Tiny With a Big Impact: True or False?
Impact of the Component Complexity on the assembly process. Miniaturized Components (01005, 03015…) in the Mix with so-called Standard Components (BGA, LED, Pin-in-Paste)

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Abstract

The electronics markets place widely varying demands on products, thus necessitating a great deal of complexity with regard to board design and connector technology. A nearly inexhaustible multiplicity of electronic components is available to this end for implementing the respective product concepts. There is of course no universal soldering process which fulfills the requirements of all of these different products at the same time.

However, the capability demonstrator board has provided us with the opportunity of exploring the limits of what is feasible and what is not, additionally pointing out the difficulties associated with the reflow soldering process of complex PCBs. In the following pages we will discuss target goals for reflow soldering derived from generally recognized rules and standards, as well as the temperature-time curves (reflow profiles) obtained with the demonstrator board. Our examinations focused primarily on convection reflow soldering, but various results obtained with vapor phase reflow soldering will be discussed comparatively as well.

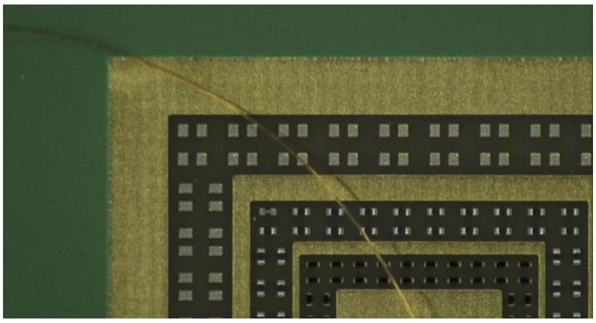


Figure 0: 0201 down to 03015(metric) compared to a human hair showing an example of miniaturization of components

1 The Reflow Profile (envelope curve profile)

A reflow profile is a temperature-time curve which reflects the thermal characteristics of a PCB during reflow soldering. The partner companies specified that the demonstrator board should be produced by means of a lead-free SAC soldering process. The initials SAC describe the utilized solder paste: tin (**S**n) – silver (**A**g) – copper (**C**u). Upon specifying the SAC solder alloy and in light of the innumerable assembly options for the demonstrator board, it was first of all possible to select a target reflow profile.

In a referenced book [1], a reflow envelope profile is introduced which was suitable as a target reflow profile for the demonstrator board (see ***figure 1***). It defines the metallurgical aspects for a reliable solder joint, as well as the limitations resulting from the components.

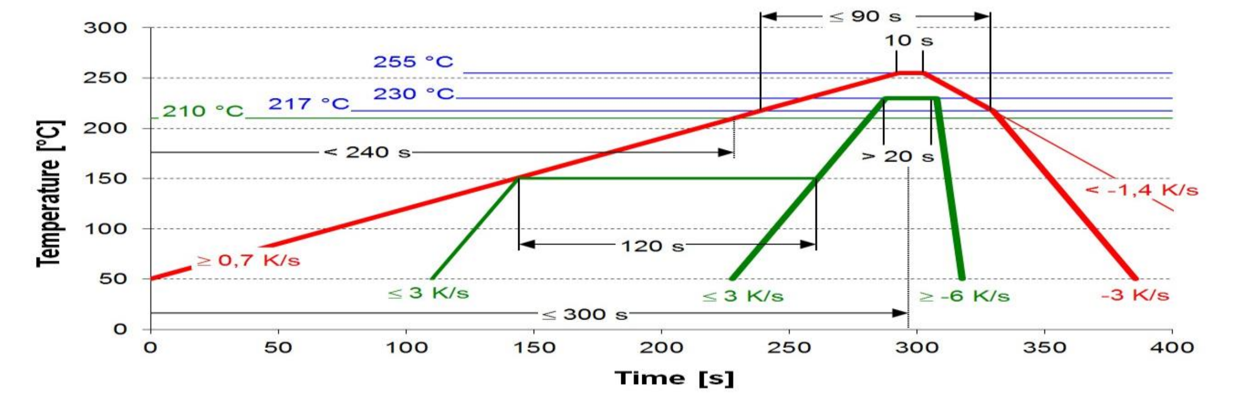


Figure 1: Target Reflow Profile for the company demonstrator board (reflow envelope profile *[1]*)

Figure 1 shows the essential target parameters for the demonstrator board's envelope profile. The minimum solder joint temperature of 230° C is based on metallurgical necessary overheating to above the melting point of the selected solder alloy. In the international standard literature such as IPC 7093 [2] and IPC 7095 [3], reference has recently been made to: "Pb-free alloy SAC 305, absolute minimum peak reflow temp., 230° C". A WLCSP, for example, is included on the demonstrator board, whose processing can be oriented towards IPC7095C standard. Furthermore, there are several moisture-sensitive components whose limitations define essential requirements for the heat gradient (+ 3 K/s) and the package temperature (T_P). Valuable references to this can be found in IPC/JEDEC 020 D.1 standard [4].

It is significant that IPC/JEDEC 020 D.1 standard does not stipulate any reflow profiles: "The reflow profiles in this document are for classification/preconditioning and are not meant to specify board assembly profiles". Package temperature (T_P) is not specified here as a soldering temperature, but rather it is the temperature measured directly on the top of the IC package. Minimum and maximum times above liquidus t_L result from the necessity of fully melting the solder paste and creating a homogenous liquid phase (t_L > 20 s), and of limiting the formation of intermetallic phases between the bulk solder and surface finish of pcb or component. (t_L < 90 s).

Table 1: Target Parameters

Demo Board Envelope Profile	**MIN**	**MAX**
T_p in °C	230	255
t_L in s	> 20	< 90
Gradient in K/s		3

2 The Test Board and System Settings

Suitable test boards had to be fabricated in order to be able to substantiate actually achieved temperature-time reflow curves. Calibrated Type K thermocouples were attached to previously-defined measuring points with SMD adhesive to this end. A total of two demonstration test-boards with various measuring points were developed (***figures 2 and 3***). Due to the number of thermocouples needed to measure and verify, two boards were used to minimize the preparation impact on the measuring results (see table 2).

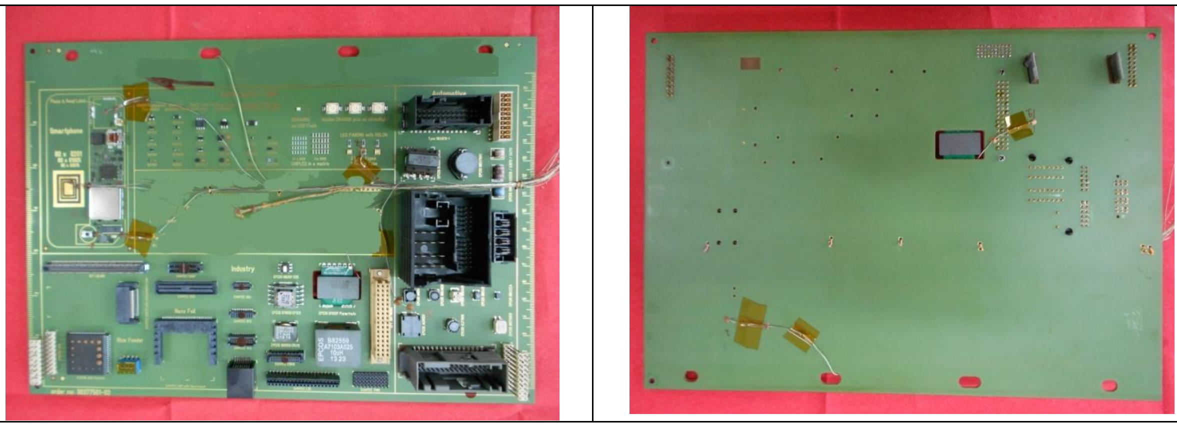


Figure 2a, b: Demonstrator Board (green preparation)

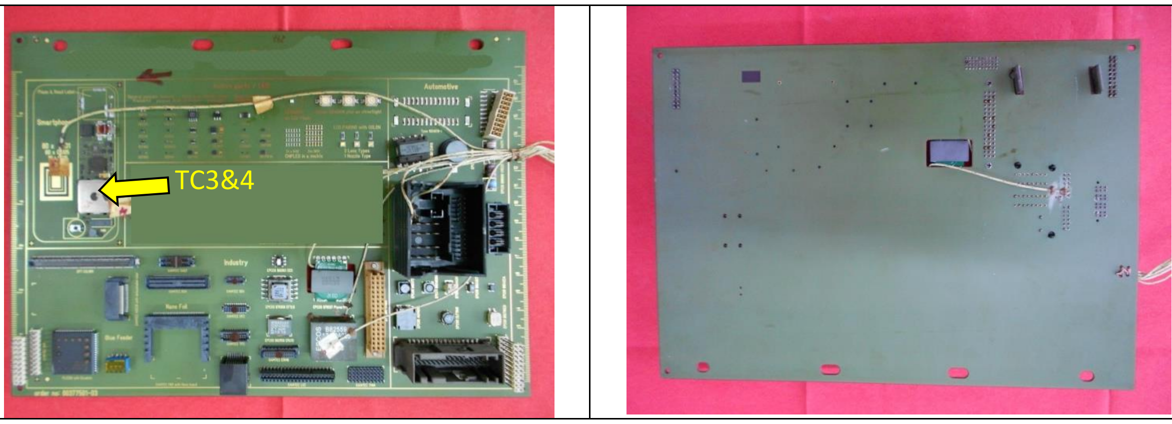
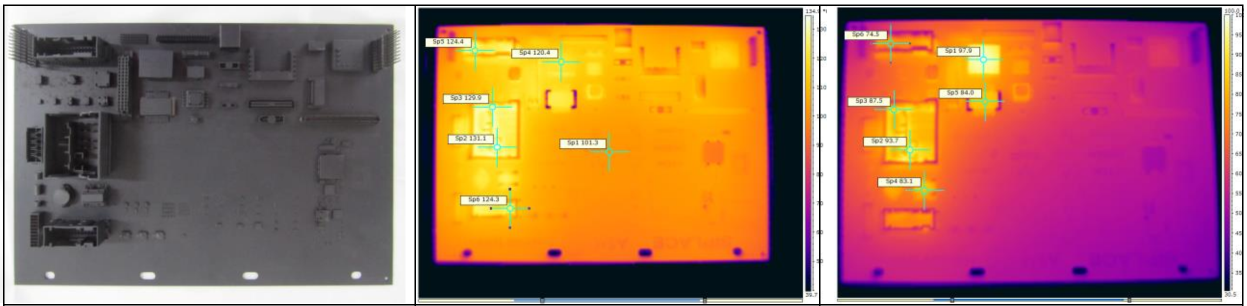


Figure 3a, b: Demonstrator Board (red preparation)

In order to adequately describe the thermal characteristics of the demonstrator board with the selected measuring points, the places of smallest and greatest thermal mass were determined with the help of a thermal imaging camera. A completely assembled demonstrator board with blackened surface was heated up to 150°C in a heating cabinet to this end, and its cool-down characteristics to room temperature were recorded with the thermal imaging camera (***figure 4***).



Initially Blackened Demo-Board	After 30 s Cool-Down	After 300 s Cool-Down

Figure 4: Cool-Down Characteristics of the Demonstrator board from an Initial Temperature of 150° C

The transformer was identified as the place of greatest thermal mass and the insertion location for the 0201, 01005 and 03015 components, amongst others, as the place of smallest thermal mass. Two essential measuring points were thus ascertained. ***Table 2*** lists all of the measuring points.

Table 2: Measuring Points on the Demo Test-Boards

T/C Nr.	Green Preparation	Red Preparation
1	Top front of PCB	Plug (large), top pin
2	Bottom front of PCB	Plug (large) package
3	01005 chip	Plug (large), bottom pin
4	03015 chip	Shielding solder joint
5	Atmosphere	Shielding on top
6	Switch package	Atmosphere
7	LED lens	Transformer solder joint
8	Top back of PCB	Transformer on package
9	Bottom back of PCB	0201 chip

Due to the fact that the shielding (see Figure 3a) appears in the thermal image as the supposedly smallest thermal mass, it would pay to take a comparative look at the reflow profiles (***figure 5***). The shielding on top nearly reaches the surrounding ambient air temperature in the peak zone. And thus it is no wonder that it appears as the smallest thermal mass in the thermal image. But since there are not any special thermal limitations for the shielding itself, only the temperatures of its solder joints are of interest. If we compare the solder joint temperatures of the shielding with that of the 0201 chip, it becomes apparent that the characteristics of the reflow profiles are almost identical. The determination of the location of the smallest thermal mass is thus verified and need not be corrected.

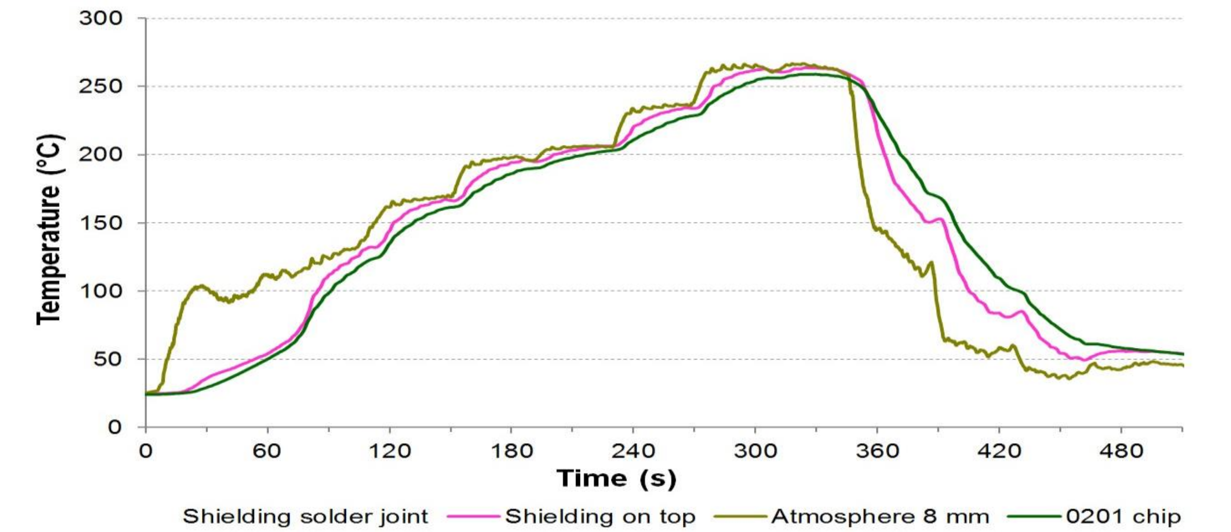


Figure 5: Comparison of Measuring Points, 0201 and Shielding

Production reflow soldering system A from the same reflow machine manufacturer were available in the application centers of two companies in order to optimize the system settings with regard to the desired demonstrator board envelope profile (target goal). The production reflow oven A is equipped with 5 preheating zones, 2 peak zones and 3 cooling zones. The settings were optimized with the goal of achieving the ideal reflow profile, as well as demonstrator board reflow profiles which are at both the upper and the lower limits of the demonstrator board’s envelope profile. These were designated OPT, MAX and MIN. The purpose of this was to evaluate the effects of the reflow profiles on the solder joints on the basis of metallurgical examinations.

It was possible to obtain the desired demonstrator board reflow profiles with the system settings listed in ***Table 3***.

Zones	Ph1	Ph 2	Ph 3	Ph 4	Ph 5	P1	P2	C1	C2	C3
T_{top} (°C)	145,0	175,0	205,0	210,0	210,0	280,0	275,0	100,0	34,0	26,0
T_{bot} (°C)	145,0	175,0	205,0	210,0	210,0	280,0	275,0	0,0	0,0	0,0
v = 530 mm/min										

Table 3a: OPT Profile Settings, Green Preparation

Zones	Ph 1	Ph 2	Ph 3	Ph 4	Ph 5	P1	P2	C1	C2	C3
T_{top} (°C)	145,0	175,0	205,0	210,0	210,0	280,0	275,0	97,0	35,0	26,0
T_{bot} (°C)	145,0	175,0	205,0	210,0	210,0	280,0	275,0	0,0	0,0	0,0
v = 530 mm/min										

Table 3b: OPT Profile Settings, Red Preparation

Zones	Ph 1	Ph 2	Ph 3	Ph 4	Ph 5	P1	P2	C1	C2	C3
T_{top} (°C)	145,0	175,0	205,0	210,0	245,0	275,0	275,0	100,0	34,0	26,0
T_{bot} (°C)	145,0	175,0	205,0	210,0	245,0	275,0	275,0	0,0	0,0	0,0
v = 530 mm/min										

Table 3c: MAX Profile Settings, Green Preparation

Zones	Ph 1	Ph 2	Ph 3	Ph 4	Ph 5	P1	P2	C1	C2	C3
T_{top} (°C)	145,0	175,0	205,0	210,0	245,0	275,0	275,0	97,0	35,0	26,0
T_{bot} (°C)	145,0	175,0	205,0	210,0	245,0	275,0	275,0	0,0	0,0	0,0
v = 530 mm/min										

Table 3d: MAX Profile Settings, Red Preparation

Zones	Ph 1	Ph 2	Ph 3	Ph 4	Ph V5	P1	P2	C1	C2	C3
T_{top} (°C)	145,0	160,0	175,0	190,0	205,0	235,0	340,0	100,0	34,0	26,0
T_{bot} (°C)	145,0	160,0	175,0	190,0	205,0	235,0	340,0	0,0	0,0	0,0
v = 950 mm/min										

Table 3e: MIN Profile Settings, Green Preparation

Zones	Ph 1	Ph 2	Ph 3	Ph 4	Ph 5	P1	P2	C1	C2	C3
T_{top} (°C)	145,0	160,0	175,0	190,0	205,0	235,0	340,0	97,0	35,0	26,0
T_{bot} (°C)	145,0	160,0	175,0	190,0	205,0	235,0	340,0	0,0	36,0	0,0

v = 950 mm/min
Table 3f: MIN Profile Settings, Red Preparation

The various settings used at the production reflow oven A for green and red test-board preparation reveal that there can be no universal reflow profiles for complex PCBs. The settings always have to be optimized depending on actual thermal mass at the measuring point (component solder joint, component package etc.). In particular, times above liquidus tL were influenced with the greatly varying conveyor speeds, in order to achieve values of > 20 s as well as < 90 s.

3 Reflow Profiles Obtained for the Demonstrator Board with the Convection Soldering System

3.1 Comparison of Thermal Masses

Figure 6 presents a comparative look at the reflow profiles (OPT, red preparation) for the greatest (transformer) and smallest thermal masses (0201 chip).

