



# Solder Joint Encapsulant Adhesive – LGA High Reliability And Low Cost Assembly Solution

YINCAE Advanced Materials, LLC

**WHITE PAPER**

April 2014

# Solder Joint Encapsulant Adhesive –LGA High Reliability And Low Cost Assembly Solution

Dr. Mary Liu and Dr. Wusheng Yin  
YINCAE Advanced Materials, LLC, Albany, NY

## ABSTRACT:

More and more Land Grid Array (LGA) components are being used in electronic devices such as smartphones, tablets and computers. In order to enhance LGA mechanical strength and reliability, capillary flow underfill is used to improve reliability. However, due to the small gap, it is difficult for capillary underfill to flow into the LGA at SMT level. Due to cost considerations, there are usually no pre-heating underfill or cleaning flux residue processes at the SMT assembly line. YINCAE solder joint encapsulant SMT256 has been successfully used with solder paste for LGA assembly. Solder joint encapsulant is used in in-line LGA soldering process with enhanced reliability. It eliminates the underfilling process and provides excellent reworkability. The shear strength of solder joint is stronger than that of underfilled components. The thermal cycling performance using solder joint encapsulant is much better than that using underfill. Bottom IC of POP has been studied for further understanding of LGA assembly process parameters. All details such as assembly process, drop test and thermal cycling test will be discussed in this paper.

## INTRODUCTION

With the advancements of the electronic industry, IC components have been miniaturized, pitch sizes have decreased and I/O numbers have increased. 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 the solder joint, and poor thermal cycling performance. YINCAE developed the world's first solder joint encapsulant a few years ago, and billions of devices have been made with approved satisfied performance in the customer field.

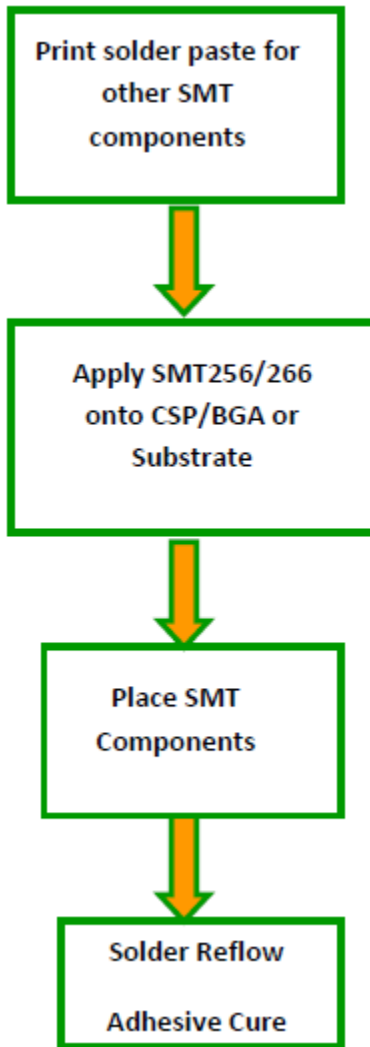
Due to the benefits of low-cost, fast heat dissipation and easy manufacturing, LGA (land grid array) has become increasingly popular IC package for electronic devices. While LGA has been claimed to have better reliability than

BGA (ball grid array), there are still some issues in the field reliability test such as solder joint cracks. It is very difficult to address these packages that don't have solder bump using traditional underfilling process. In order to resolve the reliability issue for LGA or similar package quad flat package (QFP), solder joint encapsulant can be used with solder paste for LGA assembly so that the solder joint can be reinforced by solder joint encapsulant after soldering.

Solder joint encapsulant used with solder paste not only provides assembly solution for LGA, but also for BGA with large warpage or bottom IC of POP to address process yield and reliability issues. Thus we will discuss LGA and further go to BGA with large warpage to address more detailed process parameters.

## PROCESS

The application process of YINCAE's solder joint encapsulant adhesive is shown in Figure 1.



**Figure 1. Process Flow Chart**

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. SMT256 has been designed for mass production, which can be applied by dipping, stencil printing and brushing. SMT266 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 SMT266 can remove metal oxide from pads and bumps to allow solder joint to form, then cure with the formation of 3-D polymer network encapsulating each individual solder joint. There are no adhesives in-between the solder joints to block the outgassing channel, thus ensuring higher process yield.

