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ASSEMBLY AND REWORK OF LARGE SURFACE MOUNT CONNECTORS WITH WAFERS

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ABSTRACT
The advancement in performance of motherboard-daughter-card interconnects has been significantly increasing for several years.[1] Due to the constraint of board surface real estate, the increase is seen in the higher I/O counts and the decrease in the signal integrity acceptance window. Through this evolution there has been a migration to ever more complex surface mount connectors. The complexity factor creates new challenges in assembly and rework of these connectors. The difficulty manifests itself through a number of factors; the increase in connector body size, the increase in mass, a significant increase in the number of contacts, or leads, the increase in lead density, the number of rows of leads which are now hidden by the connector housing from inspection or from touch-up all make the assembly and rework of the connector much more challenging. The use of advanced vapor phase reflow equipment is a key element to the success of this process. This paper will discuss how to assemble this type of connector, how to rework the connectors and how to assure compliance to all connector requirements without sacrificing solder joint reliability and performance.

Key words: Surface mount connector, PCBA assembly, Full connector rework, partial connector rework, vapor phase reflow and wafers.

INTRODUCTION
This paper will go through in detail the processes necessary to assemble and rework large surface mount connectors, both headers and receptacles, with wafers. Special process steps are necessary due to the large footprint and mass of the connector. The process is built around the requirements of the large SMT connector itself. See figure 1. In figure 1 the large array of signal leads and power leads can be seen. The true position and co-planarity of the leads and wafers must be maintained throughout the entire attach and rework process.

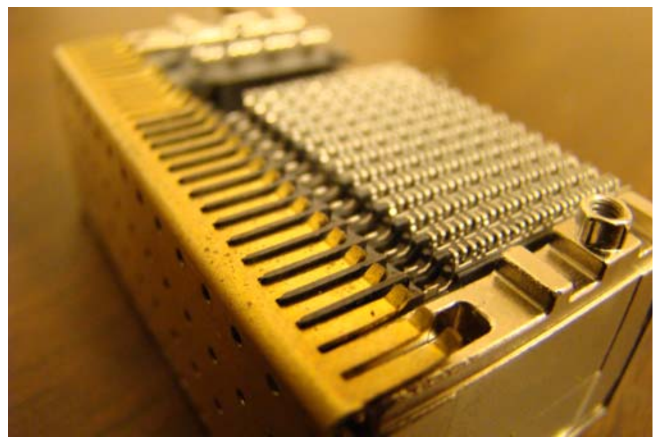

Figure 1: Large Surface Mount Connector with Wafers

Vapor Phase Reflow
Due to the thermal mass of this connector, it is difficult to increase the temperature evenly between the rest of the printed circuit assembly (PCBA) and the connector, to reflow all solder joints at a specified temperature window with the conventional convection reflow oven. [2] Vapor phase, also known as condensation soldering, involves heating an inert, electrically non-conductive fluid in a sump to its boiling point and generating saturated vapor above the fluid at the temperature of the boiling point of selected fluid. The selected fluid needs to have a boiling point higher than the melting temperature of the solder paste used for the printed circuit board; typically 215^{o}C for SnPb and 240^{o}C for Pb-free solder reflow. The PCBA to be soldered is lowered into this sump to the level of the vapor blanket above the boiling liquid. As the saturated vapor comes into contact with the room temperature PCBA, it begins to condense on the PCBA thus transferring thermal energy to the PCBA. The condensed vapor forms a boundary layer enclosing the PCBA due to the high surface tension of this fluid. The film, due to its specific heat, transfers energy and distributes it uniformly across the assembly. Condensation continues until the entire PCBA reaches the same temperature as the boiling point of the fluid. The solder

paste melts as the temperature exceeds its melting point. Since the fluid has a specific boiling point, the PCBA's maximum temperature is limited by the boiling point of the fluid. Once reflow is complete, the PCBA is slowly removed from the vapor blanket above the sump so that the condensed fluid will vaporize once more, leaving the assembly dry.[3]

Besides ensuring that the other component packages of vastly smaller thermal mass are not overheated, vapor soldering also has several other benefits:
- The fluid boundary layer which forms over the printed circuit assembly excludes oxygen during the solder reflow process, eliminating the need for the use of an inert nitrogen atmosphere.
- As the processing temperature is defined by the boiling point of the selected fluid, processing conditions are tightly controlled and reproducible.
- Through the energy transfer process the vapor pressure ensures penetration into even very small stand-offs or crevices eliminating much of the shadowing effect from the process. Even very large thermal mass SMT components can be soldered with excellent repeatability.

ASSEMBLY PROCESS

The assembly process proceeds as normal through the SMT line until just prior to reflow. The connector is placed on the PCBA, it is clamped in place and reflow is achieved in vapor rather than a hot gas convection environment.

