Vacuum Soldering and Void-Free, Lead Free Solder Joints

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Abstract
Vacuum-condensation soldering is a new process, developed to combine the advantages of condensation soldering and vacuum soldering. The lecture introduces the results of the project development, as well as the results from soldering of assembly groups.

Introduction

European legislation forced the worldwide introduction of lead free soldering with RoHS and WEEE. The technological consequences are substantially smaller process windows with reflow soldering. Therefore condensation soldering (Vapour phase soldering) had become more attractive for many applications. To heat the PCB assembly, the condensation soldering method uses the latent heat that is set free when changing from vaporous state into liquid state. The temperature stays constant during the change in state of the medium (phase transition), therefore the maximum temperature of the PCB assembly will not exceed the boiling/condensation temperature of the medium. The limitation of the maximum temperature (i.e. 240°C) is an essential advantage of condensation soldering. The disadvantages are the sometimes steep heating gradients, which can cause reflow defects like popcorning, tombstoning and splattering. With the classical vapour phase soldering you have to vertically slide into the vapour, that means a horizontal transport is not possible.

Basics

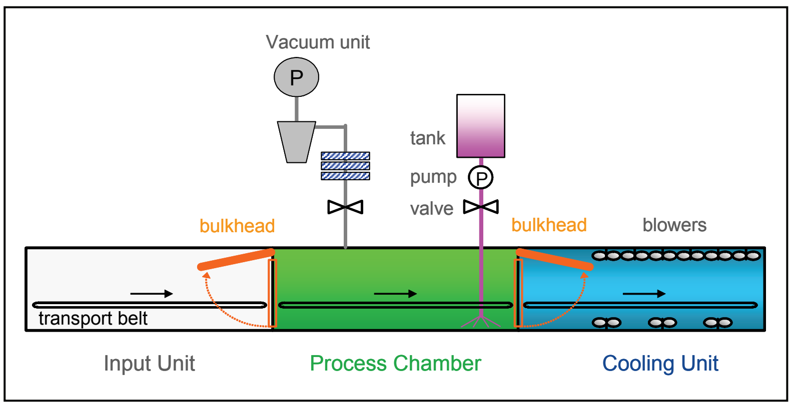

Figure 1 – The Condenso® Principle

In the context of the project, a new system for generation of vapour has been developed which, in combination with a hermetically closed process chamber, eliminates the disadvantages of classical vapour phase soldering. With the injection of a defined amount of vapour into the process chamber (which means a defined amount of latent heat) it is possible to influence the heating gradient of a PCB assembly during the condensation process. The more medium is injected into the process chamber, the more latent heat is available for the PCB or vice versa. The walls of the chamber are heated to prevent losses of latent heat. Also the heated chamber allows a vacuum process immediately after soldering. Therefore a vacuum unit is adapted at the process chamber. Two (bulkheads) locks are closing the chamber hermetically.

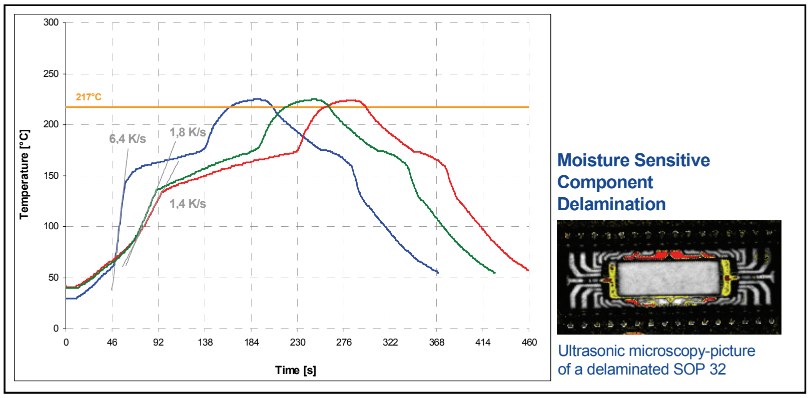

Figure 2 – Condenso® Reflow Profile

Especially moisture sensitive components quickly show the delamination, when exceeding allowable process parameters. With the help of injection principle it can be ensured reliably that during the vapour phase process the maximum gradient is not exceeded in any phase. In IPC20D standard +3K/s is the maximum gradient for moisture sensitive components. **Figure 2** shows at the right side a ultrasonic microscopy picture of a delaminated SO32 and at the left side a graph with 3 reflow profiles of one board. It understands that with less injection of medium the gradient came down.

