



SOLDER JOINT ENCAPSULANT ADHESIVE – POP TMV HIGH RELIABILITY AND LOW COST ASSEMBLY SOLUTION

YINCAE Advanced Materials, LLC

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Solder Joint Encapsulant Adhesive – POP TMV High Reliability and Low Cost Assembly Solution

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ABSTRACT:

With the advancement of the electronic industry, package on package (POP) has become increasingly popular IC package for electronic devices, particularly POP TMV (Through Mold Vials) in mobile devices due to its benefits of miniaturization, design flexibility and cost efficiency. However, there are some issues that have been reported such as SIR drop due to small gap between top and bottom components, difficulty underfilling and rework due to stacked IC components and process yield issues. Some suppliers have reported using some methods such as dipping epoxy paste or epoxy flux to address these issues, but so far no customer has reported using these methods or materials in their mass production. In order to address these issues for POP TMV assembly, YINCAE has successfully developed and commercialized the first individual solder joint encapsulant adhesive for mass production for years.

YINCAE solder joint encapsulant adhesives - SMT 256 and SMT 266 series are applied by printing, dipping or jetting process onto a substrate or component. They can remove metal oxide from pads and bumps to allow solder joint to form. SMT 256 and SMT 266 are then cured with the formation of 3-D polymer network encapsulating each individual solder joint; there is no adhesive in between solder joints blocking outgassing channels to ensure process yield. After using solder joint encapsulant adhesive for POP TMV assembly, the pull strength of solder joint is increased about five times and the SIR drop issue is addressed with high process yield. All details such as assembly process, drop test and thermal cycling test are discussed.

INTRODUCTION

With the advancements of the electronic industry, IC component becomes miniaturized; pitch size gets smaller and I/O number increases. In addition to these factors, 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. YINCAE invented a world first solder joint encapsulant a few years ago, and billions of devices have been made with approved satisfied performance in the customer field.

Due to the benefits of miniaturization, design flexibility and cost efficiency, package-on-package has become increasingly popular IC package for electronic devices. In order to address multi-core processor, higher data transfer rates and wider bus memory architectures, POP with through-mold vias (TMV) has been used in mobile devices. Like CSP/BGA, POP TMV also needs reliability enhancement to meet the end customer's needs, but the application process is much more difficult with processes like capillary underfill, corner bond, no-flow underfill and wafer-level underfill process to address this

issue, particularly for POP with TMV, which has molded cavity surface.

All the processes are encountered with unsatisfied process yield, reliability scarification and lengthy application process among other issues. YINCAE solder joint encapsulant adhesive – SMT 256 and SMT 266 can enhance solder joint reliability, and eliminate underfill materials and underfilling process, particularly for board-level underfill, which provides an excellent high reliability and low cost solution for POP assembly.

PROCESS

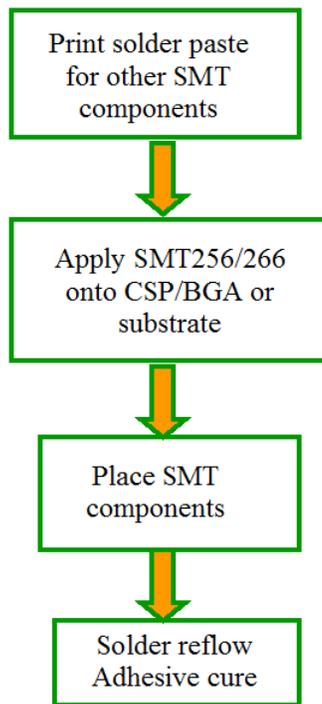


Figure 1. Process Flow Chart

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 underfilling 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 jetting, brushing or dipping. The reflow process of solder joint encapsulant adhesive is fully compatible with typical industry solder paste reflow profiles. During reflow, solder joint encapsulant adhesives SMT256 and SMT 266 can remove metal oxide from pads and bumps to allow solder joint to form. Followed by 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 Figure 2.

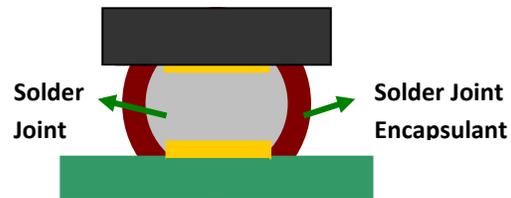


Figure 2. Schematic Cure SMT 256 or SMT 266 Encapsulated Solder Joint

Enhancement Of Solder Joint Encapsulant

Amkor POP has been used in this test coupon in this paper, which has solder alloy SAC305, 0.65 mm pitch top IC and 128 I/O; and 0.5mm pitch bottom IC, 305 I/O and Ni/Au pad finish. The pull test results are shown in Figure 2.

