

# Preparation and Properties of SMT Environmental Protection and High Efficient Lead-free Solder Paste

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**Abstract.** The components of the flux are optimized and the environmental friendly flux with excellent comprehensive performance is prepared. Then the composition of the solder paste is optimized to prepare the SMT environmental protection and high efficient lead-free solder paste, and its performance is studied. The results show that the storage stability, printability, weldability and environmental protection of the SMT environmental protection and high efficient lead-free solder paste are good, and the reliability is high. The related technical indexes have reached or superior to the commercial solder paste, and have reached the commercial level initially.

## Introduction

In 21st Century, SMT is becoming more and more popular in the global electronics industry, and has become the mainstream technology of electronic product assembly [1]. Solder paste is the important pillar of surface assembly technology, which directly affects the quality of electronic surface assembly in the aspects of printability and weldability [2]. For a long time, too much attention was paid to the welding performance and comprehensive cost of the traditional solder paste, but ignore the environmental pollution caused by some components or processes such as lead and its compounds, halogens, cleaning agents and so on [3-6].

## Test

**Materials.** The name and specifications of the main materials and equipment used for the solder paste development are shown in Table 1 [7].

Table 1 Main materials

Component name	Materials & specifications
Welding powder	SAC0307 alloy powder 4#(particle size 20 $\mu$ m~38 $\mu$ m)
Film forming agent	KE-604 rosin、A rosin(CP)
Solvent	A solvent、DGBE、B solvent(AP)
Thixotropic agent	ST500(AP)
Activator	A acid、B acid、C acid、TEOA(AP)
surface active agent	FT-900(AP)
Other additives	BTA、BHT(AP)

**Optimization of flux composition.** According to the relevant procedures of uniform design test, the level of each factor was selected in Table 2.

Table 2 Factor level

(g)

Level	X1	X2	X3	X4	X5	X6
1	42.5	37.5	4.5	7.5	0.75	0.75
2	43	38	4.6	7.6	0.8	0.8
3	43.5	38.5	4.7	7.7	0.85	0.85
4	44	39	4.8	7.8	0.9	0.9
5	44.5	39.5	4.9	7.9	0.95	0.95
6	45	40	5	8	1	1
7	45.5	40.5	5.1	8.1	1.05	1.05
8	46	41	5.2	8.2	1.1	1.1
9	46.5	42.5	5.3	8.3	1.15	1.15
10	47	43	5.4	8.4	1.2	1.2
11	47.5	43.5	5.5	8.5	1.25	1.25

**Optimization of solder paste composition.** 9 solder paste samples were prepared by mixing SAC0307 (4#) welding powder and environmental welders as shown in Table 3.

Table 3 Composition and proportion of solder paste sample

(wt.%)

No.	1#	2#	3#	4#	5#	6#	7#	8#	9#
Welding powder	87.0	87.5	88.0	88.5	89.0	89.5	90.0	90.5	91.0
Flux	13.0	12.5	12.0	11.5	11.0	10.5	10.0	9.5	9.0

**Reflow welding temperature curve.** As shown in Fig.1, the preheating temperature range is 25 to 150°C, the preheating time is 100s; the heat preservation temperature range is 150 to 190°C, the heat preservation time is 75s; the reflow temperature range is 227 to 260°C, the reflow time is 50s; the cooling temperature range is 227 to 25°C, the cooling time is 101s; the peak temperature of the reflow welding curve is 260°C.

