ROOM TEMPERATURE FAST FLOW REWORKABLE UNDERFILL FOR LGA

YINCAE Advanced Materials, LLC **WHITE PAPER**

September 2016

ROOM TEMPERATURE FAST FLOW REWORKABLE UNDERFILL FOR LGA

Mary Liu, Ph.D., and Wusheng Yin, Ph.D

YINCAE Advanced Materials, LLC

Albany, NY, USA

wyin@yincae.com

Abstract

With the miniaturization of electronic device, Land Grid Array (LGA) or QFN has been widely used in consumer electronic products. However there is only 20-30 microns gap left between LGA and the substrate, it is very difficult for capillary underfill to flow into the large LGA component at room temperature. Insufficient underfilling will lead to the loss of quality control and the poor reliability issue.

In order to resolve these issues, a room temperature fast flow reworkable underfill has been successfully developed with excellent flowability.The underfill can flow into 20 microns gap and complete the flow of 15mm distance for about 30 seconds at room temperature. The curing behavior, storage, thermal cycling performance and reworkability will be discussed in details in this paper.

INTRODUCTION

With the miniaturization of the electronic device, land grid array (LGA), or Quad Flat No Lead (QFN) advanced components have been widely used, particularly for the consumer electronic devices, so that the thickness of the devices can be dramatically reduced. Meanwhile the density of components is also being increased, for example, the space between neighboring components is being reduced to 10 - 20 microns. However the miniaturization has unavoidably led some reliability issues such as solder joint crack issues in LGA during thermal cycling and drop test.

In order to resolve these issues from the miniaturization, a few approaches have been developed: (1) solder joint encapsulant adhesive has been developed to enable solder joint strength to be enhanced by 5-10X. Normally solder joint encapsulant adhesive is used with solder paste together, the solder joint strength gets enhanced 100% after reflow, therefore the solder joint crack issues have been resolved. (2) Capillary flow underfill has been tried to develop to solve the reliability issues for LGA and QFN. However there are a lot of issues occurred in the manufacturing process. Capillary underfill can not fully fill the underneath gap of LGA or QFN due to the narrow gap of 20 microns. In addition, capillary underfill will also contaminate the neighboring components. In order to resolve these issues YINCAE has developed room temperature fast flow reworkable underfill for LGA or QFN application. Not only can this new underfill flow into 10-20 micron gap of LGA at room temperature but also won't contaminate neighboring components. All these reliability test results have demonstrated this room temperature fast flow reworkable underfill can resolve the reliability issues for LGA or QFN. In this paper we will discuss in detail.

EXPERIMENTAL

Materials

Commercial solder paste materials have been used in this study and all these materials are from the leading suppliers. Y

Underfill Flow Test

The commercial solder paste was printed onto glass slide and reflow. After reflow the solder ball was removed from the glass slide. A double side tape was adhered to the two edges of the glass and then covered by another fresh glass to form the sandwich structure and the middle tunnel was used for underfill flow test. The sandwich of glass slide was stable at room temperature of 25 °C. UNDERFILL Y underfill was dispensed onto the end of the sandwich of glass slides and automatically flew into the sandwich tunnel. The flow time was recorded for a certain distance.

After flow test the underfill SMT 88UL was cured at 150 °C for 5 min. The cured underfill slides were subject to vision voids test using optical microscope. Another group of cured underfill was checked the delamination after cooking test at 100 °C for 24 hours.

Thermal Cycling Test

Thermal cycling test was conducted for the underfilled LGA or QFN. The test conditions were: -45 °C to 125 °C; 15 min each at two extreme points; 15 min for temperature ramping up from -45 °C to 125 °C and 15 min for temperature cooling down from 125 °C to -45 °C with total time of one hour per cycle.

Drop Test

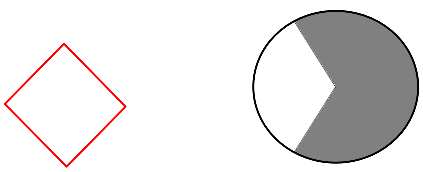
The drop test was conducted for the underfilled LGA or QFN. The test conditions were: six feet height, concrete floor and free fall.

RESULTS AND DISCUSSION

a. Solder Joint Encapsulant Adhesive

Before starting the discussion of room temperature fast flow reworkable underfill, let’s review the solder joint encapsulant adhesive. Solder joint encapsulant has been developed and approved to have strong reinforcement for solder joint. Whether the component is BGA, QFN or LGA, the reinforcement won't change with the component used because the reinforcement has been determined by the nature of solder joint encapsulant. Compared to normal BGA, LGA does not have solder bumps so the application process is challenging.