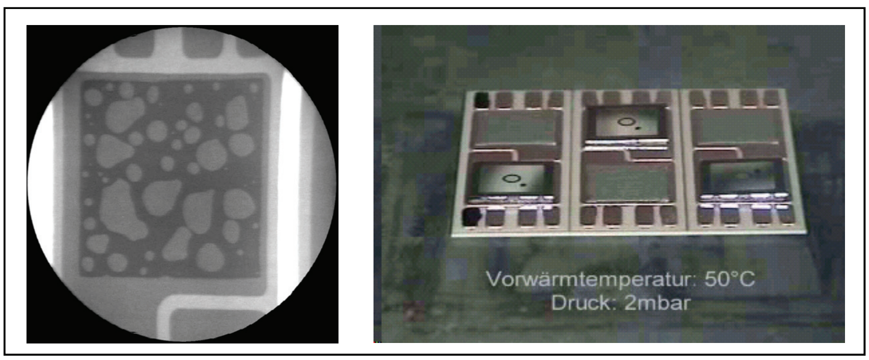

Figure 3 – Growth of Voids in Solder Joints

A vacuum process immediately after the soldering process allows the production of void free soldering joints. Voids result from gases, which could not leave the solder joint in time, before the liquid solder solidifies. A large part of the gases come from solder paste itself. The solder paste consists of up to 40% volume per cent fluxes and slightly volatile components. The video at the right side of Figure 3 shows the development of gas bubbles in a paste depot during the reflow process. Of interest are the non-placed areas. The paste deposit is 150µm. Big bubbles blow up and burst. Under a chip or component it isn't easy for the gas to escape. Therefore mostly solder joints are showing voids like those on the left picture of Figure 3.

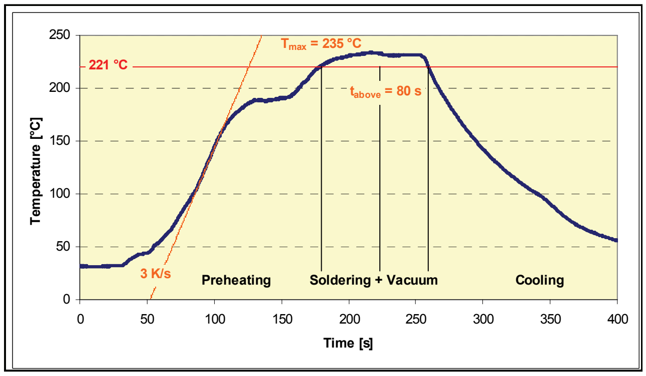

Figure 4 – Typical Vacuum Condensation Reflow Profile

Void free solder joints especially increase the reliability of power electronics through better heat lacing and avoiding hot spots. For this reason void rates of < 2 % are required for power applications. In our technology, the vacuum is immediately added on the soldering process. The heat loss of the board is very low because the process chamber is heated. 3K temperature decrease is due to evaporation of medium out of the board surface.

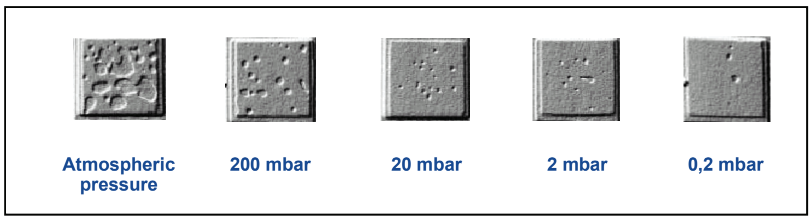

Figure 5 – Vacuum Control (end pressure) Influences the Number of Voids

Void rates, less than 2%, can be achieved only with a vacuum solder process. The void rate decreases constantly with the reduction of vacuum-limit pressure. Significant void free solder joints for power applications are reached at an absolute pressure < 50 mbar. The better the vacuum has to be, the more the vacuum unit will cost. Because of investment cost, our recommendation is to use a vacuum unit for minimum pressures of approx. 10 mbar. For most applications, you can reach less than 2% void rate with such equipment.

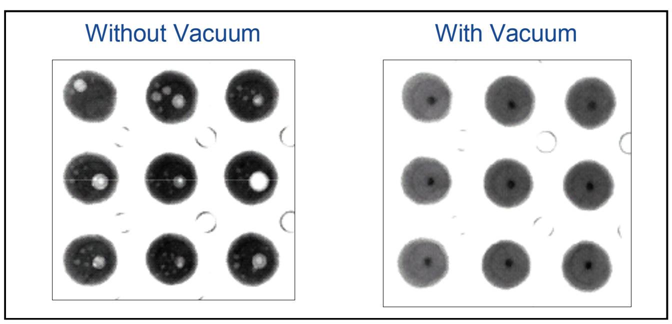

Figure 6 - X-rays of PBGA areas without and with a Vacuum Process

During the vacuum process it has to be ensured, that the liquid solder joint doesn't lose any heat energy. The loss of heat leads to temperature drop and with it to increase of viscosity of liquid solder. The higher the solder viscosity is, the more difficult it is, to remove gases from the solder joint. In order to avoid that, the process chamber has to be heated. Voids in BGA balls are also dependent on the design. Unfilled microvias are often the reason for big voids. Such design failure can't be corrected by a vacuum process.

