A First Individual Solder Joint Encapsulant Adhesive

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ABSTRACT:

In order to meet the demand of fine pitch and 3D package, and eliminate complex underfilling process, a first solder joint encapsulant has been invented. Solder joint encapsulant adhesive is to encapsulate each individual solder joint using polymer to enhance solder joint, and leave empty space in-between solder joints to avoid thermal stress applied onto solder joints. Now two kinds of solder joint encapsulants are SMT256 and SMT266, which have been used in the customer field. Using solder joint encapsulants – SMT256 and SMT266, the pull strength of solder joint has been increased by about five times, resulting in significant increase in the reliability. In this paper more details have been investigated.

INTRODUCTION

With the advancement of electronic industry, IC component becomes miniaturized; pitch size gets smaller and I/O number gets more and more. In addition to these, lead-free soldering process has to be implemented due to law requirements. As a result, there are some reliability issues such as poor process yield, weak mechanical strength of solder joint, and poor thermal cycling performance. A few methods that have been or will be implemented include capillary underfill, corner bond, no-flow underfill, underfilm and wafer-level underfill process. All the processes are encountered with unsatisfied process yield, reliability scarification, lengthy application process and so on. In order to resolve these issues, the YINCAE team have successfully developed a first individual solder joint encapsulant adhesive – SMT 256 and SMT 266, that can enhance solder joint reliability and eliminate underfilling process, particularly for board-level underfill.

PROCESS

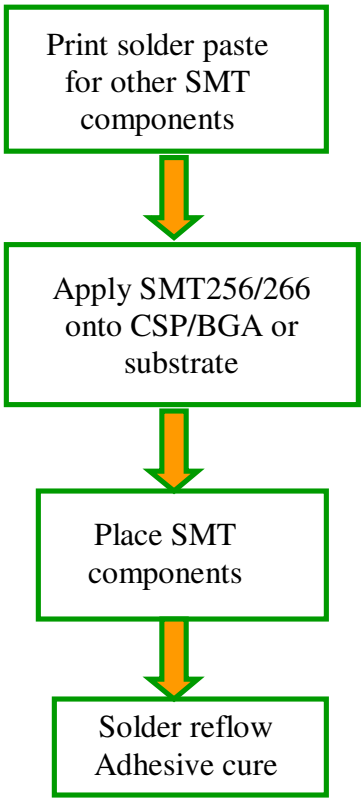


Figure 1. Process Flow Chart

The application process of solder joint encapsulant adhesive is shown in Figure 1. It should be noted that solder joint encapsulant adhesives can provide

advantages of simple, short and high throughput manufacturing process over traditional solder paste plus underffilling process. SMT 256 has been designed for mass production, which can be applied by dipping, stencil printing and brushing. SMT 266 is mainly focused on rework process which can be applied by micro-spraying, brushing or dipping. The reflow process of solder joint encapsulant adhesive is fully compatible with typical industry solder paste reflow profile. During reflow, solder joint encapsulant adhesives SMT256 and SMT 266 can remove metal oxide from pads and bumps to allow solder joint formed, then cure with the formation of 3-D polymer network encapsulating each individual solder joint, in-between solder joints there are no adhesives blocking outgassing channel to ensure process yield. The Schematic SMT256 or SMT 266 encapsulated solder joint is shown in Fig. 2.

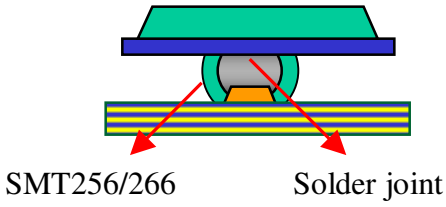
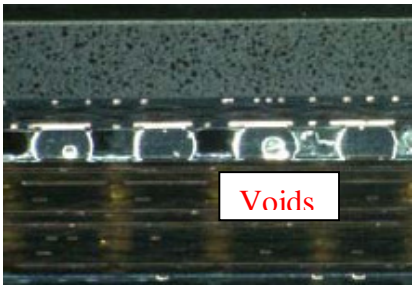


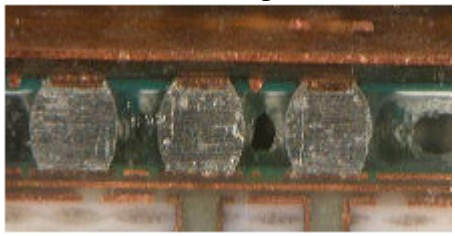
Fig. 2 Schematic cure SMT 256 or SMT 266 encapsulated solder joint

APPLICATION FOR BGA/CSP

After being used in the customer field for a few years, the implementation of SMT256 can improve the process yield, eliminating voids and crack in solder joint, eliminating head-in-pillow issue for large component during lead free reflow process. Here is an example of SMT 256 for BGA/CSP application laptop. The application method is dipping process and dip height is 85-95% of bump height. The other process parameters are same as traditional solder paste process. After the completion of assembly process, the function test has been conducted with 100% process yield. The X-ray results are shown in Fig. 3.