Normally there are a few methods which can be used to apply solder joint encapsulant material S (SJEM S) in mass production such as: dipping, jetting, step stencil printing and pin transfer. Because LGA does not have solder bumps, it seems very difficult to use dipping method in mass production due to the difficulty of process control. Jetting, step stencil printing and pin transfer are very promising methods which can be considered for mass production. In this study we mainly discuss pin transfer process for LGA assembly applications.



(a) (b)

Figure 1. Designs of (a) pin and (b) stencil

In order to apply solder joint encapsulant onto pads of PCB with solder paste, we designed new pins for pin transfer and design of stencil. The designs of pin and stencil are shown in Fig. 1. After printing solder paste and pin transferring solder joint encapsulant onto PCB pads using our new pins and stencil, the picture of PCB was taken and shown in Fig. 2.

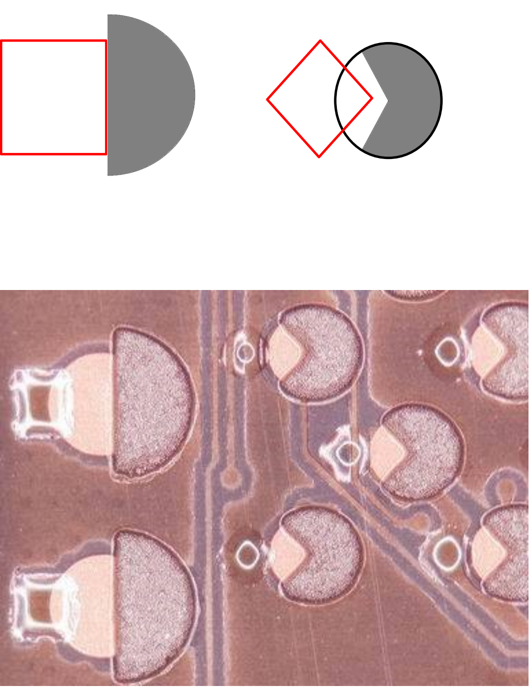


Figure 2. Picture of solder paste and SJEM S onto pads of PCB

From Fig. 2 we can see that solder paste and SJEM S () were both deposited onto pads of PCB together. Solder joint encapsulant and solder paste can be mixed very well during reflow because there is a lot of solvent in solder paste which help solder joint encapsulant spread into the whole individual pad. After reflow, shear test has been conducted for assembled LGA and the results are shown in Fig. 3.

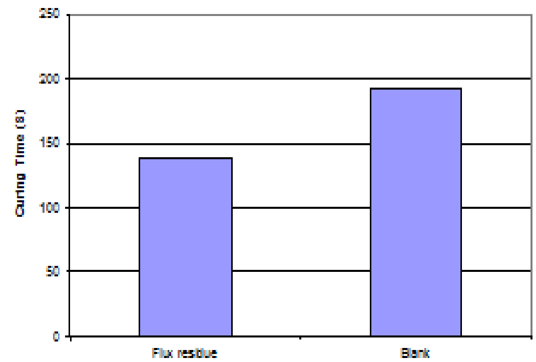
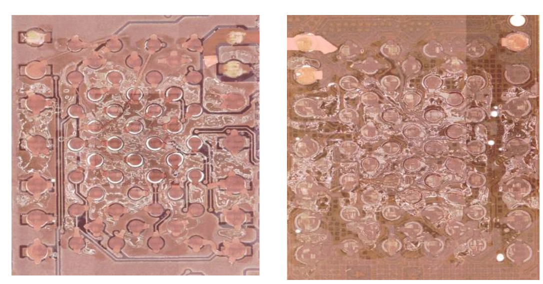


Figure 3. Shear force comparison of LGA among

SJEM S, underfill and solder paste

From Fig. 3 it can be seen that the shear force using SJEM S is better than underfill and much better than solder paste only. The failure mode was investigated after shear test and the pictures are shown in Fig. 4. From Fig. 4, it is obvious that the failure has nothing to do with solder joint, instead the pads have been peeled off on both PCB side and component side. This indicates the strength of solder joint is much stronger than the adhesion strength of pads with PCB or component.