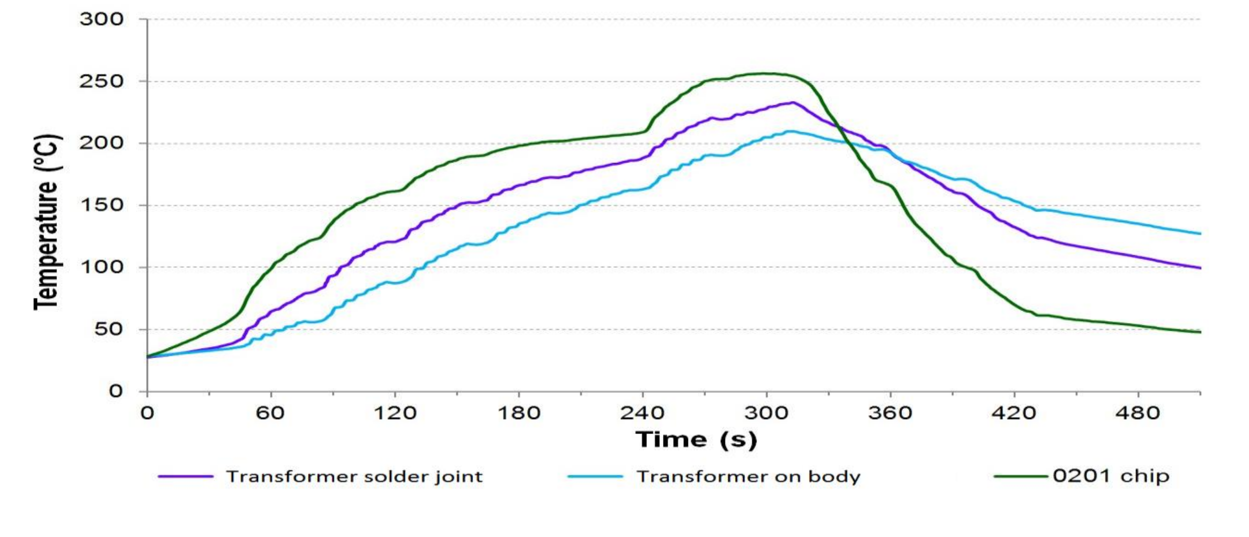


Figure 6: Thermal Masses in Comparison, Demo-Board, OPT, Red Preparation

	Temperature T_{max} in °C	**Time Above Liquidus t_L in s**	**Gradient in K/s**
0201	256	89	2,9
transformer, solder joint	233	62	1,7
transformer, on package (T_P)	210	0	1,4

Table 4: Results from ***Figure 6***

The target goals were readily achieved for the greatest thermal mass (transformer), as well as for the smallest thermal mass (0201 chip). The relatively large temperature difference of 23 K between the thermal masses must be accepted. However, the results fulfill the target reflow profile and are thus suitable for producing good solder joints, as substantiated by the micrographs (see ***figures 7a and b***).

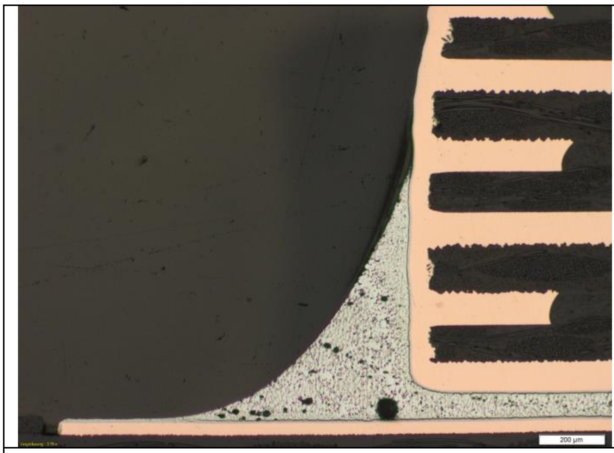


Fig. 7a: Microsection of the transformer (left hand side)

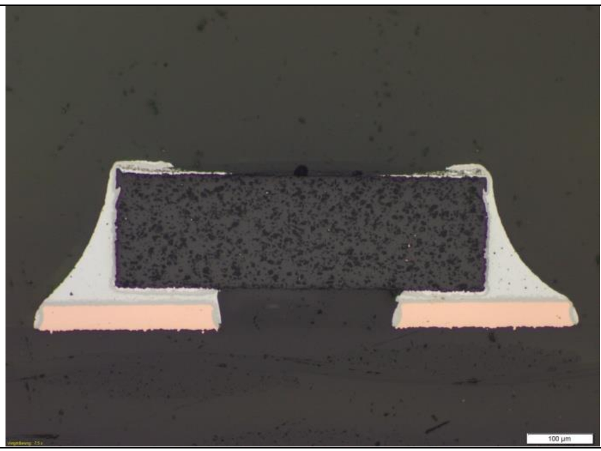


Figure 7b: Microsection of the 0201 chip (right hand side)

A comparative profile measurement in a longer type production convention soldering system B (3 additional preheating zones and 1 additional peak zone) did not result in any significant reduction of this temperature difference. This is due primarily to the PCB's dwell time in the process chamber of the production reflow oven B, which is shown in the measured reflow profile for the demonstrator board (red preparation). (***Figure 8***). Overall dwell time through the end of peak zone 3 is 264 seconds in this case, and is nearly identical to the overall dwell time of 266 seconds ascertained for the production reflow oven A. It is not possible to extend overall dwell time (by reducing conveyor speed) due to the limit for time above liquidus.

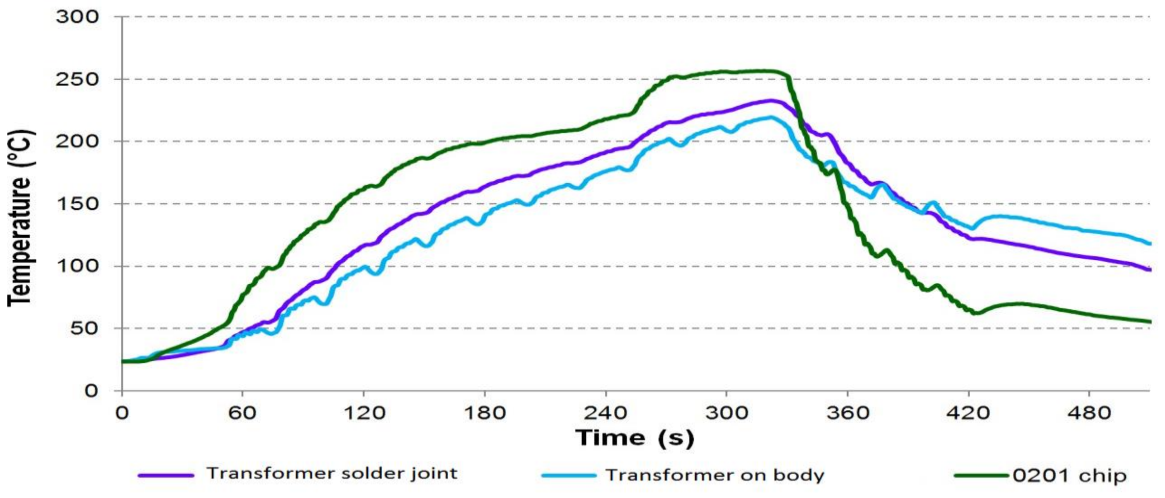


Figure 8: Thermal Masses in Comparison, Demo-Board, OPT, Red Preparation on Production Reflow Oven B

If the temperature difference between the thermal masses needs to be drastically reduced, an entirely different soldering process is advisable. Results achieved by means of vapor phase soldering will be discussed. Firstly, we will take a comparative look at the reflow profiles (MIN, red preparation), see ***figure 9***.

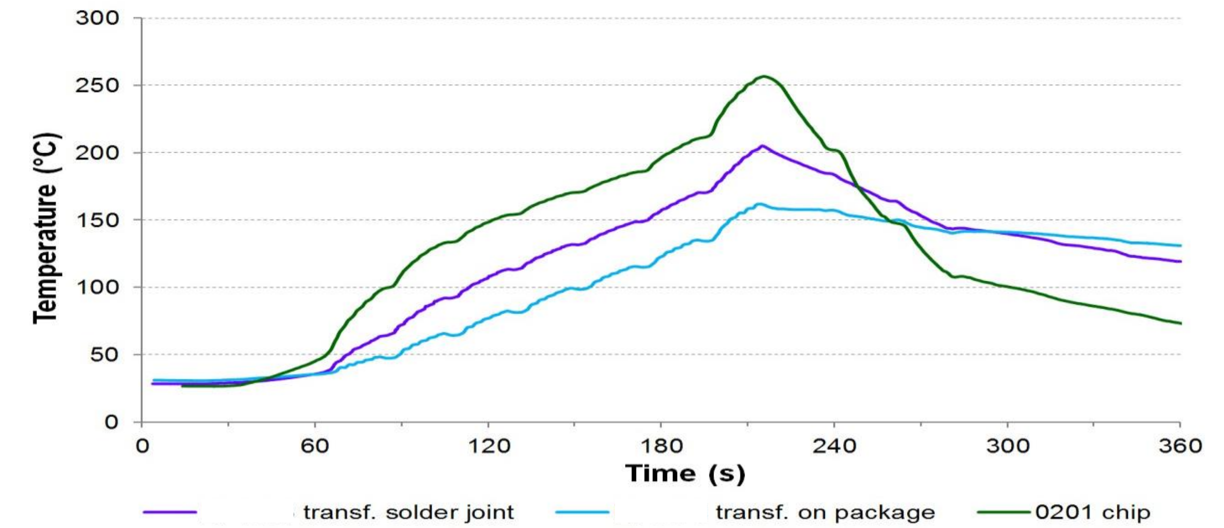


Figure 9: Thermal Masses in Comparison, Demo-Board, MIN, Red Preparation

Table 5: Results from **Figure 9**

	Temperature T_{max} in °C	**Time Above Liquidus t_L in s**	**Gradient in K/s**
0201-Chip	257	34	3,3
transformer, solder joint	205	0	2,2
transformer, on package (T_P)	162	0	2,2

When dwell time is minimized to such a great extent, the transformer can no longer be soldered with this reflow profile because the melting temperature for the SAC solder is not exceeded. The desired minimum dwell time is achieved for the 0201 chip, but the permissible limit gradient of ≤ 3 K/s is exceeded.

Only the surface of the PCB has a thermal mass less than that of the smallest components (0201, 01005, 03015), because they make practically no contribution to increasing thermal mass at the measuring point. ***Figure 10*** shows the reflow profiles of the top of the PCB and the 01005 and 03015 chips in comparison.

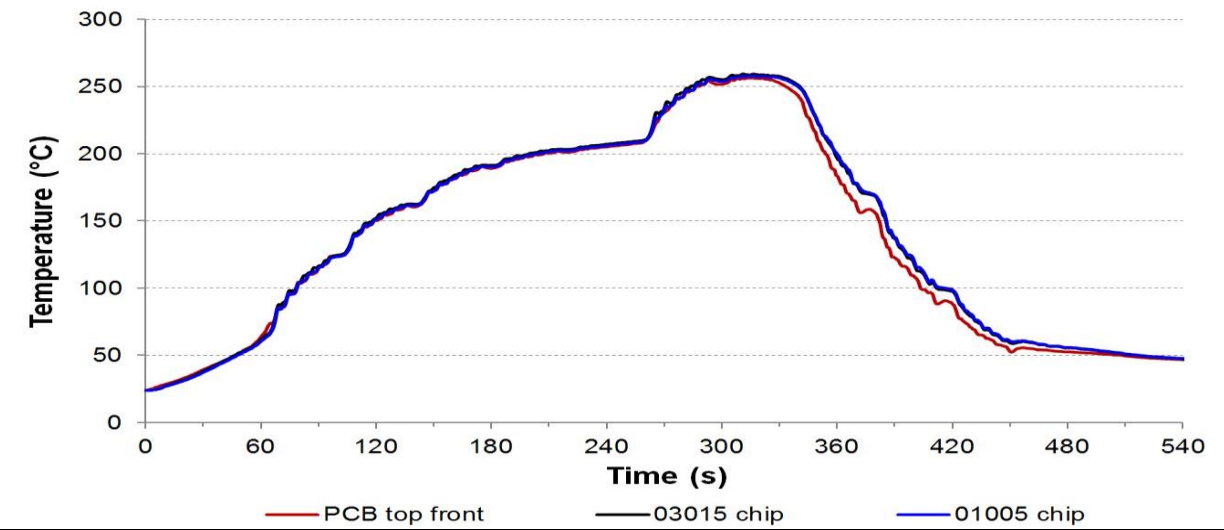


Figure 10 : PCB and Smallest Components in Comparison, Demo-Board, OPT, Green Preparation

	Temperature T_{max} in °C	**Time Above Liquidus t_L in s**	**Gradient in K/s**
Top left of PCB	257	84	2,6
01005 chip	258	89	2,6
03015 chip	259	84	2,6

Table 6: Results from ***Figure 10***

3.2 Pin-in-Paste-Reflow Soldering

Pin-in-paste reflow processes are widely established in actual practice. Thus the demonstrator board is equipped with several THD plugs whose reflow profiles are evaluated below. In the case of the pin-in-paste reflow process, it is above all important to heat up the pins to be soldered to the required temperature above liquidus without overheating the plug housing. ***Figure 11*** shows the reflow profiles for the optimum system settings.

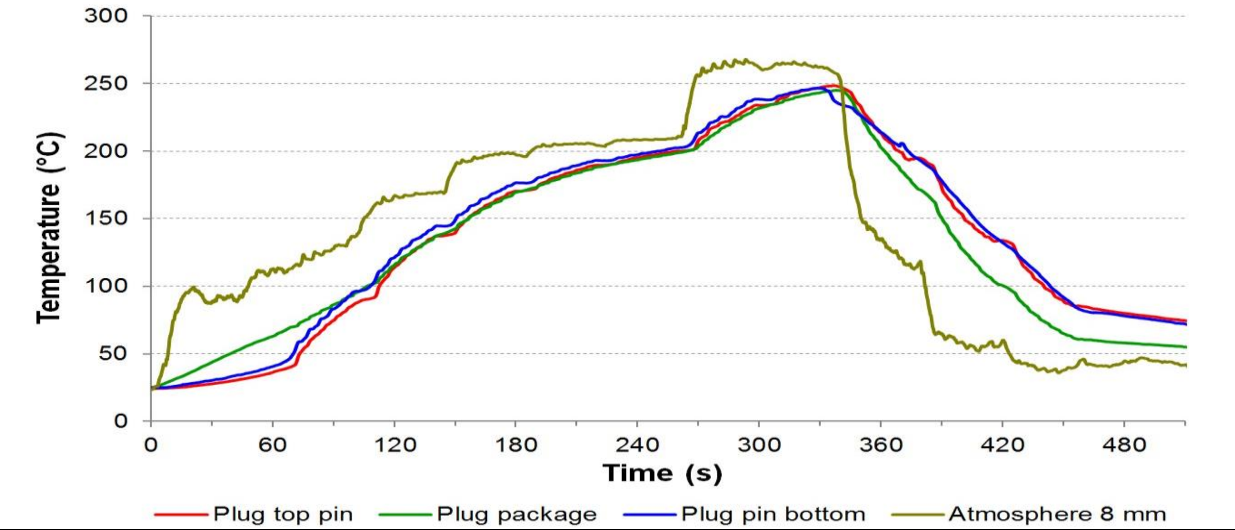


Figure 11: Pin-in-Paste Reflow Process, Demo-Board, OPT, Red Preparation

The measuring points on the pins to be soldered (pin terminal, bottom pin) demonstrate a temperature difference of only 1 K at a maximum temperature of 248° C and a time above liquidus of tL = 84 seconds. The plug's package temperature TP = 245° C remains below the limit for the target reflow profile. Conveyor speed is high enough to prevent the package from warming up to the ambient temperature of the atmosphere. This makes it possible to set up optimized pin-in-paste processes even with shorter reflow systems such as the production reflow oven A used in this case. As a prerequisite, time above liquidus must in any case fulfill the minimum requirements of tL > 20 s. This is not the case for the reflow profile "MIN red preparation", which is made apparent in ***figure 12***.

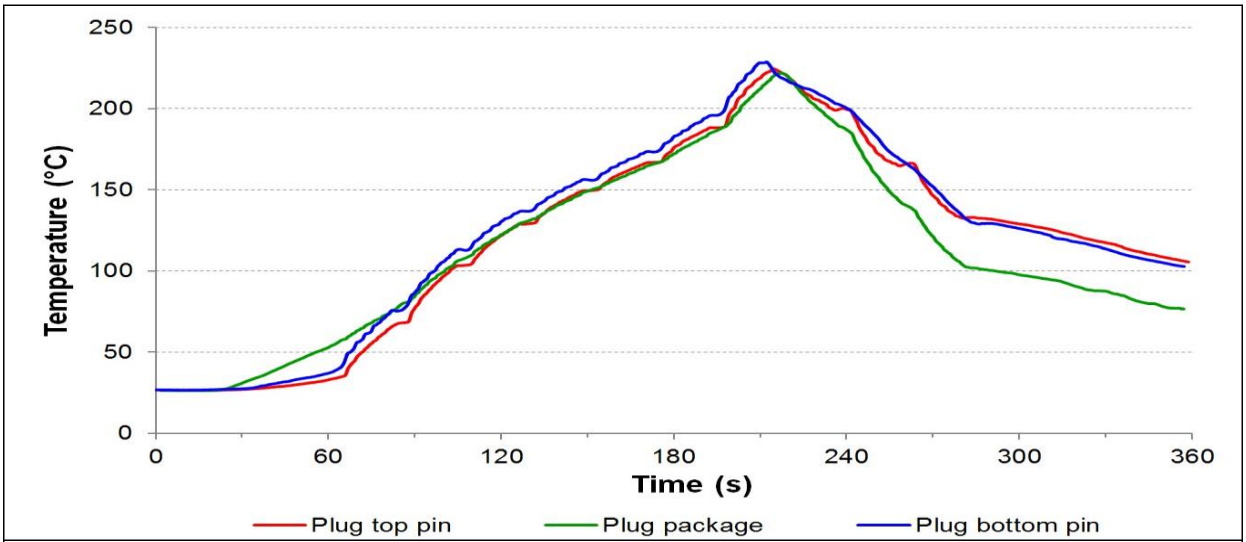


Figure 12 Non-Optimized Pin-in-Paste Reflow Process, Demo-Board, MIN, Red Preparation

A time above liquidus of only tL = 16 seconds is achieved at the pin to be soldered at a maximum temperature of 229° C. Accordingly, the micrographs of the pins show soldered pins next to unsoldered pins (see ***figures 13a, b, c***).

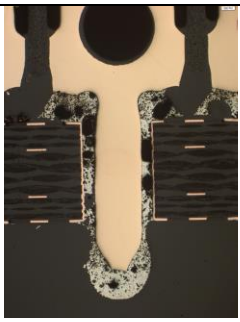
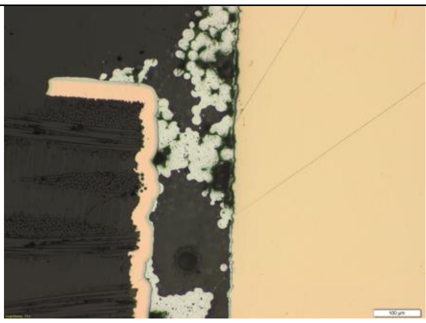
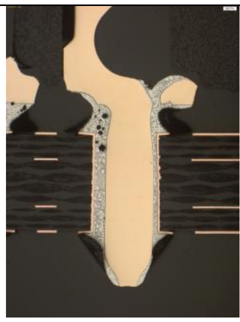
		

Fig. 13a: Unsoldered Pin	***Fig. 13b***: Detail View of Unsoldered Pin	***Fig. 13c***: Soldered Pin

Fig. 13 a, b, c: Non-Optimized Pin-in-Paste Reflow Process, Demo-Board, MIN, Red Preparation

The detail view of the micrograph in ***figure 13b*** makes it apparent that only a few grains of the solder paste have melted, and that dwell time is too short for the production of a homogenous, molten solder phase.

