Selective Flux Jetting Plays Key Role In the Optimization of Process Results For Advanced Packaging Applications

Written for *Advanced Packaging*
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Over the past few years, many new production process technologies have been driven by the migration of advanced packaging technologies, such as flip chip and chip scale package (CSP), into high-volume electronics applications. For example, the effective use of underfill has become a key factor for achieving acceptable flip chip and CSP results. By completely filling the area under the die with encapsulant, the chip is bonded to the substrate, thereby reducing stress on chip bumps. A well-controlled underfill process has proven to materially reduce the risk of damage from thermal cycling and other stresses, thereby significantly improving overall reliability of the final assemblies.

The achievement of consistent results from the underfill process has also necessitated the development of higher precision and more controllable flux application techniques. Unfortunately, traditional techniques for flux application now generally fall short of the precision and consistency requirements for achieving optimal underfill results, especially for today's ever-smaller and denser chip-level designs. The use of too much flux, the presence of flux residue and/or the inconsistent application of flux can significantly degrade the ability of the underfill encapsulant to adhere to all surfaces under the chip, thus eroding the underfill's effectiveness.

The evolution of new flux jetting techniques has significantly improved the ability to effectively control the consistency of flux application while also expanding the robustness and flexibility of the fluxing process.

The Importance of Consistent Flux Application

Precision application of flux within the die's site area is a critical factor in facilitating solder flow and reducing oxides in order to promote the formation of reliable solder joints. However, with the ultra-small dimensions used in today's advanced die-attach processes, too much flux may cause the die to float or move, resulting in misalignment with the pads. In addition, the presence of flux residues under the chip during subsequent underfill processes can cause the encapsulant to interact with the flux, preventing the underfill from properly adhering to the substrate, die and solder joints. Too much flux around the solder balls can also impede the underfill from making contact with the bumped surface causing voids. These effects can result in significant degradation of the underfill's ability to absorb and diminish stresses within the final assembly.

Contact vs. Non-contact Methodologies

Flux patterns for today's die-attach applications often require thickness of less than 1 mil, along with consistently sharp edge definitions and minimal overspray. These escalating requirements for greater precision and consistency, coupled with much smaller product dimensions and tighter working tolerances, already exceed the inherent limitations of contact-based fluxing methods, such as dipping or screen printing. The majority of applications currently use a dipping process, also known as "doctor blade," in which the inline placement machine is utilized to apply the flux. Many manufacturers are now turning to a new non-contact selective fluxing method to achieve greater precision, consistency and process flexibility.

As the newest advance in non-contact selective flux applications, flux-jetting techniques are specifically designed to overcome the limitations of previous non-contact methods such as air spray. Air spray can often require secondary masking operations in order to avoid over-spray contamination, thereby reducing overall process efficiency and throughput.

In contrast, new-generation jetting systems combine non-contact benefits with high precision and robust throughput. Flux jetting systems operate by selectively firing a high-speed series of micro-droplets onto the substrate, enabling the consistent delivery of a wide variety of flux patterns while maintaining ultra-precise edge definition. The jetting head moves in an X-Y plane to dispense pre-programmed patterns, without the need for Z-axis motion or complex height-sensing requirements. Rapid cycle times of only a few milliseconds per micro-droplet, combined with fast and precise X-Y motion systems and the complete elimination of Z-axis movements. In addition, the complete elimination of physical contact with the substrate further speeds the process while simultaneously avoiding contamination risks.

By augmenting the jet fluxing process with the use of "pulsed air assist" techniques, even greater precision control can be achieved. In essence, the pulsed air-assist process emits a quick pulse of air after each micro-droplet or line is jetted, thereby helping to break the natural surface tension and smoothly spread the material onto the substrate. Unlike a traditional spraying process in which the droplets are randomly atomized in the air, pulsed air-assist jetting is a precisely controlled process that deposits uniform lines in exact locations and then uniformly controls their flow out. When dispensing lines, sustained throughput rates as high as 4000 units per hour are achievable.

