A Lower Temperature Solder Joint Encapsulant for Sn/Bi Applications

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ABSTRACT:
The electronic industry is currently very interested in low temperature soldering processes such as using Sn/Bi alloy to improve process yield, eliminate the head-in-pillow effect, and enhance rework yield. However, Sn/Bi alloy is not strong enough to replace lead-free (SAC) and eutectic Sn/Pb alloys in most applications. In order to improve the strength of Sn/Bi solder joints, enhance mechanical performance, and improve reliability properties such as thermal cycling performance of soldered electronic devices, the company has developed a low temperature solder joint encapsulant for Sn/Bi soldering applications. This low temperature solder joint encapsulant can be dipped, dispensed, or printed. After reflow with Sn/Bi solder paste or alloy, solder joint encapsulant encapsulates the solder joint. As a result, the strength of solder joints is enhanced by several times, and thermal cycling performance is significantly improved. All details will be discussed in this paper.

INTRODUCTION

With the advancements of the electronic industry, IC components become miniaturized, pitch size gets smaller, and I/O numbers increase. In addition, lead-free Sn/Ag/Cu soldering has higher reflow process temperatures. 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, which are related to warpage. A few methods that have been or will be implemented include capillary underfills, corner bonding, no-flow underfills, underfilms and wafer-level underfill processes. All of these processes result in unsatisfactory process yields, sacrifices in reliability, and lengthy application processes, among other challenges. In order to resolve these issues, the company team has successfully developed the first lower temperature solder joint encapsulant adhesive (SJEA) for lower temperature soldering applications such as Sn/Bi, which can enhance solder joint reliability and eliminate the underfilling process, particularly for board-level underfills.

PROCESS

The application process of the company solder joint encapsulant adhesive is shown in Figure 1 below. It should be noted that solder joint encapsulant adhesives can provide the advantage of simple, short, and high throughput manufacturing processes over traditional solder paste plus underfilling process. Lower temperature SJEA has been designed for mass production, which can be applied by dipping, stencil printing, and brushing. The reflow process of solder joint encapsulant adhesive is fully compatible with typical industry solder paste reflow profiles.

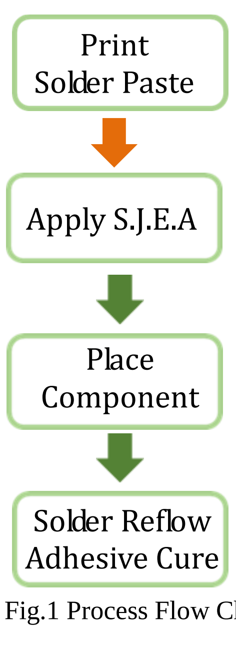

Fig.1 Process Flow Chart

During reflow, low temperature solder joint encapsulant adhesives can remove metal oxide from pads and bumps to allow solder joints to form. Then it is cured to form a 3-D polymer network, encapsulating each individual solder joint. There is no adhesive in between the solder joints to block outgassing channels, which helps to ensure process yield. The schematic of the SJEA encapsulated solder joint is shown in Figure 2 below.

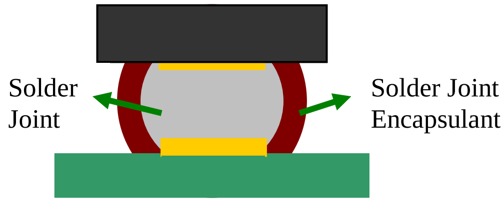

Fig.2 Schematic of Cured SJEA Encapsulated Solder Joint

REFLOW PROFILE

There are a variety of reflow profiles used in the industry now due to the low reflow temperature of Sn/Bi. However, the optimized reflow profile still follows the same guidelines as Sn/Pb or SAC solder. Here, we discuss a few different reflow profiles. Figure 3 below shows the reflow profiles that were studied. One is the linear profile with 60 to 90 seconds above solder melting temperature, which is currently the most popular in the industry. Low temperature solder joint encapsulant is typically compatible with SMT reflow process profiles. However, the soak reflow profile is recommended using low temperature SJEA. There are two factors for this recommendation. One is that solder wetting of Sn/Bi is worse than Sn/Pb, or Pb-free solders. So, the soak above melting temperature is good for advanced components such as BGA/CSP assembly. The second consideration is that the soaking reflow profile is good for SJEA cure.

