Epoxy Flux Technology – Tacky Flux with Value Added Benefits

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Abstract

Since their inception over 30 years ago, underfills have enabled numerous new packages and have provided the required support and reliability needed for highly miniaturized and lead-free devices. It is safe to say that without these essential materials, many of today's advances would not be possible. Continued developments in underfill technology such as enhancements in filler technology, better control of flow rates, new cure mechanisms, improved modulus properties and alternative application techniques have brought enhanced performance capabilities to the market. But, as the industry continues its march forward toward more efficient, flexible and miniaturized devices and component configurations, even more underfill system capabilities will be required.

To date, the four most commonly used types of underfills are capillary flow materials, fluxing (often referred to as no-flow) underfills, cornerbond and edgebond systems. Each of these have relevance for certain applications but some of the newer devices – and even some older generation packages – may benefit from a breakthrough underfill material technology in the reflow cured encapsulant class. The new material system – called epoxy flux – is enabling many applications in both semiconductor packaging and printed circuit board (PCB) assembly, as well as some of the emerging device configurations such as package-on-package (PoP).

Epoxy Flux Underfill Technology

Designed to offer process efficiency, epoxy flux underfills deliver a fluxing component that facilitates solder joint formation as well as an epoxy system that offers added device protection by encapsulating individual bumps. Because epoxy fluxes are cured during the reflow process, they offer an in-line alternative to other underfill mechanisms and eliminate the need for a dedicated dispensing system and the time required to dispense and cure. (Figure 1) These new underfill systems also provide deposition flexibility and, depending on the application and process, can be screen printed, dipped, jetted or dispensed as required. While there are certainly other fluxing – or no-flow – underfill materials that offer in-line processing, none deliver the processability of epoxy fluxes. No-flow underfill encapsulants, for example, have been used in both semiconductor packaging and PCB assembly and, although process efficient, there can be challenges with performance and reliability. Using the no-flow technique, material is applied to the substrate prior to component or die placement and then is cured during reflow. However, since moisture outgassing from the substrates and packages into the no-flow material causes voids, many packaging and assembly specialists have migrated toward reflow-cured cornerbond or edgebond materials that do not fully underfill the device or traditional capillary flow materials. Epoxy fluxes, on the other hand, only encapsulate individual spheres or bumps and, therefore, leave channels underneath the device that allow any volatile gasses from the substrate to escape, while still providing solder joint protection. And, as mentioned previously, these versatile materials can be used for a variety of applications.

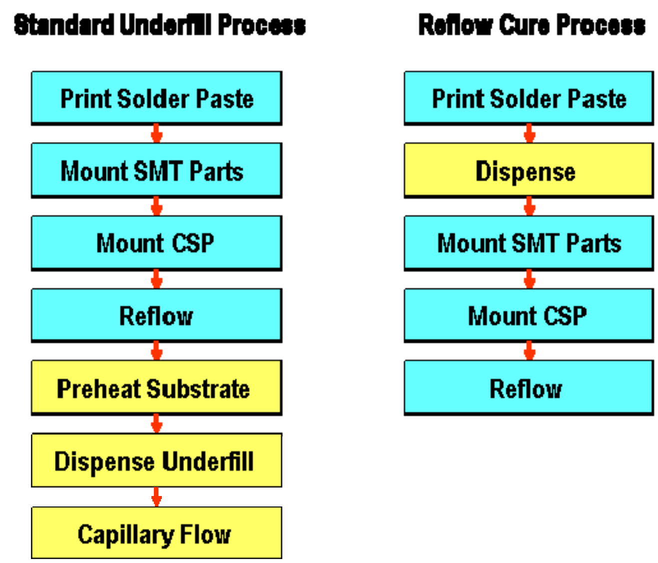

Figure 1: Reflow curable underfills offer throughput advantages

Ball Attach

From water washable to no clean, there are countless tacky flux formulations used for solder ball attach, each with unique features and benefits. Epoxy flux, however, may prove to be the most effective attachment method from a reliability standpoint. Recently, a study was conducted to test the shear strength of four flux types to evaluate the most robust solder sphere attachment mechanism. In the experiment, three solder sphere alloys (all SAC variants) were used: SAC-1, SAC-2, and SAC-3. The shear strength of each solder sphere alloy was tested against four different flux types: two water washable fluxes (Flux A and Flux B), a no-clean flux (Flux C) and an epoxy flux (Flux D). The flux was dispensed as single drops on the copper coupon and the balls were deposited individually by a ball dispenser, which picks up the ball by suction and places it onto the dispensed flux. Using the single ball shear test at a shear height of 30 um and a shear speed of 0.5mm per second, each material combination was evaluated.

With each of the three alloys, it was proven that the epoxy flux material delivered the strongest solder joint as compared to the other three fluxes that were tested. (Figures 2 through 4) These results suggest that higher reliability can be achieved by using an epoxy flux material for ball attach than by using traditional flux formulations.

