Solder Joint Encapsulant Adhesive – POP Assembly Solution

YINCAE Advanced Materials, LLC

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Solder Joint Encapsulant Adhesive – POP 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 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 assembly, YINCAE has successfully developed a first individual solder joint encapsulant adhesive.

YINCAE solder joint encapsulant adhesives - SMT256/266 are applied by printing or dipping process onto a substrate or component, which can remove metal oxide from pads and bumps to allow solder joint to form. SMT 256/266 is then cured with the formation of 3-D polymer network encapsulating each individual solder joint; in between solder joints, there are no adhesives blocking outgassing channels to ensure process yield. After using solder joint encapsulant adhesive for POP assembly, the pull strength of solder joint is increased five times, and the SIR issue is addressed with high process yield. All details such as assembly process, drop test and thermal cycling test will be discussed below.

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 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, 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 assembly solution for POP.

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.

PROCESS

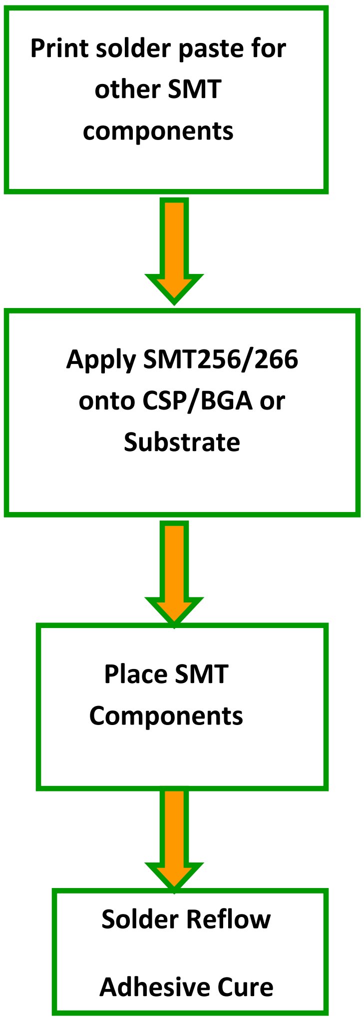


Figure 1. Process Flow Chart

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 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, then cure with the formation of 3-D polymer network encapsulating each individual solder joint, and 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.

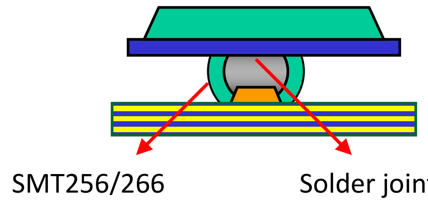


Figure 2. Schematic Cure SMT 256 or SMT266 Encapsulated Solder Joint

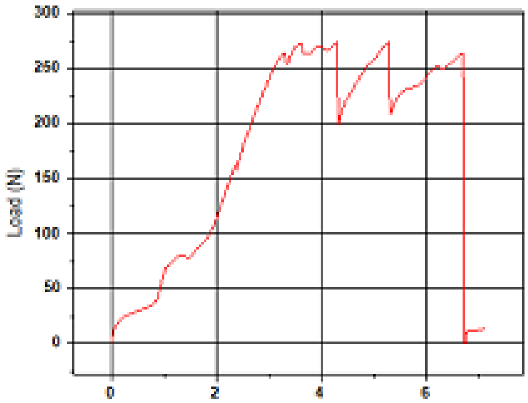
Reflow Profile

The profile is fully compatible with all typical lead-free solder paste reflow profile. The time from room temperature to peak temperature is 4-5 min and peak temperature is from 235-260°C.