There are many key elements to make high quality solder joints in production. One critical element is the connector lead true position and tight tolerance control. A special fixture is required and designed to apply uniform load to properly seat the connector. See Figure 2.

Figure 2: Fixture to apply uniform load across the connector

Once reflow is complete, the PCBA is cooled to room temperature and then removed from the fixture. At this point the assembly is complete with the large connector solder attached to it. Other than vapor phase reflow and the uniform load fixture, the rest of the process utilizes normal SMT processing.

In-process Connector Verification

Each PCBA should be inspected for solder paste volume and height before reflow. Prior to measurement, calibration of the equipment that measures the solder paste volume and height must be performed as per the manufacturer's procedures and requirements.

Requirements for Signal Connectors (signal, ground and power SMT Lands): For the process controls on the solder paste deposits:
- Solder paste volume within limits,
- Solder paste height within limits.

Bridging, insufficient solder, missing and misaligned solder paste are not allowed.

Process capability analysis is performed with excellent results. See figure 3.

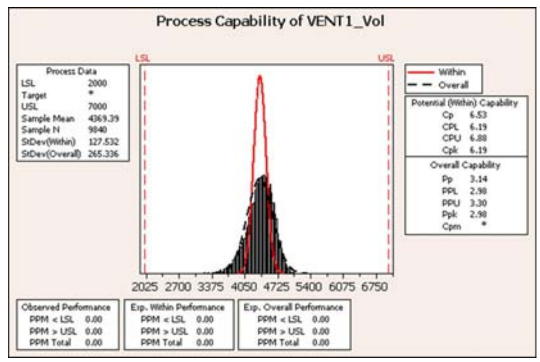

Figure 3: Solder paste process capability analysis

SMT Pallet Calibration

The SMT reflow fixtures must be calibrated for proper load to ensure that the connector has successful SMT Contact with the SMT Lands of the PCB. This calibration should consist of the combination of using pressure sensitive film and/or solder paste impressions. Solder paste impressions are a requirement for the calibration. The SMT Pallet must be able to remove global warp of the PCB and meet the site flatness requirements while the load is applied.

X-Ray Inspection

Each PCBA is inspected for the quality of solder joints post reflow. Recent transitions in the technologies and architectures used in PCBAs have reduced the access points of traditional test techniques. Larger array packages with tighter pitches and higher I/O count and signal integrity concerns make it more difficult to break out all signals to test points. Therefore, X-ray inspection provides a solution to check the solder joint quality inline. Conventional micro-focus transmission X-ray can be utilized for inspection of solder bridging, solder opens, and wetting.

Cross-section Analysis

Cross-section analysis is an offline verification method to evaluate the quality of large connector solder joints. See figures 4 and 5 for examples of excellent solder joints.

Figure 4: Cross-section of a ground solder joint connection

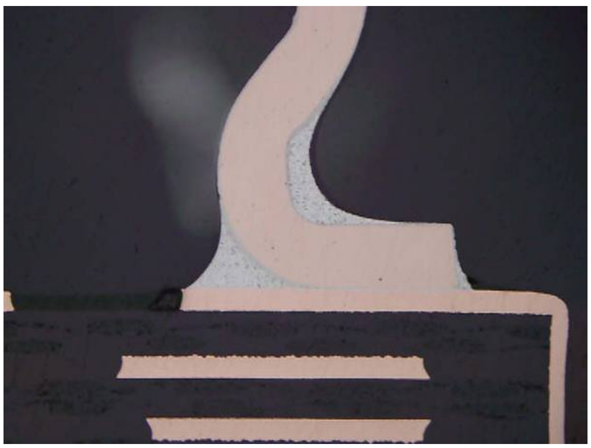

Figure 5: Cross-section of a signal solder joint connection

Rework

Rework for both the header and receptacle are performed with hot gas rework. See figure 6 for a typical rework process flow. Repeatability of the reflow process is very critical to the success of this operation. A thermal profile board is created for the purpose of developing an acceptable rework profile. For both the header and receptacle, rework is typically performed five wafers at a time.[4]

Thermocouples are placed in the solder joints of the 5 wafers to be replaced as well as the neighboring solder joints. A typical thermal profile can be found in table 1.

Table 1: Rework Thermal Profile Objective

Parameter	**Objective**
Ambient Temperature	20-30 Deg. C.
PCB Preheat Temperature	120-150 Deg. C.
Time between 135-165 Deg. C.	20-40 S.
Solder Joint Temperature	200-220 Deg. C.
Time above 183 Deg. C.	60-120 S.
Adjacent Component Temperature	< 183 Deg. C.

