Comparison of Types III, IV and V Solder Pastes

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A brand name Pb-free solder paste made with three different sizes of solder paste spheres was studied. The soldering ability of Types III, IV and V solder paste in terms of opens, shorts, solder spread, solder balls, solder beads and tombstoning was examined using two different types of test boards.

Introduction

RIM has been using a conventional leaded solder paste for many years now. Like every other company that wants to continue to sell into the European Union, the company has been working on qualifying lead-free solder pastes and other compatible materials. Details of the legislation have been given so often, it will not be repeated here. The engineers in charge of new process introduction and the RIM Materials Interconnect Lab have completed a major examination of Pb-free solder pastes. The next step was to prepare for thinner stencils and smaller components and thus smaller stencil apertures. The latter spurred this investigation of solder pastes with smaller particle size of the solder spheres.

The test boards used were a company specific board[1] and a commercially available test board called the Benchmarker II, sold by Heraeus[2]. This report keeps everything constant except the size of the solder spheres in the solder paste. As the industry goes to smaller and smaller components, the apertures in the stencils must shrink, requiring smaller solder paste spheres to be able to actually fit through the openings. The three paste types and the sizes of solder spheres in each, as defined by the IPC[3] are as follows:

Type III 25 – 45 microns
Type IV 25 – 36 microns
Type V 15 – 25 microns

Results

All testing comparisons were made on the basis of the examination of the reflowed solder pasted boards. No hot or cold slump testing was carried out. Both the Heraeus Benchmarker II and the company test board were used. Varying numbers of boards were used, so generally numerical results are reported in terms of averages.

On the Heraeus test board the sections A-D (Figure 1) and the chip component area (Figure 2) were used

Area A

Areas B-D

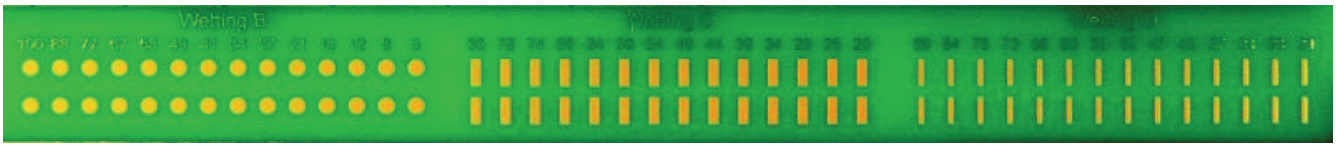

Figure 1 - Spread test areas on Benchmarker II Test Board

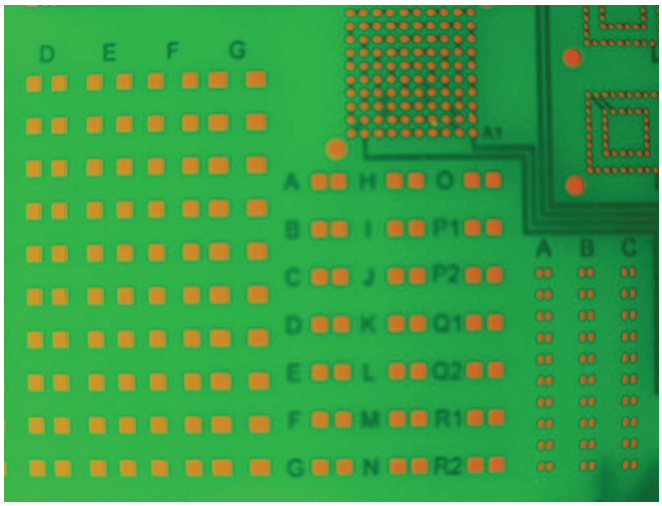

Figure 2 – Chip Placement Areas on Benchmarker II Test Board

On the company test board (Figures 3 and 4), Column one, rows 1 to 7 were used for looking for shorts and rows six and seven were used for looking for complete opens. Odd numbered boards refer to boards where the stencil squeegee was run towards the front of the printer, while for even numbered boards the squeegee was run towards the back of the printer. The results are summarized in Tables 1 and 2.