3.3 The Significance of the Temperature Gradient

LEDs are another demanding group of components on the demonstrator board. Preliminarily, we can say that all LED solder joints have been ideally implemented on the demonstrator board, as depicted by the microsections in ***figures 14a and 14 b***.

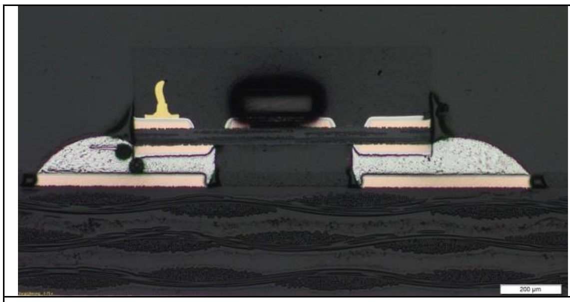
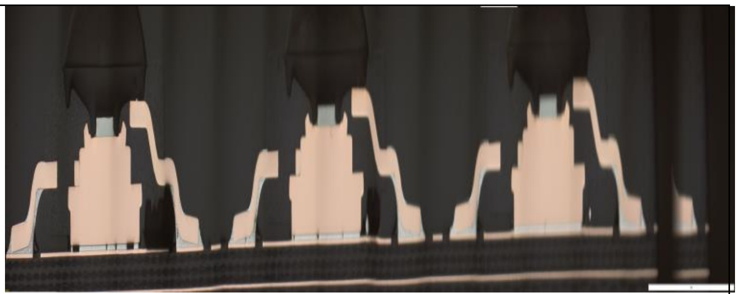
	

Figure 14a: LED 0402	***Figure 14b:*** LED B

Not only do the absolute limit parameters for time and temperature have to be observed when reflow soldering LEDs, but rather the special requirements for the temperature gradients as well. In general, calculation of the gradient is based on a time interval of 10 seconds (see IEC TR 60068-2-580 *[5]*). The gradient is calculated as follows:

$Gradient = \frac{T_2 - T_1}{t_2 - t_1}$	$T_2 - T_1$ $t_2 - t_1$	Temperature difference Time difference

This formula makes it clear that, from a mathematical viewpoint, the gradient must become larger when the time interval is reduced. Time intervals of less than the usual 10 seconds are frequently stipulated in LED specifications for the purpose of gradient calculation. For example, a LED data sheet *[6]* for a SMD LED with clear silicon lenses indicates that: "All temperatures refer to the center of the package, measured on the top of the component, slope calculation DT/Dt: Dt max. 5 s; fulfillment for the whole T-range". Here, the heat gradient is limited to +3 K/s and the cooling gradient to -6 K/s..

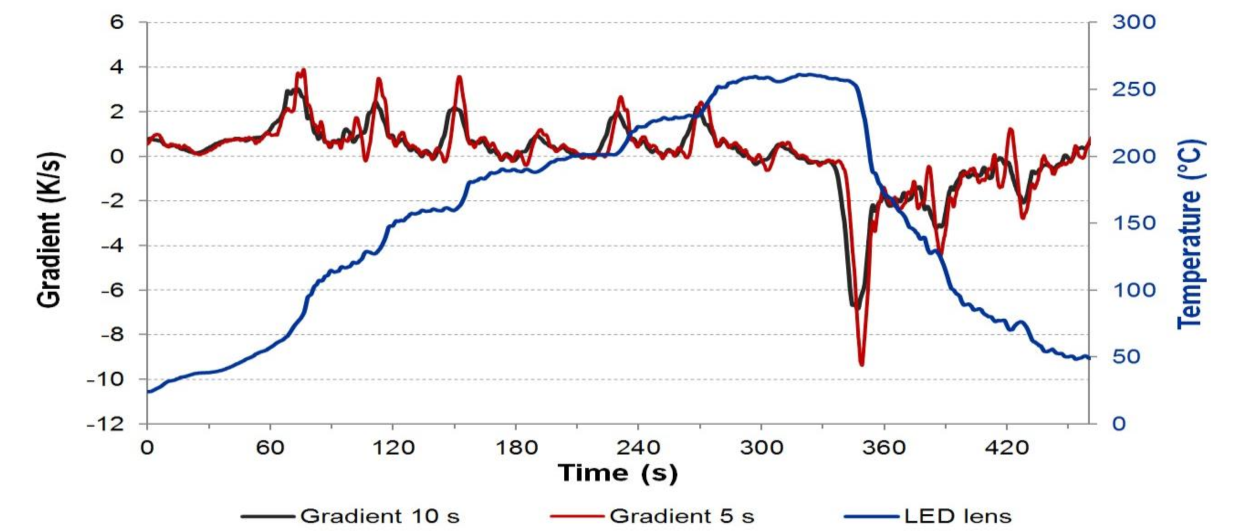


Figure 15: 3-Lens LED, Characteristic Gradient Curve on Top of the Lens, Demo-Board, MAX, Green Preparation

The lens of a 3-lens LED on the demonstrator board was contacted with a thermocouple. ***Figure 15*** shows the characteristic gradient curve for time intervals of 10 and 5 seconds over the reflow profile. Whereas a maximum heat gradient of +3.0 K/s was calculated for the 10-second time interval, the gradient is increased to +3.9 K/s when a time interval of 5 seconds is used. In order to adhere to the LED specification, an adequately long reflow soldering system must be used when soldering LEDs, which provides enough room for process optimization. Technical modifications (e.g. alternative nozzle sheets) can also lead to the desired results with shorter systems. If production reflow oven A with modified nozzle sheets is used, a reflow profile which complies with the LED's limitations can be found (see ***figure 16***).

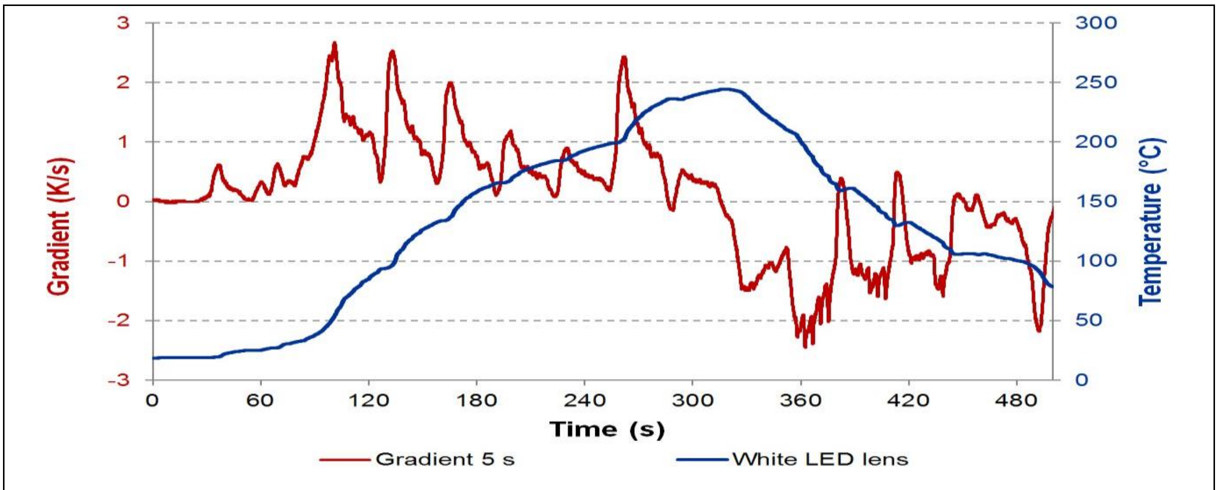


Figure 16: Optimized LED Reflow Profile, Characteristic Gradient Curve over a Time Interval of 5 s

4 Vapor Phase Reflow Soldering

Another reflow soldering technology is called vapor phase soldering or condensation soldering. This section will discuss the results obtained for the company board using a vapor phase system with injection technology [7].

A big problem of conventional vapor phase ovens is soldering of cup like components due to the drag out of the vaporization medium and the temperature drop on the location where the liquid medium is collected. Due to the low heat conductivity as a liquid it constantly cools the circumjacent area thus destroying the small delta T on the complex board.

The benefit of an injection principle is that the reflow soldering profile is controlled by injecting a predetermined quantity of heating medium into a process chamber. So the amount of medium that is present during the soldering process is limited and after the soldering process the medium can dry off the board during a low pressure cycle in the chamber to recycle the medium. In Figure 17 the vapor phase reflow soldering profile of the demo-boards is shown. A temperature difference of 12 K is measured between the 0201 resistor (lowest thermal mass) and the transformer (highest thermal mass). This is a drastic reduction as opposed to convection reflow soldering (23 K). This is due to the fact that when condensation occurs on all surfaces (in 3 dimensions), heat is transferred significantly more homogenously to the PCB and within a shorter time interval that with the convection process.

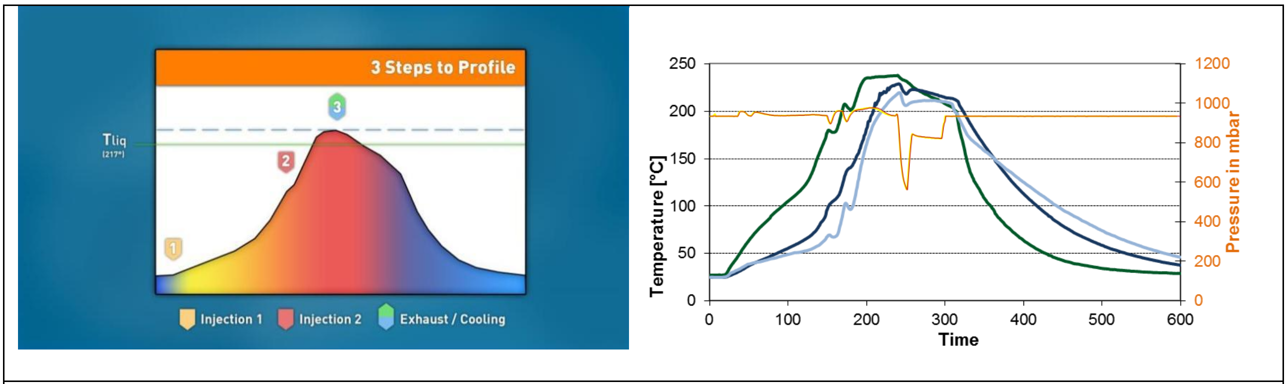
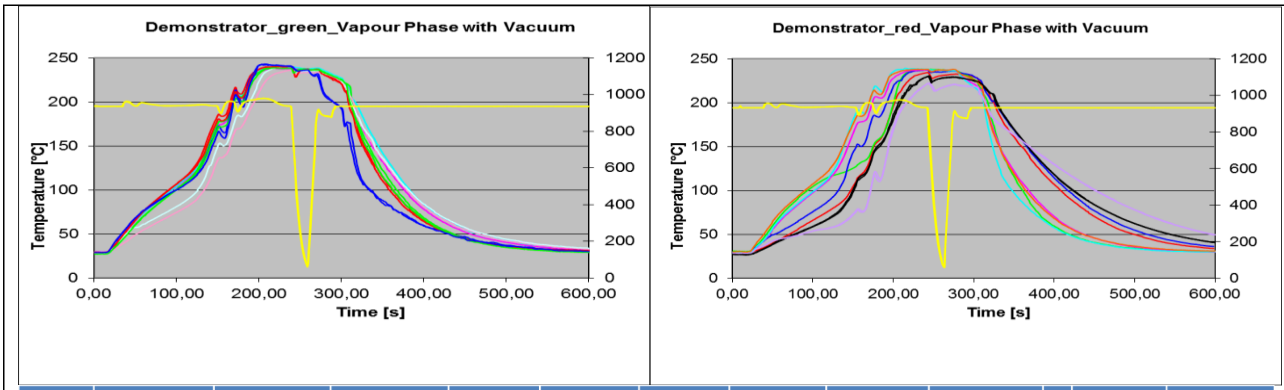


Figure-17: Vapor Phase Soldering, Soldering profile without vacuum

The pressure curve shown in Figure 17 reveals that the pressure drops during the first cooling stage. This helps the remaining liquid in the cup-like components to vaporize and to be returned to the liquid holding tank of the machine. This ensures that the entire volume of medium is once again available for the next process cycle, and that the soldered PCBs are dry when they are removed from the process chamber. The produced boards were always fully dry upon removal from the soldering system.

To verify the effect of vacuum application to the board, a pressure of 50mbar was used. As shown in Figure 18 the temperature difference could be reduced to 10K and still the time above liquidus could be kept within the specification mentioned earlier. Due to vacuum application the time above liquidus was prolonged by 25s and the overall void ratio was less than 2%.



	PCB top front	PCB btm front	01005	03015	Atmosphere	Switch body	LED lense	PCB top bck.	PCB btm bck.		Delta T / board	Delta T
Green			239.9	240		239.8					0.2	10.2
Red	237.4	238.1	237.2	229.8			230.6		238		8.3	
	Connector	Connector body	Connector Pin	Shielding	Shielding top	Atmosphere	Transformer	Transformer top	0201			

Figure-18: Vapor Phase Soldering, Thermal Masses in Comparison with vacuum application

Another aspect when comparing convection and condensation soldering is the heating gradient. In Figure 19 the result is shown that was achieved especially in regard to the sensitive LED components. The gradient specification could be satisfied with vapor phase soldering injection technology.

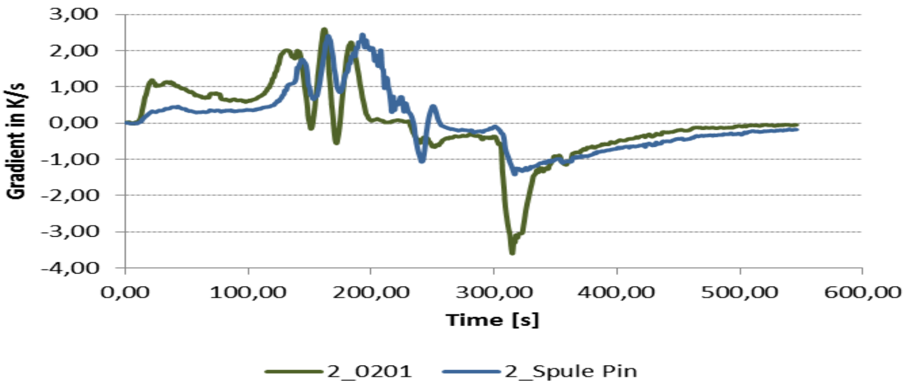


Figure-19: Vapor Phase Soldering, Thermal Masses in Comparison, Demo-Board, Without Vacuum, Red Preparation

5 Summary

The demand for mixing components onto a single board is needed due to miniaturization and reducing footprint in assemblies. This approach shows a big impact towards all disciplines in SMT assembly process. On a first look it seems impossible to combine them, but by applying the proper engineering methods and attention, the complexity of the mixture can be controlled. The indicated product demonstrator could be produced within the current standards and guidelines.

The main factor to mitigate the discovered problems is a detailed thermal analysis of the product. Just guessing and trying will ultimately fail to be successful in combining the huge range of components that are available on the market.

A further improvement in reducing the delta T between the components showed the use of a vapor phase machine. The present problem with current vapor phase machines, are in terms of a "beaker" like approach for collecting the media from the components which negatively impacts the temperature profile. Therefore a system with media recovery during the reflow process has been shown to successfully avoid this phenomenon.

References

[1] *Hans Bell, Reflow Technology, Fundamentals of Reflow Soldering, Part 2: Reflow Soldering methods, Figure 1.12, S. 19, May 2010*

[2] *IPC-7093 (March 2011): Design and Assembly Process Implementation for Bottom Termination Components, Table 6-3*

[3] *IPC 7095 C (Jan. 2013): Design and Assembly Process Implementation for BGAs, Table 6-3*

[4] *IPC/JEDEC J-STD-020D.1 (March 2008): Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices, Figure 5-1, Table 4-2 Note 2*

[5] *IEC TR 60068-2-580: Method to evaluate a possible lead-free reflow temperature profile, Table 3, 2005*

[6] *OSRAM Data Sheet 2013-06-19, LCW W5AM*

[7] *Hans Bell, Reflow Technology, Fundamentals of Reflow Soldering, Part 2: Reflow Soldering methods, Chapter 4: Condensation Soldering, May 2010.*

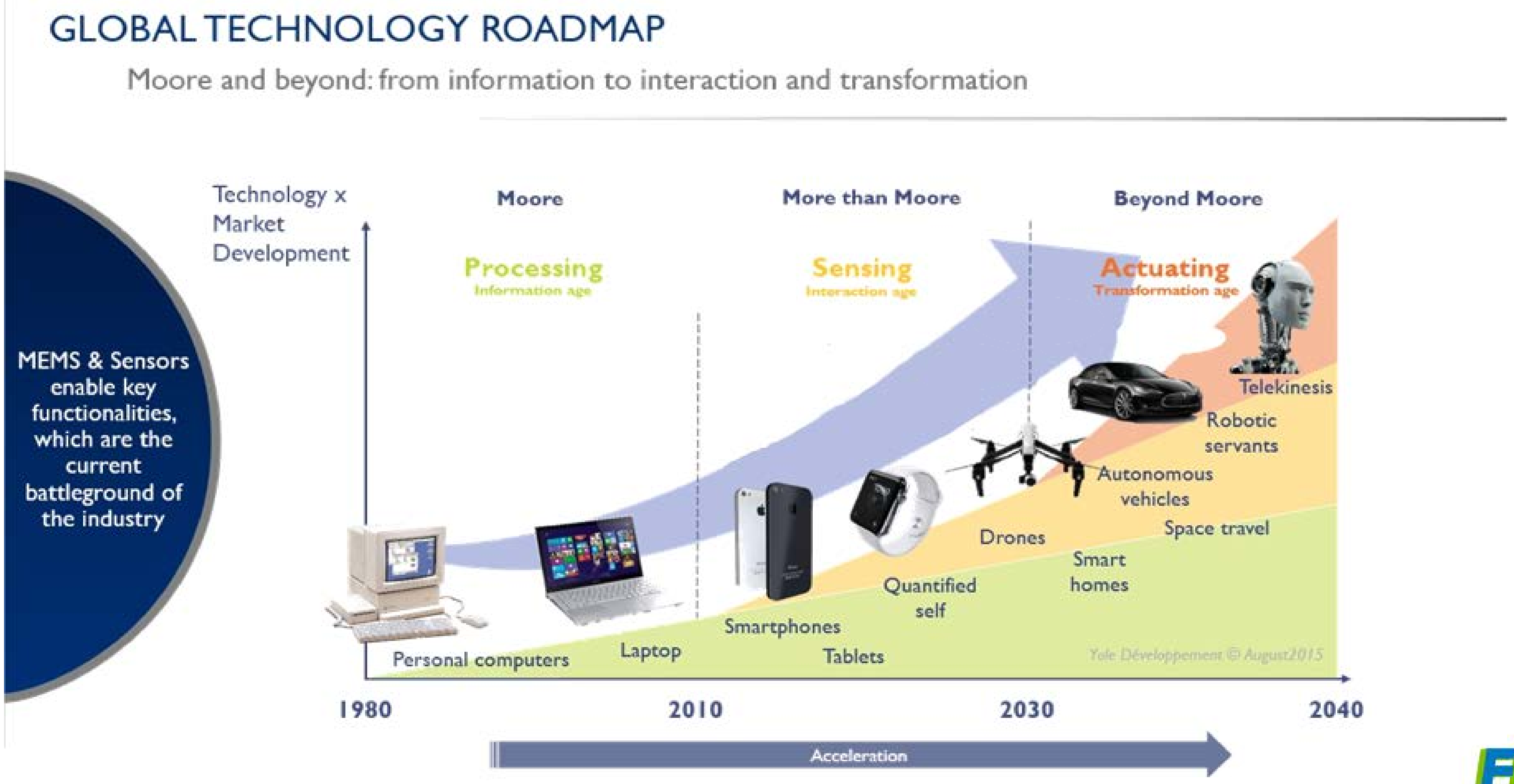
Tiny with a Big impact:
True or False?