A schematic of SMT256 or SMT266 encapsulated solder joint after reflow is illustrated in Figure 2.



**Figure 2. Schematic Cure SMT256 or SMT266 Encapsulated Solder Joint**

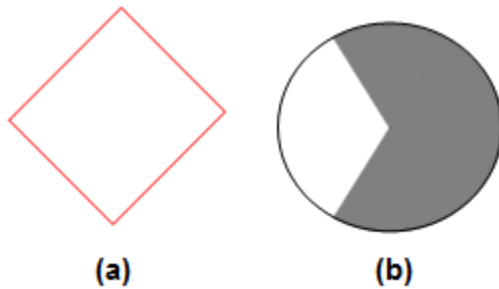
### The Assembly of LGA:

YINCAE solder joint encapsulant products have been developed and approved to provide a stronger reinforcement for the solder joint. Whether the component is BGA, QFP 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 (SMT256) 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 the dipping method in mass production due to the difficulty of process control. Jetting, step

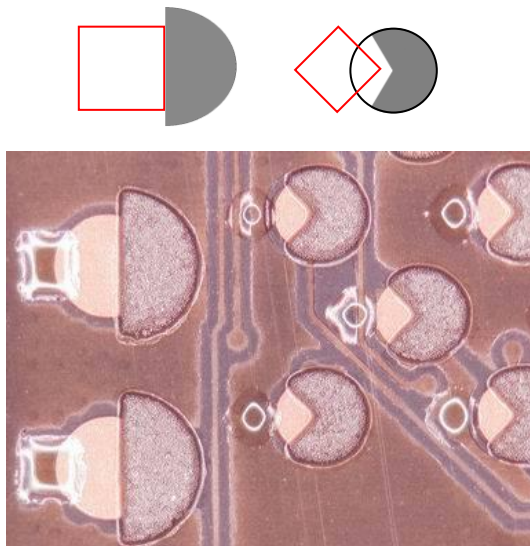
stencil printing and pin transfer are very promising methods which can be considered for mass production. In this study we mainly discuss pin transfer process for LGA assembly applications.

In order to apply solder joint encapsulant onto pads of the PCB with solder paste, we designed new pins for pin transfer and design of stencil. The designs of pin and stencil are shown in Figure 3.



**Figure 3. Designs of (a) Pin and (b) Stencil**

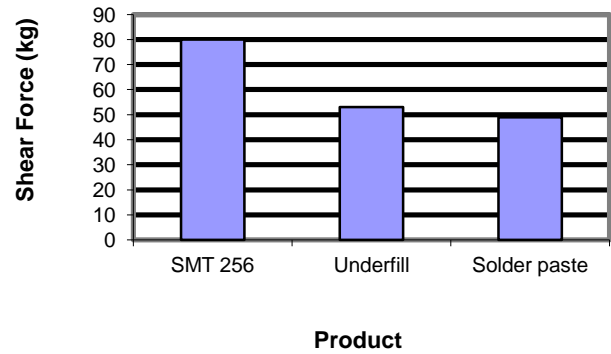
Figure 4 is a photo of the PCB after printing solder paste and pin transferring solder joint encapsulant onto PCB pads using our new pins and stencil.



**Figure 4. Photo of Solder Paste and SMT256 onto Pads of PCB**

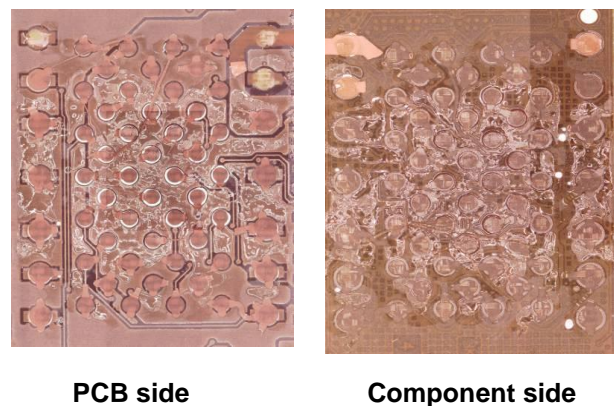
From Figure 4 it can be observed that solder paste and solder joint encapsulant (SMT256) were both deposited together onto the PCB

pads. The solder joint encapsulant and solder paste can be mixed very well during reflow because there is a lot of solvent in solder paste which helps the solder joint encapsulant spread into the whole individual pad. After reflow, shear testing has been conducted for the assembled LGA and the results are shown in Figure 5.