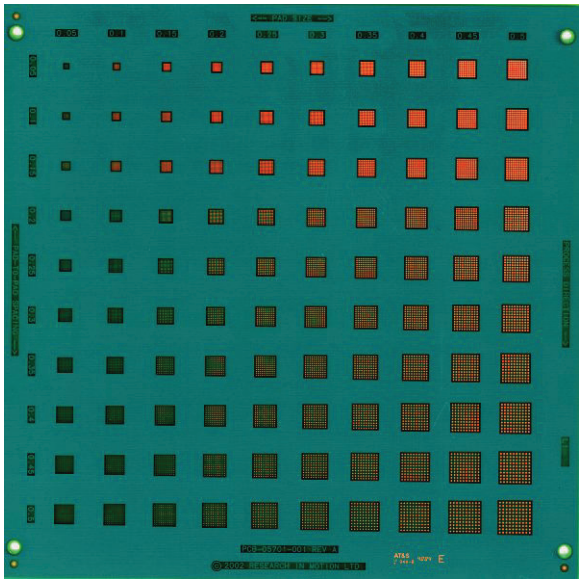

Figure 3 – Company Test Board

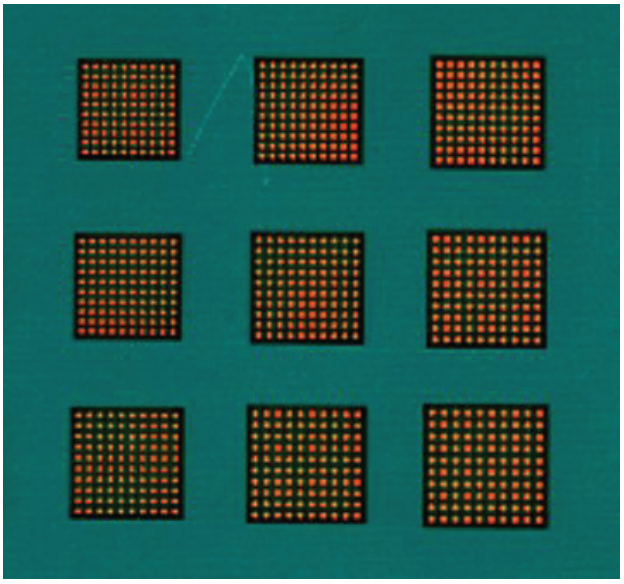

Figure 4 – Company Test Board (Close-Up)

Table 1 - Benchmarker II Test Board Results

	T3	T4	T5	Comments
Wetting				< and > refer to worse or better than, respectively
A ENIG Even	15 +/- 2	22 +/- 3	29 +/- 2	T5>T4>T3 for ENIG
A ENIG Odd		21 +/- 3	29 +/- 2	OSP vs. ENIG significant
A OSP Even	10 +/- 1	10 +/- 0	11 +/- 0	ENIG better than OSP
A OSP Odd		10 +/- 0	11 +/- 1	
B ENIG Even	70 +/- 12	64 +/-7	31 +/- 4	T5~T4<T3 for ENIG
B ENIG Odd		61 +/- 10	34 +/-0	OSP vs. ENIG significant
B OSP Even	84 +/- 8	81 +/- 6	58+/- 0	ENIG better than OSP
B OSP Odd		84 +/- 6	64 +/- 5	T5~T4<T3 for OSP
	Only odd/even ones			Significant difference
C ENIG Even	73 +/- 6	74 +/- 5	59 +/- 3	T5~T4<T3 for ENIG
C ENIG Odd		74 +/- 7	61 +/- 4	OSP vs. ENIG significant
C OSP Even	81 +/- 3	78 +/- 0	72 +/- 3	ENIG better than OSP (T5)
C OSP Odd		78 +/- 0	72 +/- 3	T5~T4>T3 for OSP
D ENIG Even	78 +/- 6	77 +/- 4	66 +/- 3	T5~T4<T3 for ENIG
D ENIG Odd		81 +/- 3	66 +/- 3	OSP vs. ENIG significant
D OSP Even	88 +/- 2	86 +/- 3	80 +/- 3	ENIG better than OSP
D OSP Odd		87 +/- 3	80 +/- 3	T5~T4<T3 for OSP
Tombstoning				
0603	0	0	1	total #
0402	0	2	0	total #
0201	0	0	0	total #

