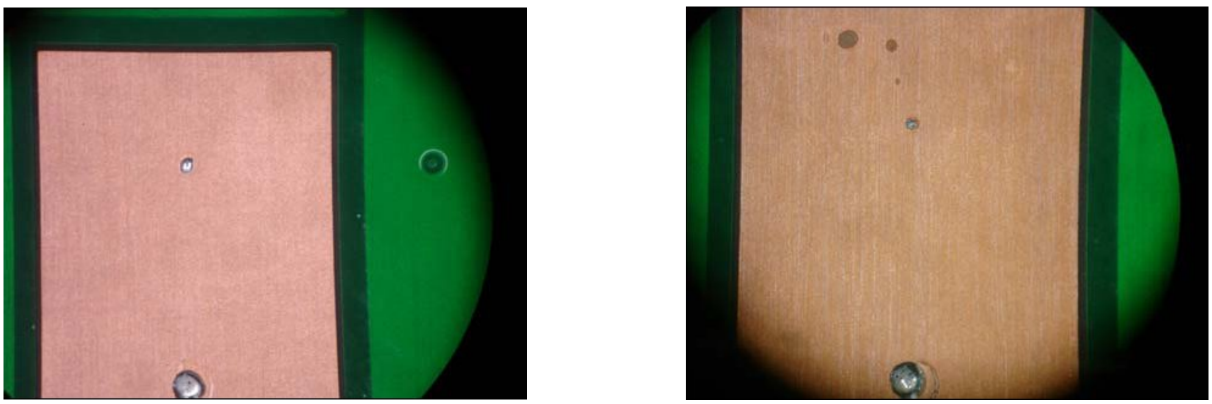

Figure 5 - Inspection point 2 : Left - Reasonable melting of solder dot (n=3); Right - Non-melted solder dot (n=1)

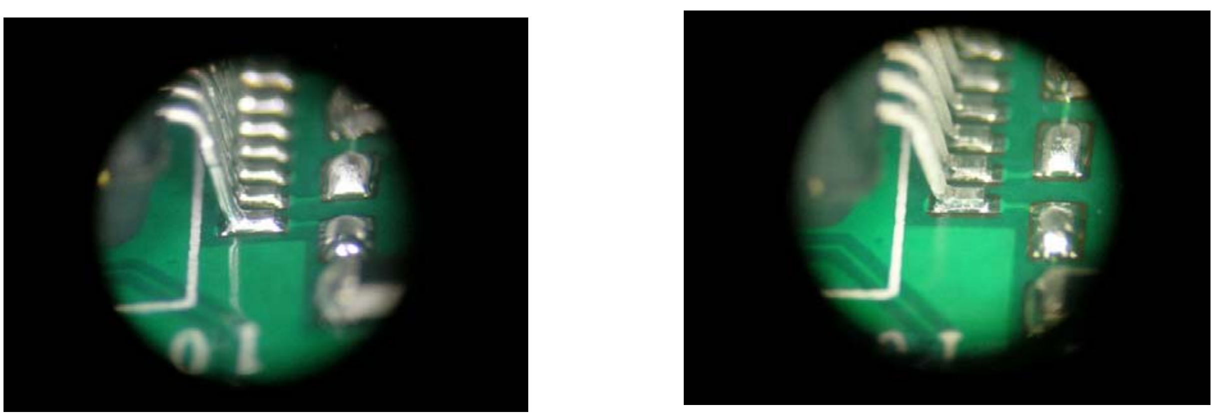

Figure 6 - Inspection point 6 : Left - Good solder fillet (n=2.5); Right - Less than ideal solder fillet (n=1.5)

Results

In general less oxidation was observed on the solder joints (shinier), less oxidation of the copper pads and less flux residue for all the boards run in nitrogen. These joints look cleaner and had better solder spreading, cover and fillet angle than those reflowed in air, indicating better wettability and solderability. As discussed previously, the data for Paste A were not really representative due to the problems on the first day, and were not used in this comparison.