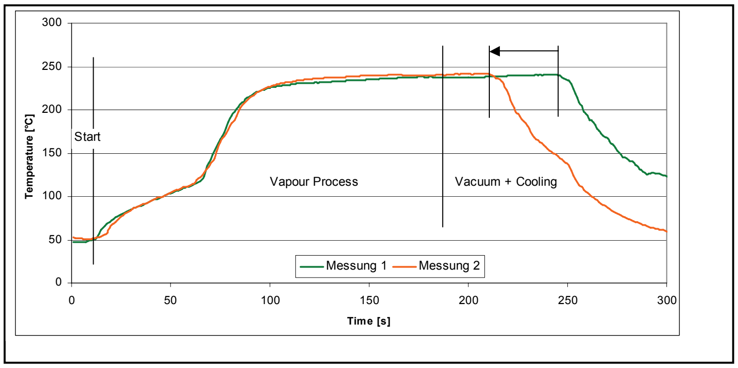

Figure 7 - Both graphs are Showing two Measurements with the Same PCB

To influence the length of the vacuum process, a perfect process control for vacuum and cooling is important. Of course, the

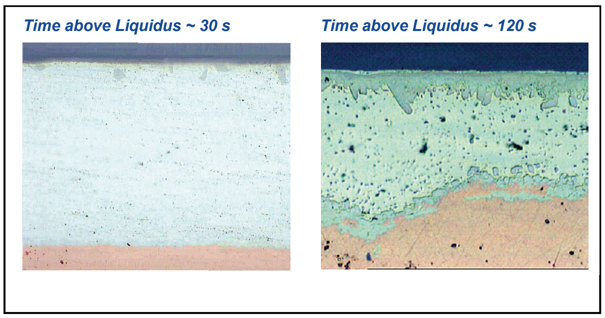

Figure 8 – Influence of Time Above Liquidus

duration of the vacuum process also influences the void rate. Please note additionally here, that the vacuum time extends the time over liquidus. This causes higher dissolution rates as well as stronger phase growth. That's why it is important for the process control, to influence the length of the vacuum time. A vacuum time of 30 - 40 s is optimal. Figure 8 shows on the right picture the strong phase growth in a Sn3,5 Ag-solder joint, through a too long time over liquidus. The IMS here is approx. 10µm thick. On the left picture you can see an excellent lead-free solder joint.

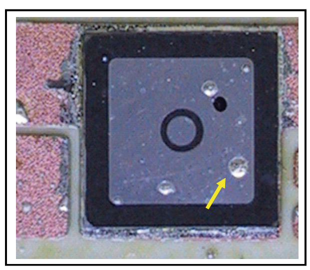

Figure 9 – Splattering

Solder defects, like splattering and solderballing have been analysed. Of course the mixture of paste is one reason for such defects. They depend on the gradient adjustment during the condensation process as well as on the subsequent vacuum process. It was found that the control of pressure during the vacuum process is an important parameter to avoid solder defects. If the limit pressure is reached too fast, the escaping gas carries along too much liquid solder, which results in solder spatters. Especially, the first pressure reduction to 100 mbar plays a decisive part here. Splattering can be avoided by stepping pressure down.

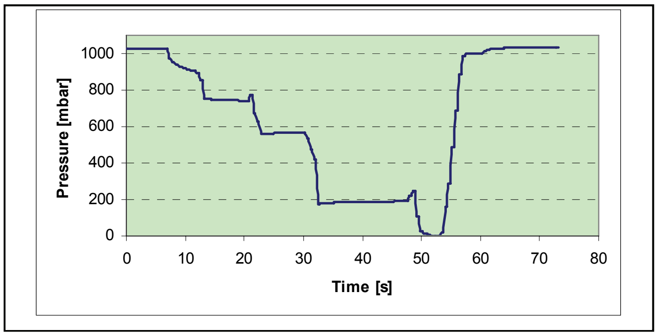

Figure 10 – Pressure profile in a Vacuum Condensation Facility

Beside the absolute pressure, the stay on different pressure level is also important. If the optimal vacuum parameters are followed, repeatable void free solder joints can be produced with this new technology.