For section A above, high # best; for sections B-D, low number best.

Solder Beading				
0603 ENIG Even	0 +/- 0	0 +/- 1	11 +/- 6	OSP vs. ENIG not significant
0603 ENIG Odd	0 +/- 0	0 +/- 0	8 +/- 4	T3~T4>T5
0603 OSP Even	0 +/- 0	0+/- 0	8 +/- 4	
0603 OSP Odd	0 +/- 0	0 +/- 0	5 +/- 3	
0402 ENIG Even	0 +/- 0	3 +/- 3	5 +/- 1	OSP vs. ENIG not significant
0402 ENIG Odd	0 +/- 0	1+/- 1	5 +/- 2	T3~T4>T5, generally
0402 OSP Even	0 +/- 0	0 +/- 0	6 +/- 4	
0402 OSP Odd	0 +/- 0	1 +/- 1	6 +/- 3	
0201 ENIG Even	7 +/- 3	4 +/- 3	19 +/- 6	OSP vs ENIG not significant for T4 & T5
0201 ENIG Odd	6 +/- 4	5+/- 4	14 +/- 7	
0201 OSP Even	12 +/- 2	1 +/- 1	18 +/- 5	
0201 OSP Odd	14 +/- 5	4 +/- 1	17+/- 2	

= no significant difference across row or at least to next neighbor in table

Table 2 - Summary of Results from Company Test Boards

	T3	T4	T5	Comments
Shorts ENIG (column 1 avg)	79 +/- 19	4 +/- 4	14 +/- 1	
Shorts OSP (column 1 avg)	29 +/- 19	0	11 +/- 5	
Complete Opens Row 6 ENIG	19	0	0	totals
Complete Opens Row 6 OSP	0	0	0	
Complete Opens Row 7 ENIG	635	86	1	
Complete Opens Row 7 OSP	259	3	2	

Heraeus test board, Solder beads, Solder Balls and Tombstoning

0603 solder beads and balls. There were none for Type III and only one for Type IV solder paste. Type V had about 11 on ENIG odd numbered boards and 8 on even numbered boards. The difference is not statistically significant. There were 8 on OSP even numbered boards and 5 on odd numbered boards. It can be concluded that there was no statistically significant difference between odd or even or between ENIG and OSP boards for 0603 solder beading. However, there was a statistically significant number on Type V boards, as compared to Types III and IV.

0402 solder beads and balls. There were again none for Type III. Type IV solder paste had on average 2 on ENIG boards and 0.5 on OSP boards, with no statistically significant difference between the ENIG and OSP boards. Type V had about 5 on ENIG boards and 6 on OSP boards, with no statistically significant difference between the two boards finishes, ENIG and OSP. However, there was some statistical difference between Type V boards, as those of Types III and IV.

0201 solder beads and balls. There were solder beads on boards for all types of solder paste. There was no statistically significant difference between odd and even numbered boards. For Type III there was a difference between the numbers on ENIG and OSP boards, but not for Types IV and V. Type IV solder paste had on average 4.5 on ENIG boards and 2.5 on OSP boards, with a statistically significant difference of the number of solder beads on the boards as compared to those where the other two types of solder paste were used. Type V had about 16.5 on ENIG and 17.5 on OSP, with no statistically significant difference between ENIG and OSP and a little difference between it and Type 3, but not much.