Inspection point 1

This component was known to be difficult to solder in air, even with the best performing paste (Paste D). Figure 7 shows clearly that inerting with nitrogen containing 2000 ppm maximum oxygen was able to improve the performance of the worst paste in air (Paste C) up to the performance of the best in air. It should however be noted that the performance of the best paste was also improved by a similar amount.

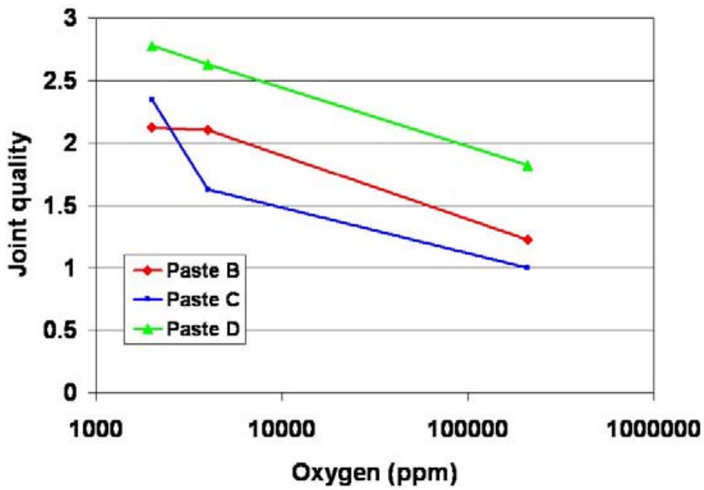

Figure 7 - Joint quality at inspection point 1

Inspection point 2
As Figure 8 shows, both Paste B and Paste C had shown significant improvements as the oxygen level decreased. Paste D, on the other hand, had printing problems because of paste viscosity problems and thus was able the print the dot on very few of the boards.

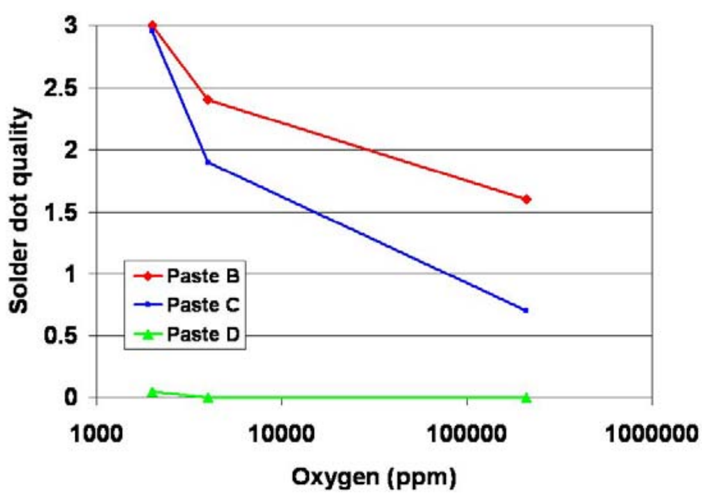

Figure 8 - Solder dot quality at inspection point 2

Inspection point 3
With the exception of Paste A reflowed in air, there were very few shorts on the test pads. Paste A improved to no shorts at 2000ppm.

Inspection point 4, 5 and 6
The trends at these three inspection points were very similar to those observed at inspection point 1, as can be seen from Figures 9, 10 and 11.