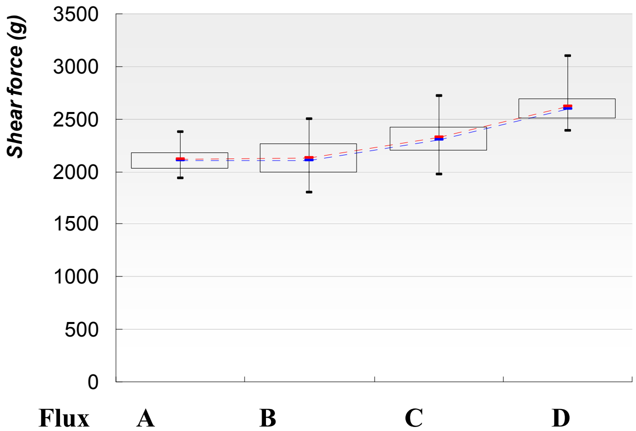

Figure 2: Various flux performance with SAC-1

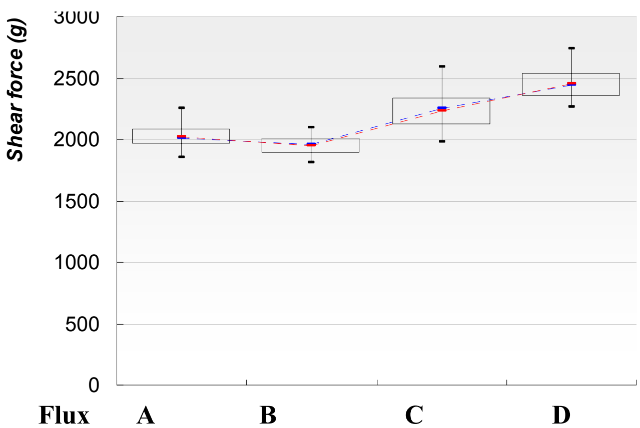

Figure 3: Various Flux with SAC-2

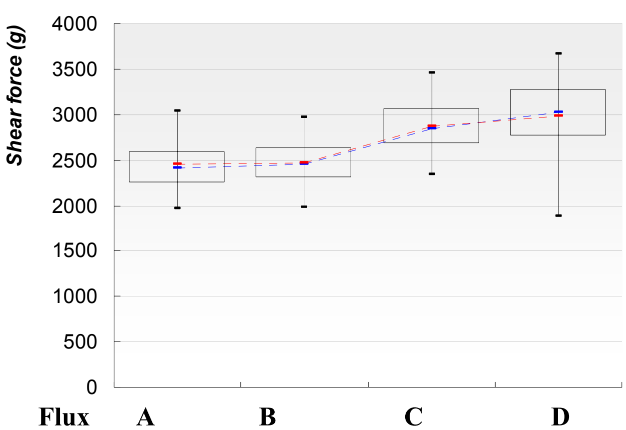

Figure 4: Various Flux with SAC-3

PoP Configurations

Like ball attach processes, epoxy fluxes are also proving to be advantageous for emerging package on package (PoP) device configurations. While PoP devices offer improved efficiency by maximizing PCB or substrate real estate, there are challenges with the second-level assembly of these packages. The bottom level package assembly is very straightforward and follows standard surface-mount procedures. The top level package, however, presents some assembly hurdles to overcome. First, many of these stacked packages experience warpage problems whereby the bottom package may warp downward and the top package may warp upward. This may result in stretched or broken solder joints. In most cases, however, this can be rectified through the use of low-warpage mold compounds. Second, the assembly method of the top package presents challenges related to stress reduction and long term reliability. The most commonly employed attachment method for the level two package is a tacky flux dip where the spheres are dipped into a tacky flux prior to component placement. This offers the flux action necessary to form the solder joint during reflow but device support and protection can be less than adequate. Early evaluations, however, indicate that epoxy flux materials offer the top level device support and reliability enhancement required for these new packages. In a recent analysis of PoP top level attachment mechanisms, four materials were studied: Tacky Flux A (no clean), Tacky Flux B (no clean), a SAC 305 solder paste (Type IV powder with 80% metal loading) and an epoxy flux. The devices were then subjected to drop testing and initial results indicate that epoxy flux offers the most robust performance with the most number of drops before the first failure. (Figure 5) This would imply that the dual function of this material – flux for solder joint formation and epoxy for bump encapsulation – delivers better performance than flux alone. As with tacky flux processes, when using epoxy flux, manufacturers dip the bottom side spheres of the top level component into the material prior to component placement. When the device travels through reflow, the solder joint is formed and each individual sphere is encapsulated with epoxy for an added level of protection. (Figure 6).