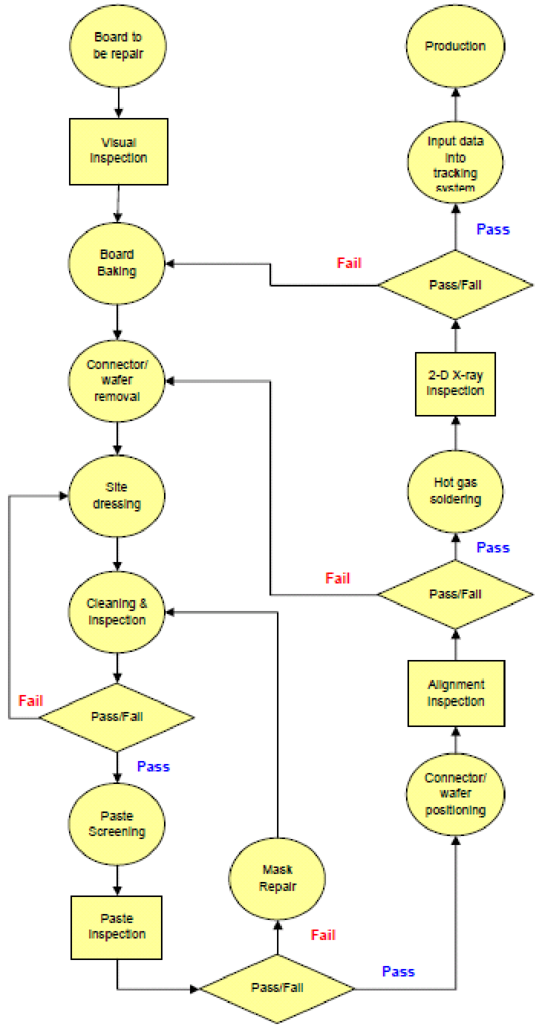

Figure 6: Typical rework process flow

After the thermal profile is established, there are several steps to the rework process[5], starting out with identifying and marking the 5 wafers that require rework. The steps for header and right angle receptacle are essentially the same when taking into account the differences in geometry between the two. Once the wafers are identified, the wafer organizer is removed with the organizer removal tool. See figure 7.

Figure 7: Organizer removal tool

The retaining screws are first removed and the organizer removal tool is used to ease the organizer(s) from the connector. Once the organizer(s) are removed, they are replaced with temporary organizers. See figures 8 and 9. Two five wafer organizers are attached to the wafers about to be removed and short organizers are placed on either side of the wafers to be removed to assure the connector maintains its true position integrity and that the adjacent solder joints are undisturbed.

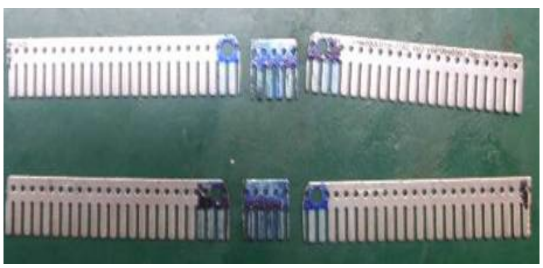

Figure 8: Temporary Organizers used for a header connector

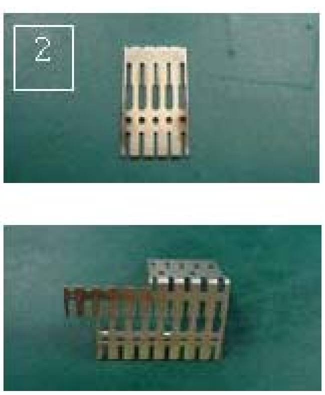

Figure 9: Temporary organizers for right angle receptacle

A special hot gas rework nozzle is attached to the five wafers to be reworked and the entire assembly with the rework nozzle is placed on the hot gas rework tool. See figures 10 and 11. The hot gas rework tool is run through its profile first with global preheat of the assembly and then reflow of the wafers to be removed. The rework tool needs to be capable of a high degree of repeatability when running the thermal rework profile. Preheat is essential to assure that flatness of the assembly is maintained during the rework process.

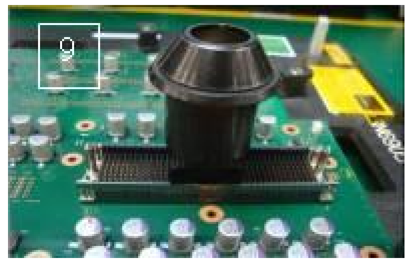

Figure 10: Connector with temporary organizers and nozzle attached.

Figure 11: Rework nozzle for right angle receptacle

Once the wafers are removed, the site is inspected for lifted pads, damaged solder mask and for general damage to the site and adjacent wafers. Also a microscope and small mirror are used to inspect the adjacent solder joints to assure they are undisturbed. Then Kapton tape is placed to protect the adjacent wafers during the redress process. See figure 12. Once the Kapton tape is in place, the solder joints are dressed with a chisel tip solder iron, flux and possibly Soder-wick.[6] The objective is to remove most of the solder without exposing the intermetallic layer beneath the solder.