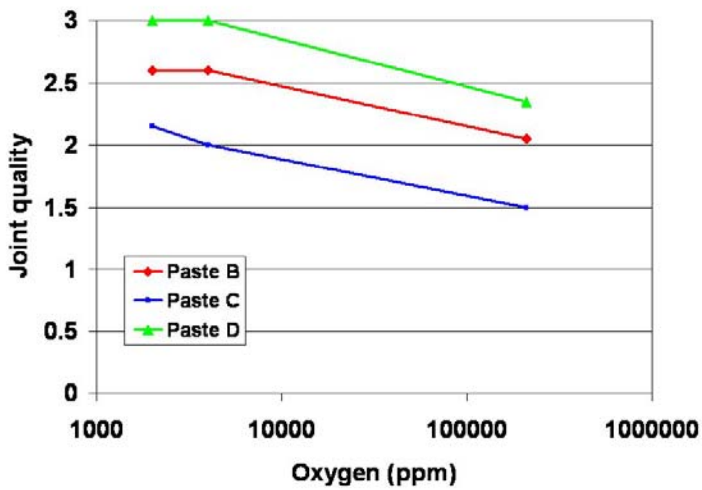

Figure 9 - Joint quality at inspection point 4

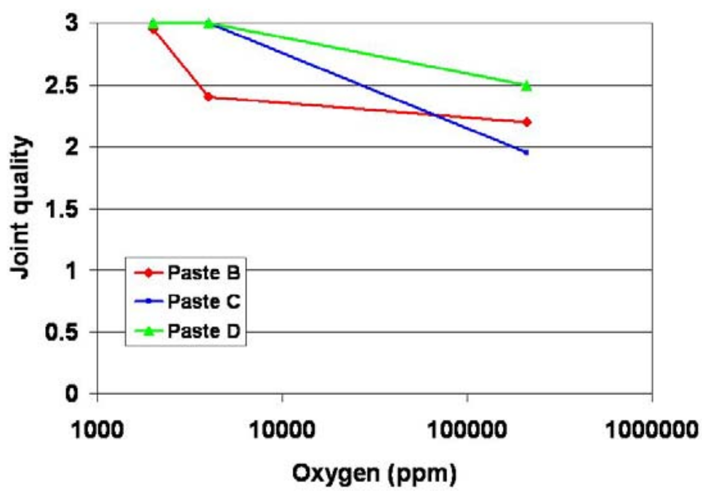

Figure 10 - Joint quality at inspection point 5

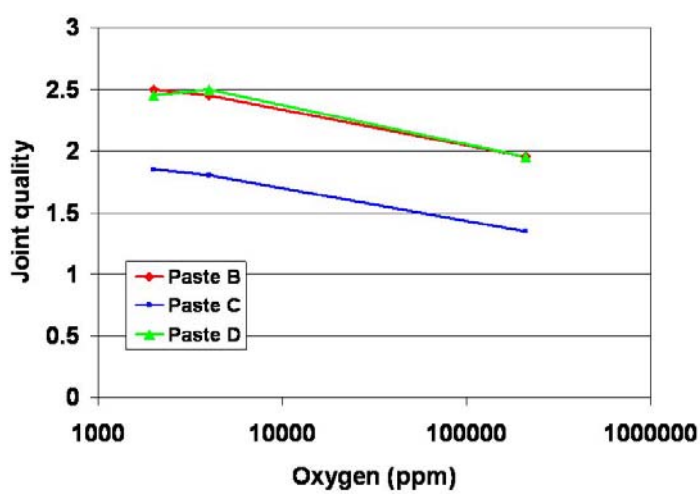

Figure 11 - Joint quality at inspection point 6

Discussion

Generally, Paste D performed better than the other pastes in air though still not really well, especially at inspection points 1 and 6. As the oxygen level decreased, the performance of all the pastes improved some more dramatically than others, to produce superior joints. In 2000 ppm oxygen conditions, the other pastes had somewhat caught up to the performance of Paste D. When compared to Paste D in air, the other pastes surpassed that performance under the nitrogen conditions. Both Paste B and Paste C when run in nitrogen, generally performed better than Paste D in air. Paste B sometimes even performed as well as Paste D in the same nitrogen atmosphere.

Conclusions

This study has shown that not only can nitrogen inserting bring the performance of the worst paste studied up to the performance of the best in air, but can improve the performance of the best paste over the full range of conditions examined.

R**eferences**

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