Considerations for Lead-Free Reflow Soldering

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Before drawing conclusions about lead-free reflow, take a detailed look at all the features of an oven.

The electronics industry is on the move to lead-free assemblies. This trend is an effort to remove lead from electronic packages and reduce the dependency on lead materials that can leach into the environment during processing or eventual disposal. This effort is driven by environmental considerations, governmental legislation and the marketing advantages of lead-free electronic packages. While many decisions must be made in the implementation of lead-free assemblies, this article will discuss equipment considerations of reflow ovens and the ability to process quality lead-free products.

Solder Pastes

The first step in a company's lead-free initiative is the selection of solder pastes. While many types are available today, the biggest hurdle is finding a drop-in replacement for current leaded materials used. The most dramatic issue facing solder pastes and reflow ovens is higher melting points, which make drop-in replacements for leaded materials difficult to find. To date, the most popular lead-free paste formulations include tin, silver, bismuth and zinc.

The selection of lead-free solder pastes has also been a subject of many technical papers and extensive research. This research suggests that the most effective solder pastes have a melting point of 217°C to 221°C. This range represents a large increase from the traditional eutectic lead pastes with melting points of 183°C. Due to component temperature issues, maximum peak temperature and maximum heating/cooling slopes tighten the reflow process window.

Profiles

With the tighter limitations of solder paste specifications and the concern for damaging components at higher processing temperatures, we must look to different profiles and machine setups to utilize lead-free materials. Two common types of profiles are used in the reflow soldering process and are typically referred to as the *soak* and *tent* profiles (Figure 1).

The soak profile is a process of subjecting the assembly to a temperature for a period just below the liquidous point of the solder to achieve a uniform assembly temperature. The tent profile is a continuous ramp of temperature from the time the assembly enters the oven until the assembly reaches the desired peak temperature.

Desired profiles will differ based on the type of solder paste used within the building of the assembly. Depending upon the chemical makeup of the solder paste, the manufacturer will suggest the best profile to achieve maximum performance.

Lead-Free Reflow Profiling

Due to the higher melting points of lead-free solder formulations, the profiling requirements will change a bit, thus requiring some changes in the setup of the reflow equipment. A change that is commonly overlooked is a flatter profile during the reflow of the solder. Due to the tighter process window, the peak temperature and time above liquidous (TAL) must be achieved without overheating the assembly or components. A longer reflow zone and effective heat transfer to the product are required.

The issues can be solved by using two zones for the reflow requirement or using a reverse spike in the reflow zone. With this method, the second to last heating zone maintains a process temperature higher than the last zone to drive heat into the product quicker. The final zone is used to sustain a uniform temperature in the assembly.

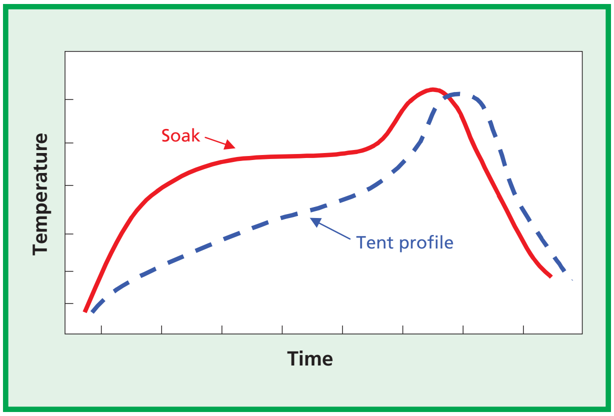

FIGURE 1: Two common types of reflow profiles are the *soak* and *tent* profiles.

Equipment Considerations

Thermal Transfer

The assumption is that a high temperature reflow oven is required for lead free, which is not always the case. What is more important is the efficiency of the machine to transfer the energy to the assembly.

Some reflow systems enhance heat transfer capabilities by enveloping products in evenly mixed process gas. A heat-on-intake design would allow for three independent zone intakes for process gas mixture. The center intake may utilize a finned rod heating element for thermal transfer from the heater to the process gas. This approach allows for a reduction of heater wattage that translates to reduced power consumption. This heating design may reduce power consumption up to 50% over traditional reflow solutions.

The gas heated by the heater elements would be mixed through the blower unit and create a mild back pressure behind the pressure plate. This mild pressure would create concentric circles of air that evenly overlap at the process level for thermal transfer to the product. Another design benefit could be the zone-to-zone segregation of the heated zones for better control of the thermal profile of products being processed.

Cooling the product is just as important as heating in reflow. Extended periods above liquidous times and extreme peak temperatures can cause damage to the product and components. Systems must be designed with recipe-controlled cooling parameters.

In the case of nitrogen systems, a chilled medium such as water is the preferred choice for cooling the process gas for the removal of heat from the product. The chilled water design system should also allow for easy access in the design. In one example, the heat exchangers in which the chiller water passes are mounted vertically to allow flux contaminates to drain naturally via gravity into a flux collection jar. Water connections are made through connection points that allow a tool-free removal.

Nitrogen

Nitrogen serves a couple of purposes in a reflow environment. The use of nitrogen protects board surfaces through multiple reflow passes, prevents oxidation of pads and leads, allows better wicking of leads and produces shiny solder joints.