(a) Solder paste

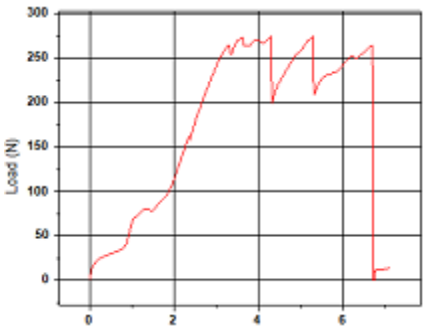


(b) SMT 256 or SMT 266

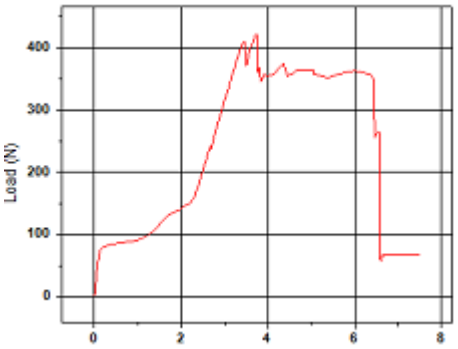
Fig. 3 X-section of assembled BGA using (a) solder paste and (b) solder joint encapsulant adhesives – SMT 256 or SMT 266

It is well known that voids of solder joint is easily formed due to high temperature process, high surface tension of lead-free solder and the limitation of flux chemistry using lead-free solder paste for lead-free process, as is shown in Fig.3 (a). However, no voids of solder joint were observed using solder joint encapsulant adhesive SMT 256 or SMT 266. The major contributor for free void of solder joint is that SMT 256 or SMT 266 has formed an encapsulant layer, which can function as an oxidation barrier during the reflow process.

Fig. 4 shows the comparison of pull strength of solder joint using (a) solder paste plus underfilling process and (b) SMT 256 – solder joint encapsulant adhesive.



(a) solder paste plus underfill



(b) SMT 256-solder joint encapsulant

Fig. 4 Pull strength of assembled BGA using (a) solder paste plus underfilling process and (b) SMT 256 – solder joint encapsulant adhesives.

It can be seen from Fig. 4 that the max pull strength is about 274 N using solder paste for soldering and followed by underfilling process, while the pull strength is up to 438 N for only dipping SMT 256 – solder joint encapsulant. The pull strength is 1.5 -2 times higher using SMT 256 than using solder paste plus underfilling process.

APPLICATION FOR POP

Amkor POP has been used as test coupon in this paper, which is shown in Fig. 5.

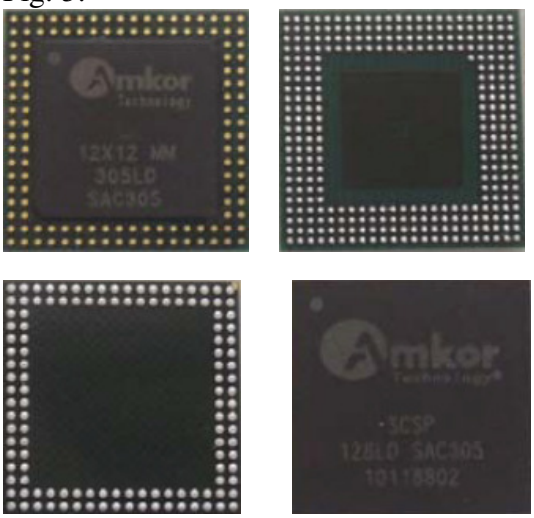


Fig. 5 Amkor POP test Coupon

Fig. 5 shows the pull strength changing with dipping height of SMT 256 and flux. The dipping height is measured by the percentage of bump height. With increasing dipping height from 70% to 95% of bump height, the pull strength is increased from 79N to 350 N. However, the recommendation height should not be higher than 95%, otherwise process defect will be observed.

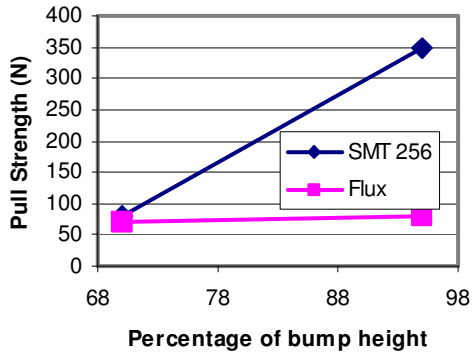


Fig. 5 Pull strength changing with the dipping height

From Fig. 5, it should be noted that the pull strength does not change with

increasing dipping height by using flux, and the most important part is that using flux will lead to larger data scattering of pull strength than using SMT 256, which is larger potential challenging for the quality control of the end product. Table 1 lists the raw data of pull strength using dipping height of 70% bump height.

Table 1: Comparison of pull strength between SMT 256 and flux.

No.	Pull Strength (N)	
	SMT 256	Flux
1	99	79
2	68	35.6
3	75	101
4	81	74
5	82	66.5
Average	81	71.22
Standard deviation	10.30	21.20

From Table 1 it can be seen that the pull strength is not only higher, but also has smaller standard deviation using SMT256 solder joint encapsulant than that obtained using flux, which means using solder joint encapsulant will lead to much smaller RMA number than using flux for end products. The most interesting point is that the standard deviation is close to the minimum pull strength obtained using flux.

