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GOING LEAD FREE WITH VAPOR PHASE SOLDERING - LEAD FREE IS STILL A CHALLENGE FOR MAJOR INDUSTRIES

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ABSTRACT

As of today, the electronic industry is aware of the requirements for their products to be lead free. All components are typically available in lead free quality. This comprises packages like BGAs with BGA solder balls to PCB board finishes like HASL. The suppliers are providing everything that is needed. It is harder to get the old tin leaded (SnPb) components for new applications today, than lead free ones.

So why has not everybody changed over fully yet and how can the challenges be overcome?

A big concern in this transition process is reflow soldering. The process temperatures for lead free applications became much higher. Related with this is more stress for all the components. It affects the quality and reliability of the electronic units and products.

Many companies are running a mix of lead free components with a SnPb solder paste. This allows them to stay at the same and approved (low) process temperatures. It is no long-term solution, because it is not lead free. But it is still accepted from customers and legislator yet sometimes it is tricky. The mix of the different solder that are supposed to form one solder joint, do dot mix as well as expected or known from the past.

Other companies have changed over to lead free completely. They were facing more or less trouble with the typical lead free problems, higher temperatures, smaller process windows, decreased wetting, and so on. Some products have a lower first pass yields and more defects. Some simple products though show no problems at all.

The majority of solder paste produced and used in production is still the old tin lead solder paste. Automotive industries, aviation, military, science and medical industries are keeping their approved processes as long as they have no adequate or better solutions. Low PPM failure rates and highest reliability are standards and a risk or drop in quality is absolutely not acceptable. Many tests have to be made to approve new materials and processes. Many companies have not found the right solutions to change over to lead free yet. Vapor phase reflow soldering can be an answer for them.

SOLDER AND PROCESS TEMPERATURES

We need to go into the soldering details to understand the difficulties of lead free soldering and the benefits of alternative processes.

With lead free soldering, the recommended reflow temperatures are raising from a 200°C - 225°C range to 235°C - 250°C.

The tin lead solder pastes, coatings and solder balls had all the same mixture and a eutectic melting point of 183°C. The right process temperature and profile was mainly a matter of the total mass and the different masses of the components on a PC board. The solders from different manufacturers were mixing well.

With lead free soldering this is different because there are many different solder mixtures of tin, silver, copper and other elements on the market. Some are patented so others cannot use the same mixtures. A SAC305 for example is melting between 217°C - 221°C while others, such as SnCu melt at 227°C – 228°C and Sn coatings or Sn solder balls in BGAs may melt at 231°C.

To achieve good inter metallic structures the melting temperature has to be above the melting point of the solders used in an application. In many cases this means above 232°C.

This does not seem to be so much. But to reach the melting temperatures at hidden solder spots or under BGAs, the convection oven has to be set to even higher temperatures around 260°C up to 290°C. At the same time as a high mass components barely reaches the melting temperature of the solder, small mass components get overheated under such conditions.

Heat transfer coefficient: α [$Wm^{-2}K^{-1}$]		
radiation	20 - 30 60	preheating peak
convection	5 10 - 20 40 - 60	air in rest at 5 m/s at 5 - 20 m/s
condensation	100 - 400	
contact (liquid solder)	4000	

Heat transfer rates

This effect is related to the low heat transfer rate of air. The lower the heat transfer rate, the longer it takes for heating up, and the bigger are the temperature differences of low and high mass components when heating up.

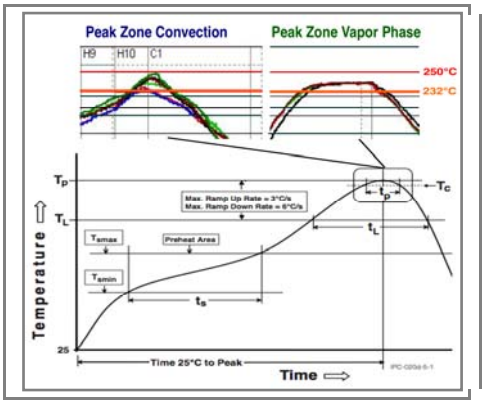
Temperatures of 250°C and higher are critical for most components and will damage them. Failing components, delaminations, pop corning and other problems appear.

VAPOR PHASE PROCESS TEMPERATURES

The vapor phase process is different from convection. The Vapor has a high heat transfer rate, about ten times higher than forced convection (See picture above). Big sized and high mass components are heating equal and without shadowing effects.

At the boiling point the liquid creates a vapor and the temperature of the boiling liquid and the vapor are identical. Components in the vapor cannot get higher temperatures than the vapor, as the heat transfer is conducted by condensation and therefore can physically not get overheated.

To be above the melting points of the different lead free solders in an application, a boiling point of 235°C is useful.



Lower maximum temperatures in Vapor Phase and no DT between components provide highest quality

Applications with heavy multi layer boards, metal core boards, ceramics, BGAs and heat sinks can be perfect soldered without the danger of overheating.