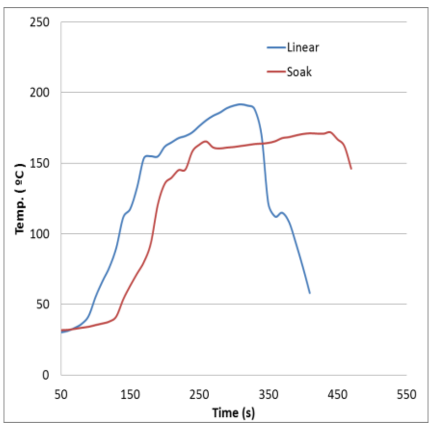

Fig.3 Reflow Profiles of Sn/Bi Solder

SOLDER WETTING

A solder joint encapsulant adhesive was used to mix with Sn/Bi powder (T4) to make low temperature solder paste. SJEA paste and traditional Sn/Bi paste were printed onto copper coupons and then sent to the reflow oven for the solder wetting test. Figure 4 below shows the pictures of the solder wetting. It can be seen that SJEA solder paste demonstrated better solder wetting than traditional Sn/Bi solder paste.

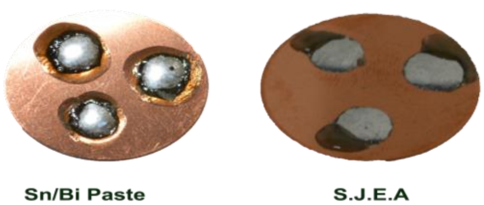

Fig.4 Comparison of Solder Wetting

The spread diameter of solder is shown in Figure 5 below. It can be seen that the spread diameter of Sn/Bi solder paste is 5.8mm and SJEA is 6.5mm. There is about a 15% larger spread diameter using SJEA than that of traditional Sn/Bi solder paste. This indicates that using SJEA to make solder paste can improve Sn/Bi solder wetting. Therefore, SJEA solder paste can replace traditional Sn/Bi solder paste in terms of solder wetting, with much better reliability.

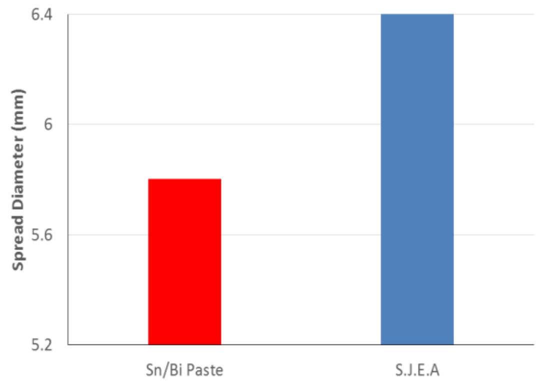

Fig.5 Spread Diameter after Reflow

STABILITY OF SJEA

Figure 6 below shows the viscosity of low temperature SJEA (solder joint encapsulant adhesive) changing with time at room temperature. From the figure below, it can be seen that the viscosity of low temperature solder joint encapsulant adhesive does not change too much during a few months. This indicates that low temperature solder joint encapsulant adhesive solder paste is stable at room temperature.

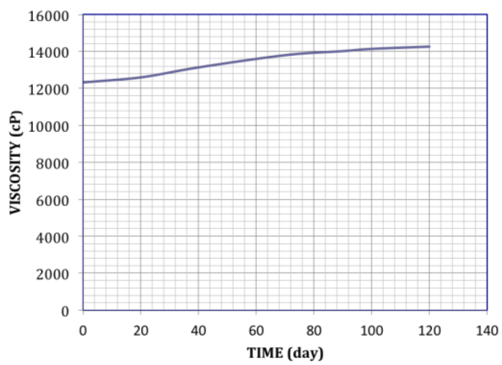

Fig.6 Viscosity of SJEA Changing With Storage Time

It is very important to have room temperature stable solder joint encapsulant adhesive solder paste for mass production, and not be limited to applications for just selected areas like underfilling. However, it is also very challenging to reach this goal due to the existence of the cure reaction of epoxy.