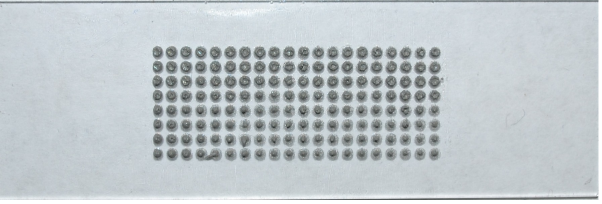
PCB side Component side

Figure 4. Pictures of PCB and component sides after shear test

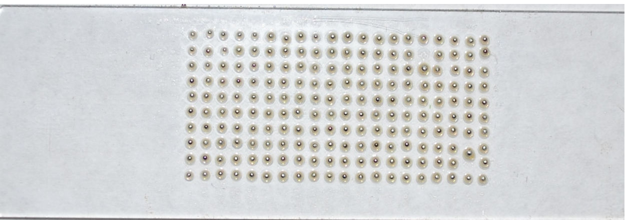
b. Room Temperature Fast Flow Reworkable Underfill’s

Underfilling Flowability

Normally the flow test is conducted using new glass slides, however the flux residue coated glass slides are used for underfill flow test in this study, as shown in Fig.5. All underfill flow test was conducted at room temperature and the flow test data was collected and shown in Table 1.



(a) Paste on the glass slide



(b) Solder Ball onto the glass slides after reflow

(c) Flux residue after removal of solder ball

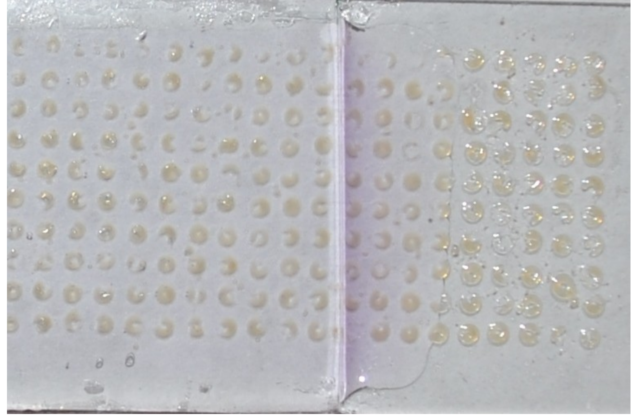
Figure 5. Preparation of flow test glass slides

*: 16 h at room temperature

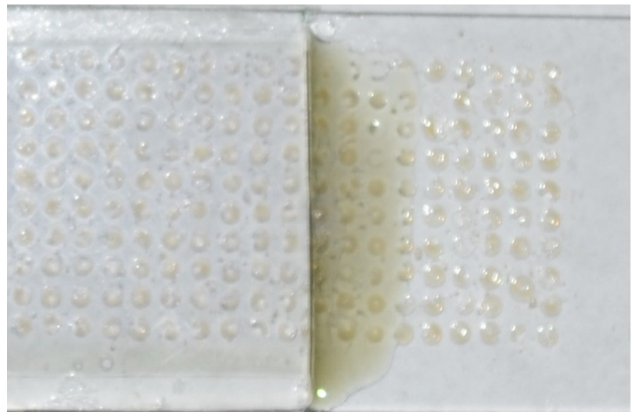
Table 1. Flow time of Underfill (Underfill Y) at room temperature

Gap (μ)	Distance(mm)			25
50	Flow time(s)	2	19	55
50*	Flow time(s)	2	19	55
20	Flow time(s)	4	25	86

From Table 1 it can be seen that underfill flew slower at 20 μ gap than 50 μ gap. It should be noted that all the flow time is less than 30 s at the distance of 15 mm, which can meet the requirements of mass production. However the underfill started to flow slowly when the distance is longer. As we know the flow rate of underfill are controlled by not only underfill surface tension and viscosity but also chemical reaction in underfill. At the initial stage of underfilling the flow rate is mainly controlled by the surface tension and viscosity of underfill. With the increasing flow distance, chemical reaction in underfill generates increasing impact on the flow rate. Not only does chemical reactions in underfill change the surface tension but also it can increase the viscosity of underfill. Therefore underfill flows slower with increasing flow distance.