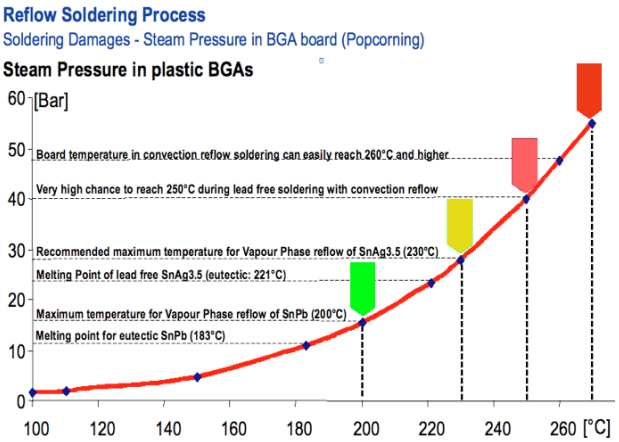
DELAMINATION AND POPCORNING

Lower soldering temperatures are limiting the stress for the components. They avoid delaminations on substrates and limit the risk of popcorning.

This stress is created from expanding gases inside plastics and laminates. Plastics can take on moisture from the surrounding air and correct storage regarding moisture sensitivity levels is crucial. The stress can crack layers and plastics. The affected parts loose their protection of the circuits and will damage or cut the electrical connections in some cases. These failures are hard to detect as defects may occur later and cannot be found with AOI systems.

Popcorn crack in a package

The lower temperatures in a vapor phase process will prevent popcorning and delamination. Fluids are available with various boiling points of 230°C, 235°C, 240°C and more.



Steam pressure in plastics are temperature related

OXYGEN AND SOLDERING

The vapor in a vapor phase oven is oxygen free and the soldering parts and boards are protected during heat up and soldering. Thus a Vapor Phase oven provides the best possible wetting. No additional protective gases are required resulting in low running cost.

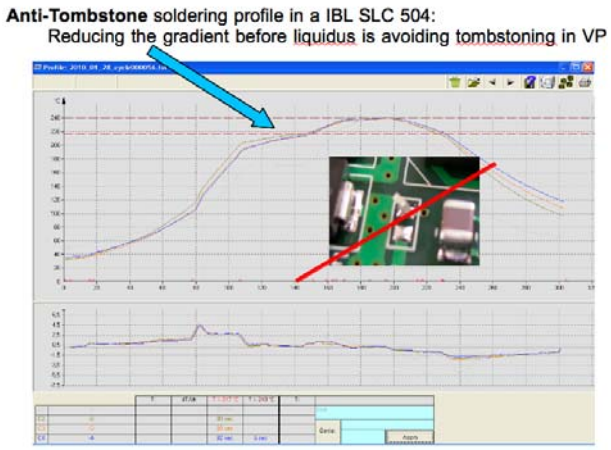
Other soldering methods use nitrogen to create oxygen free process zones. Nitrogen is a big cost factor. It needs process control as well as storage space, piping systems etc.

A clean and oxygen free metal surface is required for soldering and wetting between solder and metal surfaces of components.

Higher temperatures are increasing the chemical reactivity of the metal surfaces with oxygen. For high quality lead free soldering more oxygen free systems will be required.

PROFILING AND PROCESS CONTROL

Difficult solder applications and sensitive components very often need a specific or customized profile. These profiles will assure the best solder quality and will help to prevent tombstoning and reduce voiding.



Vapor Phase solder profile to avoid tombstoning

Since modern vapor phase systems have perfect process control and extended profiling capabilities they can combine the advantages of special heating profiles with the protection against overheating. Soldering related tombstoning will be reduced to zero.

Increased voiding with lead free soldering is often influenced by aggressive flux systems. The chemical reactions between fluxes and metal surfaces of components and PCB boards are producing gases. When the skin in the liquid phase of the solder is formed around the solder joint, these gases cannot escape. They stay in the solder joint as voids. A good profile can ensure that the flux has finished its activities before the solder gets molten.

CONCLUSION

Keeping the process temperatures as low as possible and the absence of oxygen during soldering will result in excellent quality applications and products.

Modern Soft Vapor Phase systems perfectly combine these attributes. Equal temperature distribution and the physical limitation of maximum temperatures are automatically provided. Double sided and densely packed PCB boards with BGAs, LEDs with metal core boards, ceramics and GCB units can be soldered perfectly lead free. Power electronic units, as they appear with new electric and hybrid technologies in the automotive industry work excellent on vapor phase systems.

The heat needed for great solder results in Vapor Phase soldering is only a few degrees above the melting point of the solder pastes.

Vapor Phase ovens are available from table top machines up to big inline systems. The size of a Vapor Phase system is not related with the solder profiles it can produce and the profile is done in only one chamber. The energy cost for a VP system is only a third compared to a convection system.

Negative effects like tombstoning and voiding can be influenced with a good soldering profile in today's Vapor Phase systems.

Other reflow methods require more than 30°C – 50°C excess heat for the same task due to their lower heat transfer rate.

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