Figure 3 shows the pull strength changing with dipping height of SMT 256 and flux. The dipping height is measured by the percentage of bump height. Increasing the dipping height from 70% to 95% of bump height, the pull strength is increased from 79N to 350N. However, the recommended dipping height should not be higher than 95%, otherwise process defects will be observed.

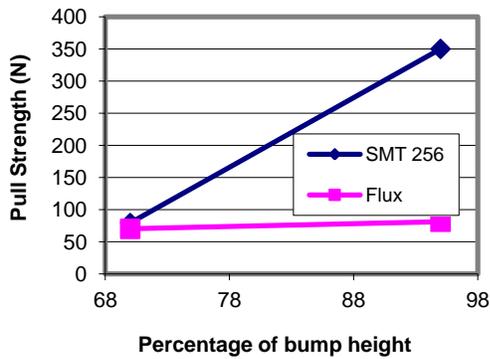


Figure 3. Pull Strength Changing with the Dipping Height

From Figure 3, 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 a big potential challenge for the quality control of the end product. Table 1 lists the raw data of pull strength using dipping height of 70% bump height.

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

Table 1: Comparison of Pull Strength Between SMT 256 and Flux.

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 (Returning Materials Authorization) 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.

Top IC Assembly in POP TMV:

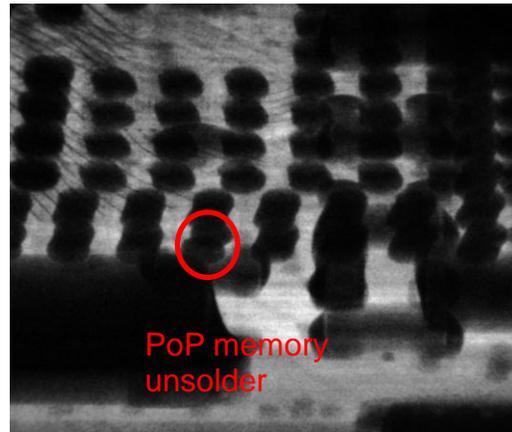


Figure 4. X-ray Image of Assembled POP Using Solder Paste and Flux.

Figure 4 shows the X-ray image of assembled POP obtained using solder paste and flux. From Figure 3 it has been found that there was open joint. The open solder joint was further confirmed by cross-section, and the cross-section picture is shown in Figure 5.

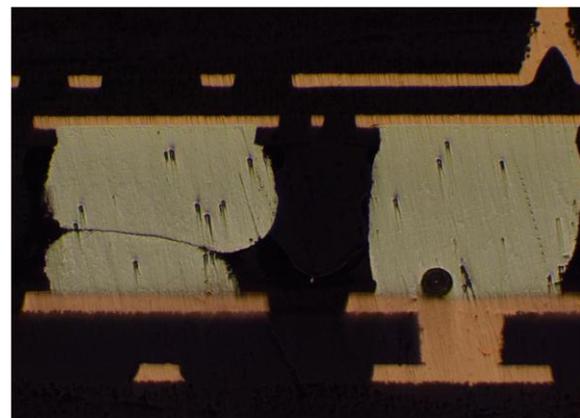
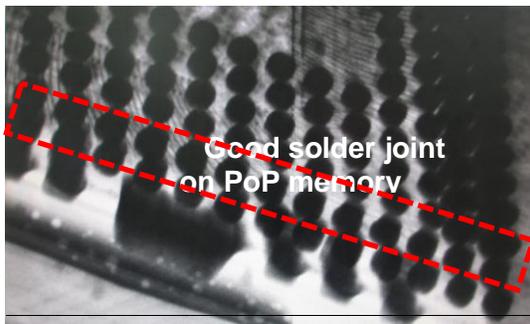


Figure 5. Cross-section of Open Solder Joint

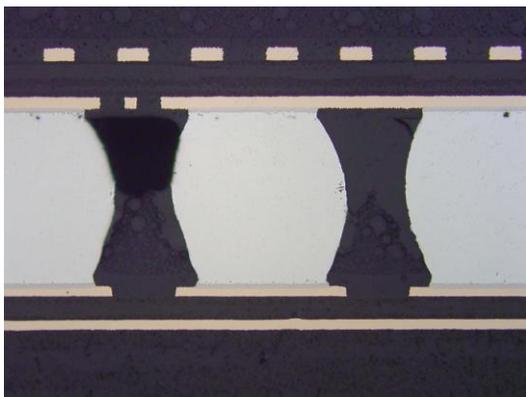
From Figure 5, it is very obvious to see that the open solder joint was caused by head-in-pillow phenomenon. It is well understood that head-in-pillow is normally caused by heavy oxidation of solder and warpage of substrates and components. POP encounters more warpage than regular BGA due to the stacked components.