Figure 12: Kapton tape used to protect adjacent wafers during site dress

The target condition after site redress is nice shiny pads, with no icicles, no dewets/non-wets, no solder mask damage and no damage to the adjacent wafers. A post redress inspection is performed to assure that the site is acceptable and ready for solder paste printing. A micro-stencil is registered to the pads underneath it with a microscope and then taped in place. Paste is applied to the stencil and spread across the site. See figure 13.

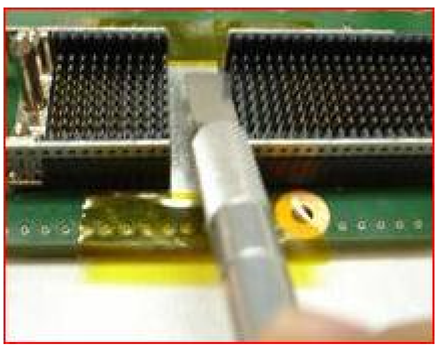

Figure 13: Applying solder paste to the rework site

Carefully, the stencil is lifted and removed once the solder paste has been printed. The solder paste is inspected for proper height and volume and to assure there is no extraneous solder paste on either the five wafer site or the adjacent wafers. This is performed with automated paste inspection equipment and backed up with a stereo microscope. At this point the temporary organizers are removed.

Replacement wafers are inspected for bent leads and the general condition of the wafers. Once they are deemed acceptable, they are loaded into product organizers that will be placed back on to the connector. See Figure 14.

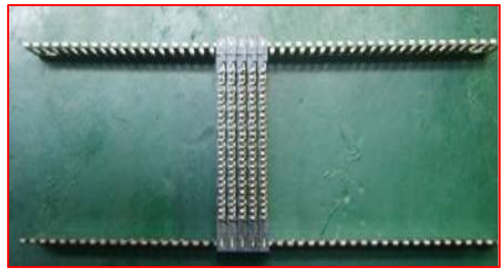

Figure 14: Replacement wafers loaded into product organizers for header connector

The process is now reversed where the organizers with the replacement wafers are now reinserted onto the product. They are aligned and the organizers are slightly engaged with the mating features on the remaining wafers of the connector. Then the organizer replacement tool, very similar to the organizer removal tool, is used to gradually seat the organizers and wafers squarely in place. The screws are now replaced and the rework nozzle is attached to the replacement wafers and the entire assembly is again brought to the hot gas rework tool. See figure 15.

Figure 15: Rework nozzle in place to solder the replacement wafers in place

Once the reflow cycle is complete and the assembly is cooled to room temperature, the assembly is ready for verification.

After rework the connector is inspected with a microscope examining the exterior rows of the connectors that can be seen. A mini-mirror is often used to aid in this operation. After inspection the connector is sent through X-ray to inspect for opens and shorts. Now the assembly is ready to go through electrical test.

CONCLUSION

High mass, high I/O surface mount wafer type connectors can be assembled with the use of vapor phase reflow technology. Lead co-planarity control during reflow is a key element of forming quality solder joints. Calibrated compression loading fixture should be used to guaranty high repeatability.

Grouped wafer handling is the optimized rework solution. Adjacent wafer protection is critical to maintain the reworked connector integrity. Paste volume inspection has to be employed to ensure the robustness of the process.

Thermal mechanical reliability tests were conducted during assembly qualification. All specified solder joint reliability requirements were met.

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REFERENCES

[1] Bielick, J., Chapman, B., Ferrill, M., Fisher, M., Isaacs, P., Kobeda, E. and Lewis, T., "High Thermal Mass, Very High Lead Count SMT Connector Rework Process: Process and Problem Resolution." Proceedings from 2010 SMTA Pan Pacific Conference, pp.
[2] Lewis, T. and George, J., "Vapor Phase Reflow for Reliable Assembly of a New High Performance Interconnect Technology," IMAPS Symposium on MicroElectronics, Nov. 11-15, 2009, San Jose, CA. pp.193-200.
[3] Condensation Reflow Soldering Machine VP 2000 - Operating Instructions, ASSCON Systemtechnik-Elektronik GmbH.
[4] Ventura SMT Assembly & Connector Rework Guideline, Amphenol, Mar 2007.
[5] Isaacs, P. and Puttlitz, K., *Chapter 20, Area Array Component Replacement*, Area Array Interconnection Handbook, 2001, Kluwer Academic Publishers, Norwell, Massachusetts. pp. 804-837.
[6] Soder-Wick is a registered trademark of the ITW Chemtronics Company, Kennesaw, GA.