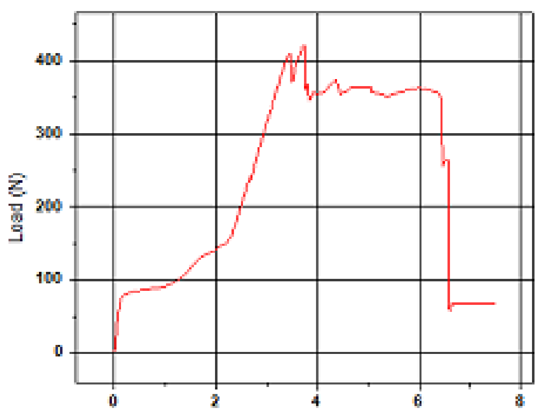
POP Test Coupon

Amkor POP has been used as test coupon in this paper, which is shown in Figure 3. Solder alloy is SAC305. Top IC is: 0.65 mm pitch and 128 I/O, and bottom IC is: 0.5mm pitch and 305 I/O. Pad finish is Ni/Au.

Figure 3. Amkor POP test Coupon



(a) Solder Paste Plus Underfill



(b) SMT 256-Solder Joint Encapsulant

Figure 4. Pull Strength of Assembled BGA Using (a) Solder Paste Plus Underfilling Process and (b) YINCAE 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 to 2 times higher using SMT 256 than using solder paste plus underfilling process.

Figure 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 defects will be observed.

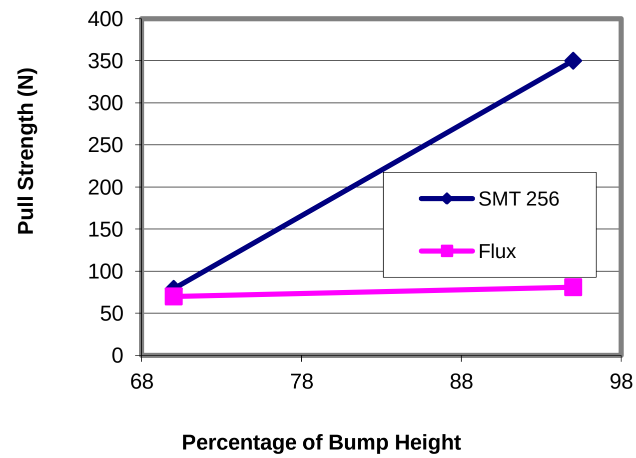


Figure 5. Pull Strength Changing with the Dipping Height

From Figure 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 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 YINCAE 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 YINCAE 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.

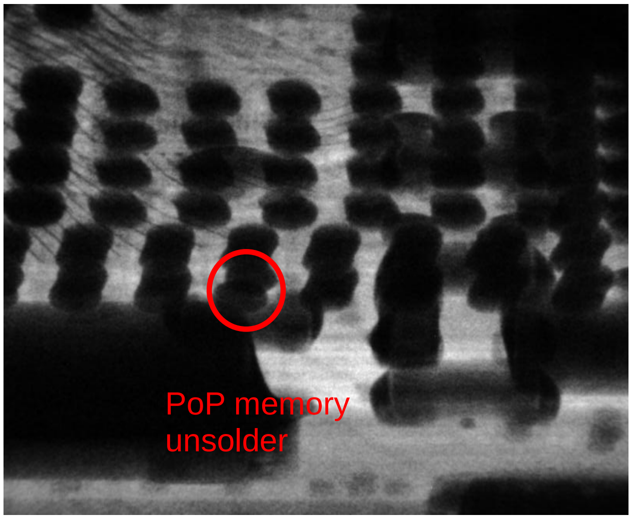


Figure 6. X-ray i\Image of Assembled POP Using Solder Paste and Flux.

Figure 6 shows the X-ray image of assembled POP obtained using solder paste and flux. From Figure 6 it has been found that there was an open joint. The open solder joint was conducted by cross-section, and the cross-section picture is shown in Figure 7.