Figure 6 below shows the X-ray image (a) and cross-section picture (b) of assembled POP using YINCAE solder joint encapsulant. There were no head-in-pillow open solder joints found in the assembled POP and every solder joint has been approved to be high quality from X-ray and cross-section results.

The mechanism of eliminating head-in-pillow phenomenon is proposed: Solder joint encapsulant covers solder bump and pad after dipping; the solder joint encapsulant functions as oxidation barrier preventing solder bump and pad from oxidizing during reflow. In addition, the solder joint encapsulant starts to cure more and more with increasing temperature, resulting in shrinkage stress to pull bump to contact the corresponding pads so that the head-in-pillow phenomenon is eliminated.



(a) X-ray image of POP using SMT 256



(b) X-section of POP using SMT 256

Figure 6. X-ray and X-section of Assembled POP Using SMT 256

In order to overcome head-in-pillow phenomenon, N₂ has to be used in the reflow process when traditional tacky flux or dipping solder paste is used for POP TMV assembly.

Figure 7 below shows the dendrite in assembled POP using solder paste and flux, which is causing the current leakage problems experienced after sales. Normally the dendrite cannot be found immediately after manufacturing. After sale to the end user, the dendrite starts to form, resulting in higher RMA (Returning Materials Authorization), which could lead to millions of dollars lost. Obviously solder joint encapsulant can be cured to form 3D polymer network and encapsulate solder joint, which can easily prevent dendrite formation and electromigration.

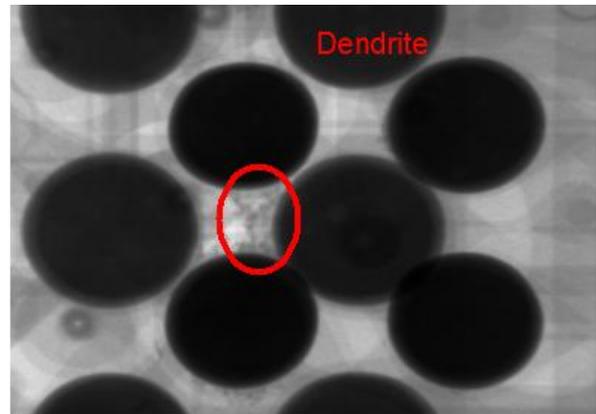


Figure 7. Dendrite in Assembled POP

Bottom IC Assembly in POP TMV

For the bottom IC assembly SMT 256 is recommended to use with solder paste together, e.g., printing solder paste onto substrate, and dipping the component into SMT 256, followed by assembly together.

Figure 8 shows X-ray image of bottom IC assembled using solder paste plus SMT 256. It could be seen that every solder joint looks perfect.

After this the shear test has been conducted for comparison with traditional underfilling process and solder paste only process.

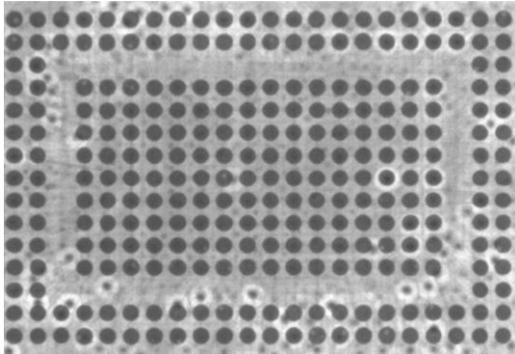


Figure 8. X-ray Image of Bottom IC of POP TMV Assembled Using SMT 256 Plus Solder Paste

The shear force results are shown in Figure 9 below.