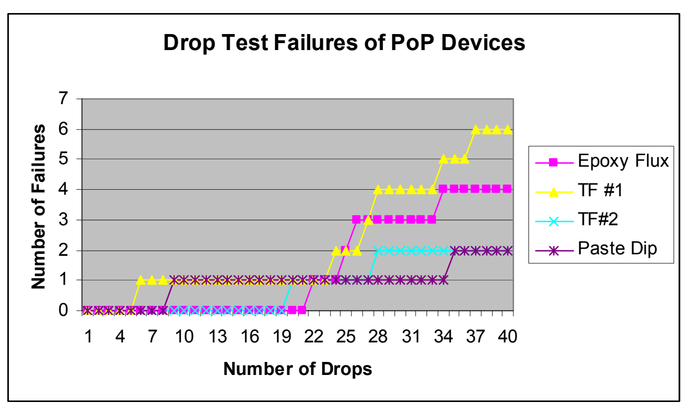

Figure 5: Drop test time to first failure comparisons illustrates reliability of epoxy flux material

Failure analysis was performed on a small subset of devices that showed failures, utilizing a dye and pry method Devices were tested that showed failures at both top and bottom interconnections as well as devices that electrical failures detected only at the bottom interconnection. For the tacky flux system, in both cases we saw cracks on the top interconnection.

On the left in Figure 7 we can see full cracks (these are the devices that had electrical failures on the top and bottom). On the right in Figure 7 we can see partial cracks – this is the device where we only detected electrical failures on the bottom interconnection.

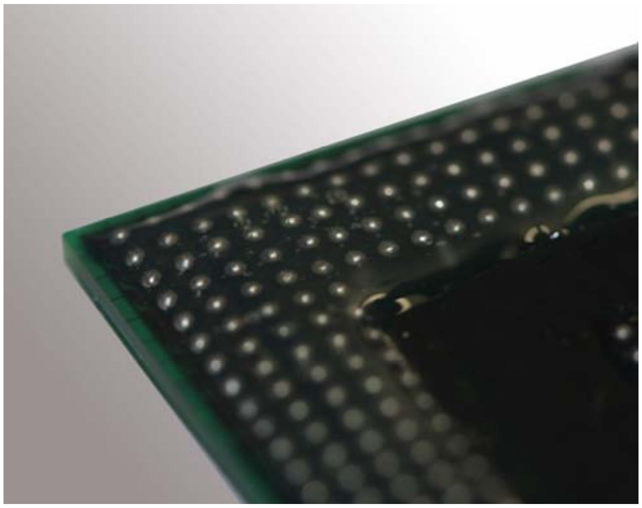

Figure 6: Epoxy flux on a level two PoP device

Figure 7: Cracks found at the top interconnect on both tack flux devices tested using dye and pry

For the solder paste dip system we found cracks on the top where we have electrical failures top and bottom (Figure 8, left). In the epoxy flux system we found that on the two devices tested, no cracks were found at the top interconnect. In fact, only one device fractured at all (at the top interconnection), the other had the stud, used to pry the devices apart, fail first, Figure 9.

Large footprint BGA and CSP Devices

Epoxy fluxes are also delivering cost-efficiencies for traditional assembly operations as well, particularly in the case of large format BGA and CSP devices. With larger devices – generally in the range of 23 x 23 mm or more – traditional underfill techniques require increased volumes of material to be dispensed in order to completely cover the device area. In addition, flow rates and cure times for such large volumes of standard underfill may adversely affect throughput rates and negatively impact units per hour (UPH). Epoxy flux methods allow production specialists to process these large devices in-line, while eliminating the need for dedicated dispensing equipment, cure ovens and the time required for these additional process steps.

Figure 8: Cracks found on top interconnect only where there is an electrical failure at the top level for the solder dip process

Figure 9: No cracks found on epoxy flux system

Conclusions

New package configurations, finer pitches and the need for ever increasing throughput rates are pushing current underfill systems to their limit. Of course, there will always be a place for traditional capillary underfills as well as the newer class of cornerbond and edgebond alternatives. But, for stacked packages, large footprint array devices and many other emerging technologies, older material systems can't offer the in-line processing advantages in tandem with the high level of reliability required for these new products.

Next-generation epoxy flux materials, though, are providing not only the UPH, performance and reliability required for high-volume manufacturing, but also offer a level of versatility heretofore unavailable. With a dual function flux and underfill in one material, epoxy fluxes have a broad application range for both packaging and board assembly environments. With capability for ball attach, PoP assembly, large area array device assembly and protection and much more, manufacturing firms can conceivably source one material for production of various products. And, because the material may be applied via dispensing, screen printing, jetting or dipping, manufacturing flexibility is unprecedented.

The pace of new package development is tremendous. Consumers continue to demand higher functioning, low cost products and manufacturers must keep pace. High volume, high reliability solutions are the only answer for optimization of production environments and new underfill materials technology is enabling these advances.

AcknowledgmentsThe authors wish to thank L Titarenco, H Wang, , TD Chen and Ray Tsai of Henkel for the ball attach data. Also D.Maslyk, J Alonte ,B. Toleno for the PoP data.

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