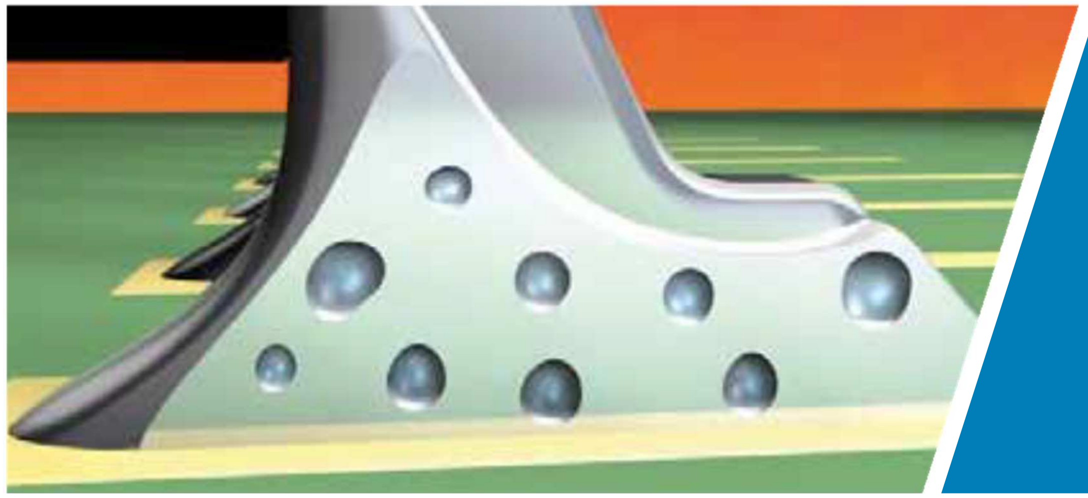
Expert report



Vacuum reflow soldering – the simple solution for pore reduction

Vacuum reflow soldering

The simple solution for pore reduction in soldering points
In the course of production of increasingly more complex and efficient electronics, such as for example new hybrid components for the automotive sector, low-porosity solder points are required that cannot be produced with conventional reflow technology.

Soldering points cross section

higher pore percentage

pores are extracted from the solder point in the vacuum mode

EXPERT REPORT / VACUUM REFLOW

Bubble-free soldering is a basic requirement for high-performance electronics.

Vital devices, control technology in airplanes and the driver assistance system in the automobile sector all have one thing in common: Over the years they must function with absolute safety and be free of any errors. One condition here is the high-strength, nearly non-porous solder connection. Pores in a solder point must therefore be reduced to a reliable minimum.

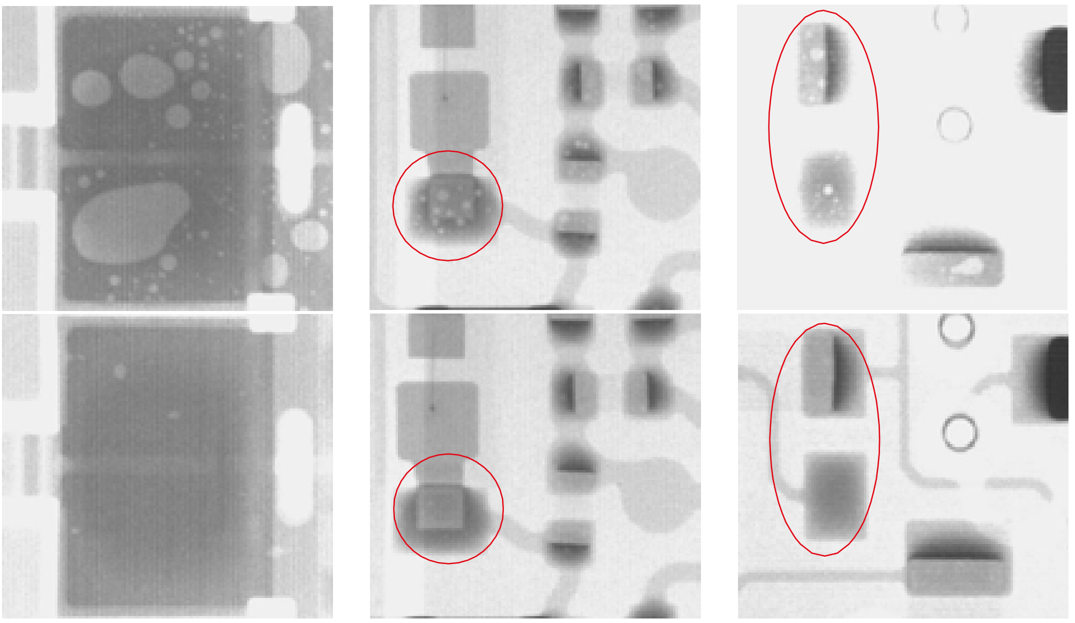
Pores are gaseous inclusions within the solder point which can lead to lower thermal conductivity. [1,2] In components with high electric currents, the resulting heat may not be sufficiently discharged via the pore filled solder point. Components reach very high temperatures and this eventually leads to decreased performance or component lifetime.[3] With the help of vacuum soldering processes, the pore percentage within the solder point can be reduced and the thermal conductivity of the solder point can be improved.