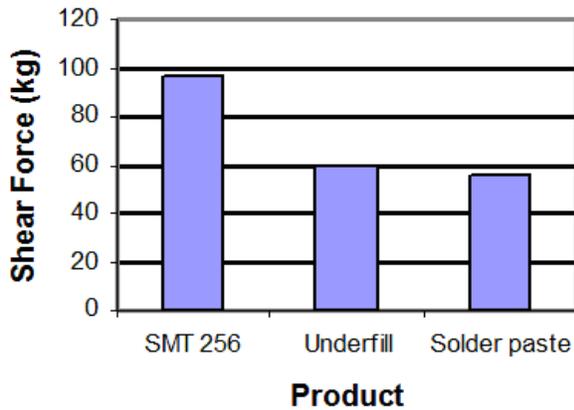


Figure 9. Shear Force Comparison Among SMT 256, Underfill and Solder Paste

From Figure 9 we can see that the shear force is 97 kg for SMT 256, 60kg for underfill and 56kg for solder paste. The results indicates the enforcement of SMT 256 is better than underfill and much better than solder paste. However we still recommend dipping height of SMT 256 is about 60% of bump height when SMT 256 is used with solder paste together because excess SMT 256 is used some solder ball or bridge will appear. In another word,

when solder ball or solder bridge shows up, the dipping height should be slightly reduced.

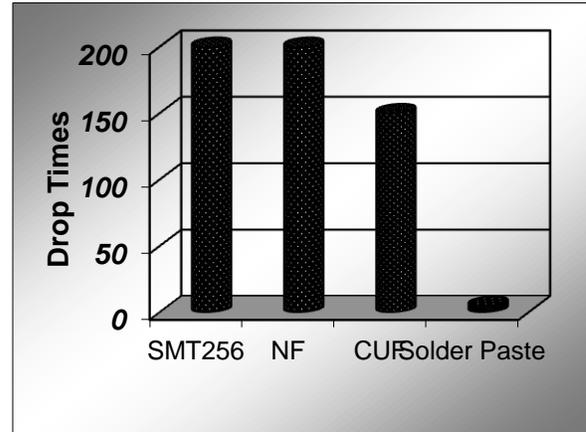


Figure 10. The Drop Test Performance Using SMT 256, NF (No-Flow Underfill), CUF (Capillary Underfill) and Solder Paste
(The drop test conditions are: six feet height, concrete floor and free fall)

From Figure 10 we can 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 the pull test.

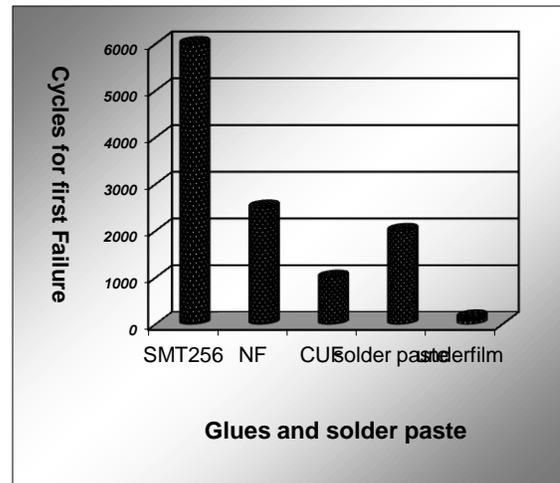


Figure 11. Thermal Cycling Performance Using SMT 256, No-flow Underfill (NF), Capillary Underfill, Solder Paste and underfill.

Figure 11 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 decrease reliability resulting in 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 as high as 6000 cycles which is at least 4000 to 5000 cycles higher than other process.

REWORK PROCESS:

Using the above autopfile which is shown in Figure 12 and Summit rework system temperature control, BGA225 solder joints achieved a maximum temperature of 237°C and were above melting point for 67 seconds. The profile was used to place six BGA225s on a VJE training board, followed by BGA removal for site analysis.

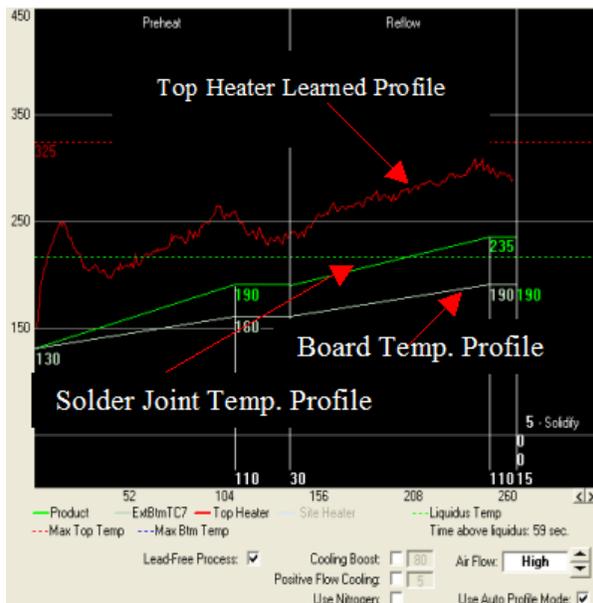


Figure 12. Autoprofile for Rework Process

External TC control was used to regulate board-conditioning temperature prior to top heating. This ensures that the starting board temperature will be the initial requested site temperature and minimizes top heater temperature spike at the beginning of top heating. It also provides for consistency of process temperatures for each site.