(a) Cured underfill



(b) Cured underfill after cooking

Figure 6. Pictures of (a) cured underfill and (b) cured underfill after cooking

Fig. 6 shows the pictures of cured underfill and cured underfill after cooking. From Fig.6 it can be seen that there is no voids in the cured underfill at all, furthermore there is no delamination observed during cooking test and no void either. These test data indicate room temperature fast flow reworkable underfill Y is very compatible with flux residue and won't delaminate during the reliability test. The flux residue compatibility test was previously conducted by DSC and the same results was obtained, indicating this underfill is totally compatible with typical flux residue.

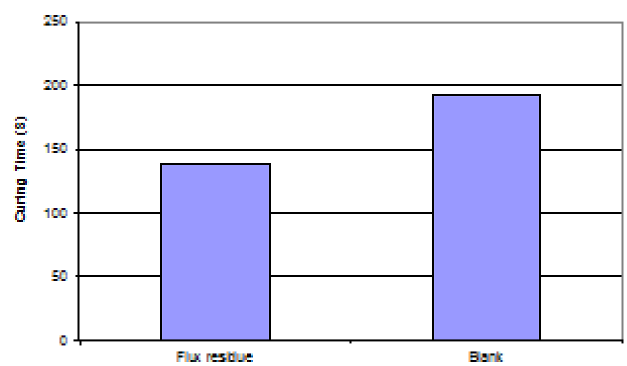


Figure 7. Curing time of underfill with and without flux residue

In order to further understand the effect of flux residue on curing reaction of underfill, the curing time of underfill was tested with and without flux residue, as shown in Fig.7. From Fig.7 we can see the curing time of underfill with flux residue shorter than that without flux residue, indicating the undefill (Underfill Y) was cured faster than that without flux residue. Therefore flux residue won't retard the curing reaction of underfill Y. There is no "catalyst poison" issue in the room temperature fast flow reworkable underfill.

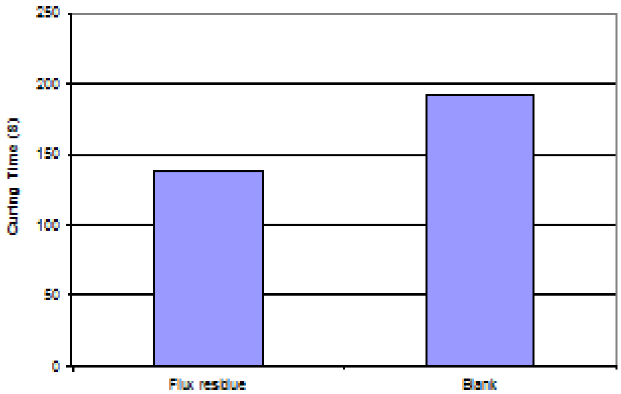
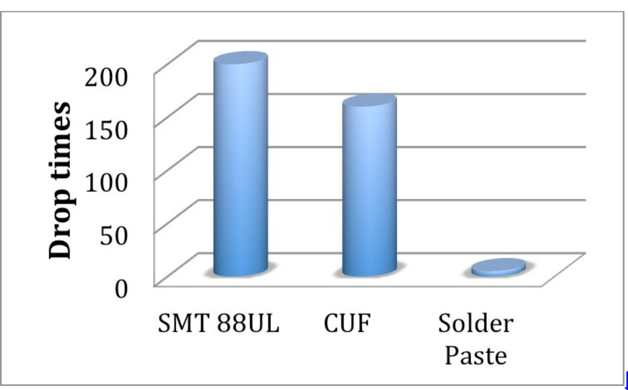


Figure 8. Curing profile of room temperature fast flow reworkable underfill

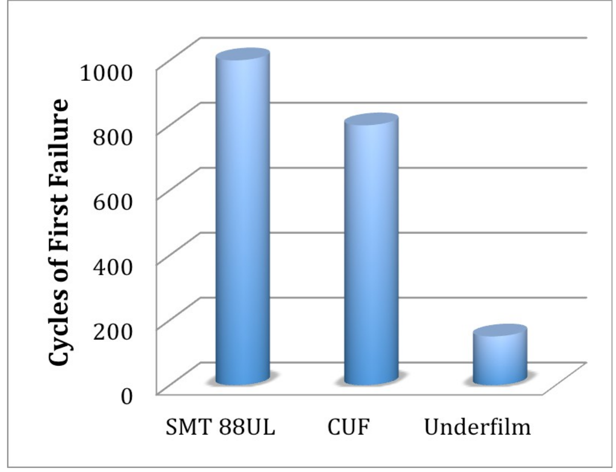
The curing profile of room temperature fast flow reworkable underfill is shown in Fig. 8. It could be found that this room temperature underfill Underfill Y can be cured at 150 °C for a few minutes, which can be used in in-line process. However SMT 88UL can be cured at lower temperature from 110 °C to 140 °C with a little longer curing time.