Impact of the Component Complexity on the assembly process.
Miniaturized Components (01005, 03015…) in the Mix with so-called Standard Components (BGA, LED, Pin-in-Paste)

H. Öttl, Dr. Hans Bell

Roadmaps

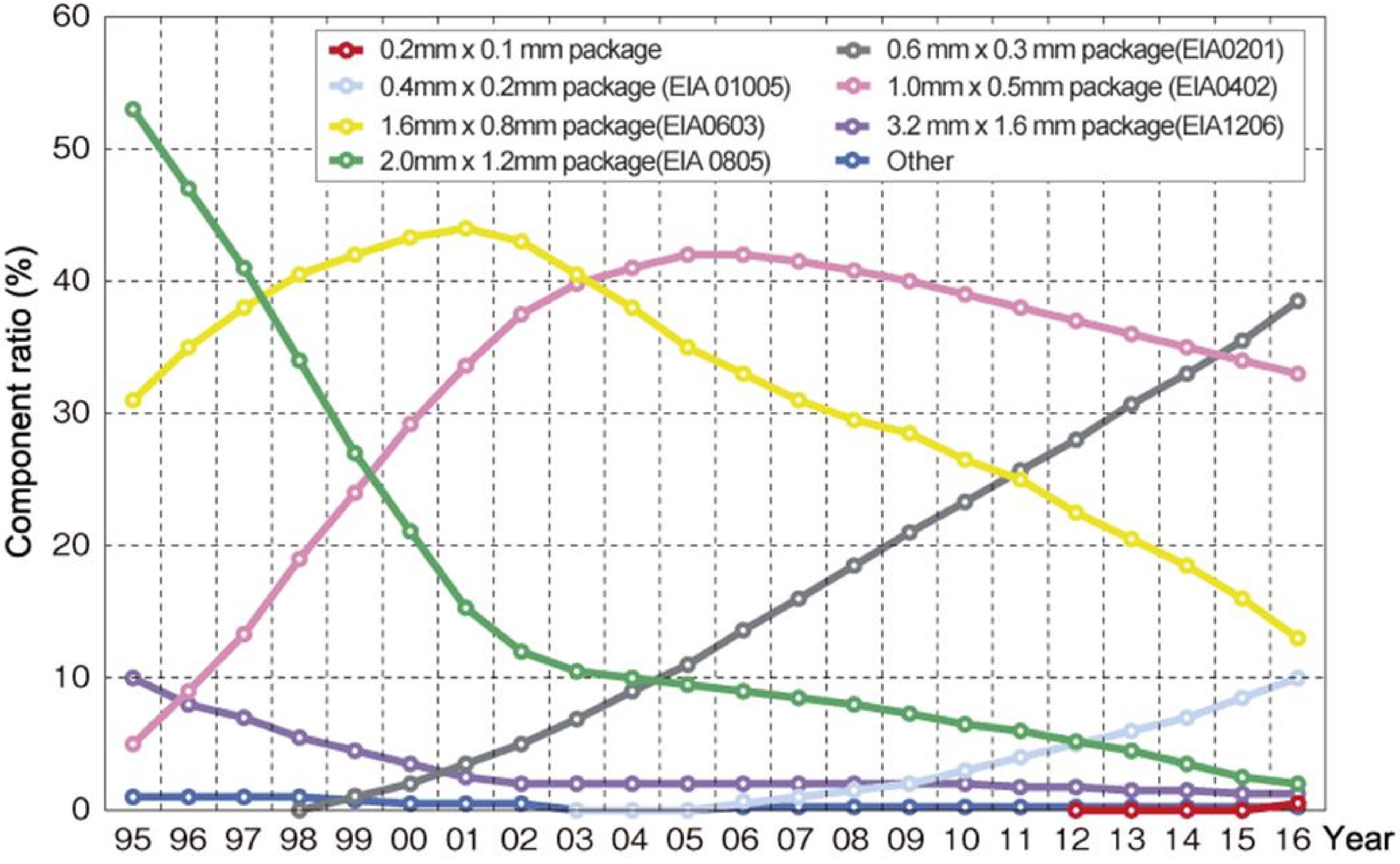
Challenge: Miniaturization



Source: http://www.i-micronews.com/imaging/6485-ams-purchase-of-cmosis-is-a-sign-of-exciting-times.html