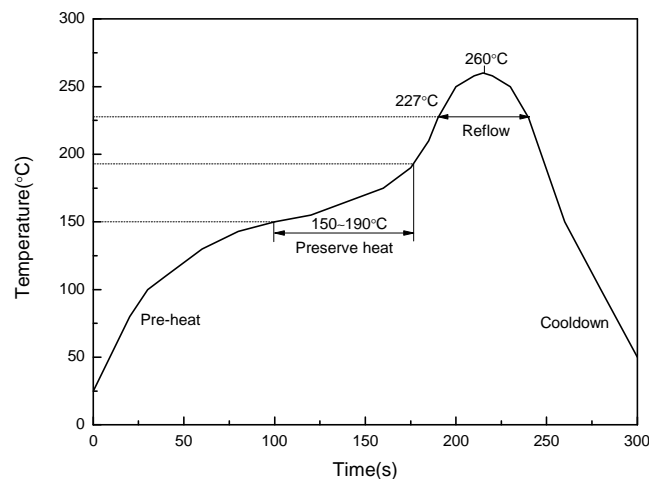


Fig.1 Reflow welding temperature curve

**Performance test of solder paste.** According to IPC-TM-650 [8], IPC ANSI/J-STD-005A-2012 and other relevant standards, the storage stability, storage stability, printing, weldability, environmental protection, reliability and reliability of the environmentally friendly lead-free solder paste (HG0307) are tested, and the performance of the same type of commercial solder paste (SP0307) with better quality in the market is compared.

## Results and Analysis

**Optimum formula of flux.** According to the factors and levels of Table 2, the uniform design table  $U_{11}(11^6)$  is adopted, and the test plan and result are shown in Table 4.

Table 4 Test plan and results

No.	1	2	3	4	5	6	7	8	9	10	11
Y/%	85.12	87.85	84.26	79.59	78.33	88.37	82.56	87.63	79.27	82.51	85.57

According to Table 4, there are 3 kinds of flux components with a spreading rate of more than 87%, and the serial numbers are 2, 6 and 8 respectively. With the spreading rate greater than 87% and the lowest cost, the content of the No. 2 test plan is the best content of each component of environmental flux. The content of film forming agent, solvent, thixotropic agent, activator, surfactant and other additives in environmental flux is 44.1 wt.%, 40 wt.%, 5.2 wt.%, 8.6 wt.%, 0.9 wt.%, 1.2 wt.%.

**Optimum proportion of solder paste.** Influence of welding powder content on the printing performance of solder paste.

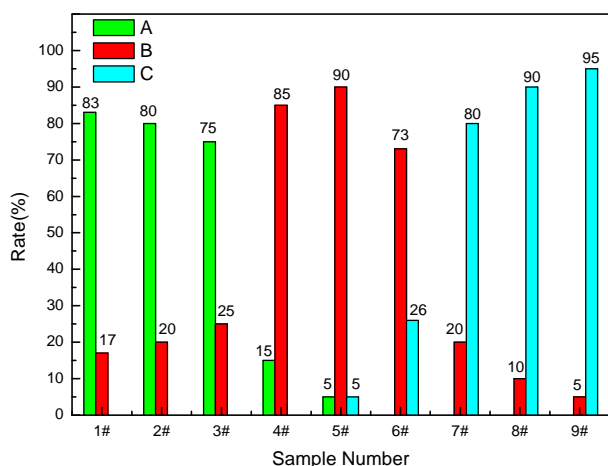


Fig.2 Printing effect statistics of solder paste made from different contents of solder powder (A.Overprint; B.Suitable printing quantity; C.Too little printing)

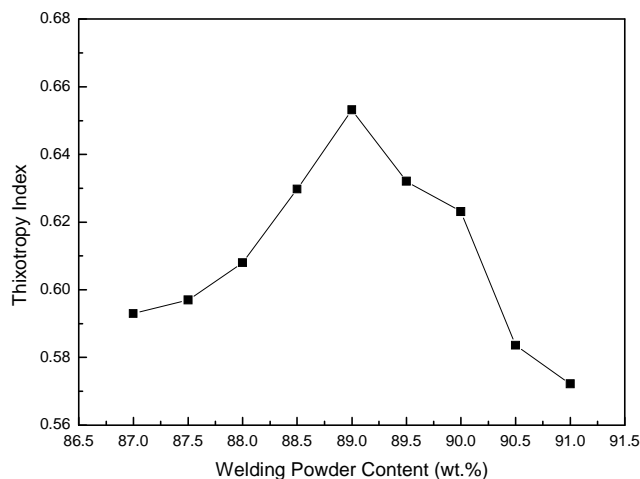
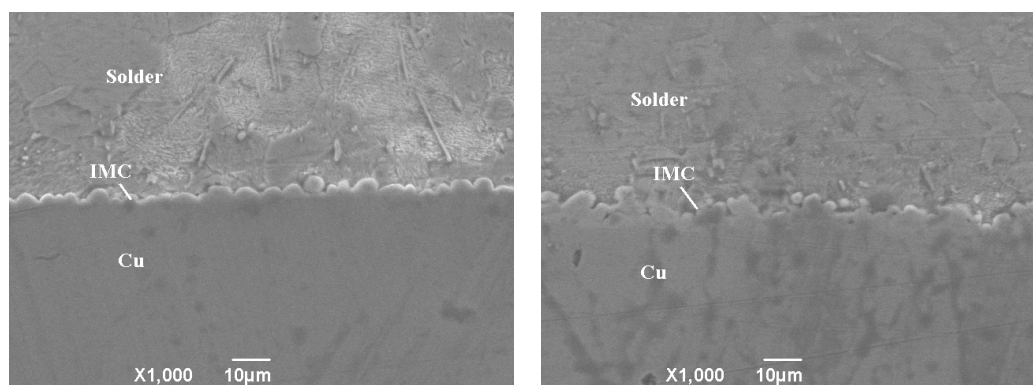


