A NOVEL LOW TEMPERATURE FAST FLOW AND FAST CURE REWORKABLE UNDERFILL

YINCAE Advanced Materials, LLC

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ABSTRACT

In order to meet the increasing demand of device miniaturization, high speed, more memory, more function, low cost, and more flexibility in device design and manufacturing chain, underfilling has increasingly become an essential process for the good reliability of electronic devices. Filled capillary underfill has been selected for use in package-level where there is large thermal stress caused by CTE mismatch issue, but the underfill is usually not reworkable. Unfilled capillary underfill has been used for board-level application such as BGA/CSP, POP, WL-CSP where there is need for mechanical shock resistance, the underfill is usually reworkable.

In order to meet the demand of electronic devices' advancement, YINCAE Advanced Materials, LLC has developed a novel low temperature fast flow and fast cure reworkable underfill – SMT 88U underfill series. SMT 88U underfill series can be dispensed at room temperature and flow into the underneath of components during curing process. SMT 88U can be cured 150 °C for 1 second, 120 °C for 8 seconds or 88 °C for 5 min. The features of friendly storage condition, excellent reliability and reworkability make SMT 88U underfill materials more attractive. The details will be discussed in our full papers.

INTRODUCTION

The strong competition of the electronic industry has dramatically driven the price of electronic devices down but still with reasonable profit. Manufacturing high performance and low cost products is the key to winning in this rigorous competition field. The manufacturers are focusing on how to lower down (1) the cost of components, substrate and materials; (2) the cost of manufacturing process such as throughput and defect rate. In order to reduce the manufacturing cost, some cheap substrates have been used in the electronic devices and some finer pitch size and smaller IC components are increasingly being used. However current underfill materials have encountered some challenges to meet this advancement of electronic devices. The high curing temperature of underfill materials (above 120 °C) is obviously big hurdle for the cheap substrates. The longer curing time of underfill materials (above 15 min.) is a bottleneck for the manufacturing of cheap electronic devices such as RFID.

In order to meet the demand of electronic devices' advancement, YINCAE Advanced Materials, LLC has developed a novel low temperature fast flow and fast cure reworkable underfill – SMT 88U underfill series. SMT 88U underfill series can be dispensed at room temperature and flow into the underneath of components during curing process. SMT 88U can be cured 150 °C for 1 second, 120 °C for 8 seconds or 88 °C for 5 min. The features of friendly storage condition, excellent reliability and reworkability make SMT 88U underfill materials more attractive, which can function a capillary underfill, or a replacement for UV curable adhesive/encapsulant. The details are discussed below.

EXPERIMENTAL

Materials

Commercial underfill materials have been used in this study. SMT 88U underfill series are from YINCAE Advanced Materials, LLC, and the other different underfill materials from leading underfill suppliers. Commercial flip chip flux materials are used for the assembly of components.

Underfill Flowability Test

The commercial flip chip flux was transferred into a glass slide. The flux residue was left onto the glass slide after reflow. 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 for underfill flow test. The sandwich of glass slides was heated up to 70°C, 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 this screening flowability test on the glasses, two underfills with better flowability were selected to for assembled RFID chips for the real life flowability test without heating up the substrates. The underfilling and flowing processes were completed at room temperature. The underfilled chips were cross-sectioned and inspected to see underfilling efficiency and voids using optical microscope.

The underfilled flip chips or other advanced IC were applied four kilogram force onto the top and slowly moved from one side to another side to see if there is any crack occurred in these devices. The test schematic drawing is shown in Figure 1.

Bending Test

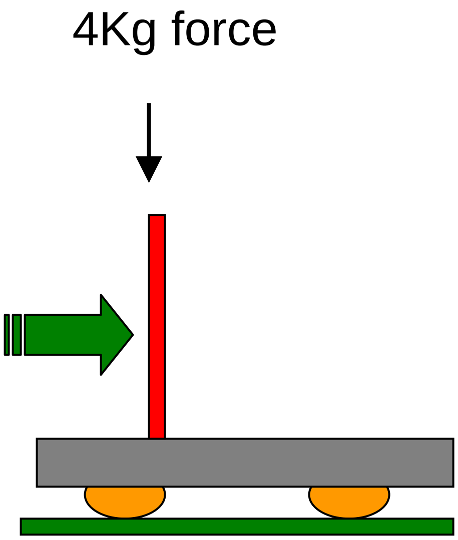


Figure 1. Schematic Bending Test

Thermal Cycling Test

Thermal cycling test was conducted for the underfilled IC components. 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.