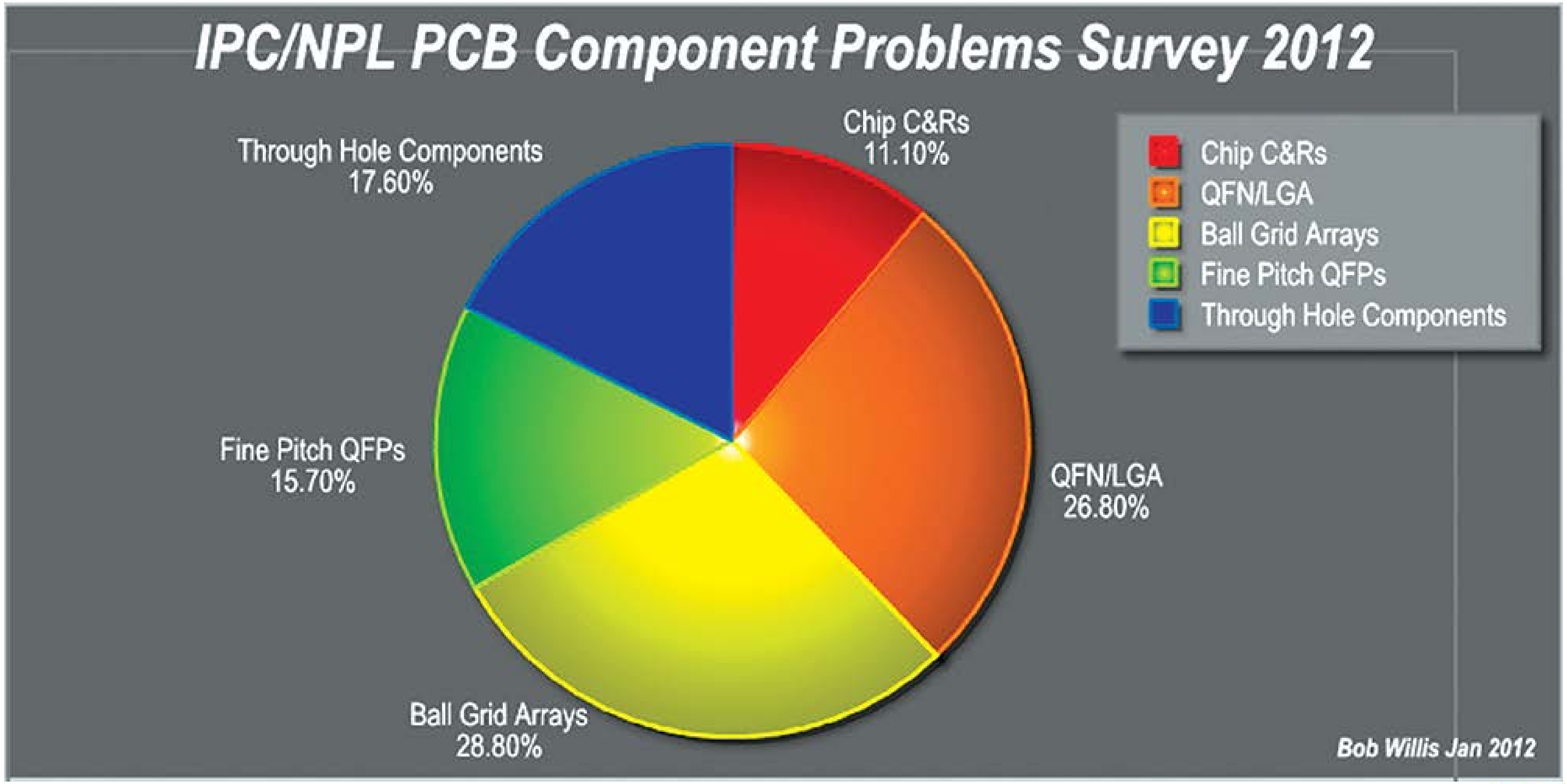
Roadmaps

Challenge: Miniaturization

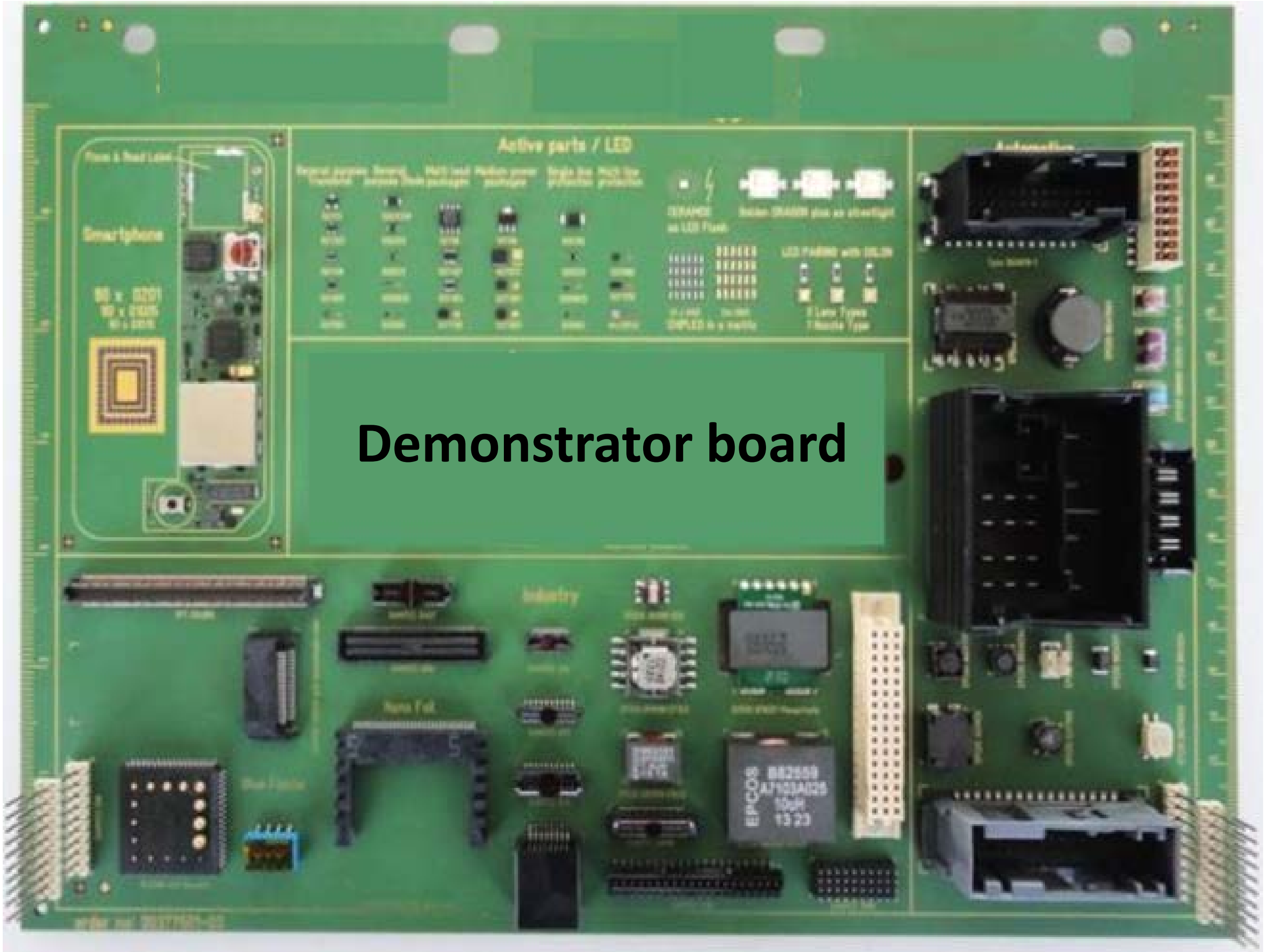


Source: http://www.murata.com/products/article/pp09e1/3.html

IPC/NPL Component Problems Survey 2012

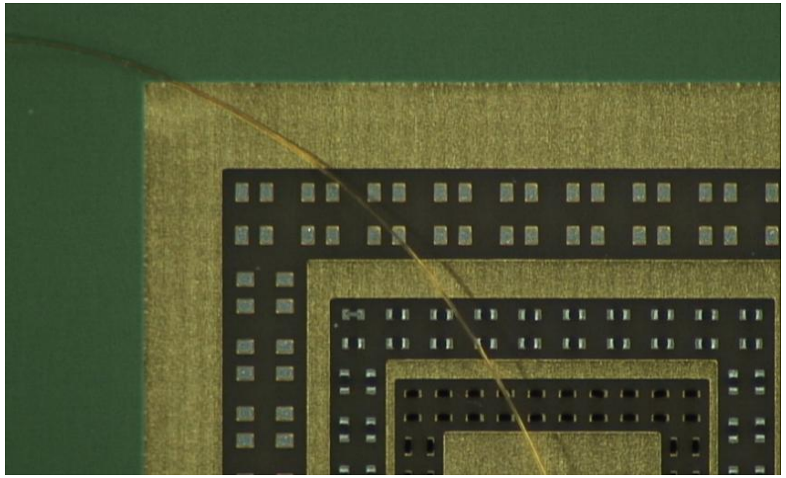


Challenges due to miniaturization

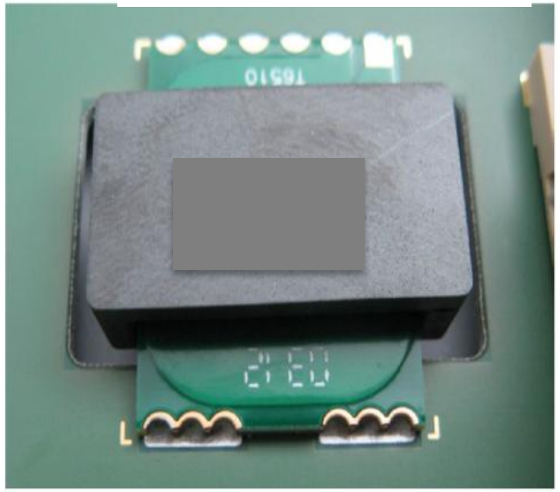


Challenges due To Miniaturization

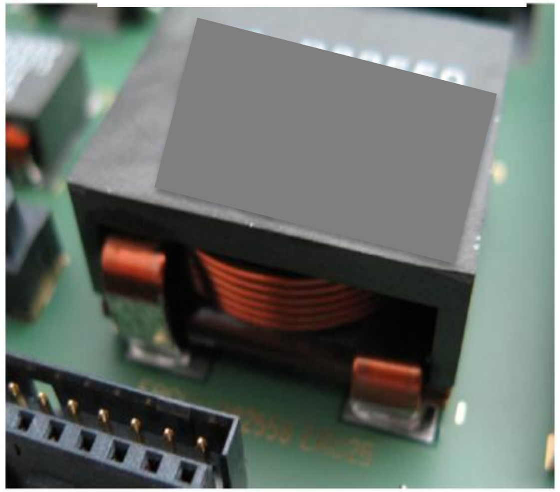
Demonstration board



Planar transformer

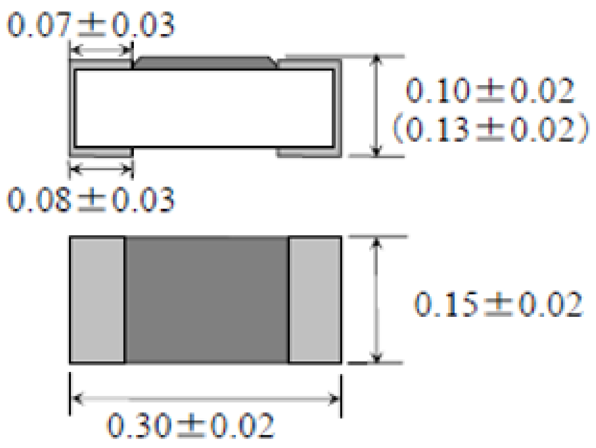


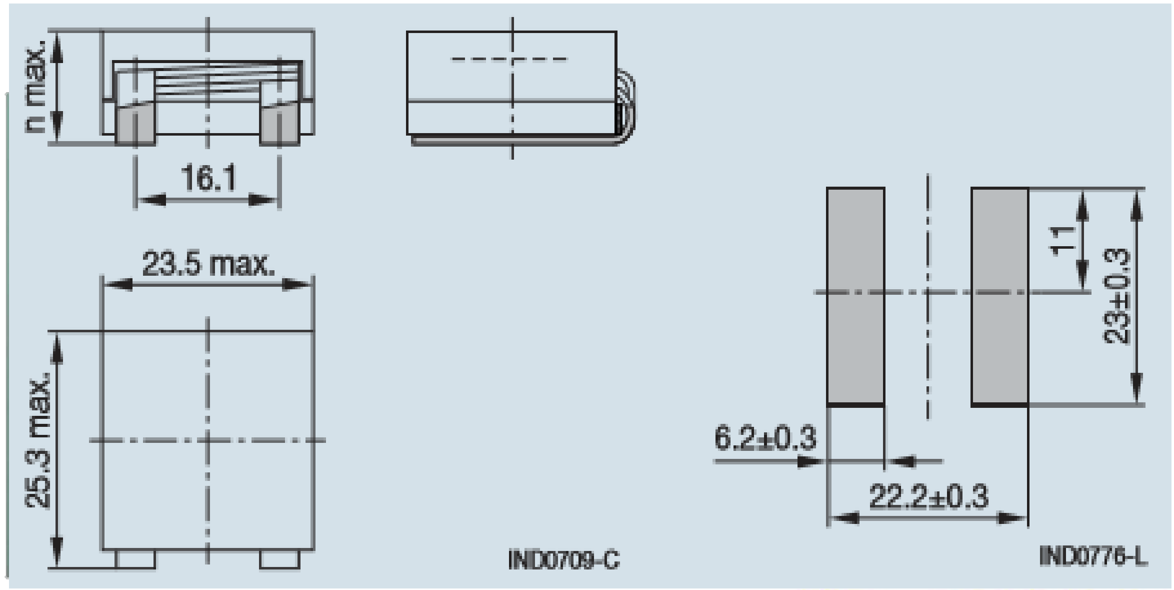
Power transformer



Challenges due to miniaturization

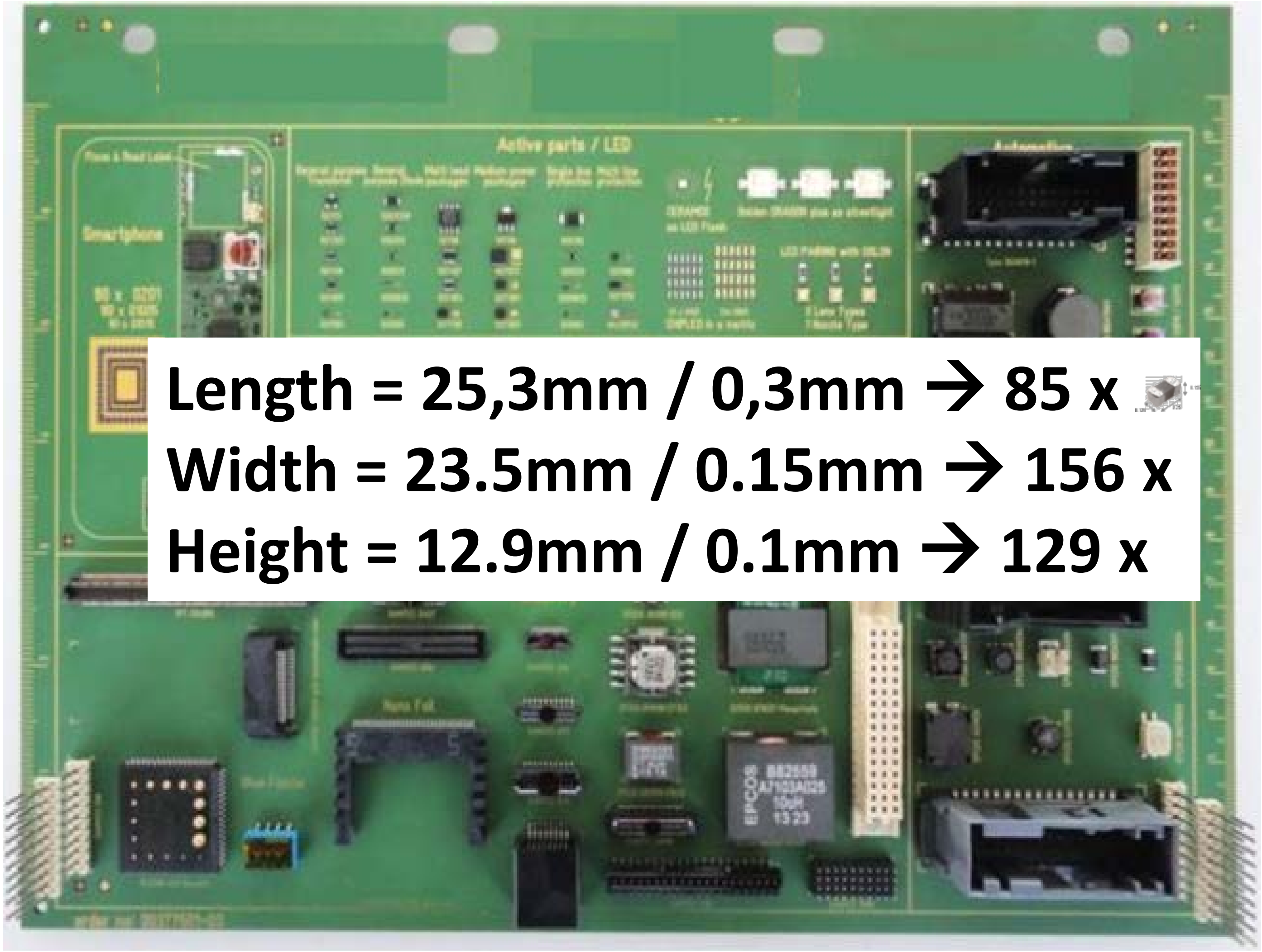
Demonstration board





Challenges due to miniaturization

Demonstration board



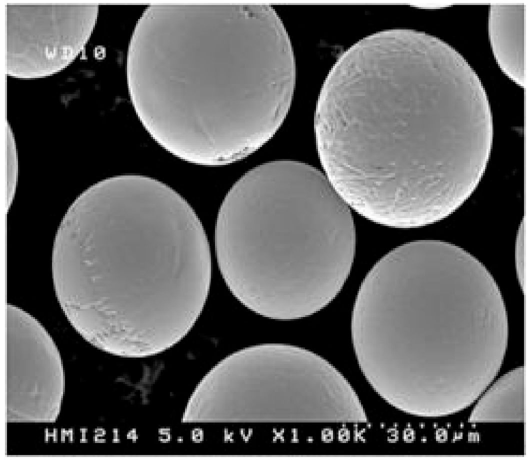
Length = 25,3mm / 0,3mm → 85 x
Width = 23.5mm / 0.15mm → 156 x
Height = 12.9mm / 0.1mm → 129 x

Paste Printing

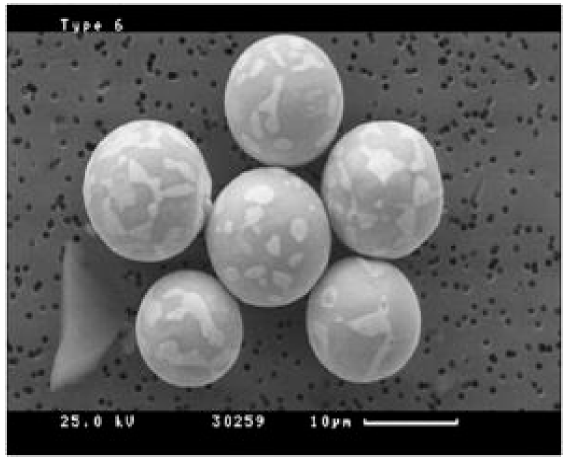
Solder Powder and Solder Paste

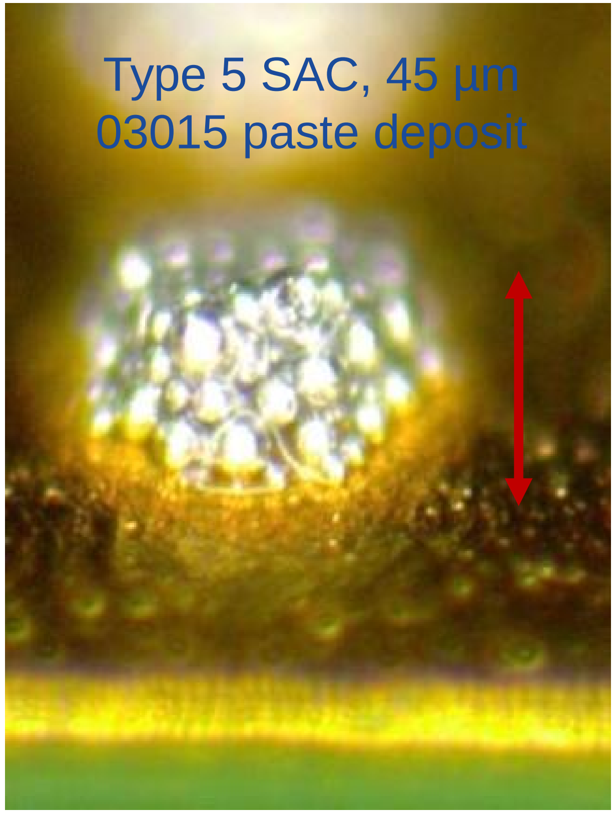
> Ideal solder balls are required for a fine pitch solder paste

Type 6, Sn96,5Ag3,5



Type 6, Sn63Pb37





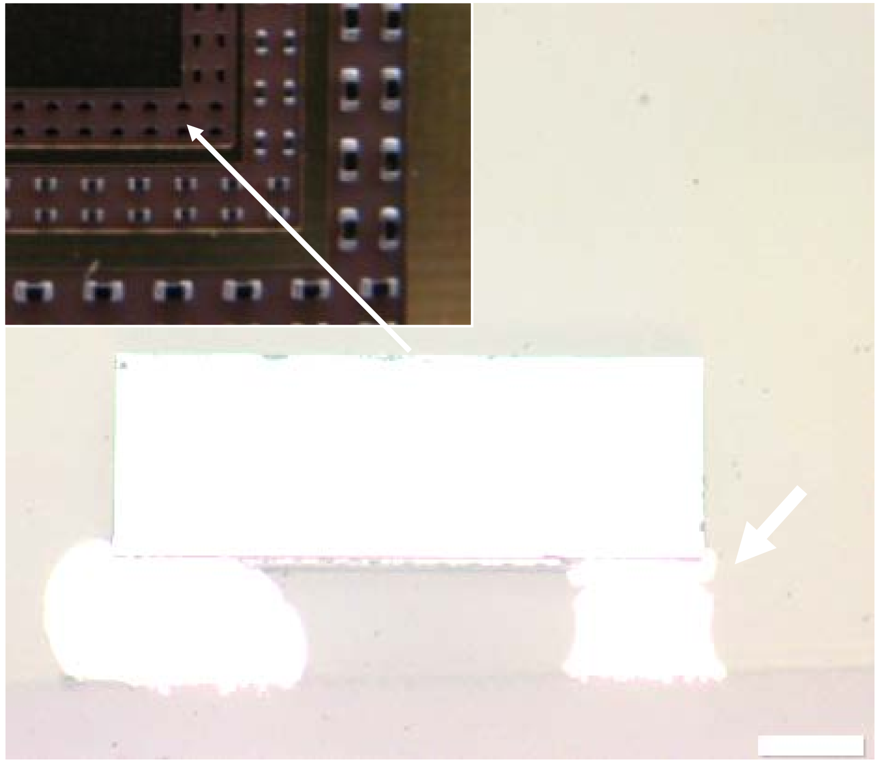
Source: J. Trodler, High Reliability Connection for Packaging Technology, Nürnberg 2.9.2008
Right picture: U. Schäfer, Challenges 03015,Technology Day REHM, 16.07.2014

Paste Printing

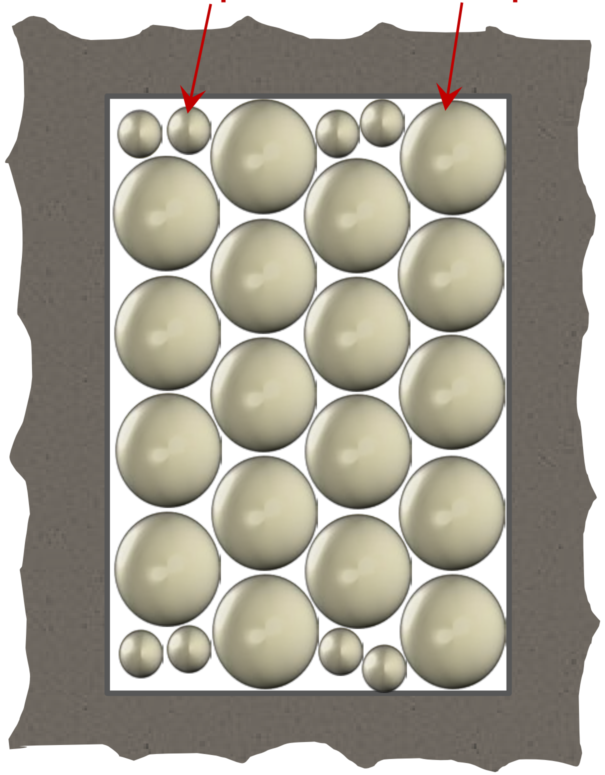
Demonstration board

03015: Insufficient solder

> Stencil printing becomes more difficult

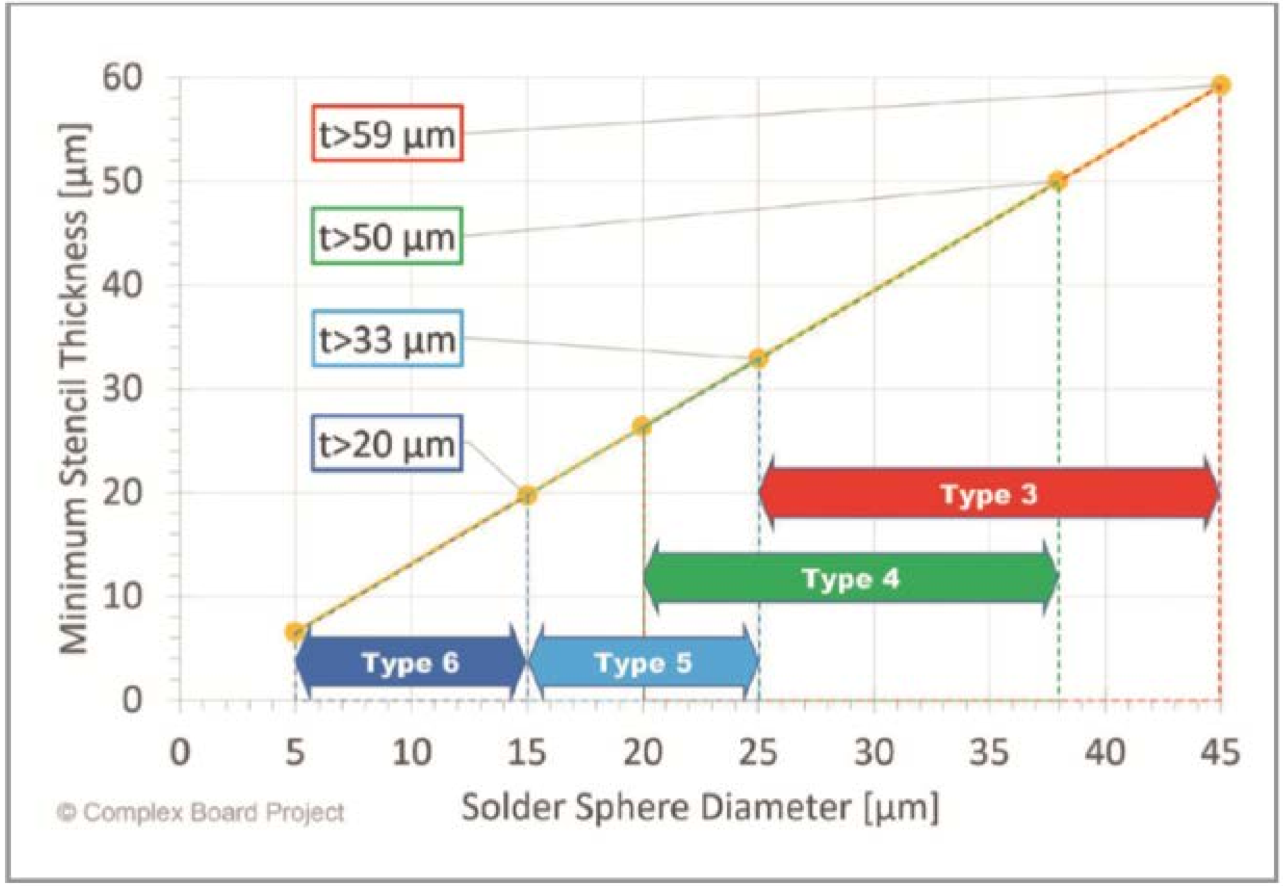


Stencil 95x135x40 µm WxHxT
Paste type 5 (10-25 µm)
Balls Ø 10 µm and Ø 25 µm



Physics of Printing

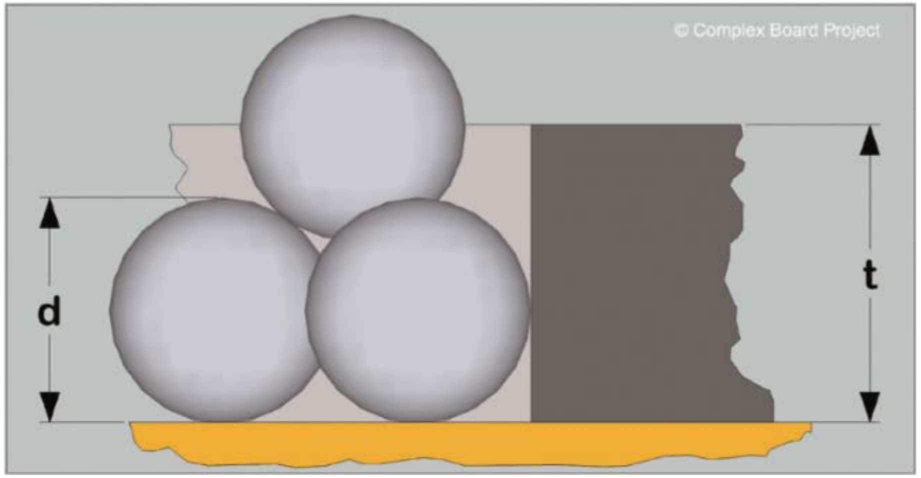
Paste transfer efficiency and stencil thickness



Source: H. Grumm, Christian Koenen

Physics of Printing

Formula for thin stencil thickness and solder paste



Source: H. Grumm, Christian Koenen

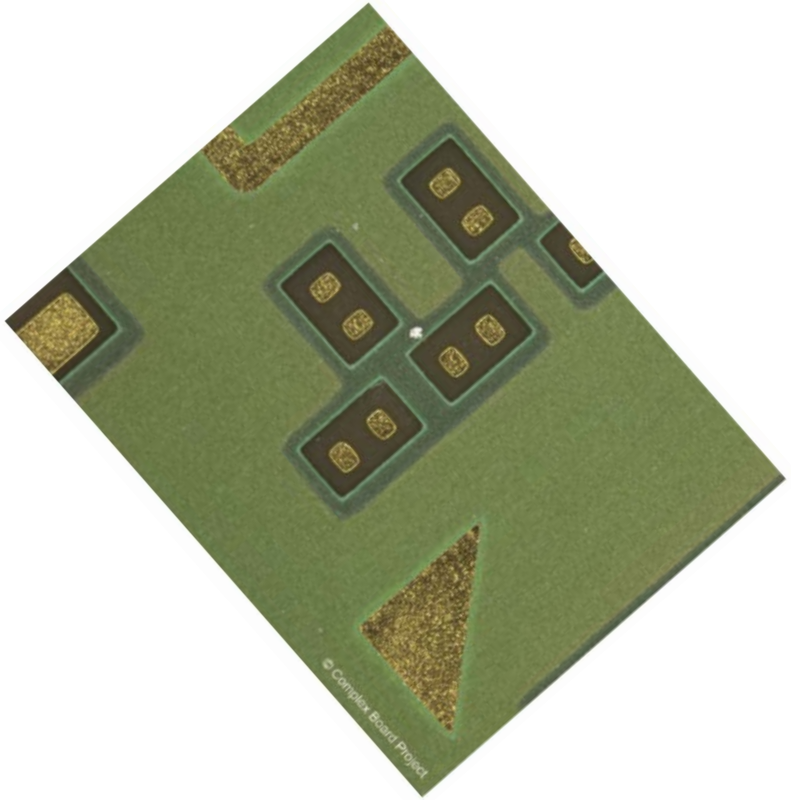
$$t \gg \frac{d}{2} \cdot \left(1 + \sqrt{\frac{8}{3}}\right)$$

