Vapor Phase Reflow Soldering Helps Eliminate Manufacturability Challenges

BY LEONARD LACHMANN AND SERGIO CORCUERA

Advancements in technology give us the ability to precisely light rooms with minimal energy use, open doors electronically and use a variety of handheld products that fit easily in our pockets. However, the smaller form factors that come with those conveniences can create manufacturability issues. Smaller products translate to denser printed circuit board (PCB) layouts, smaller, more complex components and inaccessible interconnections. This adds technical complexity to manufacturing process, particularly in the area of reflow soldering. At the same time, many of these products are in competitive markets with pressure to continually reduce price. The end result is that contract manufacturers must find ways to address technical complexity while finding ways to reduce cost.

Protech Global Solutions, LP (www.protechglobalsolutions.com), an electronics manufacturing services (EMS) provider with manufacturing facilities in El Paso, Texas and Juarez, Mexico uses vapor reflow phase soldering technology to deal with many of these challenges.

Vapor Phase: An operator loads the vapor phase reflow soldering system.

In convection reflow soldering, printed circuit board assembly (PCBA) temperatures can easily reach 260 degrees C or higher. At those temperatures steam pressure in plastics and laminates can cause the PCB surface to popcorn or delaminate. Those high temperatures can also damage heat-sensitive components and as result of combination of these factors, make it a difficult task to achieve robust solder joints in the reflow solder process. This is due to the fact that in convection reflow, heating elements in combination with blower motors are creating various hot air zones. The electronic units are moved through the zones on a conveyor. Required conveyor speed, PCB metallization characteristics and heat transfer variances in components can result in overheating if profiles are not carefully designed and the oven doesn't have a large enough number of zones.

Comparatively, the maximum temperature for vapor reflow soldering in this contractor's process is 235 degrees C. This is because a boiling fluid is creating a vapor blanket. The temperature is physically limited by the boiling point of the fluid. The electronic units are moved into this vapor, which is condensing on the cooler electronic units. In most cases, the temperature stays in the 217-227 degrees C range for the bulk of the process. The vapor blanket is inert, which provides perfect wetting properties, minimizing the time required at peak temperature. Speed of immersion and position of the PCBA in the vapor blanket is controlled, which limits tombstoning.

While this contractor continues to use convection reflow soldering for some products, vapor phase reflow soldering technology is used for products with thermal sensitivity, ball grid array (BGA), land grid array (LGA), Chip Scale Package

(CSP) components or mixed technology.

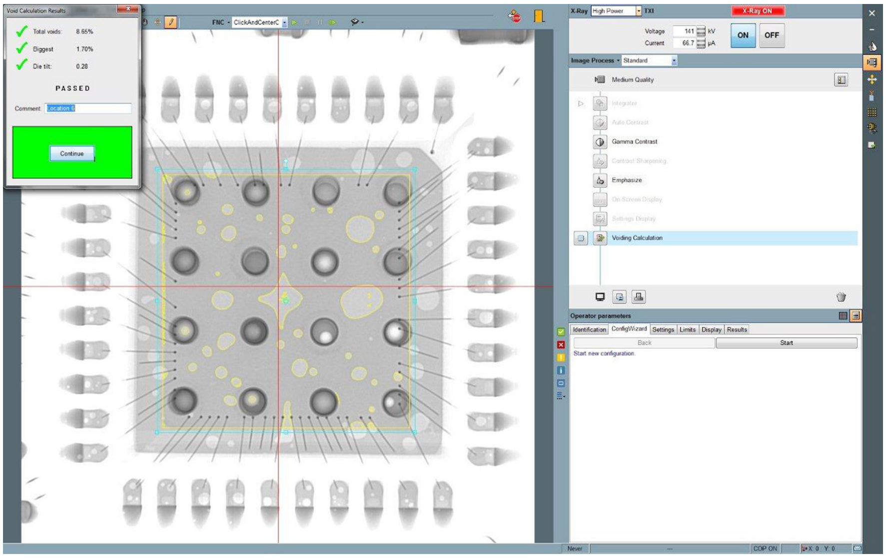
For example, vapor phase reflow soldering solves several manufacturability challenges for one LED lighting product. The PCBA uses an FR4 substrate with 2 ounces of copper to help dissipate the heat generated from the LEDs. There are open thermal vias near the LEDs, to further help with heat dissipation. The solder mask is white for maximum reflection of the light generated by the LEDs. The unit uses CREE LEDs with a soft silicon dome requiring a reduced speed for SMT placement resulting in a longer placement cycle time.