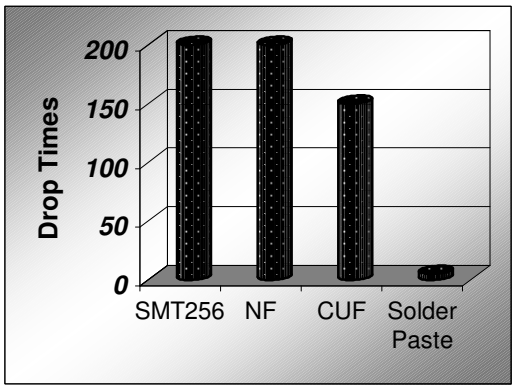


Fig. 6 The drop test performance using SMT 256, NF (no-flow underfill), CUF (capillary underfill) and solder paste. The drop test conditions are: six feet height, concrete floor and free fall.

From Fig. 6 we could see the drop times is up to 200 times using SMT 256 solder joint encapsulant which is same as that obtained using no-flow underfill, but much better than that obtained using solder paste. The drop test performance is in agreement with the results of pull test.

Fig. 7 shows the thermal cycling performance using different approaches for enhancement. Thermal cycling conditions are: one hour per cycle; temperature from –55 °C to 125 °C and 15 min dwell time at two extreme temperatures. It is very interesting to note that traditional capillary approach could make the reliability such as thermal cycle sacrifice, the failure was observed at 140 cycles using underfilm approach, while using solder joint encapsulant SMT 256 or SMT 266 the first failure cycles is high up to 6000 cycles, at least 4000 – 5000 cycles higher than other process.

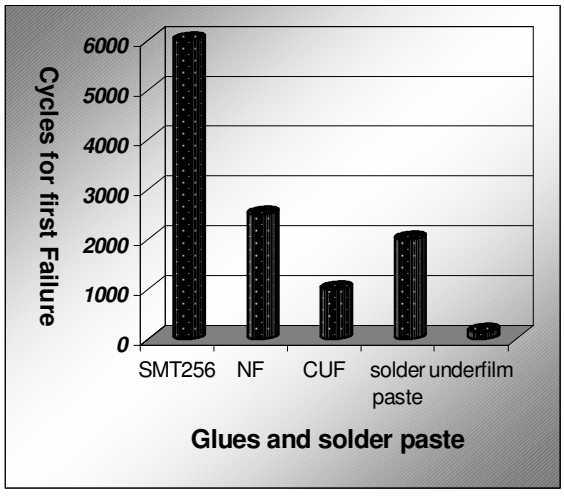


Fig. 7 Thermal cycling performance using SMT 256, No-flow underfill (NF),

capillary underfill, solder paste and underfill.

REWORK

Using SMT 256 or SMT 266 solder joint encapsulant the rework process is as easy as solder paste. After removal of solder, brush PCB using MEK to clean the residue. The advantages of solder joint encapsulant adhesive were summarized in Table 2.

Table 2 Advantages of solder joint encapsulant adhesive

Performance	WL-underfill	Capillary underfill	No-flow underfill	Corner bond	underfilm	**SMT256/266 adhesives**
Solder voids	Yes	Yes	No	Yes	Yes	**NO**
Solder Open	Yes	Yes	Yes	Yes	Yes	**NO**
Joint cracking	Yes	Yes	Yes	Yes	Yes	**NO**
Pull strength	Ok	Ok	Ok	Ok	Ok	**HIGH**
Process Compability	Difficult	More steps	Difficult	Ok	Ok	**Excellent**
Process yield	Low	Ok	Low	Low/Ok	Ok	**HIGH**
Reworkability	Difficult	Difficult	Difficult	Difficult	Difficult	**EASY**
Drop performance	Excellent	Excellent	Excellent	Ok	Ok	**Excellent**
Thermal Cycling Performance	800-900	800	3000	140-150	140-150	**6000**
Operation Cost	High	High	High	High	High	**LOW**

SUMMARY

Solder joint encapsulant adhesives SMT 256/266 have been successfully designed and proved to allow high-quality solder joint to be formed and said solder joint to be encapsulated. Compared with solder paste, SMT256/266 can provide void free Pb free solder joint and excellent wetting; eliminate solder joint cracks. SMT 256/266 are totally compatible with SMT production line including reflow profile, pad finishes and advanced components such as POP.

Using solder joint encapsulant can greatly increase solder joint strength by up to 4 to 5 times, and the performance of drop test has been improved by 2 orders of magnitude and the thermal cycling performance up to 6000 cycles. SMT 256 or SMT 266 solder joint encapsulant can bring the following benefits for customers:

a. Shorten process steps;
b. Improve process yield;
c. Enhance reliability;
d. Reduce manufacturing cost;
e. Better for advanced package application such as POP, fine pitch application;
f. Easy rework.