Test Vehicle

1. RFID Test Coupon

Figure 2. RFID Paper Substrate

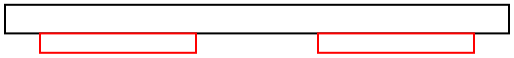


Figure 3. Schematic of a Flip chip

The chip dimension is 120µ X 120µ with four bumps of 10-30µ bump height.

2. BGA Test Coupon

BGA dimension is 12 x 12mm, I/O: 228; SAC 305; bump height: 10mil. The pictures of BGA are shown in Figure 4.

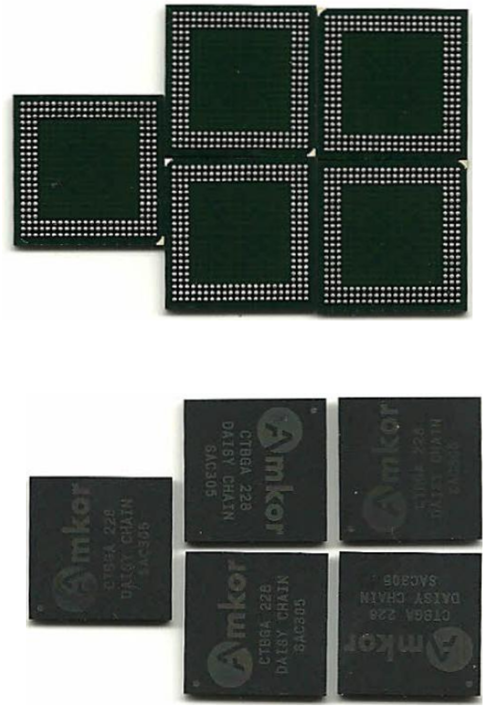
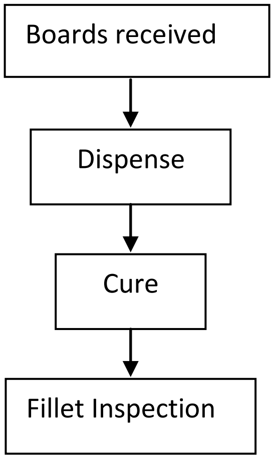


Figure 4. Dummy BGA used in this test

RESULTS AND DISCUSSION

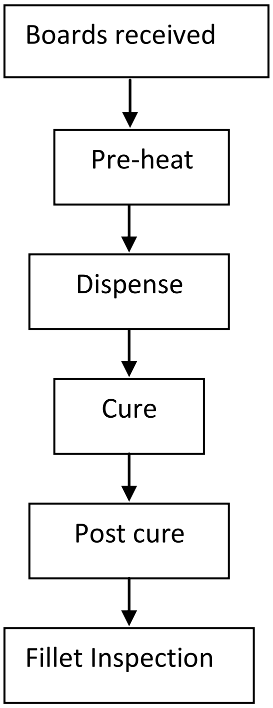
Underfilling Process

SMT 88U underfill series is room temperature underfilling without the request to heat the substrate. Figure 5 shows the comparison of underfilling process and traditional underfilling process. From Figure 5 it is very obvious to see that using SMT 88U can shorten the underfilling process and overcome the difficulty in underfilling process in mobile devices.