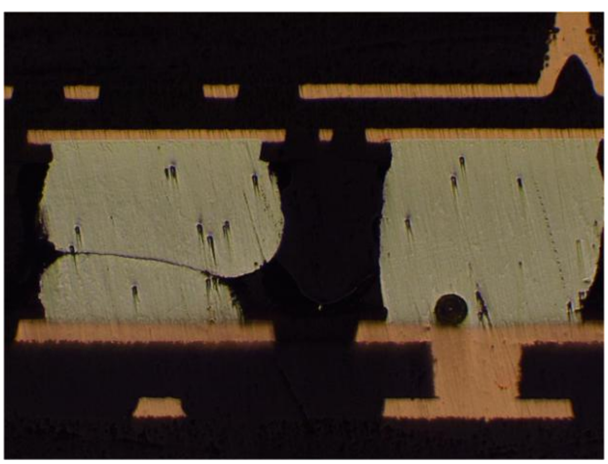
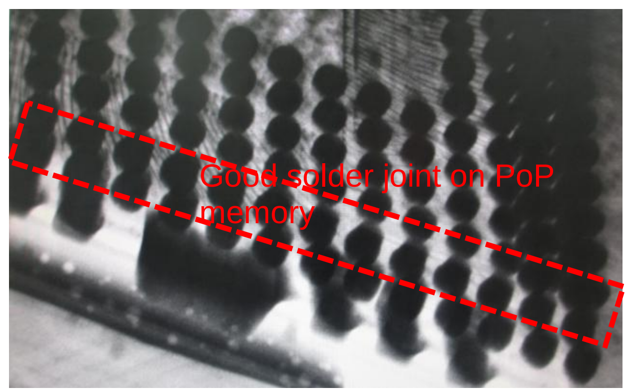


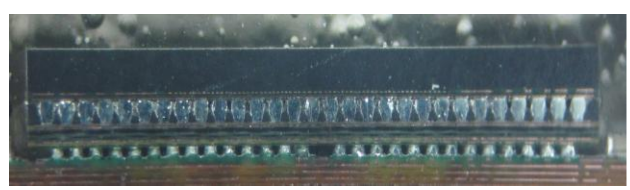
Figure 7. Cross-section of Open Solder Joint

From Figure 7, 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 8 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 pheonemenon 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 8. X-ray and X-section of Assembled POP Using YINCAE SMT 256.

Figure 9 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. It is very obvious that solder joint encapsulant can be cured to form 3D polymer network and encapsulate solder joint, which can easily prevent dendrite formation and electromigration.

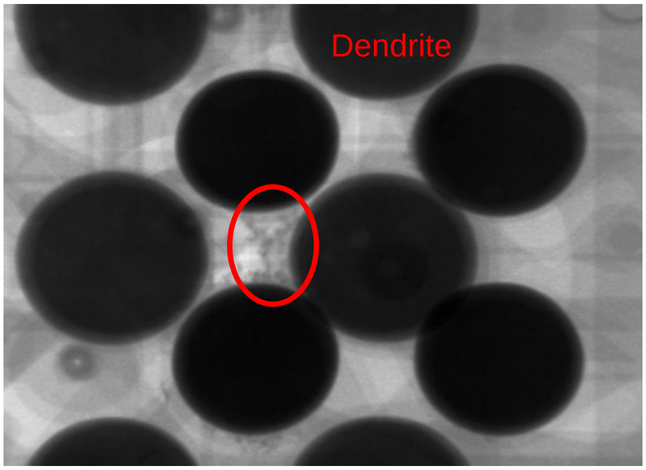


Figure 9. Dendrite in Assembled POP

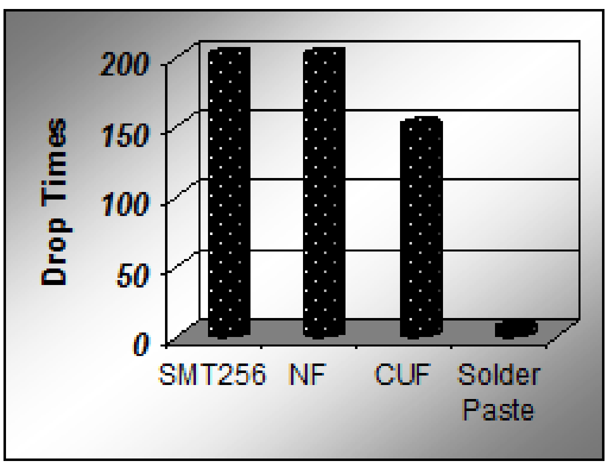


Figure 10. The Drop Test Performance Using SMT 256, NF (no-flow underfill), CUF (capillary underfill) and Solder Paste. (The drop test conditions are: six feet height, concrete floor and free fall)

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.