SMT Maschinen- und Vertriebs GmbH in Wertheim, Germany, has developed a vacuum reflow soldering system that interfaces the conventional reflow soldering process with a vacuum process to meet the high requirements for low-pore solder points.

Transistor component | **Diode** | **resistance and condenser in chip structure**

without vacuum

vacuum

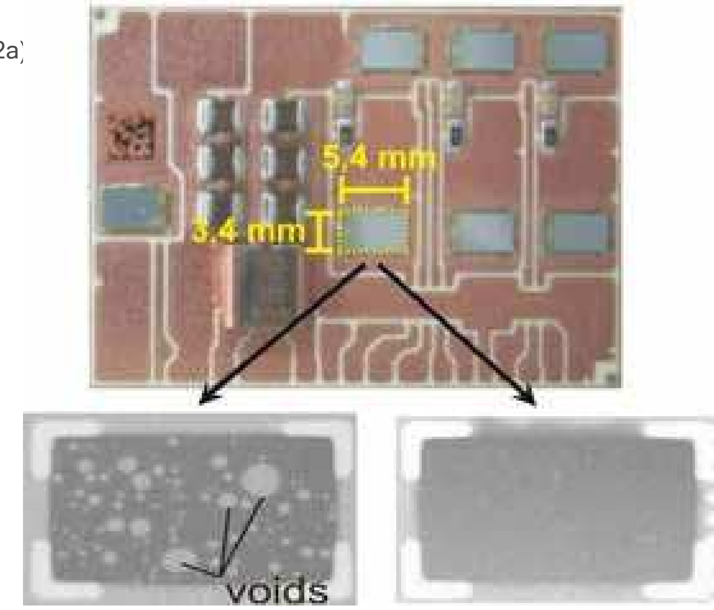


The clearly visible reduction of pore percentage was achieved in the above shown examples via the use of a reflow vacuum soldering system type SMT VAC S.

Solder point and pores

The qualitative comparison of X-ray images clearly shows that many pores with a large surface area within the solder point are present during the conventional reflow process, whereas the number of pores during the vacuum process is reduced to nearly zero.

2a)



2b) conventional reflow

2c) vacuum reflow

2a) image of the component.
The examined solder point has been marked in yellow as an example of bare-die.
2b) X-ray image of bare-die solder point according to conventional reflow process. 2c) X-ray image of bare-die solder point according to vacuum reflow process.

Literature reference
1 W.B. Hance, Lee Ning-Cheng, Poreing Mechanisms in SMT, Soldering & Surface Mount Technology, 13, 1993.
2 *N. Zhu, Thermal impact of solder voids in the electronic packaging of power devices, Semiconductor Thermal Measurement and Management Symposium, p. 22-29, Fifteenth Annual IEEE, 1999.*
3 S.T. Nurmi, J.J. Sundelin, E.O. Ristolainen, T. Lepistö, (2003) "The influence of multiple reflow cycles on solder joint voids for leadfree PBGAs", Soldering & Surface Mount Technology, Vol. 15 Iss: 1, pp.31 - 38.

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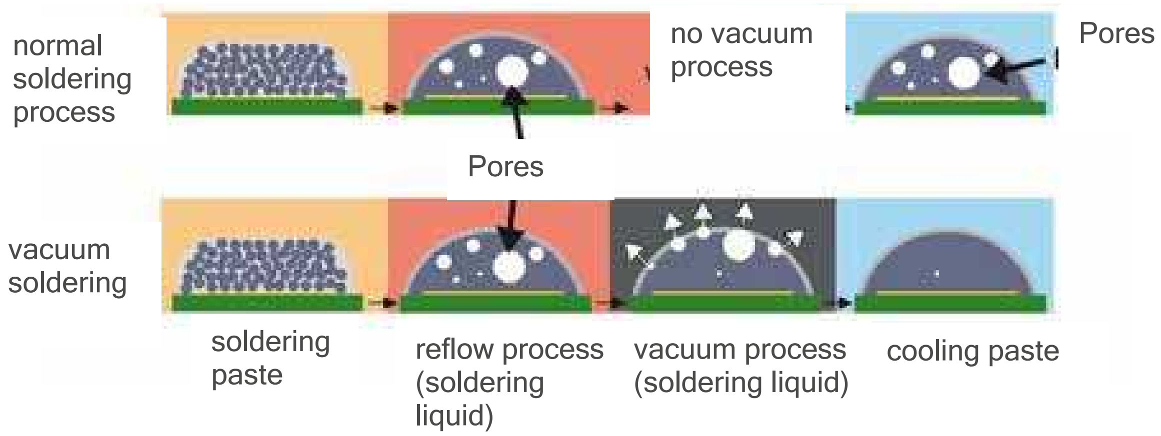
Comparison of conventional processes with vacuum reflow process