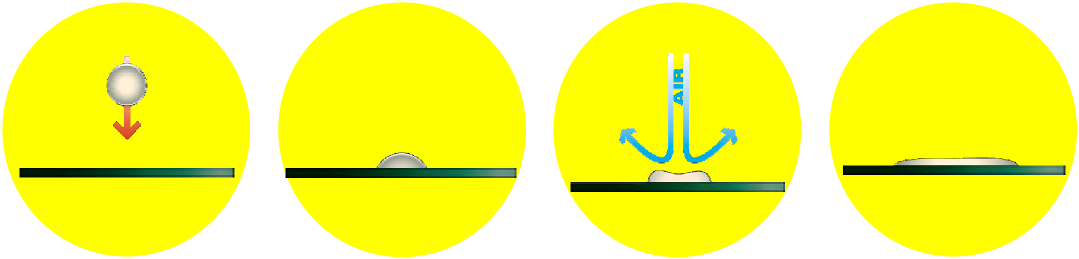

Figure 1 - Coaxial air ™ - Pulsed air-assist technique

Pulsed air-assisted jetting techniques also allow flux to be deposited on the substrate in continuous lines with extremely thin film thickness. By programming the system to dispense micro-droplets or lines, the process engineer can flexibly define the overall shape and thickness to create virtually any required flux pattern on the substrate.

Leveraging Process Flexibility

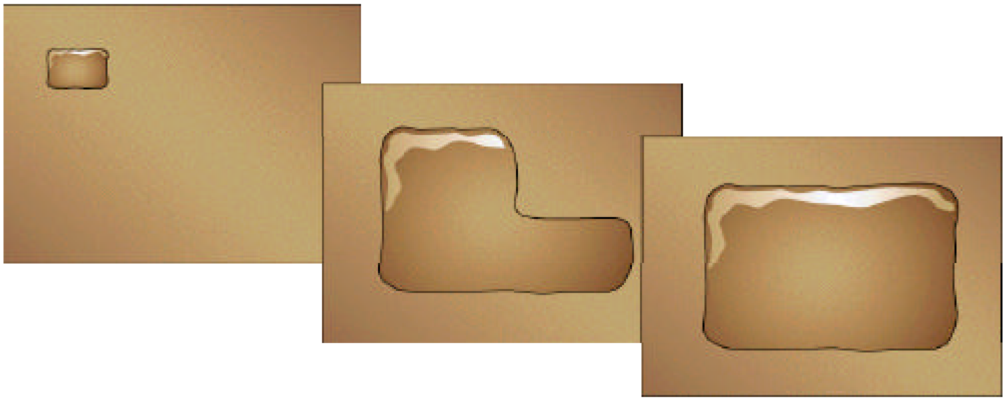

Figure 2- Different Flux Patterns

Selective flux jetting also allows process engineers greater latitude for effectively handling mixed technologies, such as the use of flip chip and CSP devices on the same substrate. These mixed-technology designs have become key to implementing highly integrated miniaturized products. Mixed technologies, however, pose particular problems with traditional dipping techniques. For example, because flip chips use 3 mil solder balls and CSPs use 12 mil, the optimal flux thickness is significantly different for each technology. Dipping processes are not adaptable for applying different levels of flux thickness on the same substrate. On the other hand, a flux jetting process can be readily tailored to deliver a variety of thicknesses on the same substrate by simply modifying the software program to apply the appropriate amount of flux.

Re-evaluating the Tradeoffs of “Tackiness”

The “tackiness” characteristics of flux have become an interesting and sometimes controversial factor that entails some legitimate tradeoffs. Traditionally, high viscosity tacky fluxes have been considered necessary due to the widespread belief that extra tackiness was needed to help keep components in place during subsequent assembly steps prior to reflow. More recent experience proves that flip chip designs typically have so little mass and inertia that they do not require a significant level of flux tackiness to keep them in place. This technology has been successfully implemented in many factories worldwide.

Analysis of flux residue indicates that tackier fluxes have a higher potential for leaving unwanted flux residues after reflow. Tacky fluxes have evolved from solder paste flux formulations and typically include a rosin or synthetic resin base compound that accounts for the majority of the content, with a solvent used to moderate the overall viscosity. In contrast, liquid fluxes such as those used in jetting applications have evolved from wave solder fluxes and consist primarily of solvent as the suspension agent for the active ingredients. Practical real-world experience has shown that tacky fluxes can leave a residual residue of from 25 to 45 percent, thereby significantly degrading the desired results of subsequent underfill processes. In contrast, liquid flux formulations have demonstrated much lower residual residue levels of between 1 to 5 percent.