With conventional reflow soldering, the additional copper causes unbalanced wetting forces which lead to tombstoning. The thermal vias near the LEDs would require careful control of atmospheric pressure in the inner chambers of a convention reflow system to control airflow through the vias. The white solder mask would discolor and darken with post reflow residue if peak temperatures reach 270 degrees C. With vapor phase reflow soldering, the inert vapor blanket eliminates the potential for uneven heating or damage related to hot air flow during reflow. Since the maximum temperature is 235 degrees C, there is no discoloring of the solder mask and flux residues have a clear color.

Vapor phase reflow also addresses an issue created by the longer SMT placement cycle time. When solder paste is exposed to air, it dries out and loses its flux. With convection reflow soldering, this can result in bad solder fillets due to insufficient wetting. However, with vapor phase reflow soldering the longer exposure of solder paste to air due to the extended cycle time was not an issue because wetting is enhanced when reflow is done in an inert atmosphere. In fact as a test to determine what issues long-term air exposure could cause, a screen printed PCBA was left out for 24 hours and components were placed and then reflowed using vapor phase. The wetting and solder fillet quality were visually identical to a PCBA assembled using a screen print, place, reflow cycle time designed to minimize the time that the solder paste was exposed to air.

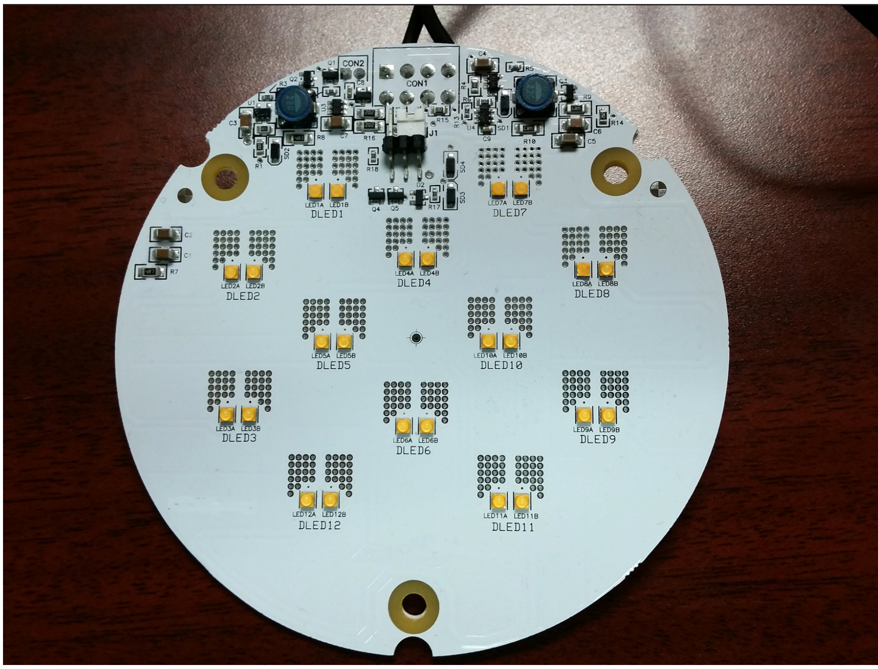
Vapor phase reflow soldering and a good stencil design can eliminate common defects found in convection reflow soldering of PCBAs incorporating BGAs, LGAs, quad flat no leads (QFNs) and small components, such as 0201s. Convection reflow soldering uses forced hot air. Different packaging styles and sizes, particularly those where the interconnection is entirely under the component can impact the overall efficiency of that process and the speed at which solder melts around or under the component. With vapor phase reflow soldering, the soldering chamber is filled with an inert liquid for the creation of the vapor. The liquid, in this case Galden fluid, possesses a boiling point equal to the process temperature. On start-up the liquid is heated up to its boiling point and vapor rises above the liquid, since due to its higher molecular weight the vapor displaces the ambient air above it. The phase change from vapor to liquid sets free large amounts of thermal energy without any differences in temperature. Even high mass parts in the vapor blanket are thoroughly heated up to the vapor temperature without higher reflow temperatures in this inert (non-reactive) vapor phase as vapor surrounds the PCBA from both above and below. Since densely packed PCBAs, BGAs and LGAs heat uniformly in the vapor, issues caused by uneven heat distribution such as tombstoning, shadowing and excessive voiding are eliminated.

For example, the contractor also assembles a PCBA used in a handheld door opening product. Components include 0201s and a QFN, plus a large copper ground plane. In a convection reflow process, the PCBA would need to travel at lower conveyor speed to achieve optimum wetting on the QFN. However, that would also cause excessive heat build-up in the copper ground plane and could negatively impact the solder joint quality of the 0201s. In short, profiling would be difficult because of the length of cycle time and uneven heat distribution caused by the ground plane. Conversely, the vapor phase reflow process eliminates these thermal challenges. Good wetting is achieved more rapidly with the QFN and the 0201s heat evenly, minimizing the chance of tombstoning or alignment issues. X-ray inspection of the PCBA following vapor phase reflow soldering showed 2 percent voids, roughly a tenth of the allowable limit.