(a) SMT 88U underfilling process

Figure 5(a). Comparison of Underfill Process: SMT 88U Underfilling Process Flow Chart



(b) Traditional underfilling process

Figure 5(b). Comparison of Underfill Process: (b) Traditional Underfilling Process Flow Chart

Underfilling Flowability

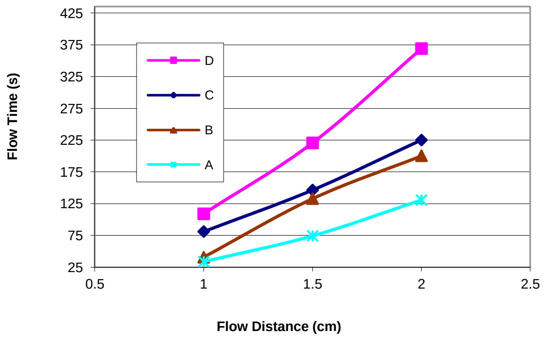
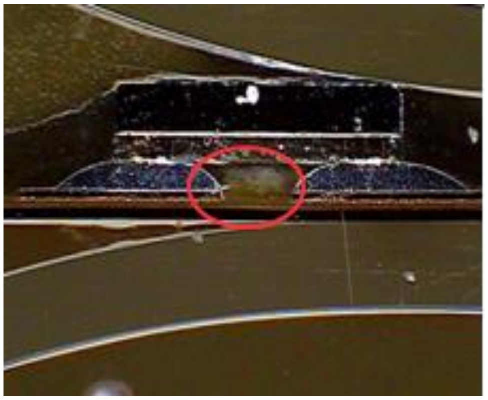


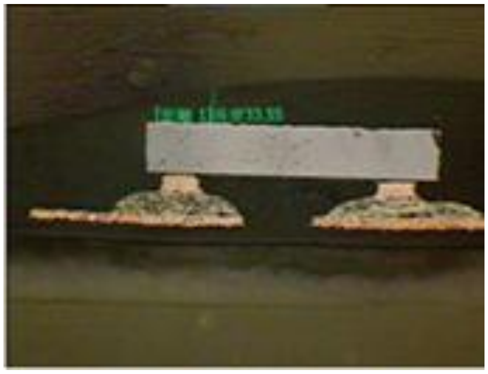
Figure 6. Flow time vs. flow distance of underfill: A – YINCAE SMT 88U; B,C,D – Leading competitors'

The flow test results are shown in Figure 6. It can be seen that flow time difference is increased with the increasing flow distance. There are two factors responsible for the observation of flow time. One is that at the initial stage, the flow rate of underfill was mainly controlled by the surface tension of underfill and interaction between underfill and glass. There is some similarity among underfills from different vendors in terms of epoxy chemistry, in spite of different additives. The second is that with increasing time, the flow rate of underfill is controlled not only by the physical properties but also chemical reactions. There is different chemistry in different underfill vendor supplier. The more and quicker reactions happen at the flow time, the slower flow underfill will be. YINCAE has balanced all physical properties and chemistry very well so that A underfill has performed very well at the beginning of underfilling, much better than other competitors' underfill with increasing flow time.

RFID (120μx120μ) with 10-30μ is used to test the flowability of underfill. The cross-section results are shown in Figure 6 after underfilling process. From Figure 7 (a), we can see there is no underfill underneath the RFID chip using the leading competitor's underfill; but there is 100% underfill filled underneath the RFID chips using SMT 88U underfill which is shown in Figure 7b.



(a) Leading competitor's underfill



(b) SMT 88U

Figure 7. Cross-section Results of Underfilled RFID Chips; (a) using leading competitor's underfill; (b) using SMT 88U underfill

Curing Profile

The curing profile is shown in Figure 8. It could be found that SMT 88U can be cured at very high speed such as a few seconds at 120°C which is similar to UV curable underfill encapsulant or a few minutes at low temperature such as 88°C. This low temperature, high-speed cure underfill can dramatically reduce the risk of electronic compound from exposure to the heat, which usually causes the reliability issue. The curing profile from our leading competitor's has been claimed to more than 8 min. at 130°C. when the heat sensitive electronic component in the device, the heat can be a big issue for manufacturing process if the curing temperature of underfill is more than 100°C.