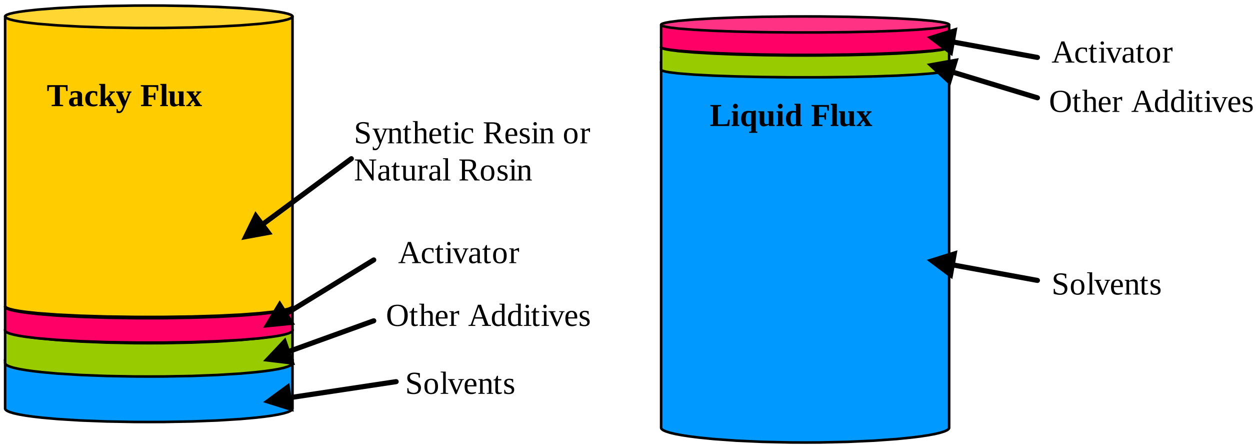

Figure 3 Comparison Between Tacky vs. Liquid Fluxes

The inherent tackiness of fluxes used in dipping applications can also lead to some difficult process control challenges, especially with today's small-size, low-mass components. For example, for small die such as 3mm by 3mm, the force of the flux adhering to the bottom of the die after dipping can be stronger than the force exerted by the vacuum pickup head used to remove the die from the dipping disk. As a result, small die can sometimes be left sitting in the disk, causing disruptions in the process flow and a degradation of overall throughput rates.

Material Control, Clean-up and Environmental Issues

Of major concern with any flux dispensing process is maintaining adequate control over issues such as material pot life or contamination, as well as the management of clean-up and environmental factors.

Contact-based technologies that expose the flux to air can lead to evaporation of flux solvents, causing both environmental concerns and process issues. As the solvent evaporates, the flux can thicken, resulting in the need to replace the unused flux and frequently clean the system. In addition, the die is more susceptible to contamination during the dipping and transfer processes.

In contrast, a closed-loop selective fluxing system eliminates all environmental and materials management issues associated with open-air fluid systems. The liquid flux within the closed reservoir and jetting head is maintained under closely managed pressure, temperature and atmospheric conditions until the moment that it is jetted on to the substrate. In addition, the risk of contamination is greatly reduced through the avoidance of any physical contact between the dispensing system and the components being assembled.

Optimizing Machine Utilization and Return on Investment

For today's high-volume production environments, overall equipment utilization and efficiency are among the primary considerations that are currently driving migration of the fluxing operation to dedicated jet dispensing systems. Because dipping operations are generally handled by expensive component placement equipment, costing $500,000 or more, the negative Return on Investment (ROI) impact of an inefficiently managed process can be quite significant.

As discussed above, dipping processes can necessitate frequent workflow stoppages for issues such as failed pickups of small die, replacing prematurely thickened material, dealing with contaminated parts, cleaning the system, and/or tweaking the process to maintain acceptable consistency. In addition, mixed technology applications can require either multiple process set-ups for different levels of flux thickness or result in sub-optimal settings.

The bottom line is that the primary purpose of sophisticated placement machines is to provide rapid and accurate component placement. These expensive machines are simply not well-designed to readily handle fluxing operations. Not only does the slow, contact-based nature of a dipping process run at cross-purposes to the high-speed placement activities that form the machine's primary task; the introduction of flux into a precision placement machine can result in a maintenance nightmare. Instead, handling the entire fluxing process within a dedicated closed-loop jet dispensing system virtually eliminates the cleaning, maintenance and process-tweaking issues that can otherwise lower the efficiency of a placement machine.

Experience to date has shown that overall production efficiency can be increased by as much as 20 to30 percent by offloading the fluxing process to a dedicated selective flux jet dispensing system. From a return on investment perspective, a 30 percent improvement in productivity and equipment utilization can yield an immediate ROI boost of as much as $150,000 for a typical $500,000 inline placement machine. Not only does the ROI improvement more than offset the entire cost of the dedicated fluxing system, the additional benefits in flexibility, adaptability, and process robustness can continue paying future dividends in the form of faster product introduction cycles and higher quality levels.

References

- Bacher, Brent, Dexter, “Flip Chip Process Guidelines and Considerations,”
- Master, Raj, Ajit Dubey, Maria Guardado, O.T. Ong, Advanced Micro Devices, “Novel Jet Fluxing Application for Advanced Flip Chip and BGA/CGA Packages.

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