Fig.3 Influence of welding powder content on thixotropy index of solder paste

As shown in Fig.2, with the increase of the content of the alloy powder, the proportion of B increased first and then decreased, the proportion of A gradually decreased, and the proportion of C gradually increased. The printing effect of the 5# sample (89wt.%) was the best.

Influence of welding powder content on thixotropy of solder paste.

As shown in Fig.3, with the increase of the alloy powder content, the thixotropy index of solder paste increased first and then decreased. When the alloy powder content was 89 wt.%, the thixotropy index of the solder paste was the largest, indicating that printing performance of the solder paste was better. To sum up, the ratio of 89:11 of 5# sample is selected as the best ratio of SAC0307 (4#) solder alloy powder and environmental flux.



(a)Self-made HG0307 solder paste (b)Commodity SP0307 solder paste

Fig.4 SEM diagram of solder paste welding interface

**Comparison of microstructure of solder paste welding interface.** As shown in Figure 4 (a) and (b), the solder interface of the two solder paste was followed by solder layer, IMC layer and Cu matrix layer. The IMC layer had a continuous scallop like distribution between the solder layer and the Cu matrix, and there is no obvious micro crack and other welding defects. It showed that the solder and the Cu matrix have formed a complete and effective metallurgical connection. The average IMC thickness of the welding interface between commercial SP0307 solder paste and self-made HG0307 solder paste was 3.6  $\mu\text{m}$  and 2.7  $\mu\text{m}$  respectively. The contrast showed that the IMC layer of the HG0307 solder paste interface was thinner and smooth, and the welding quality was better than that of the SP0307 solder paste.

**Comparison of comprehensive technical indexes of solder paste.** According to Table 5, it is known that SMT environmental protection and high efficiency lead-free HG0307 solder paste has good comprehensive performance. It meets the relevant technical requirements.

Table 5 Comparison of comprehensive technical indexes of solder paste

Technical indicators	Technical requirement	HG0307 solder paste	SP0307 solder paste
Storage stability	—	10 months	8 months
Printing effect	Graphic integrity	Good	Preferable
Spreading rate	$\geq 75\%$	87.61%	85.63%
Solder ball	No level 1, less than 3 level 2	Level 1	Level 2
Welding effect	—	Good	Good
Residual corrosivity	—	No obvious corrosion	Less
insulation resistance	$\geq 1.0 \times 10^{11} \Omega$	$8.5 \times 10^{13} \Omega$	$7.9 \times 10^{13} \Omega$
Welding strength	—	Higher	Higher
Halogen content	—	No	Little
RoHS prohibited	—	Least, within the limit	Less, within the limit

## Conclusion

The best formula for environmental flux is film forming agent 44.1 wt.%, solvent 40 wt.%, thixotropic agent 5.2 wt.%, activator 8.6 wt.%, surfactant 0.9 wt.%, and other additives 1.2 wt%. SMT environmental protection and high efficiency lead-free solder paste is composed of 4#SAC0307 solder alloy powder and environmentally friendly flux according to the best mass ratio of 89:11. The storage stability, printability, weldability and environmental protection of the SMT environmental protection and high efficient lead-free solder paste are good, and the reliability is high. According to the RoHS environmental instruction and related technical requirements, the related technical indexes have reached or superior to the commercial SP0307 solder paste, and have reached the commercial level initially.

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