Void Calculation: X-ray inspection of the PCBA following vapor phase reflow soldering showed 2 percent voids, roughly a tenth of the allowable limit.

Another technical benefit is that immersion in an inert vapor blanket results in an increase in solder joint strength and cleaner PCBAs than found in a reflow soldering process. The oxygen-free atmosphere in vapor phase soldering system allows the use of low residue, no-clean soldering flux paste, which significantly increases the overall cleanliness of the assemblies. After leaving the vapor phase any remaining fluid on the PCBA evaporates and a dry and securely soldered PCBA leaves the soldering chamber. This lack of excess



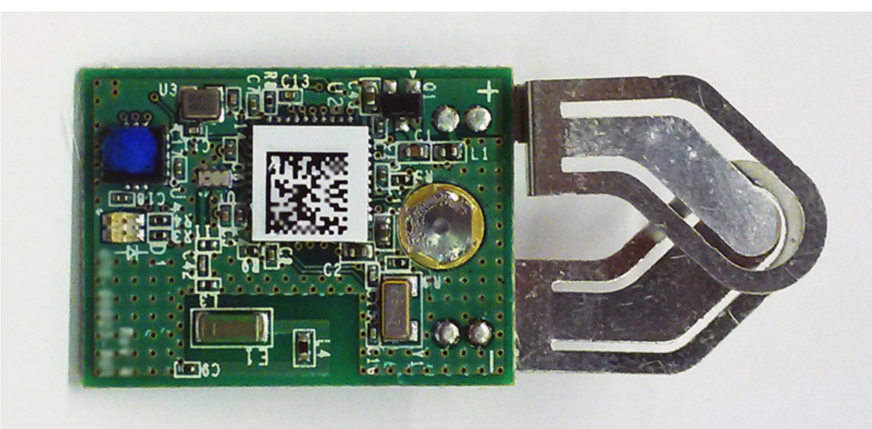
Board 1: Example 1, a PCBA which includes temperature sensitive solder mask and LEDs, FR4 substrate with 2 ounces of copper, open thermal vias near the LEDs and extended placement cycle time.

flux or other residues often eliminates the need for additional post-solder cleaning steps, cleaning of flux residues in restrictive areas and cleaning equipment. The process also results in shiny solder joints. While not significantly different in interconnect quality from dull solder joints, the shiny appearance improves the overall visual appearance of the PCBA.

From a high mix, variable demand perspective, there are a number of advantages. Vapor phase reflow has a broader process window, which translates to fewer profiles and faster changeovers. Other than profile adjustments, no changes are required to switch from leaded to lead-free product. It can also be used to solder through-hole components. As the number of through-hole components continues to shrink on mixed technology PCBAs, the ability to eliminate manual or selective solder processes becomes an increasingly attractive option and, more importantly, cost effective. Finally, elimination of defects such as tombstoning and excessive voiding reduces rework in BGA and CSP technologies.

Environmentally, vapor phase reflow soldering uses less energy, since 90 percent of the heat generated is focused on heating the PCBA. Direct energy consumption is typically one-fifth of that used by convection reflow soldering equipment. It is a closed loop process with minimal waste as the fluid used to generate the vapor blanket is reused. There is also no need for nitrogen storage and use, since the vapor blanket creates an inert environment.

In a perfect world, PCBAs are designed to be manufacturable within the manufacturer's existing equipment parameters. However, the pace of change in the electronics industry seldom allows that degree of conformity. The diversity of customers and design constraints found in the contract manufacturing environment does not easily support rigid conformance to a narrow range of automated assembly options. In this contractor's experience, the addition of vapor phase reflow soldering technology has added flexibility in cases where application-driven PCBA design choices added complexity to convection reflow soldering. Additionally, the technology has also eliminated the need for secondary processes such as selective soldering, rework or cleaning on some products. This, in combination with reduced programming and changeover time compared to convection reflow soldering, aligns well with Lean manufacturing philosophy. The technology also contributes to an environmentally friendly process reducing the use of solvents and cleaning equipment along with lowered energy costs. In an industry continually driven to build things better, faster and cheaper, vapor phase reflow soldering technology provides a solid, cost effective solution to difficult-to-profile PCBA designs.



Board 2: Example 2, a PCBA which includes a QFN, 0201s and a large copper ground plane.

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