These results are most evident in the lead-free process. Higher lead-free temperatures will act as a catalyst for the process of oxidation. Nitrogen will help protect against oxidation. Although not required for lead-free processing, nitrogen may allow wider process windows. It also reduces surface oxides and allows better wetting of solder joints.

Reflow systems that are designed for either air or inert configurations are good choices when considering a thermal system. Balanced air flow within the heated zones translates into lower nitrogen consumption with the reduction of turbulence within the oven. Time should be spent on the thermal transfer design and concept with the manufacturer to consider the balance of air flow. The combination of closed-loop blower control and variable speed blowers incorporated into reflow system designs enhances performance and decreases nitrogen consumption.

However, the use of nitrogen can have a downside, which includes initial cost of equipment, the cost of nitrogen and the extra machine maintenance due to the flux volatiles trapped in the machine. When reviewing reflow systems and the use of nitrogen, an efficient system design should be considered.

Volatile Management

Another factor to consider is flux volatile management. The oven should allow for a scrubbing of flux-laden gas in a remote chamber and the return of clean gas to the process chamber.

One example recently developed involves a two-stage filtration/separation system and incorporates self-cleaning to reduce maintenance requirements. The first stage utilizes a mesh strainer contained within a housing. Upon entry into the housing, the flux vapor undergoes an expansion, increasing the pressure and creating liquid droplets, which, if large enough, will fall out of the air stream.

The remainder of the vapor is passed through the strainer, which separates the larger, heavier particles out of the vapor. These particles mainly consist of any entrapped metals, resins and rosins, and they remain attached to the outside of the strainer. This portion helps eliminate the build-up of the highly viscous, sticky and difficult-to-clean residue downstream in the system.

The cleaning of this strainer is achieved through the periodic spinning of it via an attached motor. The centrifugal force exerted on the particles overcomes the adhesion force, attaching them to the strainer, and the particles are thrown outward to the walls of the housing. Since it does not incorporate active cooling, the system remains warmed by the chamber gases passing through. This allows the heavy liquids attached to the walls to run down to the drain jar at the bottom of the housing.

The second stage consists of a packed bed of stainless steel balls contained within a housing. The small, lightweight particles, consisting mainly of alcohols and solvents, contained in the vapor after passing through the first stage are again subjected to an expansion, which increases droplet size. The vapor then passes through the packed bed, making multiple collisions with the steel balls.

Since the liquid contained within the vapor will spread out on the surface of the steel balls, these balls are determined to be wettable. Therefore, upon initial collision of the particles with the balls, heterogeneous nucleation occurs, and the balls become covered with a film of liquid. Once the balls are completely covered by the film, the particles within the vapor collide with this film of liquid. Since these are like substances, homogeneous nucleation occurs and the liquid builds up, forming droplets that flow into a flux collection jar for removal.

Energy Efficiency

Reflow ovens present a concern regarding power consumption in an electronics manufacturing environment. This concern is understandable due to the nature of the process of transferring heat to product, then expending energy to remove heat for the cooling cycle. Efficient heat transfer techniques must be considered to deliver proper reflow profiles for leaded and lead-free processing. But efficient heat transfer becomes even more important in the consideration of power consumption.

A tremendous improvement has occurred in the thermal efficiency and reduced power consumption by improved heat transfer capabilities and improved airflow with newer reflow system designs. Legacy reflow systems tested averaged 21 kW per hour running a leaded reflow profile under idle conditions. Compared with recently introduced reflow systems, power consumption was reduced from 21 kW per hour to 12.2 kW per hour with the new system design. This result is a 41% reduction in power consumption for similar profile performance.

Conveyor Considerations

Conveyor rail systems are the most popular method to transport electronic assemblies through a reflow system. With the higher operating temperatures of lead-free processing, the conveyor rails must be able to maintain strength. Exposed conveyor support shafts and small rail profiles may be taxed at the higher operating temperatures and assemblies with higher mass.

Proven rail system designs allow for thermal expansion and maintain a parallelism of the rail system, reducing the opportunity for printed circuit board (PCB) drop or jam within the system. The rail extrusions may have multiple angles incorporated in the design to reduce the opportunity for rail twisting during the thermal expansion process.

Due to the higher temperatures in lead-free reflow, assemblies may be more prone to warping and board-drop issues. Higher reflow temperatures are closer to the transition stage of the board laminate and, combined with more mass from components, can lead to problems further down the process line.

Center board support (CBS) conveyor systems may resolve the problem. A CBS unit will allow better product support during the higher lead-free reflow temperatures and combat board warping and board-drop issues.

Conclusion

Before drawing conclusions about lead-free reflow, take a detailed look at all the features of an oven. When considering the move to lead-free materials, determine the material and profile requirements. Once these are selected, consult with the oven manufacturer to help develop the desired profiles for your products. With some investigation work, this ideal profile may be accomplished through a tent or a reverse spike profile.

Reflow system options are also important considerations. The use of nitrogen process environments, cooling considerations, conveyor systems and overall system costs of the operation should also be discussed with the reflow supplier. ■

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