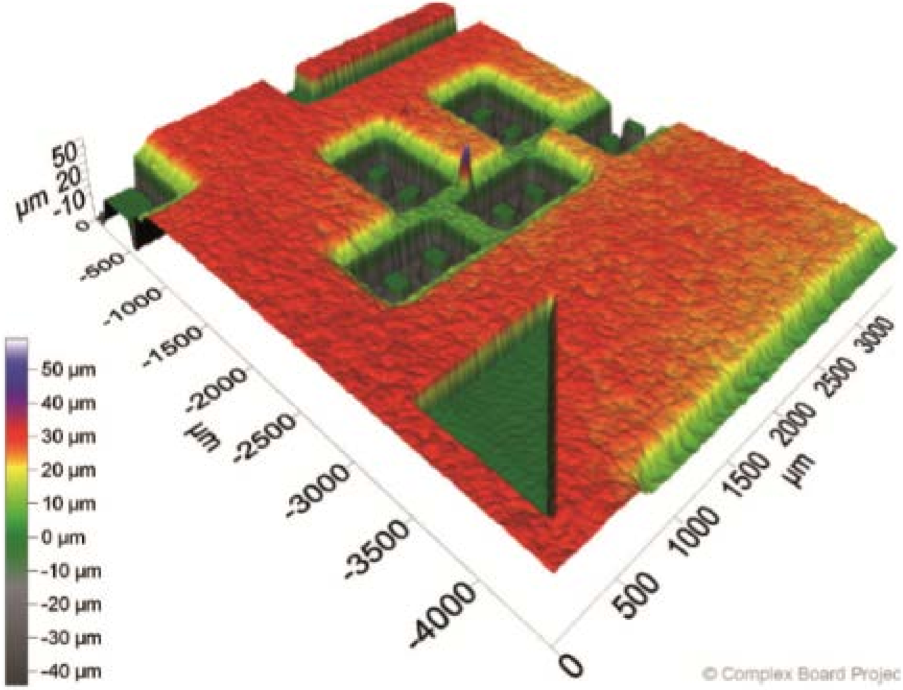
$$t \gg d \cdot 1.32$$

with: t=stencil thickness; d=solder sphere diameter

Physics of Printing

Influence of solder resist

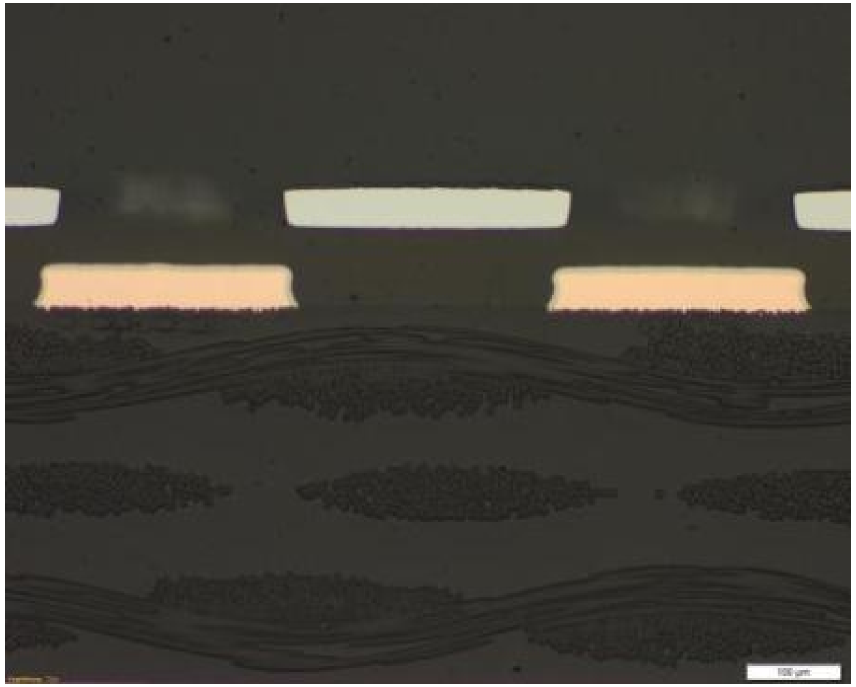




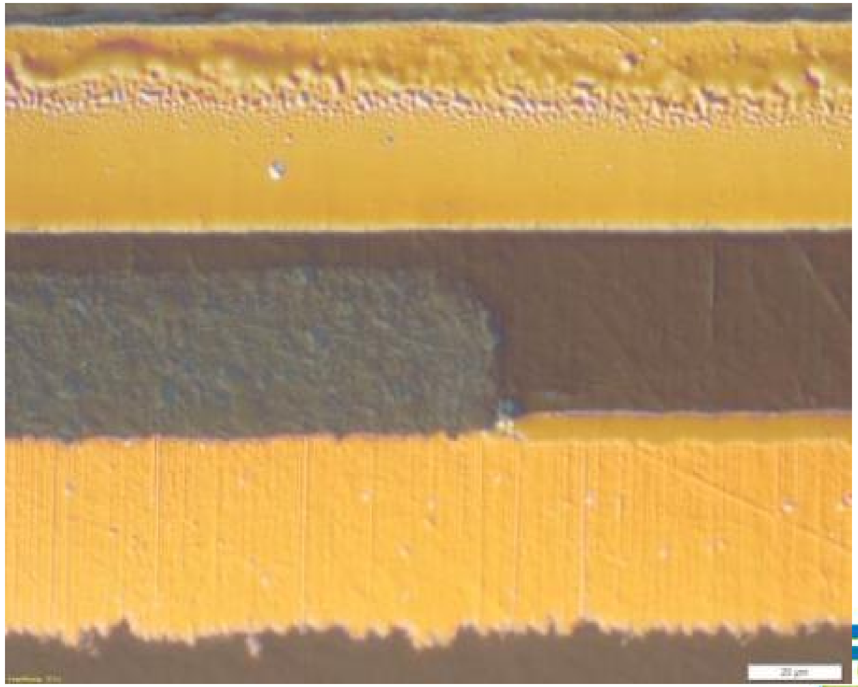
Physics of Printing

0201 Stencil and PCB

Magnification 200x



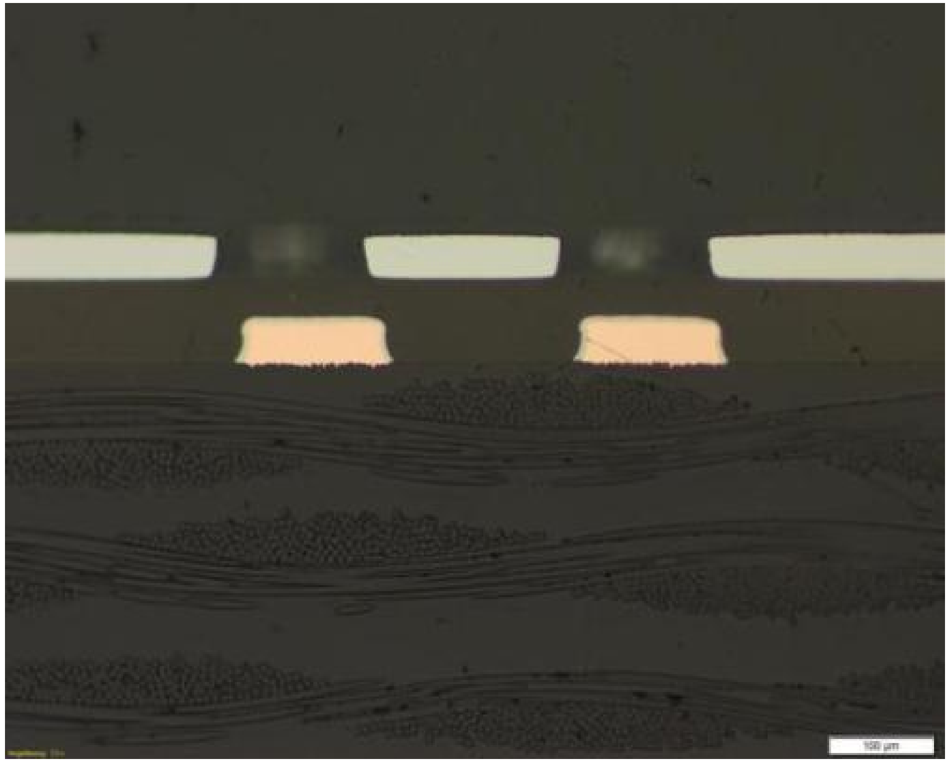
Magnification 500x



Physics of Printing

01005 Stencil and PCB

Magnification 200x



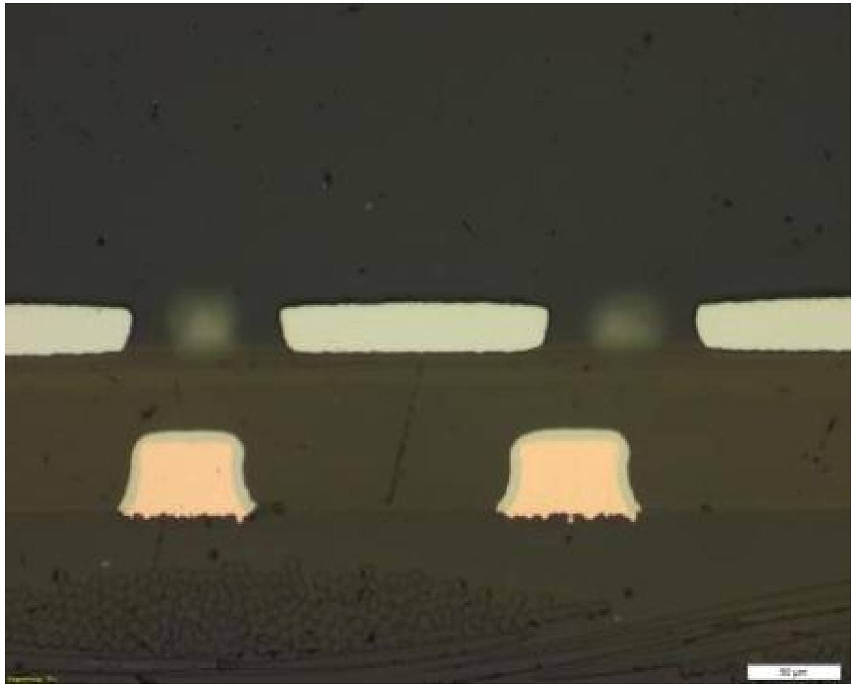
Physics of Printing

0305 Stencil and PCB

Step stencil on the PCB

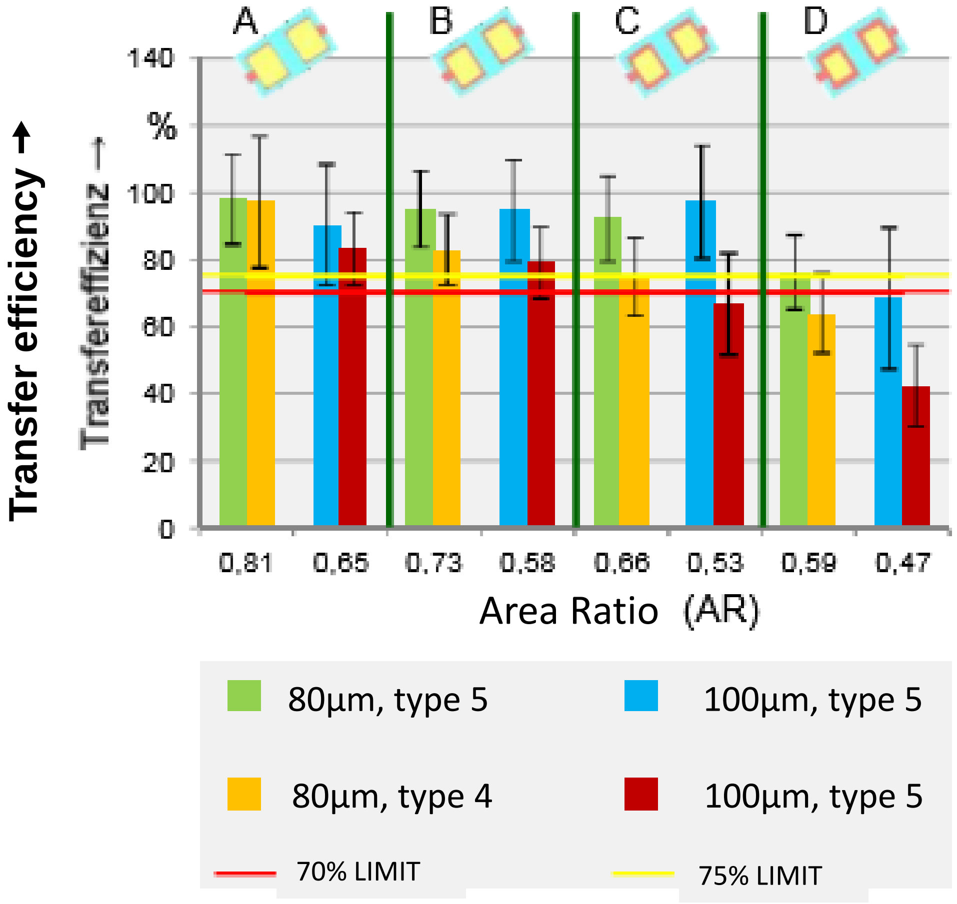
> Offset between stencil and PCB is due to the PCB

Magnification 200x



Printing process

Challenge: Optimizing the paste printing

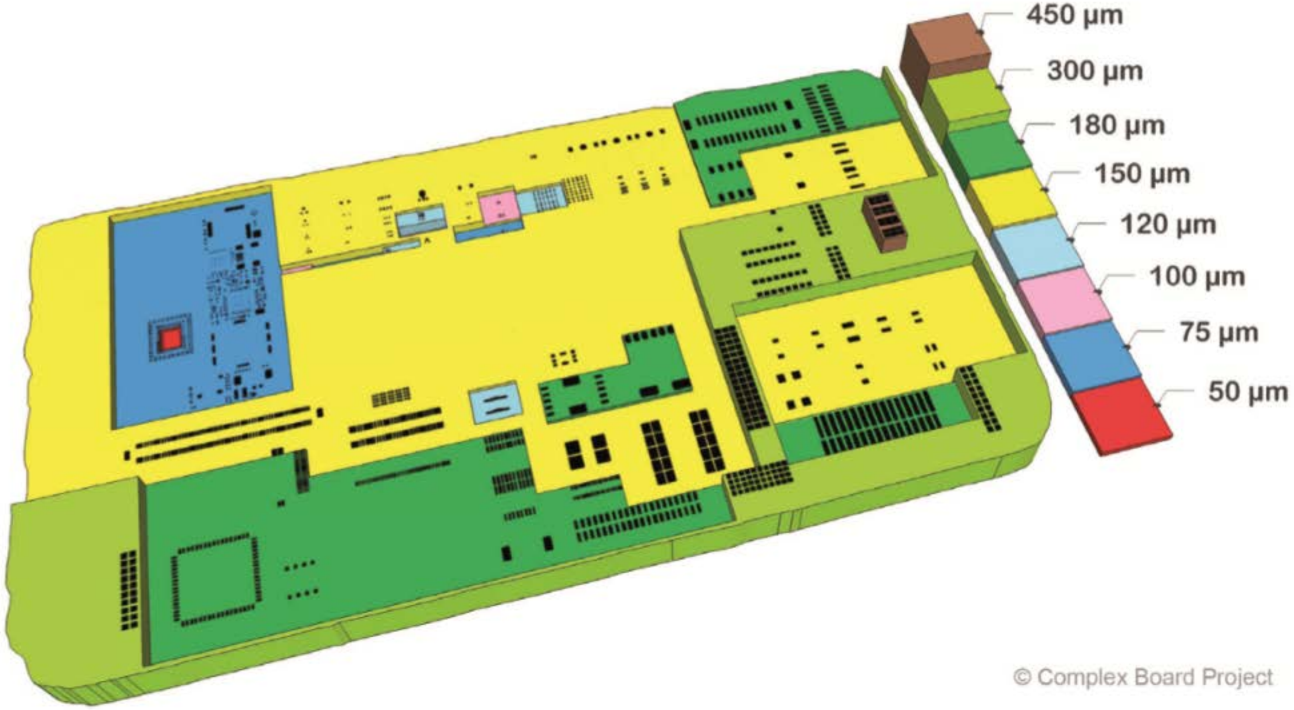


Source: St. Härter, C. Läntzsch; Assembly of highly miniaturized components with size 01005 in the electronics production, DVS GMM Feb. 2014, Fellbach