**Figure. 5 Shear Force Comparison of LGA Among SMT256, Underfill and Solder Paste**

From Figure 5 it can be seen that the shear force using SMT256 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 Figure 6. From Figure 6, 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.



**Figure 6. Photos of PCB and Component Sides after Shear Test**

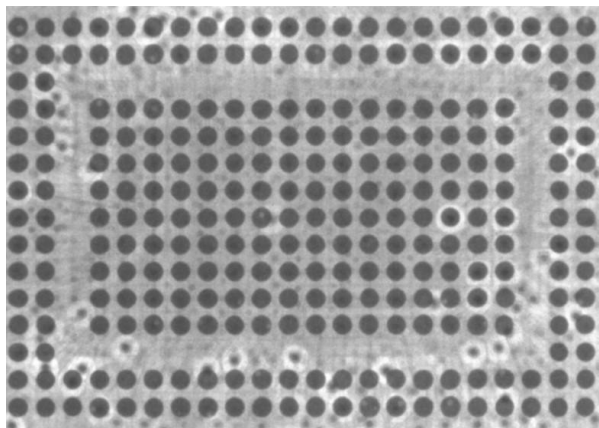


### Bottom IC Assembly in POP TMV

In order to further understand how to use solder joint encapsulant, we have also studied bottom IC assembly in POP with TMV. This can help us understand the application of solder joint encapsulant for LGA assembly.

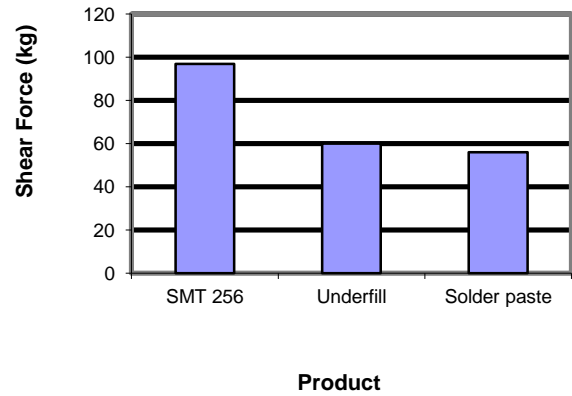
Normally there are some issues for bottom IC assembly in POP TMV due to large warpage. For bottom IC assembly, SMT256 is recommended to be used with solder paste, e.g., printing solder paste onto substrate, then dipping the component into SMT256, followed by assembly together.

Figure 7 shows an X-ray image of bottom IC assembled onto PCB substrate using solder paste with SMT256. From X-ray results, it can be seen that every solder joint looks perfect. In order to verify the reinforcement of solder joint encapsulant, the shear test has been conducted and compared with traditional solder paste plus underfilling process and solder paste only process.



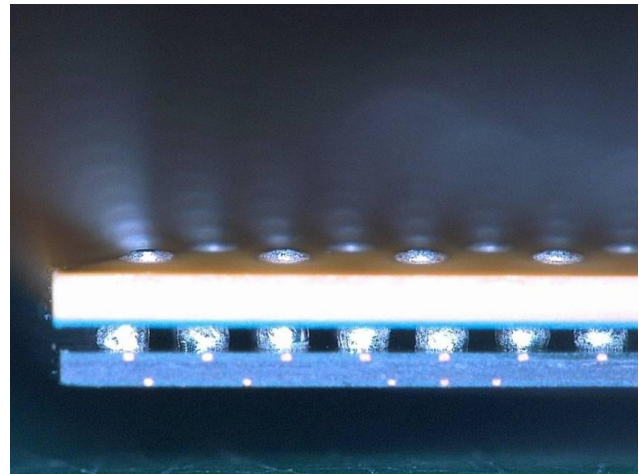
**Figure 7. X-ray Image of Bottom IC of POP TMV Assembled Using SMT256 Plus Solder Paste**

The shear force results of these POP TMV tests are shown in Figure 8. There we can see that the shear force is 97 kg for SMT256, 60kg for underfill and 56kg for solder paste.