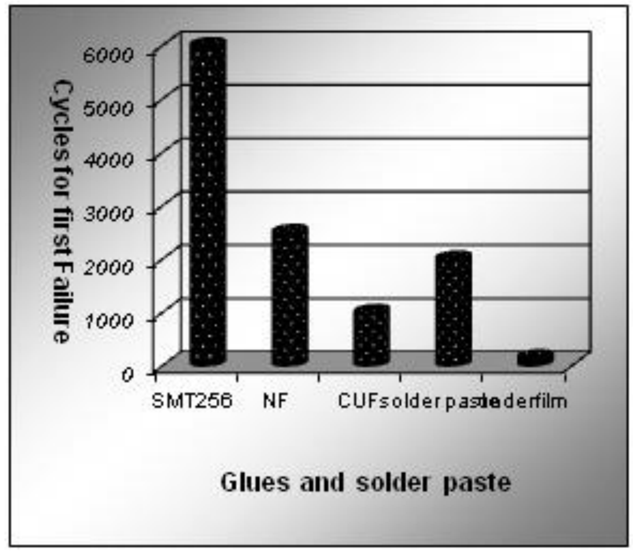


Figure 11. Thermal Cycling Performance Using SMT 256, No-flow Underfill (NF), Capillary Underfill, Solder Paste and Underfill

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, at least 4000 to 5000 cycles higher than other process.

REWORK PROCESS:

Using the above autoprofile which is shown in Fig. 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.

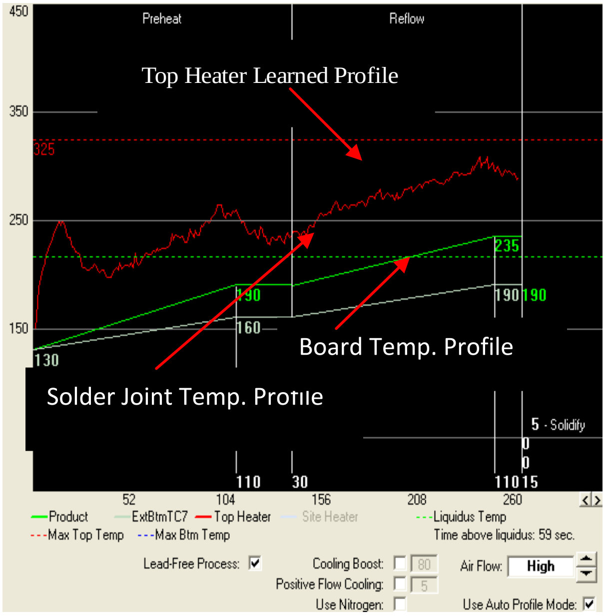


Figure 12. Autoprofile for Rework Process

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, which is shown in Figure 13 below.

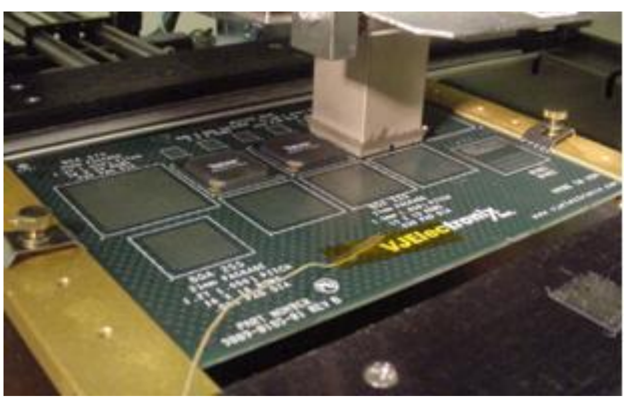


Figure 13. External TC Control

One issue 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. Removed parts showed rings of encapsulant surrounding the solder joint, seen in Figure 14.

