High Reliability and High Throughput Ball Bumping Process Solution – Solder Joint Encapsulant Adhesives

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ABSTRACT:

The miniaturization of microchips is always driving force for revolution and innovation in the electronic industry. When the pitch of bumps is getting smaller and smaller the ball size has to be gradually reduced. However, the reliability of smaller ball size is getting weaker and weaker, so some traditional methods such as capillary underfilling, corner bonding and edge bonding process have been being implemented in board level assembly process to enhance drop and thermal cycling performance.

These traditional processes have been increasingly considered to be bottleneck for further miniaturization because the completion of these processes demands more space. So the interest of eliminating these processes has been increased. To meet this demand, YINCAE has developed solder joint encapsulant adhesives for ball bumping applications to enhance solder joint strength resulting in improving drop and thermal cycling performance to eliminate underfilling, edge bonding or corner bonding process in the board level assembly process. In this paper we will discuss the ball bumping process, the reliability such as strength of solder joints, drop test performance and thermal cycling performance.

INTRODUCTION

With the advancements of the electronic industry, IC components become miniaturized and solder balls are getting smaller. In addition, lead-free Sn/Ag/Cu soldering has higher reflow process temperatures. As a result, there are some reliability issues such as weak mechanical strength of solder joint, and poor thermal cycling performance, which are related to the miniaturization. A few methods that have been or will be implemented in SMT assembly process including capillary underfills, corner bonding, no-flow underfills, and underfilms processes to enhance the reliability of solder joints.

Traditionally the bumping process includes: a): using solder ball and tacky flux; b): using electroplating process; c): using solder paste; d): using molten solder. In order to meet the demand of miniaturization and overcome the reliability issue, the YINCAE team has successfully developed lead free solder joint encapsulant adhesive (SJEA) for ball bumping application, which can enhance solder joint reliability and throughput, and eliminate the cleaning process in ball bumping stage and underfilling in SMT assembly process, particularly for board- level assembly. In this paper we will discuss ball bumping process, yield and the reliability.

PROCESS:

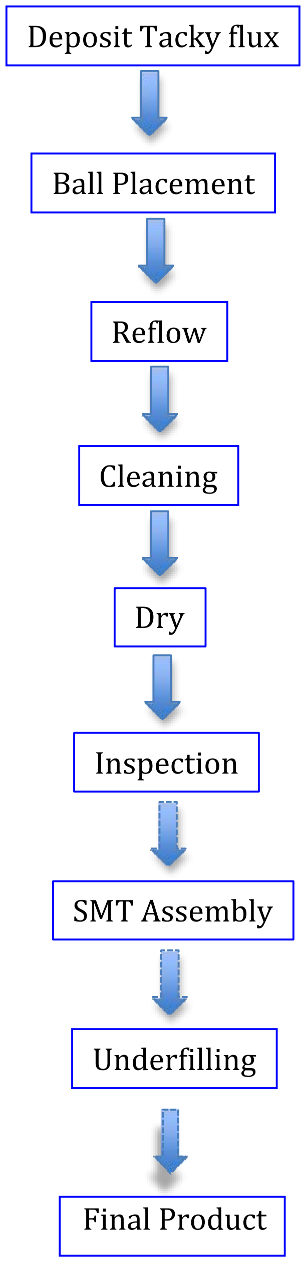


Fig. 1 (a) Traditional Process

Traditional ball bumping process plus brief SMT assembly process chart is shown in Fig.1 (a) and the ball bumping process using solder joint encapsulant (SJE) adhesive shown in Fig.1 (b). Compared (a) to (b) in Fig.1, it is obvious to see that a few manufacturing processes of cleaning, dry and underfilling can be eliminated using solder joint encapsulate adhesive for ball bumping process because of the nature of epoxy and the enhancement of solder joint encapsulant adhesive.

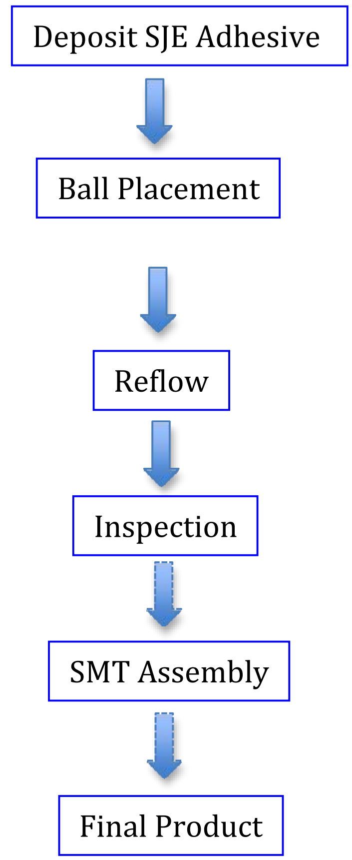


Fig.1 (b) Ball bumping using solder joint encapsulant (SJE) Adhesive

SOLDER JOINT ENCAPSULANT ADHESIVE:

Solder Joint encapsulant adhesive is an epoxy-based resin with flux function incorporated in. Flux function is an essential condition for ball bumping. Using solder joint encapsulant adhesive for ball bumping process normally will face some new challenges. (a) Solder joint encapsulant adhesive has to be stable at room temperature for a period of at least 8 hours; (b) it has to be compatible with the current pin transfer process or printing process. In order to figure out the possibility of process compatibility, the stability of solder joint encapsulant adhesive, the physical properties of solder joint encapsulant adhesive and assembly process have been studied in this paper.

The viscosity of solder joint encapsulant adhesive (SMT 256T) changing with time is shown in Fig.2. It has been found that the viscosity of solder joint encapsulant adhesive does not change with time and is very stable within 48 hours. This provides the foundation for solder joint encapsulant adhesives to be used in the ball bumping process. However, the real working environmental temperature is higher than room temperature. In order to catch the obvious change in the viscosity, the viscosity has been tested at 50°C changing with time, which is shown in Fig.3.

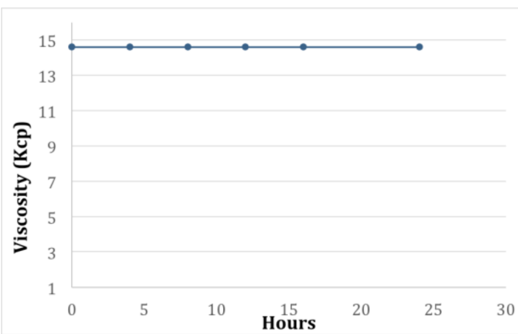


Fig.2 Viscosity of SJE adhesive changing with time at room temperature

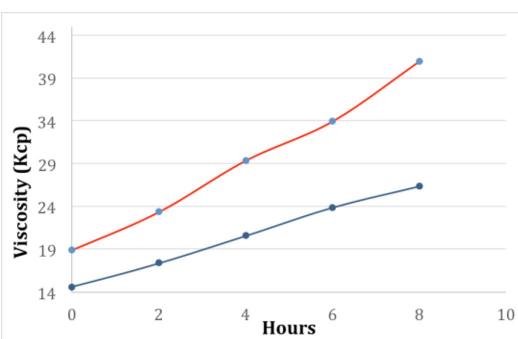


Fig.3 Viscosity of SJE1(-) and SJE2 (-) Adhesives changing with time at 50°C.

Fig. 3 shows the viscosity of SJE1 and SJE2 two solder joint encapsulant adhesives changing with time at 50°C. Although the viscosity of SJE1 and SJE2 both does not change with time in 24 hours at room temperature, the viscosity of SJE1 was more than double in 8 hours at 50 °C, which will lead to process issues for the ball bumping process, and the viscosity of SJE2 was increased by only 40% at 50°C, which still meets the requirement of mass production.

Results and Discussion

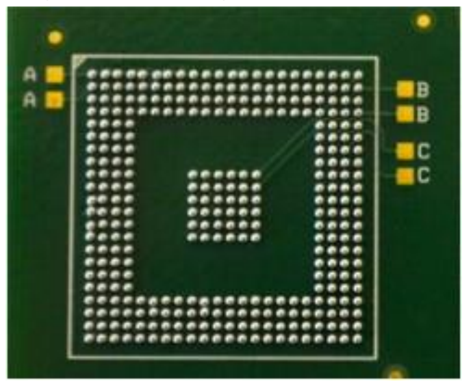
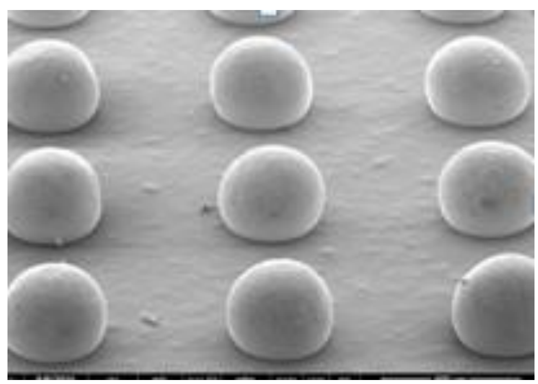