The results of drop test are showed in Fig. 9. From Fig. 9 we can see the drop times is up to 200 times using Underfill Y room temperature fast flow reworkable underfill which is slightly better than that using leading commercial capillary underfill (CUF), but much better than that obtained using solder paste. The better drop performance of room temperature fast flow underfill mainly comes from better flowability and compatibility.



[ARF1]

Figure 9. Drop test of room temperature Underfill Y, Capillary underfill (CUF) and solder paste



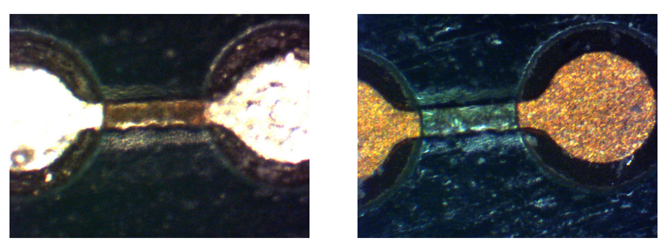
[ARF2]

Figure 10. Thermal cycling performance of room temperature underfill Underfill Y, Capillary underfill (CUF) and solder paste

Fig. 10 shows the thermal cycling performance using different approaches for enhancement. Room temperature fast flow reworkable underfill Underfill Y has demonstrated better thermal cycling performance than traditiona capillary underfill, and much better than underfilm. It is believed that the better thermal cycling performance is mainly from the better homogeneously underfilling property of room temperature fast flow reworkable underfill Underfill Y, resulting in dissipating mechanical stress effectively.

REWORK

The rework process is same as traditional capillary underfill. First heat up the underfilled component to 245 °C, remove underfill fillet, then remove the component. The wooden pad was used to remove major underfill, then copper ribbon was used to wick up solder. After wicking away solder, toothbrush was used to clean all residue using MEK or other cleaning agent. Fig. 11 shows the reworked PCB and new PCB. It should be noted that there is no any damage on the pad and solder mask. So room temperature fast flow underfill is easily reworkable.



(a) Pads after rework (b) New Pads

Figure 11. Images of pads after rework and new one

CONCLUSION

1. Underfill Y can flow fast at room temperature and easily flow into narrow gap of advanced components such as LGA and QFN;
2. Room temperature fast flow underfill is compatible with the flux residue of solder paste;

3. Underfill Y can provide excellent reliability and underfill voids free, high throughput process and also very easy to rework.

REFERENCES

1. Mary Liu and Wusheng Yin presented " A First Room Temperature Stable and Jettable Solder Joint Encapsulant Adhesive" in IMAPS New England - 38 the Symposium & Expo, May 3, 2011
2. Mary Liu and Wusheng Yin had technical poster" A First Individual Solder Joint Encapsulant Adhesives" in Raleigh NC, IMAPS, November 3, 2010
3. Mary Liu and Wusheng Yin Presented " World First Solder Joint Encapsulant Adhesives" in Shenzhen (China), NEPCON, August 31, 2010
4. Mary Liu and Wusheng Yin presented " A First Individual Solder Joint Encapsulant Adhesives" in San Francisco, SEMICON West/IMAPS, July 14, 2010
5. Mary Liu and Wusheng Yin presented "Solder Joint Encapsulate - Miniaturization Solution" Las Vegas, Nevada, APEX , March 25- 27th, 2014.

6. Mary Liu and Wusheng Yin presented "An Innovative Reliability Solution to Interconnect of Flexible/Rigid Substrates." Rosemont, IL, SMTAI, September 30th to October 1st, 2014.

7. Mary Liu and Wusheng Yin presented "Low Temperature Solder Joint Encapsulate For Sn/Bi Application" San Diego, CA, APEX , February 25, 2015.
8. Mary Liu and Wusheng Yin , "Underfill for Ultra-Low Bumped (10u) 3D TSV Package" and "A First Individual Solder Joint Encapsulant Adhesives," November 3rd-4th, IMAPS 2010

9. Mary Liu and Wusheng Yin , "A Low Cost Manufacturing Solution - Low Temperature Super-Fast Cure and Flow Reworkable Underfill," July 13th, SEMICON West 2011