Figure 7 below shows the pictures of two different solder pastes made from low temperature solder joint encapsulant adhesives after room temperature storage for some time. Paste A was totally solid after it was stored at room temperature for a few days. This is because (1) low temperature solder joint encapsulant reacts with solder paste and (2) low temperature solder joint encapsulant can self cure at room temperature. Paste B was still stable at room temperature after being stored for a few months. This indicates that not only is low temperature solder joint encapsulant self-stable, but also less active with solder powder.

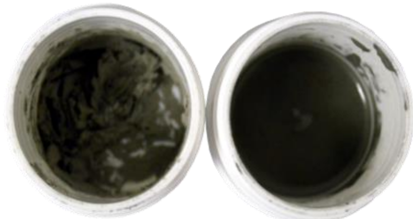

Fig.7 Pictures of Paste A and Paste B After Room Temp. Storage

DROP TEST
The big issue of Sn/Bi solder is that it is too brittle. This makes it very difficult to use in mass production in reliable electronic devices due to its poor mechanical shock. However, the low temperature soldering process of Sn/Bi will not cause too much internal stress for advanced components like Sn/Pb or SAC solders. Low temperature solder joint encapsulant is designed to overcome the weakness of Sn/Bi solder paste.

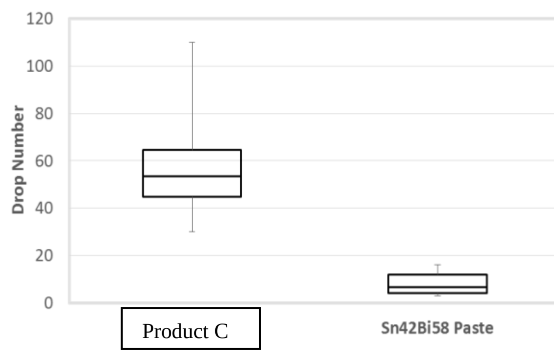

Fig.8 Drop Test of Product C and Sn/Bi Solder Paste

Figure 8 shows the drop test performance of Product C (low temperature solder joint encapsulant solder paste) and traditional Sn/Bi solder paste. The drop test conditions are: six feet drop height and concrete floor. It can be seen that Product C has at least 10 times better drop performance than traditional Sn/Bi solder paste, which means low temperature solder joint encapsulant not only enhances solder joint strength, but also increases ductility.

THERMAL CYCLING TEST

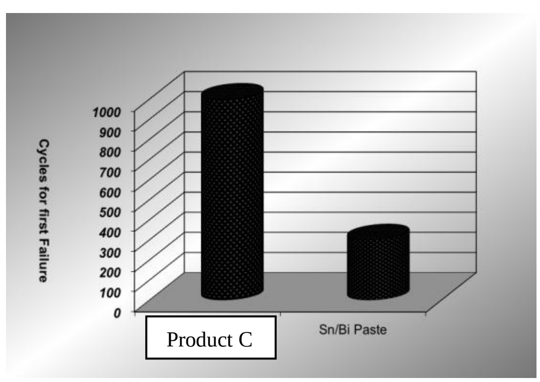

Fig.9 Thermal cycling performance of Product C and Sn/Bi paste (0.5mm pitch, SAC305, I/O 208)

The thermal cycling test was conducted from -45C to 125°C, one hour per cycle. The results are shown in Figure 9 above. It is clear that there is no first failure before 1000 cycles using Product C, but first failure at 300 cycles using traditional Sn/Bi solder paste. This indicates that using low temperature solder joint encapsulant could significantly improve the reliability of Sn/Bi joints.

CONCLUSIONS

A new low temperature solder joint encapsulant adhesive, which is good for low temperature solders such as Sn/Bi has been successfully developed. Low temperature solder joint encapsulant solder paste has demonstrated excellent solder wetting and room temperature stability, which is good for mass production processes. Compared to using traditional Sn/Bi solder paste, using low temperature solder joint encapsulant dramatically improved drop test performance by over 10 times. There was no first failure observed before 1000 cycles, much better than the performance using Sn/Bi solder paste.

REFERENCES

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