**Figure 8. Shear Force Comparison Among SMT256, Underfill and Solder Paste**

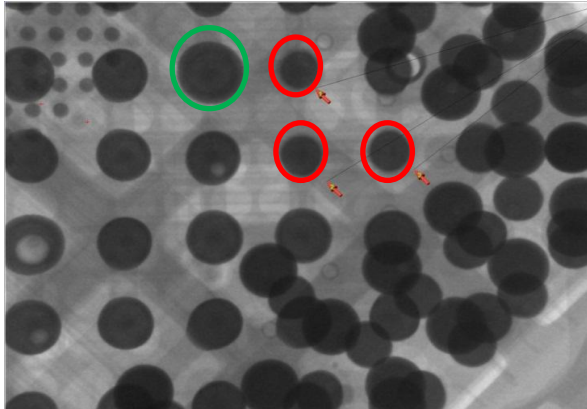
The results indicate the reinforcement of SMT256 is better than that of underfill and much better than solder paste only. The reinforcement by the solder joint encapsulant is confirmed again.



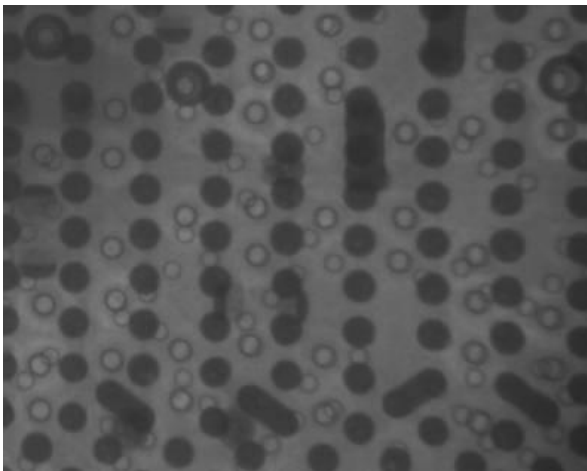
**Figure 9. Picture of POP with 100% Dipping Height**

Solder joint encapsulant has been demonstrated to be able to reinforce solder joint. Normally the more solder joint encapsulant is used the better reinforcement the solder joint gets. However there is still an upper limit of usage of solder joint encapsulant. Figure 9 illustrates POP dipping at 100% of bump height. After dipping, the POP was assembled onto PCB. There are some defects after reflow. These

defects include uneven solder joint, solder voids and solder bridging, which are shown in Figure 10 below.



(a) Uneven solder joint and voids



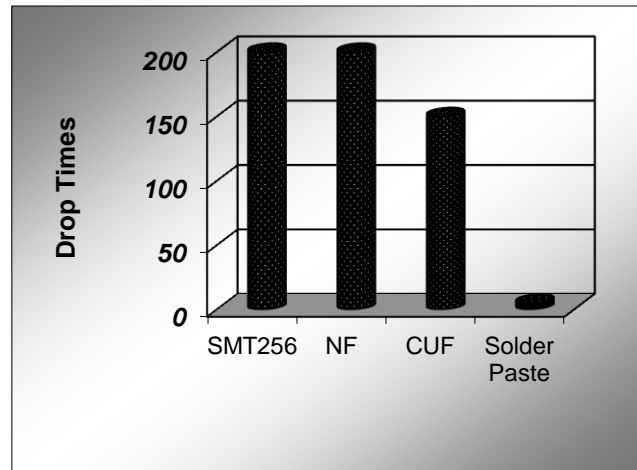
(b) Solder Bridging

**Figure 10. Possible Defects of POP Using Excess SMT256: (a) Uneven Solder Joint and Voids; (b) Solder Bridging**

From Figure 10, it should be noted that when too much SMT256 is used, there are some defects of uneven solder joints, solder voids and solder bridging. This is because dipping too much SMT256 causes the outgassing channels to be blocked. During reflow outgassing, a large amount of solvent evaporation from solder paste is generated, which pushes liquid solder away to form uneven solder joint, or solder bridge. Meanwhile, the solder joint encapsulant is unable to flow away from liquid solder. It is

trapped in the solder joint to form solder voids because the space between solder joints has been filled. Therefore, we recommend about 60% of bump height when SMT256 is used with solder paste. If some solder ball or bridging occurs, the dipping height should be slightly reduced. Otherwise the dipping height can be slightly increased for better reinforcement of solder joint.