For 0603 and 0402's, the amount of solder beading increased in going from Type III to Type IV to Type V. This is not surprising, as the amount of oxide present would be expected to increase in this same order. More oxide would impede coalescing of the solder paste. However, this is confounded by the 0201's, where the amount of solder beading was the least for Type IV solder paste (Table 3).

Table 3 - Soldering as a Function of Solder Paste Type and Component Size

	Type III	Type IV	Type V
0603	0	0	8
0402	0	1	5
0201	10	4	17

Tombstoning – There was no tombstoning for Types III and V and Type IV only had two tombstones, so essentially there was none and thus there was no difference between the types of solder paste. Here the slight pasty range of the solder paste overshadows everything else.

Section A – D of the Heraeus Benchmarker II Test Board – Solder Spread
Except in the case of the OSP boards, section B, there was no statistically significant difference between odd and even numbered boards found for Type IV and V in this study Therefore in going back and looking at the Type III data no attempt was made to divide up the results in terms of odd and even numbering of the boards.

Section A (See Figure 5)
The results of spreading were significantly better on ENIG than OSP for all paste types. Spread was best with Type V, less so with Type IV and poorest with Type III on ENIG. There was essentially no difference on OSP – all poor.

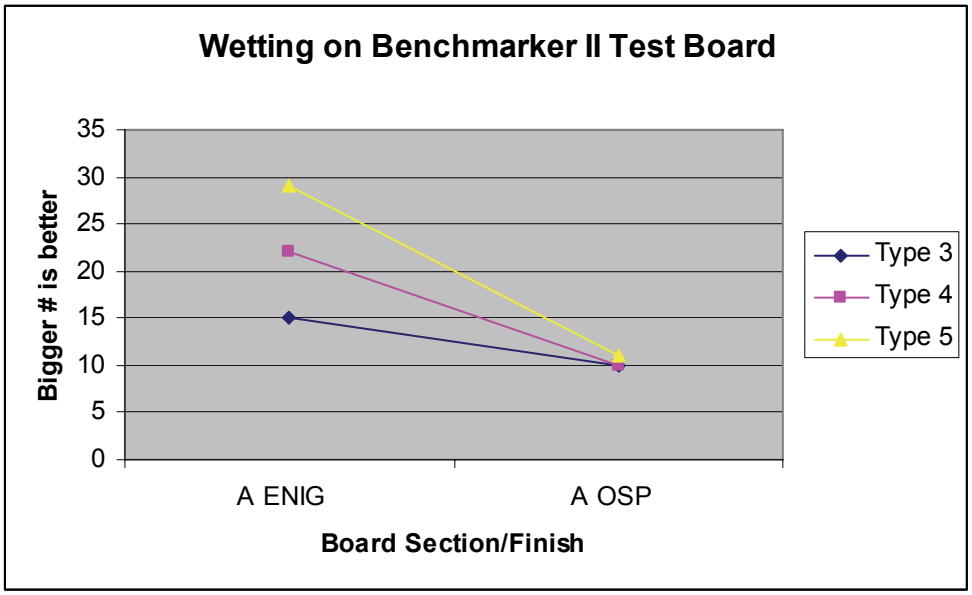

Figure 5 - Wetting Results for Section A of Heraeus Test Boards

Section B (See Figure 6)
The results of spreading were significantly better on ENIG than OSP for all paste types. Spread was better with Type V than with Type IV and poorest with Type III on ENIG. There was essentially no difference on OSP for Types III and IV (poor), but quite a bit better for Type V.