Physics of Stencil Manufacturing

Step stencil for the Demonstrator Board

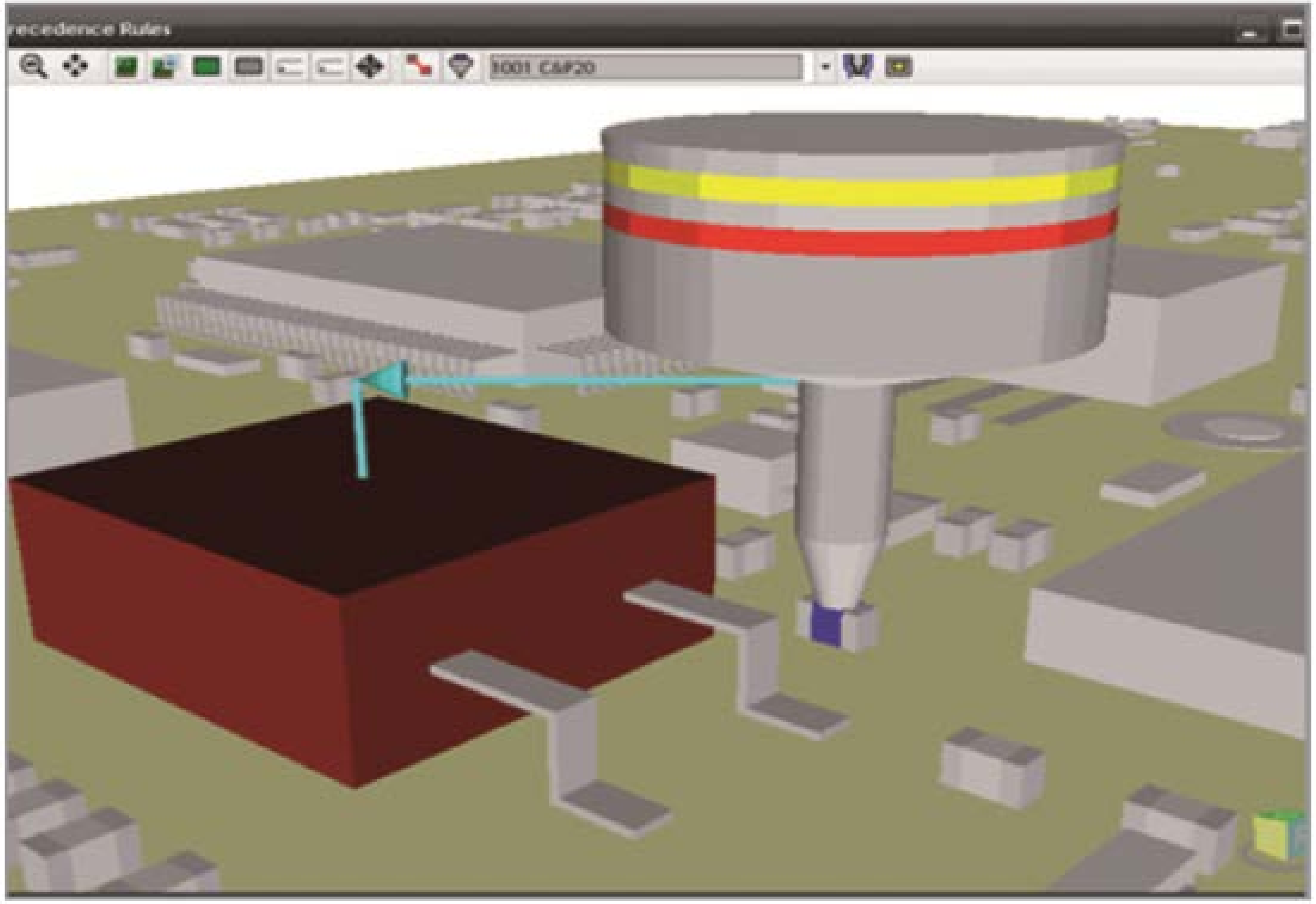
→ Steps balance height differences and local solder paste needs



Source: H. Grumm, stencil design for complex boards,Technology Day REHM, 16.07.2014

Physics of Placement

Component placement



Source: ASM Siplace

03015 Surface Mount Process

Summary

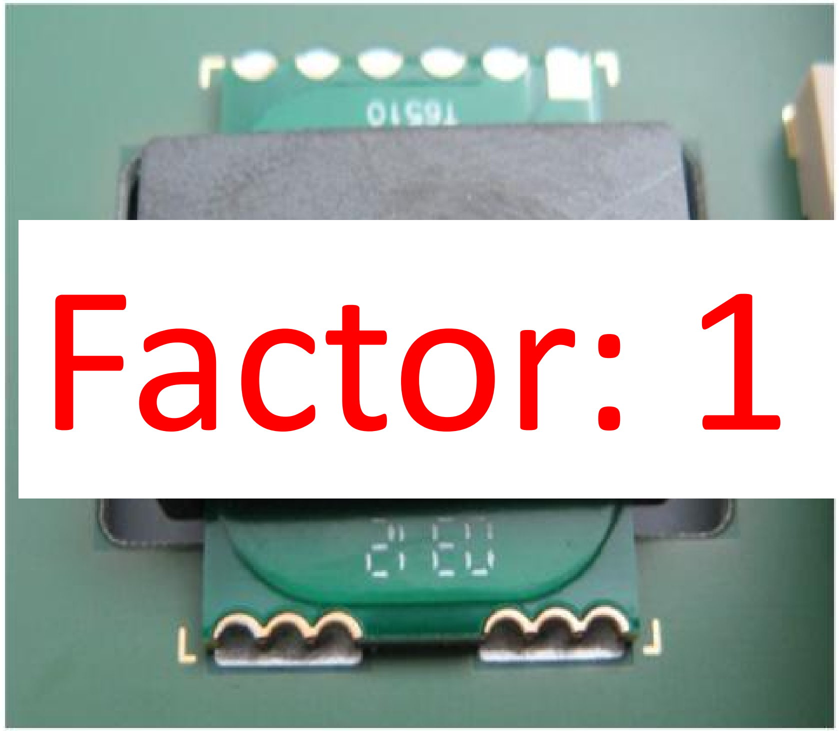
- ✓ PCB technology pattern plating is recommended
- ✓ Paste type 5 is recommended for 03015
- ✓ A coated stencil is recommended, e.g. plasma coating
- ✓ Tolerances and height differences must be taken into account for the aperture design of the stencil
  - → Step stencil can be a optimized solution
- ✓ The cleaning of the stencil after few prints must be optimal

Thermal Challenges due to miniaturization

Demonstration board

Planar transformer

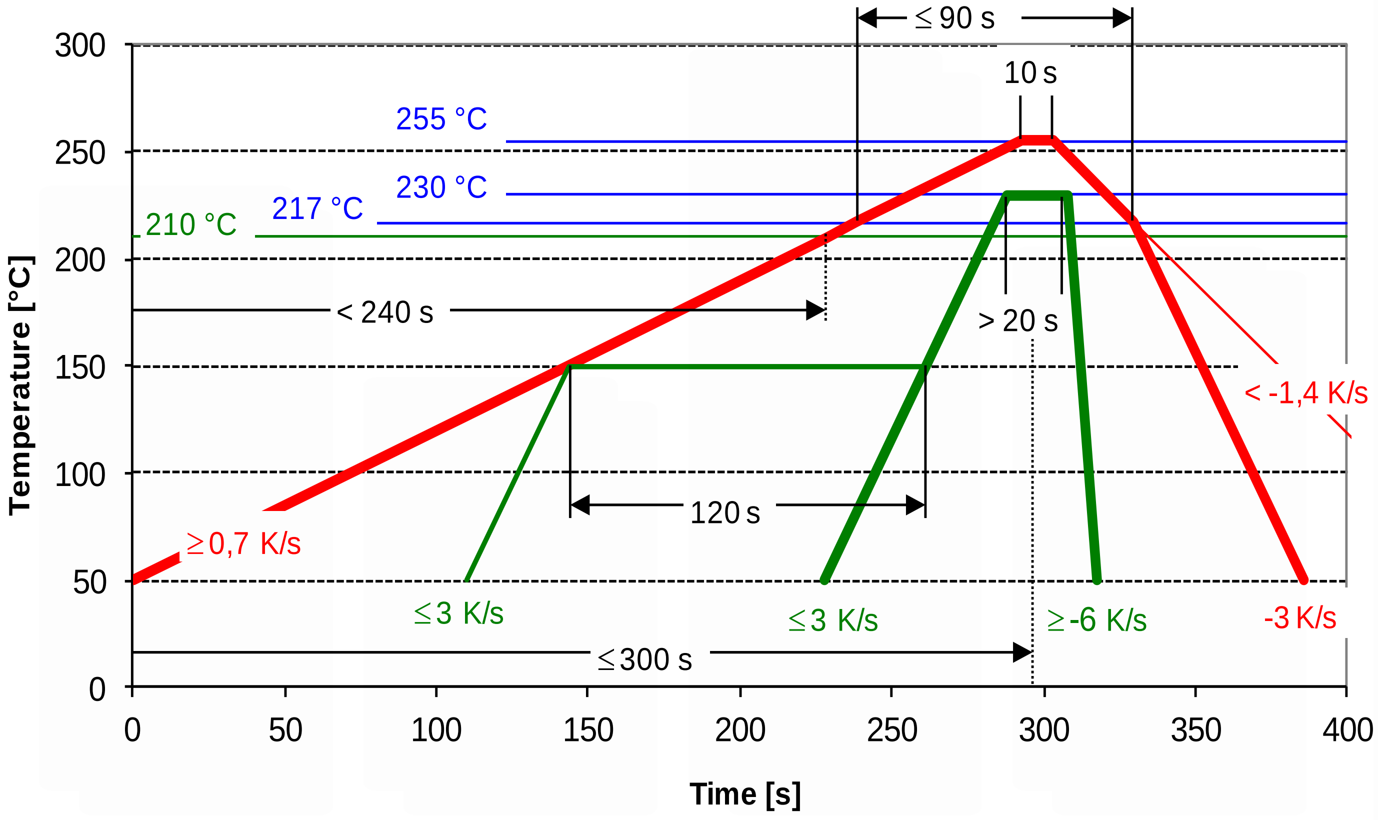
Power transformer ~28g



Factor: 1 647 058 x

Standards and guidelines

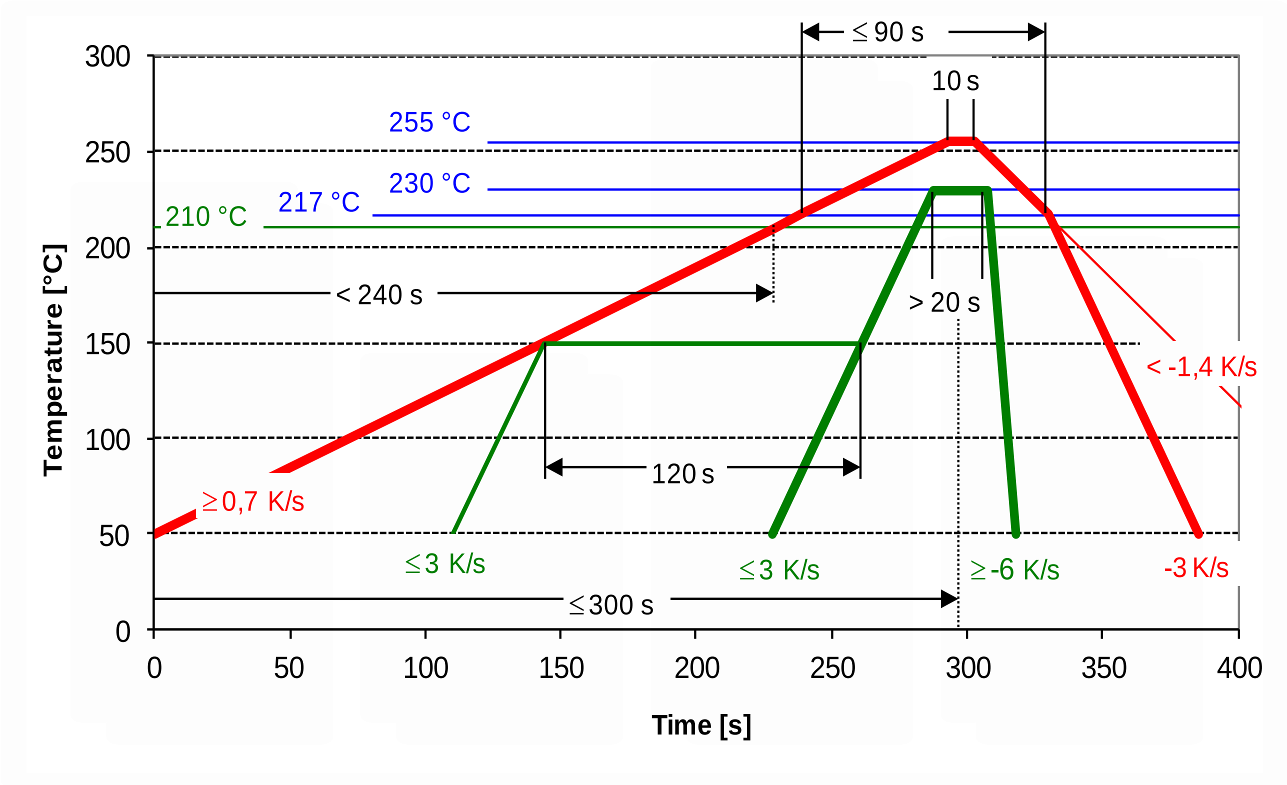
Envelope curve for a lead-free SAC process



Reflow Soldering: Target

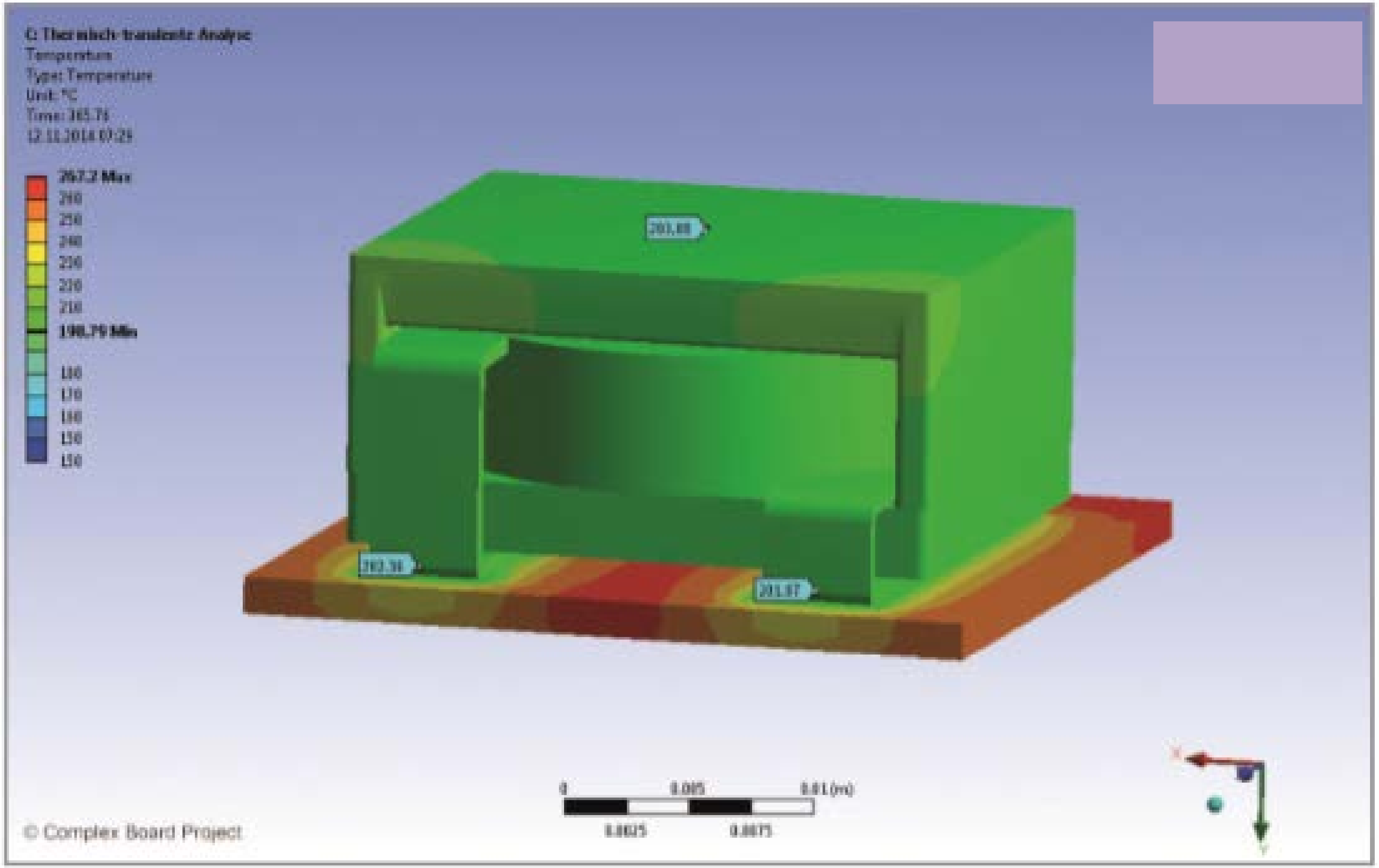
Envelope curve for the demonstration board

Reflow profile	MIN	MAX	OPTIMAL
T_{max} in °C	230	255	?
t_L in s	20	90	?