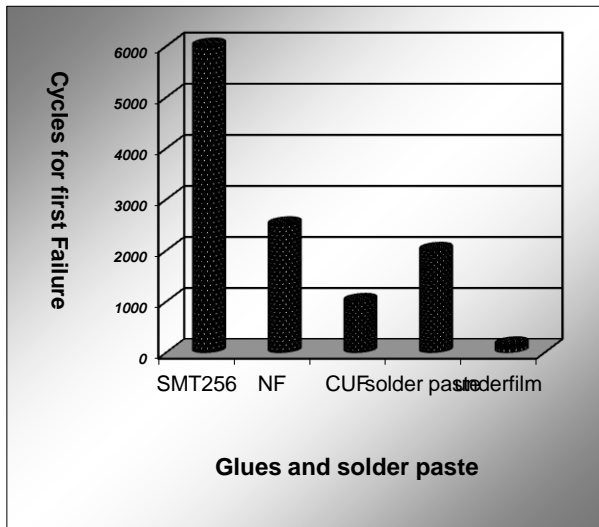
From Figure 11 it can be seen that the drop times is up to 200 times using SMT256 solder joint encapsulant, which is same as that obtained using no-flow underfill, but much better than that obtained using solder paste. The drop test performance is in agreement with the results of the pull test.



**Figure 11. Drop Test Performance Using SMT256, NF (No-flow Underfill), CUF (Capillary Underfill) and Solder Paste. [Drop Test Conditions are: Six feet height, concrete floor and free fall]**

Figure 12 below shows the thermal cycling performance using different approaches for reinforcement. Thermal cycling conditions are: one hour per cycle; temperature from  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  and 15 min dwell time at two extreme temperatures. It is 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 the first failure cycles is as high as 6000 cycles using solder

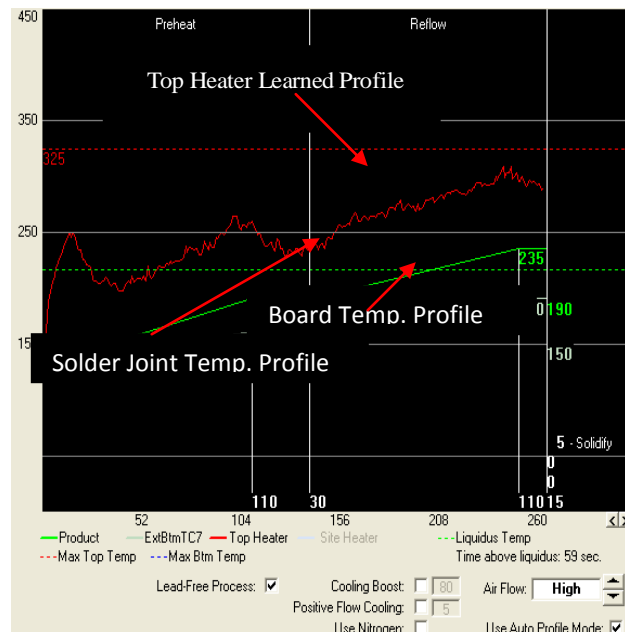
joint encapsulant SMT256 or SMT266 – at least 4000 to 5000 cycles higher than other processes.



**Figure 12. Thermal cycling performance using SMT256, No-flow underfill (NF), capillary underfill, solder paste and underfill.**

**REWORK PROCESS:**

Using the autoprofile shown in Figure 13 and Summit rework system temperature control, BGA225 solder joints achieved a maximum temperature of 237°C and were above melting point for 67 seconds.



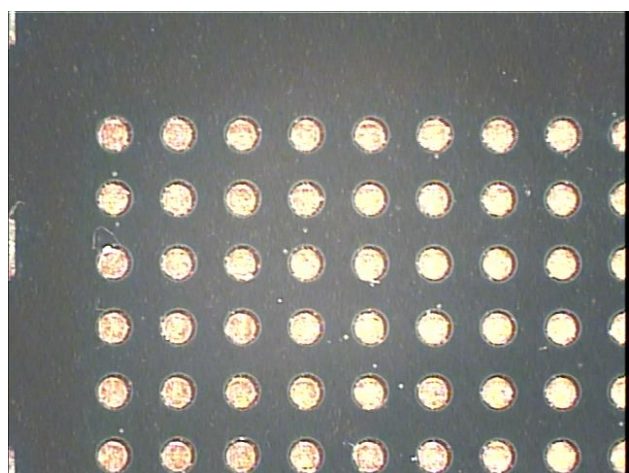
**Figure 13. Autoprofile for Rework Process**

The profile was used to place six BGA225s on a VJE training board, followed by BGA removal for site analysis.