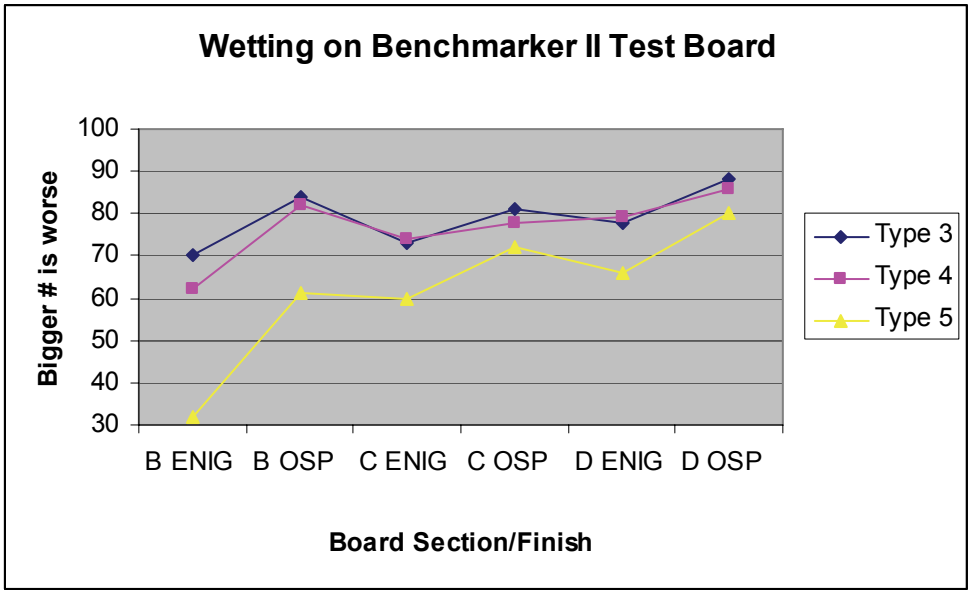

Figure 6 - Wetting Results for Sections B-D of Heraeus Test Boards

Section C
Results were quite similar to section B, except the results for Type V were not quite as good.

Section D
The results for all combinations are converging – on poor.

Company Test Board
Reflowed Shorts ENIG is certainly better than OSP for Type III. However, there is no difference between the two finishes for Types IV and V. In comparing the types of solder powders, Type IV is best, Type V less so and Type III definitely the poorest.

Reflowed Opens
It should be pointed out the number of test boards used for Type III was different from the numbers used for Types IV and V. However, the results are such that this is immaterial to the analysis. Essentially there were no complete opens on row 6 except for the initial board for the Type III run. For row 7, OSP was almost always better than ENIG. This is probably because of like attracting like. ENIG is a smooth flat, metallic surface onto which one is putting an organic-containing metal powder, whereas in the case of OSP the solder paste is touching another organic material. There is probably some attraction of the solder paste organics for the organic coating of the OSP. There is a dramatic improvement in the number of opens in going from Type III to Type IV and then to Type V for ENIG. For OSP the dramatic change all takes place in going from Type III to Type IV, with Types IV and V both very good in comparison to the Type III powder.

Conclusions

- No particular board pad finish or type (size) of solder powder affected tombstoning.
- Solder beading was more of an issue with the Type V solder paste.
- Solder beading was the worst for 0201's.
- For 0201 solder beading, Type IV was actually the best.
- On the Benchmarker II board, Type V wet the best.
- On the Benchmarker II board, ENIG was wet better than OSP.
- As the pads became narrower going from section B to D on the Heraeus test board, the difference between paste types & pad finish was less discernible.
- With the company test board, ENIG had more shorts and opens. The latter is probably due to the fact that solder paste sticks better to OSP.
- Type III solder paste gave the most shorts and opens.

- Type V was best for opens.
- Type IV was best for shorts.

References

1. David Connell and Beverley Christian, U.S. Patent 6,888,360 B1, Evaluation Board Having Varied Board Pad Characteristics, May 3, 2005.

2, R. Lathrop, “Defining Solder Paste Performance via Novel Quantitative Methods”, Proceedings of APEX 2003, Anaheim, California.

3. J-STD-006A - Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders, IPC, 1995.