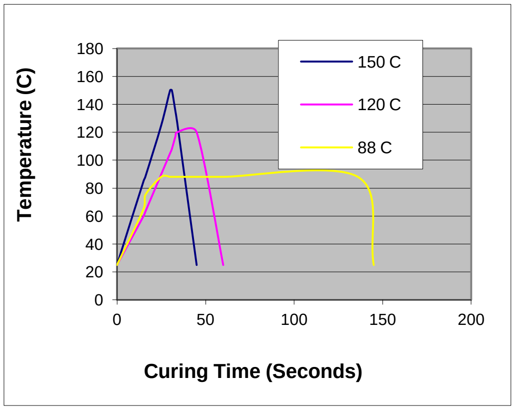
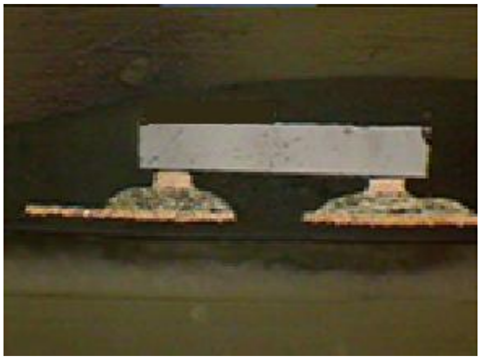
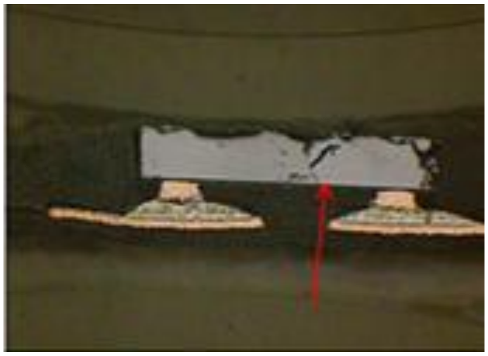


Figure 8. The curing profile of SMT 88U

Bending Test



(a) SMT 88U



(b) Traditional underfill

Figure 9. Cross-section of Underfilled RFID Chips After Bending Test Using: (a) SMT 88U; (b) Traditional Underfill

The underfilled RFID chips were subject to 4 kg bending test. The cross-section results of underfilled RFID chips after bending test are shown Figure 7. From Figure 9a, we could not find any crack using SMT 88U after bending test because there is 100% underfill underneath the RFID chips to dissipate the mechanical stress. From Figure 9b, it can be found that RFID chip were cracked using leading competitor's underfill after bending test. It sounds reasonable that poor underfilled chips could not dissipate the mechanical stress efficiently during the bending test and the weak section started to initiate the crack.

Drop Test And Reliability

The drop test conditions are: six feet height, concrete floor and free fall. Dummy BGAs were used in the drop test.

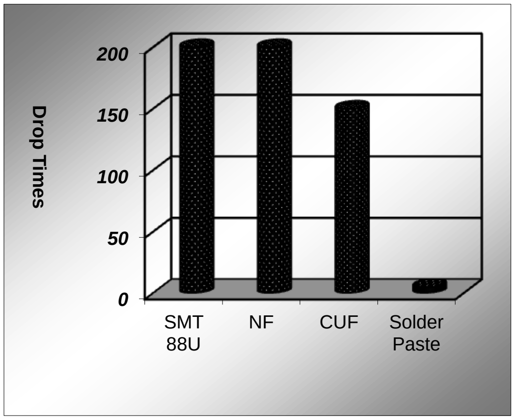


Figure 10. Drop test performance

From Figure 10, we could see the drop times is up to 200 times using SMT 88U underfill which is same as that obtained using no-flow underfill (NF) and similar to that using capillary underfill (CUF), but much better than that obtained using solder paste. The drop test performance is in agreement with the results of the leading competitor's underfill.

Figure 11 shows the thermal cycling performance using different approaches for enhancement. Thermal cycling conditions are: one hour per cycle; temperature from –45°C to 125°C and 15 min dwell time at two extreme temperatures. From Figure 11, we can see the SMT 88U has demonstrated better the thermal cycling performance than leading competitor's capillary underfill (CUF), much better than underfilm process. It is believed that the better thermal cycling performance is mainly from the better homogenously underfilling property from SMT 88U, resulting in dissipating mechanical stress effectively.