Fig.4 The picture of bumped dummy BGA using SJE Adhesive



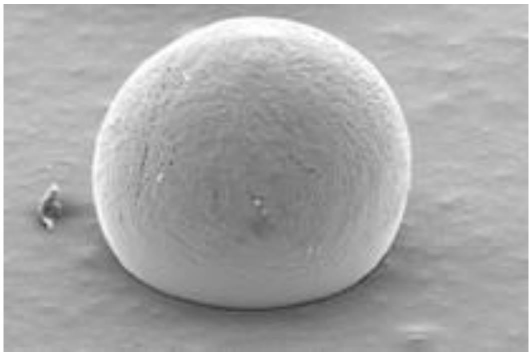


Fig.5 (a) SEM image of ball bumps using Tacky flux

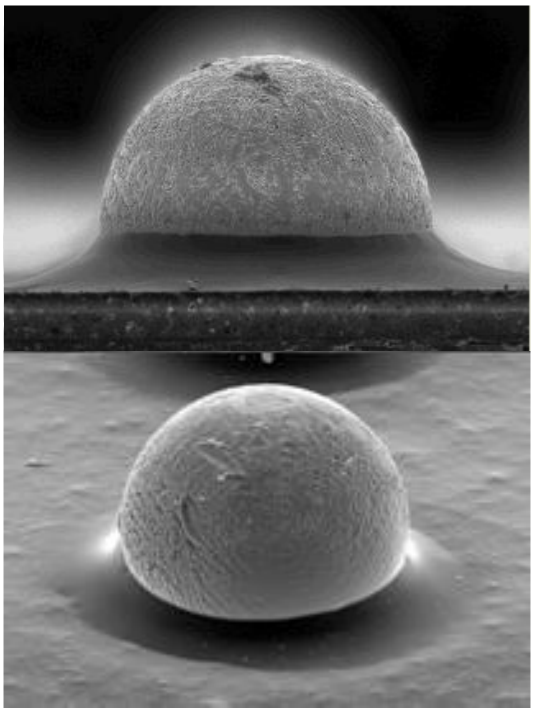


Fig. 5 (b) SEM image of ball bumps using solder joint encapsulant adhesive

Fig. 4 shows the pictures of ball bumped dummy BGA. The bumped solder has a shiny smooth surface, and there is obvious cured epoxy observed due to the colorless solder joint encapsulant adhesives. Therefore, it is unnecessary to clean the components because the nature of cured solder joint encapsulant adhesives is the same as the epoxy in the components and has no cosmetic issue.

Fig. 5 shows the SEM images of bumped solder balls using (a) tacky flux and (b) solder joint encapsulant adhesive. From Fig. 5(a) it can be seen there is nothing encapsulating the solder bumps using tacky flux; while from Fig. 5(b) it can be easily seen that cured solder joint encapsulate adhesive surrounding solder bump on the component side and there is nothing contaminating the top surface of solder bumps, therefore using solder joint encapsulant adhesive won't influence the inspection after ball bumping process.

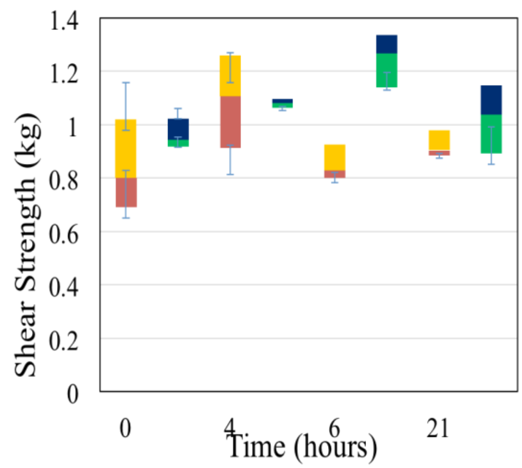


Fig. 6 Ball shear strength using SJE1 ( ) and SJE2( ) in ball bumping process.

From Fig.6 we can see the ball shear strength is over 1kg for 0.3mm SAC solder ball using SJE2. The shear strength is a little lower using SJE1 due to the different chemistry of solder joint encapsulant adhesives. The shear strength is normally from 300 -400g for each SAC solder ball. The results of ball shear strength indicate the solder bonding strength can be improved through the different chemistry.

Process Compatibility:

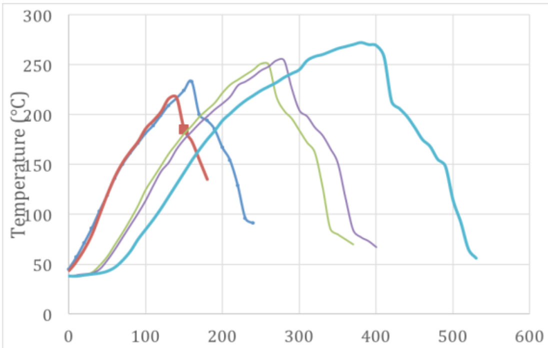


Fig. 7. Different Pb-free reflow profiles

Fig. 7 shows the reflow profiles used in this study with reflow time from short to normal, to long time. Solder joint encapsulant adhesives are typically compatible with industries typical reflow profile, and there is no issue for the other profiles. For ball bumping process the typical industry reflow profile are used here.