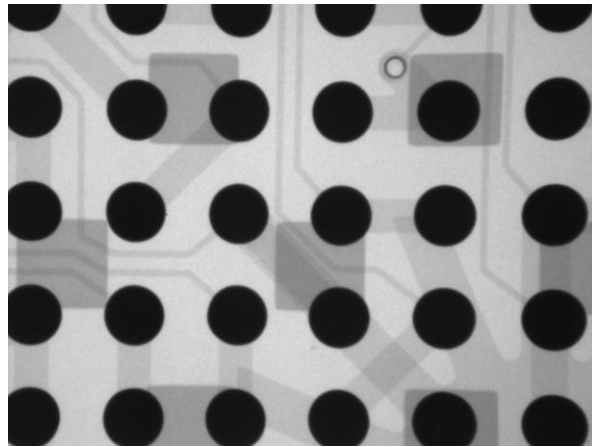
External TC control was used to regulate board-conditioning temperature prior to top heating. This ensures that the starting board temperature will be the initial requested site temperature and minimizes top heater temperature spike at the beginning of top heating. It also provides for consistency of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

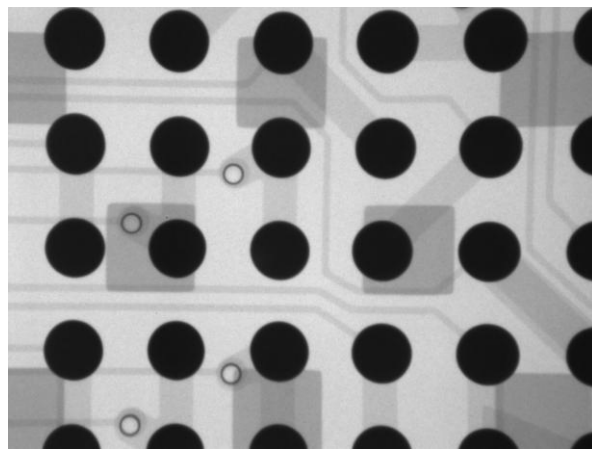
Removal of cured encapsulants from the site was quite easy. Vigorous scrubbing with MEK was not required. Light dabbing of the site with a cotton swab soaked in MEK was adequate. RossTech 119EC flux remover also proved equally effective in removing the cured encapsulant. From Figure 14 below, we can see there is no damage on the reworked substrate.



**Figure 14. Substrate after rework**



(a)



(b)

**Figure 15. X-ray Images of Assembled BGA with Fresh (a) and (b) Reworked Substrates**

Figure 15 shows X-ray images of assembled BGA with fresh and reworked substrates. It is very obvious to see that there are no voids in solder joints and all solder joints are in very good shape and high-quality.

#### **CONCLUSION:**

A new LGA assembly solution has been developed by using solder joint encapsulant with solder paste. Solder joint encapsulant has demonstrated the ability to provide great reinforcement for solder joint in LGA, which are better than underfill and much better than solder paste. In addition, solder joint encapsulant can also be a good solution for bottom IC of POP assembly when used with solder paste. Using solder joint encapsulant for

LGA and POP assembly would have the following benefits:

- a. Eliminate difficult underfilling process, particularly for LGA and POP with TMV;
- b. Enhance reliability;
- c. Provide easy 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 displayed a technical poster "A First Individual Solder Joint Encapsulant Adhesives" in Raleigh NC, at 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 Adhesive" in San Francisco, SEMICON West/IMAPS,

#### **For additional information Contact:**

YINCAE Advanced Materials, LLC  
19 Walker Way  
Albany, NY 12205  
(518) 452-2880  
<http://www.yincae.com/>  
[info@yincae.com](mailto:info@yincae.com)