One issue we examined was difficulty of removal. Underfilled parts can be difficult to remove during rework. Either the underfill does not sufficiently soften, or the shear volume is just too much to overcome the pull force required for removal. However, the encapsulant proved to provide easy removal after reheating to reflow temperature. Pickup tube flex seals were not required to provide additional removal force to remove the BGAs.

Removal of cured encapsulants from the site was quite easy. Vigorous scrubbing with MEK was not required. Light dabbing of the site with a q-tip soaked in MEK was adequate. RossTech 119EC flux remover also proved equally effective in removing the cured encapsulant. From Fig. 12 below, we can see there is no damage on the reworked substrate.

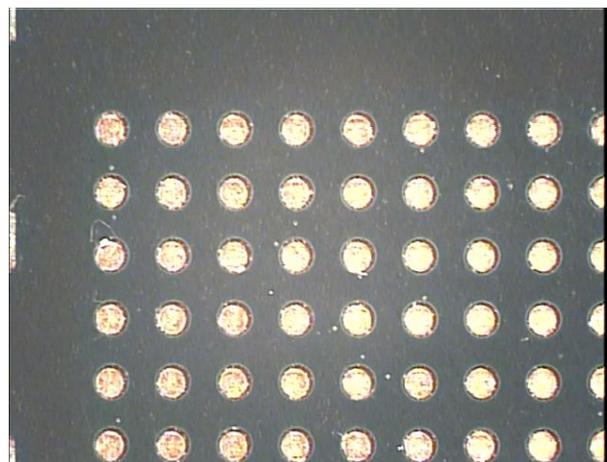
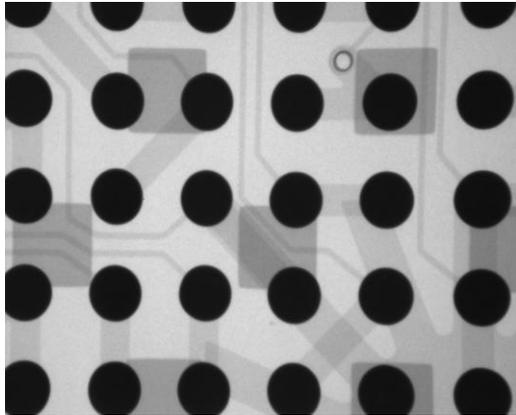
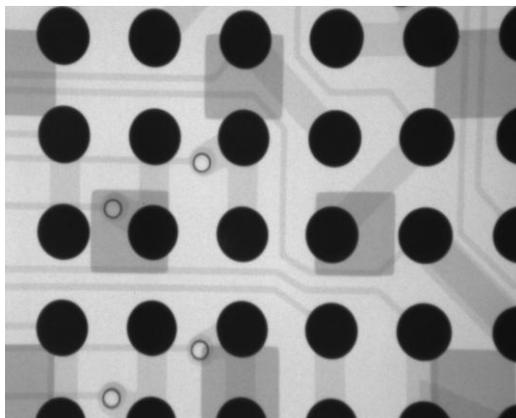


Figure 13. Substrate After Rework



(a)



(b)

Figure 14. X-ray Images of Assembled BGA with Fresh (a) and (b) Reworked Substrates

Figure 14 shows X-ray images of assembled BGA with fresh and reworked substrate. It is very obvious to see that there is no void in solder joints and all solder joints are in very good shape and high quality.

CONCLUSION:

A new solder joint encapsulant has been developed which is not only good for top IC of POP TMV assembly with Nitrogen with enhancement of solder joint strength by 5 times, but also can be used with solder paste together for bottom IC of POP TMV assembly. Solder joint encapsulant can provide the total assembly solution for advanced POP such as POP with TMV. Using solder joint encapsulant for POP assembly would have the following benefits:

- a. Eliminate head-in-pillow issues
- b. Prevent dendrite formation
- c. Eliminate difficult underfilling process, particularly for POP with TMV
- d. Enhance reliability
- e. Easy rework

REFERENCES:

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