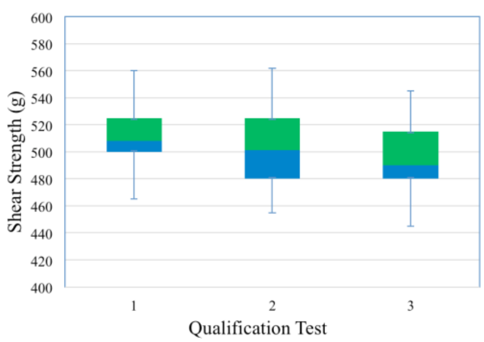


Fig. 8 The ball shear strength from pilot run (3000 BGA)

In order to test the process compatibility, 3x3000 BGA has been ball bumped using solder joint encapsulant adhesive, and the process yield was above 99%. The ball shear strength has been conducted for each lot, as shown in Fig. 8. From Fig. 8 it can be seen that the ball shear strength of three lots is very consistent and there is not a quality issue, which means it is good for mass production.

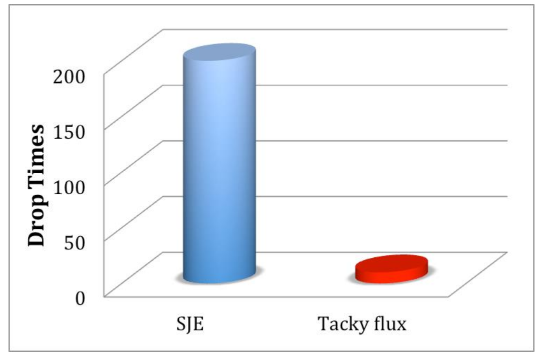


Fig. 9 Drop test of BGA using SJE and Tacky flux for ball bumping

BGA normally has drop test issues using SAC as solder bumps. The drop test has been conducted for BGA using solder joint encapsulant adhesive and tacky flux according to IPC standards, as shown in Fig.9. From Fig 9, it is clear to see that the BGA can pass 200 drops using SJE adhesive for SAC ball bumped BGA, whereas the BGA failed at around 10 drops using traditional tacky flux. Therefore, using solder joint encapsulant adhesive for ball bumped BGA can improve ball bonding strength and this enhancement can help eliminate the underfilling process in SMT assembly stage.

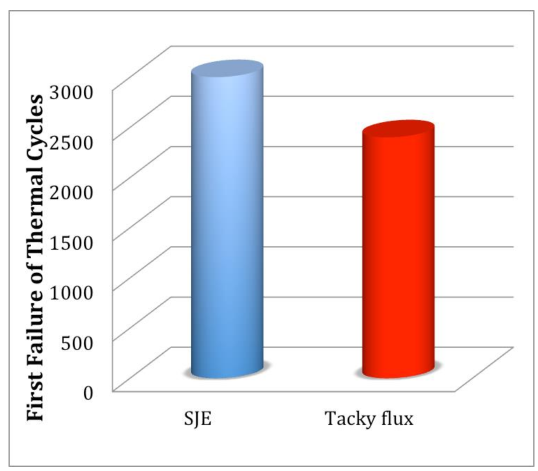


Fig. 10 Thermal cycling test of SJE and Tacky flux

The thermal cycling results of assembled solder ball bumped BGA using SJE adhesive and traditional flux are shown in Fig. 10. The test conditions are: -45 – 125°C, one hour per cycle, 15 dwell time at two extreme temperature. The board-level underfill normally makes the thermal cycling performance scarified due to the large CTE of the board-level underfill. From Fig. 10, it has been found that the BGA bumped using SJE has demonstrated better thermal cycling performance than the BGA using traditional tacky flux. This improvement is because the BGA has better ball bonding strength using SJE for BGA ball bumping process.

CONCLUSION:

A solder joint encapsulant has been successfully developed for the solder ball bumping process. Using solder joint encapsulant adhesive can improve solder ball shear strength and eliminate cleaning for the balling process. The enhancement of solder joint encapsulant adhesive can help eliminate underfilling in SMT assembly stage, as demonstrated by the drop test performance and thermal cycling. A large quantity of solder ball bumped BGA has been pilot-run. The process and reliability data from the pilot-run has demonstrated it is good for mass production.

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