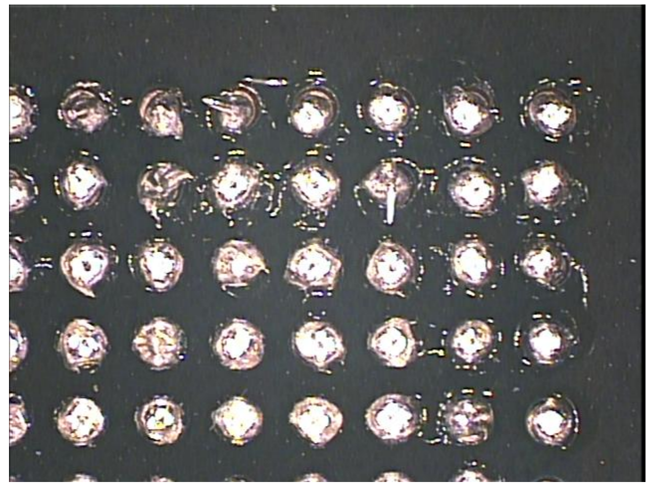


Figure 14. Substrate after BGA Removal

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 Figure 15 below, we can see there is no damage on the reworked substrate.

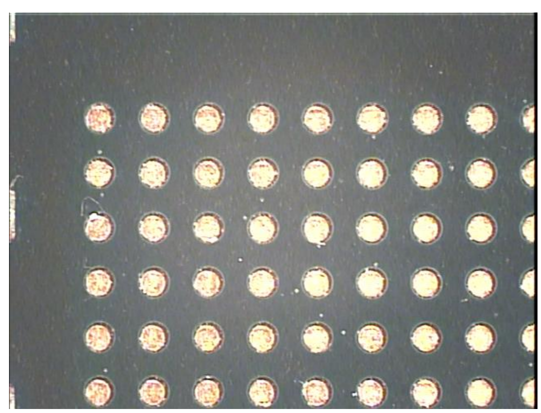
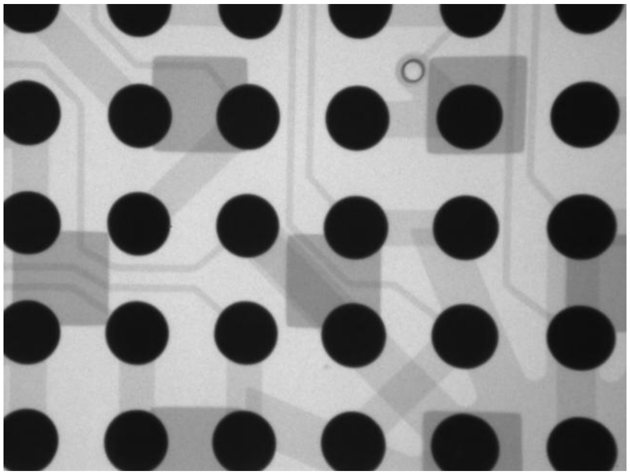
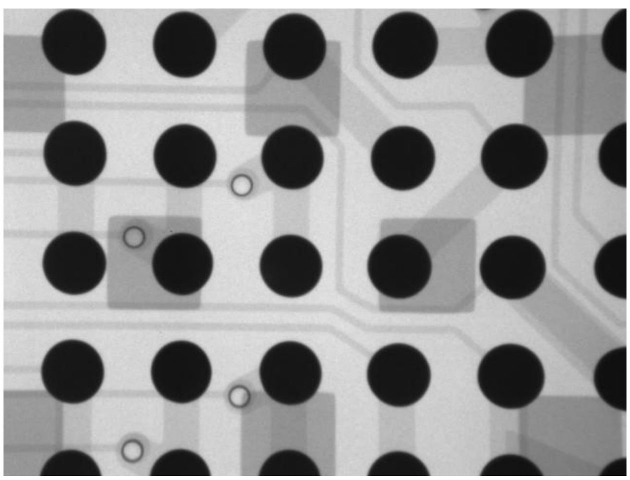


Figure 15. Substrate After Rework

Figure 16 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.



(a)



(b)

Figure 16. X-ray images of Assembled BGA with Fresh (a) and (b) Reworked Substrates

CONCLUSION:

A new solder joint encapsulant has been invented which can not only increase solder joint strength by 5 times, but also provide excellent reliability for advanced IC components which provides 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:

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

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