A schematic representation of the conventional and the vacuum reflow melting process of the soldering paste is depicted in image 3. The soldering paste is melted via the reflow process in hot air or in hot N2 atmosphere. This creates gaseous inclusions within the solder connection which during the conventional reflow process are enclosed by cooling and solidifying of the solder.

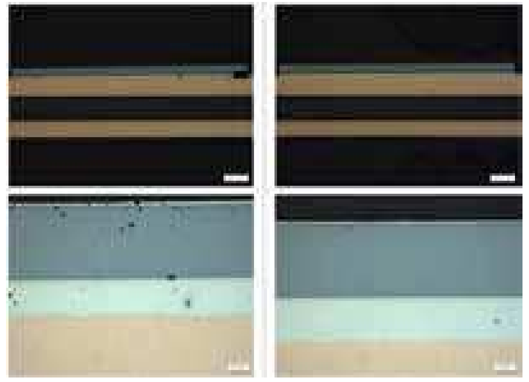
The solder is also heated and melted during the vacuum reflow process employed here. This is followed by the vacuum step during which the pores expand and are discharged via the solder surface into the vacuum. The pore percentage within the solder point is reduced, the solder point is more solid and consequently possesses a higher thermal conductivity, which leads to positive results for component performance and lifetime.

During remelting of components another image was visibly shown after using soldering with and without a vacuum. While only a slight shift and tightening of the pores occurred during further melting without vacuum, but no reduction, the use of the vacuum showed very positive results. This way the pores become significantly smaller during soldering and most of all the pore percentage can be reduced substantially.



Schematic comparison of conventional (image above “normal soldering process”) and vacuum reflow processes (image above “vacuum soldering”). During vacuum reflow processes the vacuum process is programmed as the next step after the actual melting process, which extracts the pores from the liquid solder. This is followed by cooling of the component.

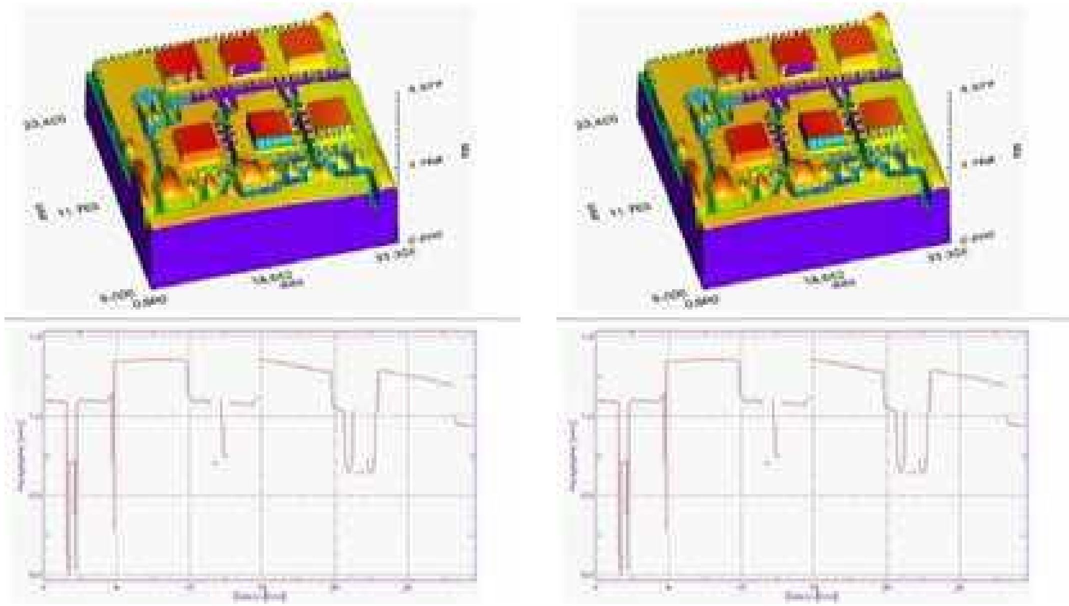
During metallographic analysis of the solder point it becomes evident that with both soldering variants a good and homogeneous solder connection can be seen. However, without a vacuum a few isolated flaws are visible. The intermetallic phases are visibly more uniform in the homogeneous interfaces with vacuum process.