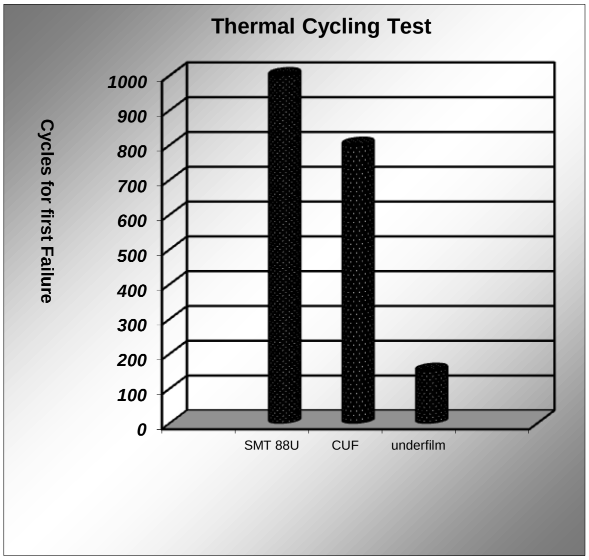
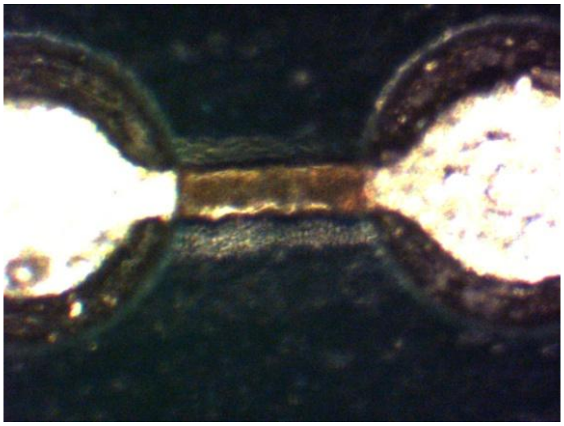


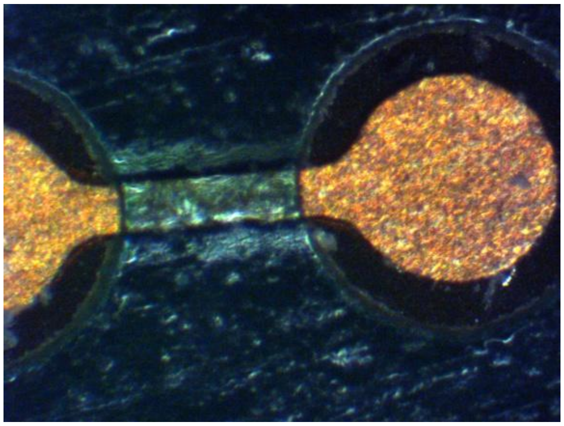
Figure 11. Thermal cycling performance of (a) SMT 88U, (b) CUF and (c) underfilm

The rework process is similar to traditional capillary underfill. First heat up the underfilled component to 245 °C, remove underfill fillet, then remove the component. The SMT 88U underfill and solder were left on PCB side and there was nothing on component. So the component can be bumped directly. The SMT 88U left on the PCB should be brittle and easily removed. Figure 12 shows the image of reworked PCB and new PCB. It should be noted that there is no any damage on the pad and solder mask. So SMT 88U is easily reworkable.

REWORK



(a) After rework



(b) New PCB

Figure 12. Images of PCB: (a) After Rework and (b) New PCB

CONCLUSION

1. SMT 88U has been designed to cure as fast as UV curable adhesives, and overcome the disadvantage of shadow cure, so it is good replacement for UV curable encapsulant;

2. SMT 88U can shorten capillary flow underfill process; fasten curing process and lower down the curing temperature. It can make all kinds of components easily underfilling;

3. SMT 88U can provide excellent reliability and underfill voids free and high throughput process; Cured SMT 88U is very easy to rework.

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