Metallographic analysis of ceramics with chip

Another positive effect could also be achieved with vacuum soldering. Specifically in chip solder connections due to downstream processes (such as e.g. bonding), a high planarity is required through which pores can be strongly influenced. This could be verified with a profile measurement.

The following depiction shows as an example the differences between soldering processes with and without vacuum. Solder gaps show great variety in chips soldered without vacuum and tilting is often noticeable. The heights of vacuum soldered chips are much more even and more homogeneous.



Profile analysis of ceramics with chip

Vacuum reflow process description

The depicted light gray left area on the solder system consist of a preheating and a peak zone. The vacuum model is located to the right, next to the heating chamber and is depicted dark in image 6a. It possesses an additional peak zone to adjust the overall temperature profile of the soldering process more flexibly. In this entire hot section the component is heated by convection via air or nitrogen until the solder is melted.

The component with liquid solder is transported from the convection zone further into the vacuum chamber where the actual vacuum process takes place. After this vacuum process, the component is transported into the cooling zone (right, light gray area in image 6a) and cooled down to the desired temperature via air or nitrogen.

Image 6b shows the temperature profile of the bare-die measured with the temperature recorder as a function of the overall process time. At the time t=0 s the component is located at the beginning of the first preheating zone. At t=118 s the component is transported into the peak area. The melting point (Liquidus) of the solder is 219 °C. The temperature profile of the actual vacuum process is marked with a colored bar in image 3b. Heat is applied to the vacuum chamber to provide the component and the chamber with the same process temperatures. The thermal radiation balance between chamber and component guarantees the constant temperatures of the component even within the vacuum, the solder remains liquid.

Image 6c shows the pressure gradient of the vacuum process in the section of the overall process time. To simplify the comparability of both images 6b and 6c the time ranges of the vacuum process are marked in color. The initial and end periods of the vacuum process are marked with arrows. The component with the liquid solder is transported into the vacuum chamber, the chamber closes (left “white” area in image 6c).

In the following process steps, the chamber is evacuated, the vacuum is held and thereafter the chamber is ventilated with air or nitrogen (colored area in image 6b and 6c). The evacuation time, final pressure, vacuum holding time and ventilation time can be set individually. Chamber pressures of up to 5 mbar are possible. The pores are effectively drawn out of the solder point, as shown in the schematic depiction in image 3.

After the vacuum process, the chamber opens and the component moves with the liquid solder into the cooling zone. The solidification process of the solder occurs there by blowing cold air or nitrogen into the component.

Image 6:
a) Picture of the SMT reflow solder system QP S Vac. The vacuum module (dark) is located between the active convection zone (=preheated zone + peak zone, left) and the cooling zone (right).
b) Measured temperature profile of bare-die as function of time. The actual time of the vacuum process is marked in color.
c) Vacuum pressure profile as a function of the time. The time range with the colored background corresponds to the same as in image 6b.

Frank Ehehalt
Process
technology

SMT Maschinen- und Vertriebs GmbH & Co. KG

6 a)

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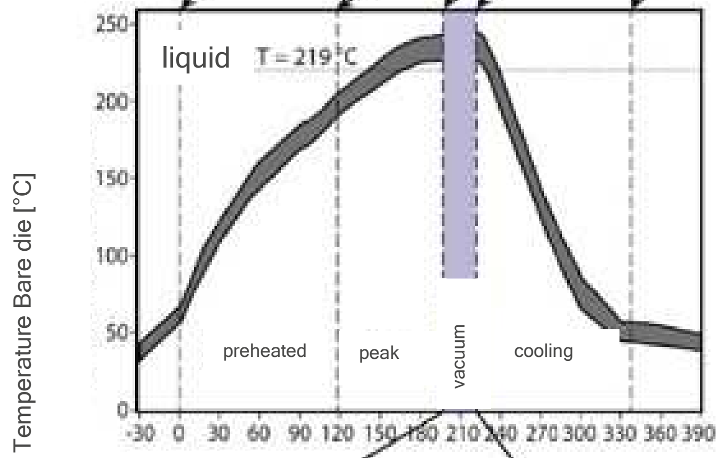

6 c)