Mismatch simulation - profiling

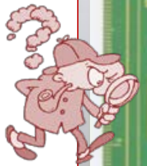
Thermal simulation of the transformer

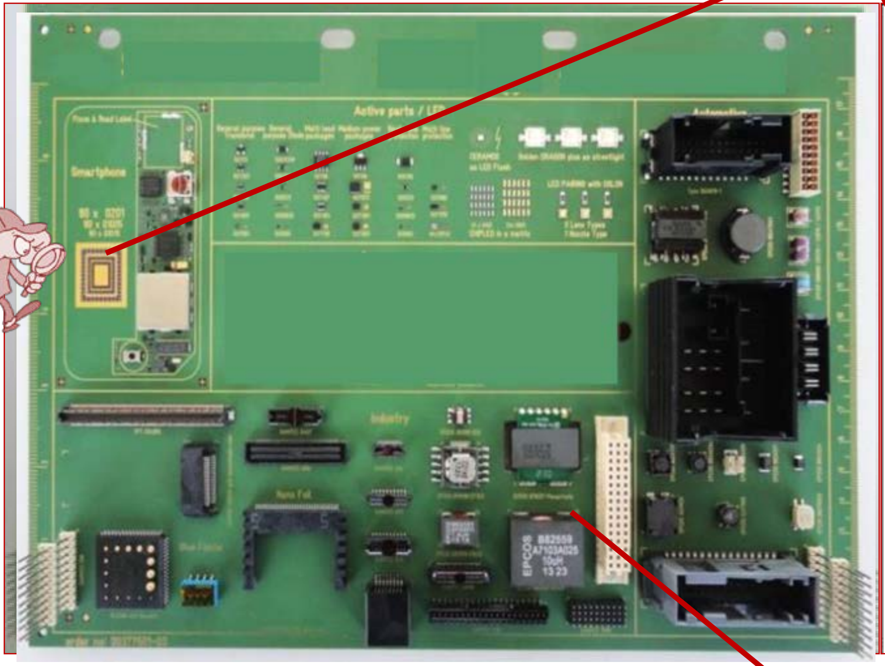


Demonstrator Board

How to find the right profile???
Analysis with thermal imaging camera

Small thermal mass, 0201, 01005, 03015

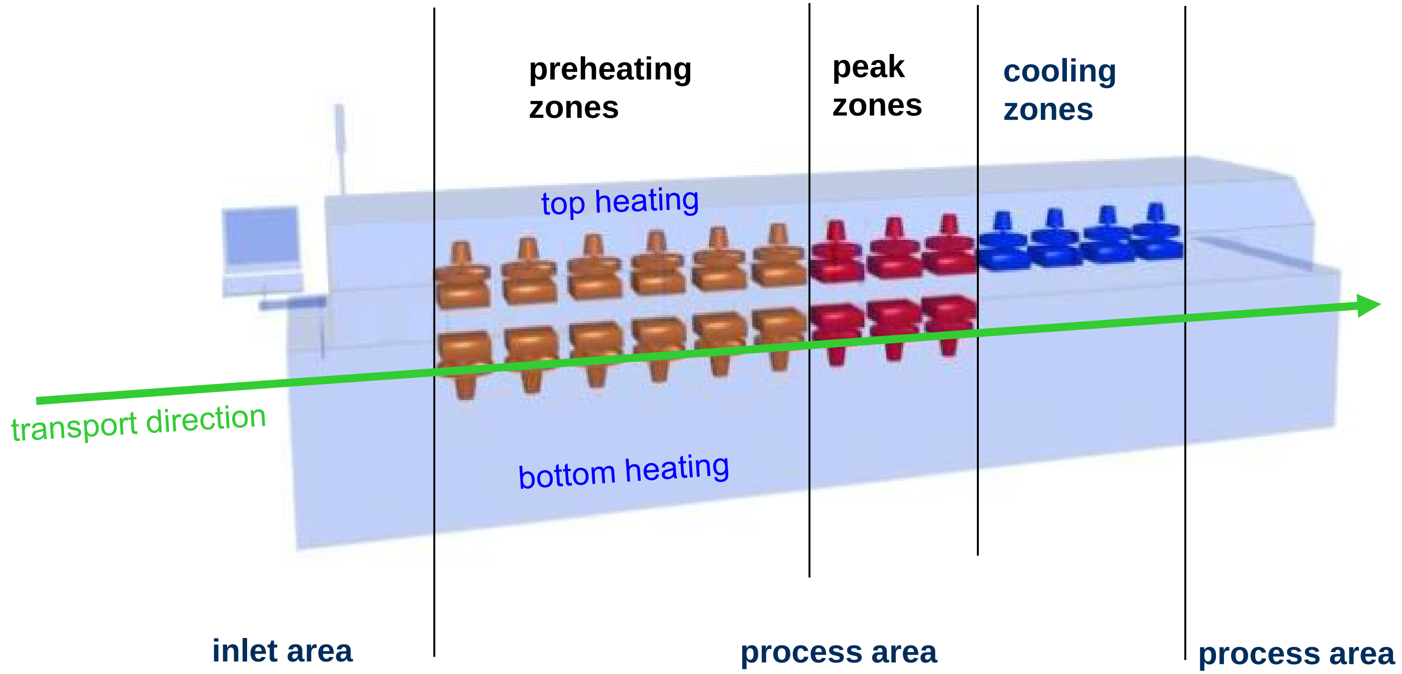




Large thermal mass → Transformer

Modular Design Concept

System buildup



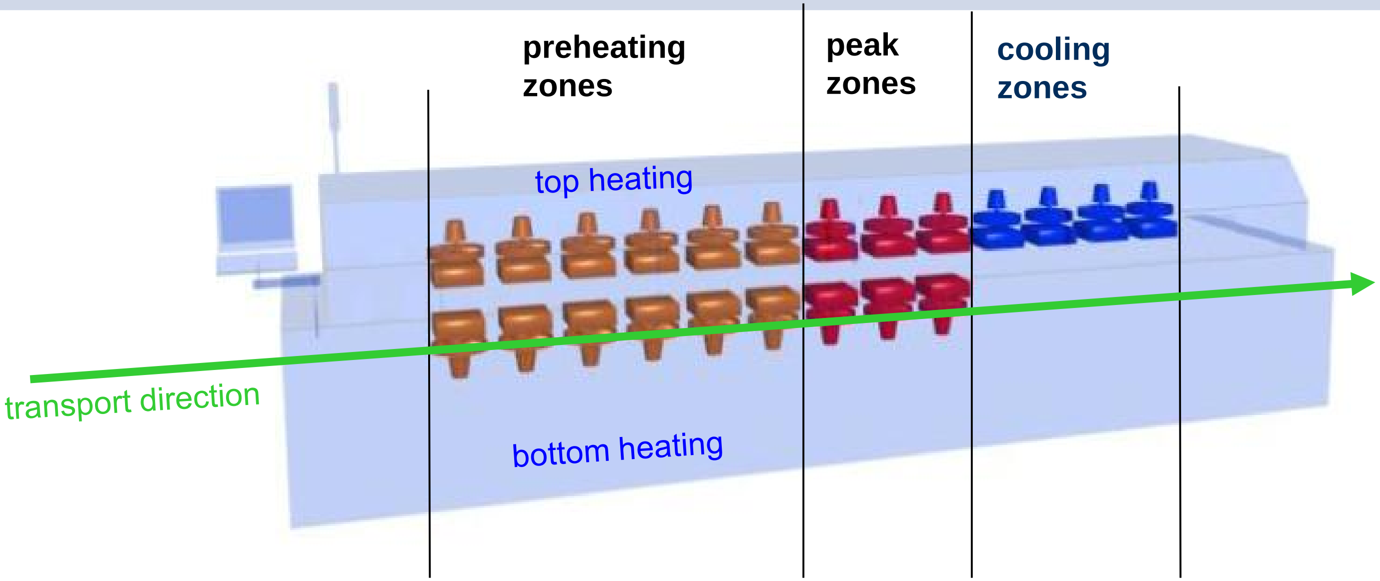
> Top and bottom heating for all heating zones
> Active cooling from second cooling zone onwards
> Modular grid 350 mm

Modular Design Concept

Settings for an "optimal“ reflow profile

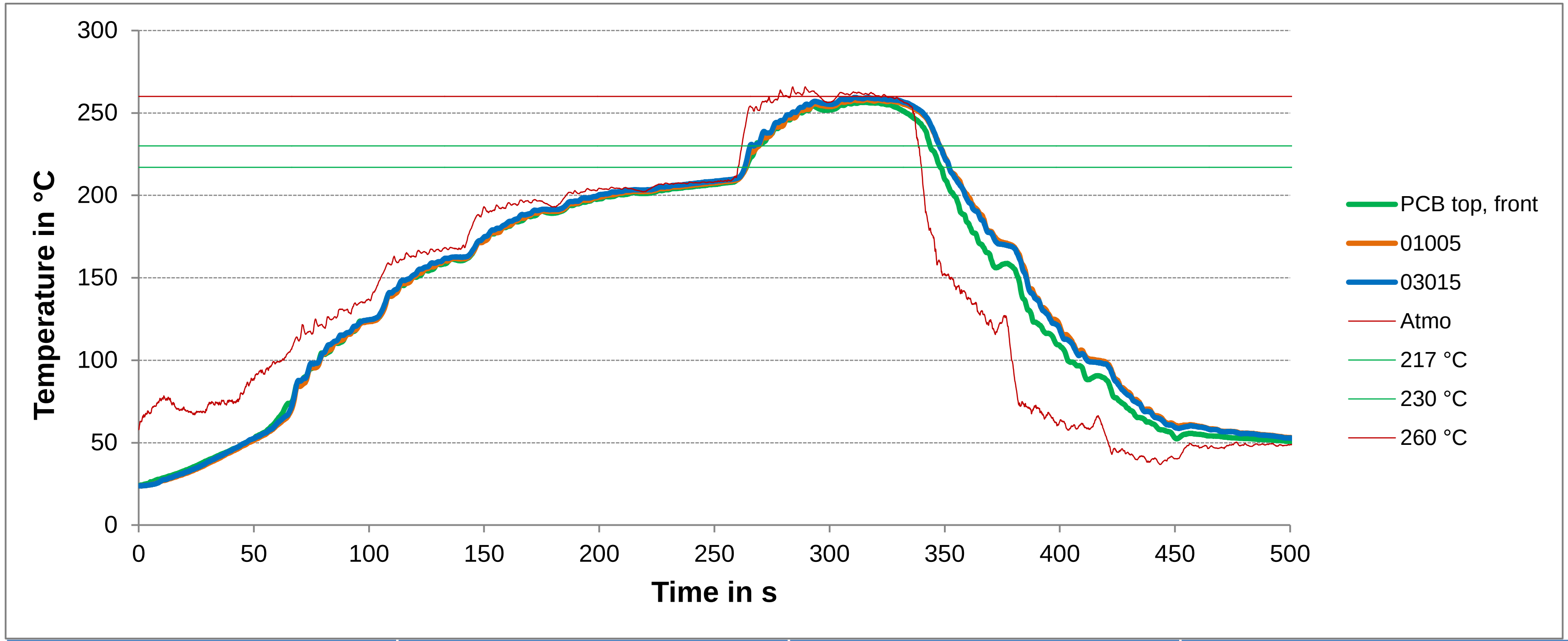
Convection oven **A**

	PH1	PH2	PH3	PH4	PH5	P1	P2	C1	C2	C3
top	145	175	205	210	210	280	275	95	35	25
bottom	145	175	205	210	210	280	275			
Transport speed: 530 mm/min										



Product board

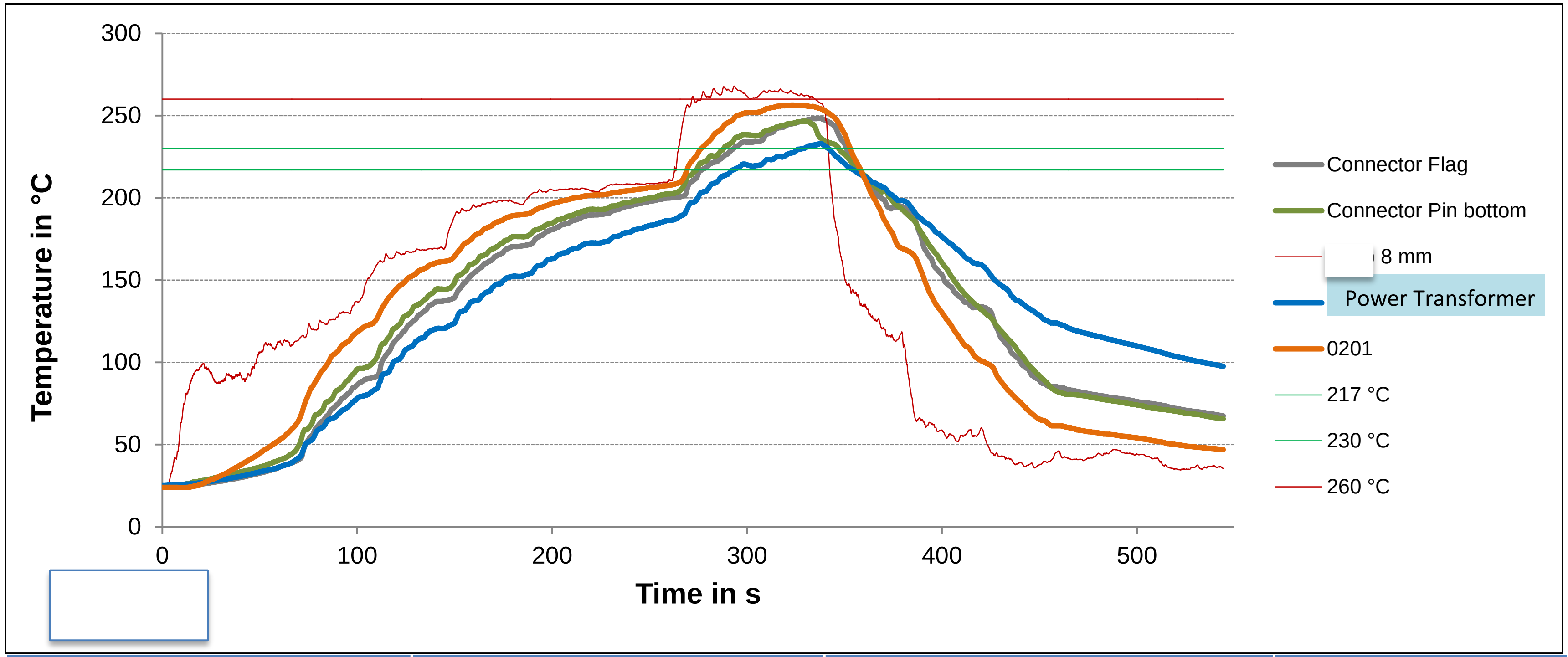
Real temperature profile for a lead-free SAC process



	Temp. T_{max} (T_P) in °C	Time above L t_L in s	ΔT in K
PCB top	257	84	2
01005	258	88	
03015	259	89	

Product board

Real temperature profile for a lead-free SAC process

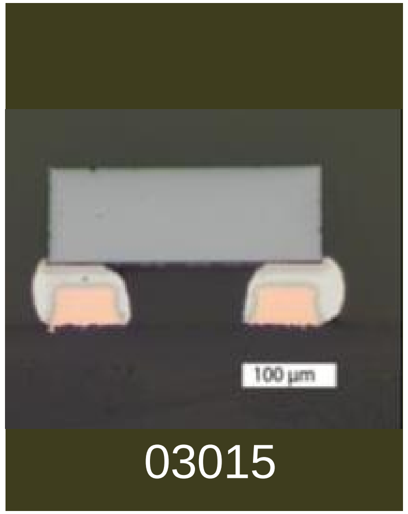


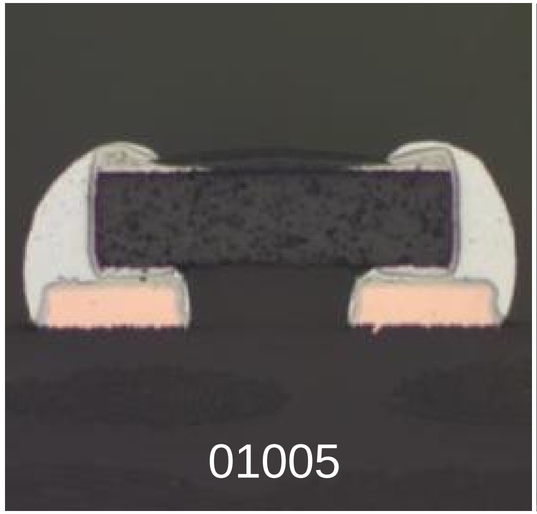
	Temp. T_{max} (T_P) in °C	Time above L t_L in s	ΔT in K
Connector pin bottom / top	247 / 248	84 / 81	23
Power transformer	233	62	
0201	256	89	

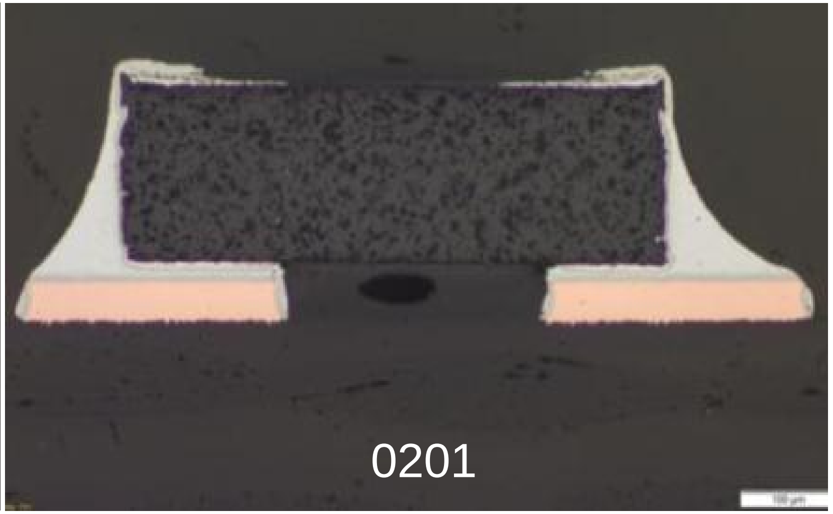
Reflow Soldering

Chip components: Overall good solder joints

Component	Length in mm	Width in mm	Height in mm
03015	0,3	0,15	0,1
01005	0,4	0,2	0,13
0201	0,6	0,3	0,23

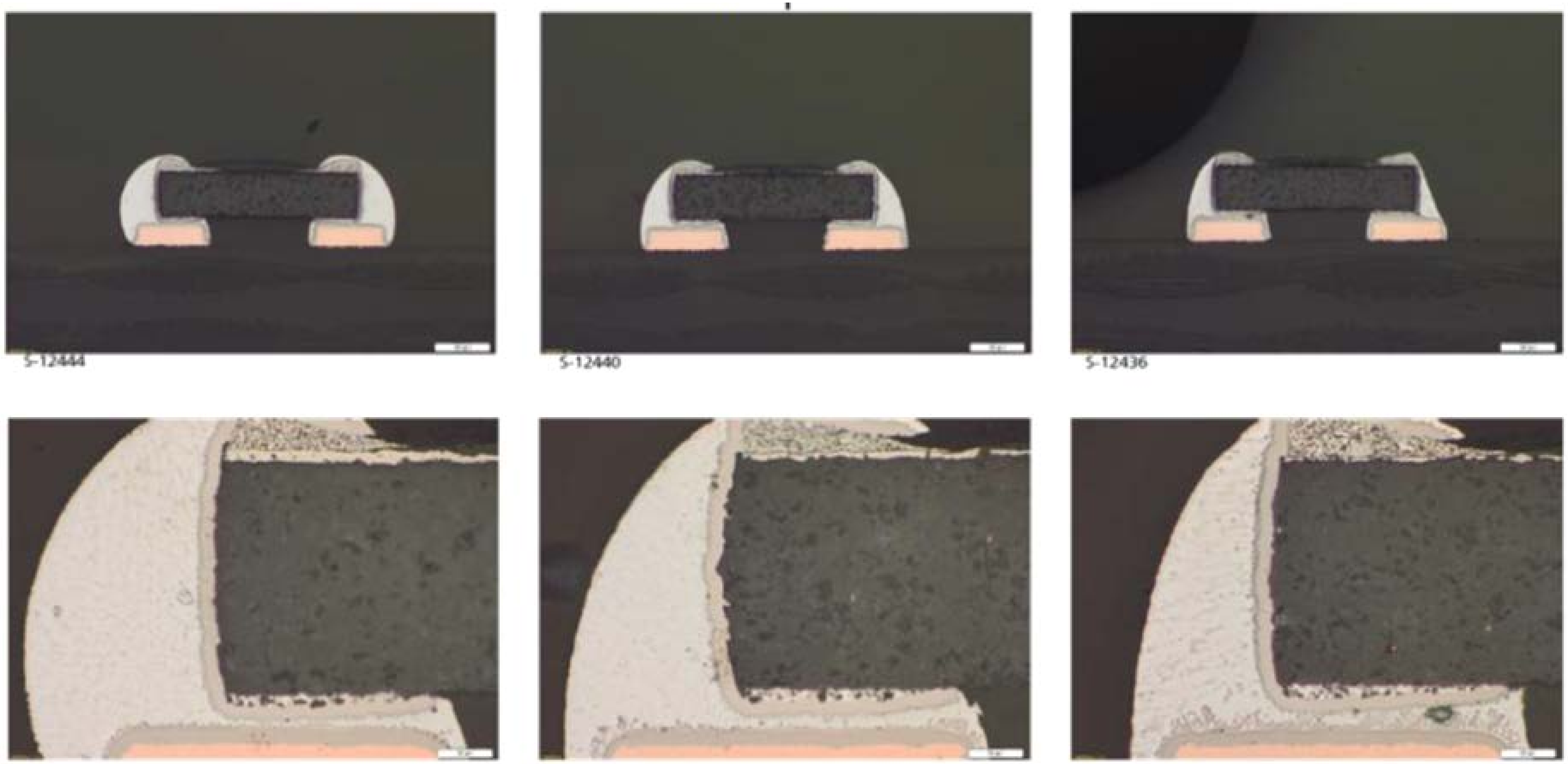






Reflow Soldering 01005

Profile Minimum | Profile Optimum | Profile Maximum

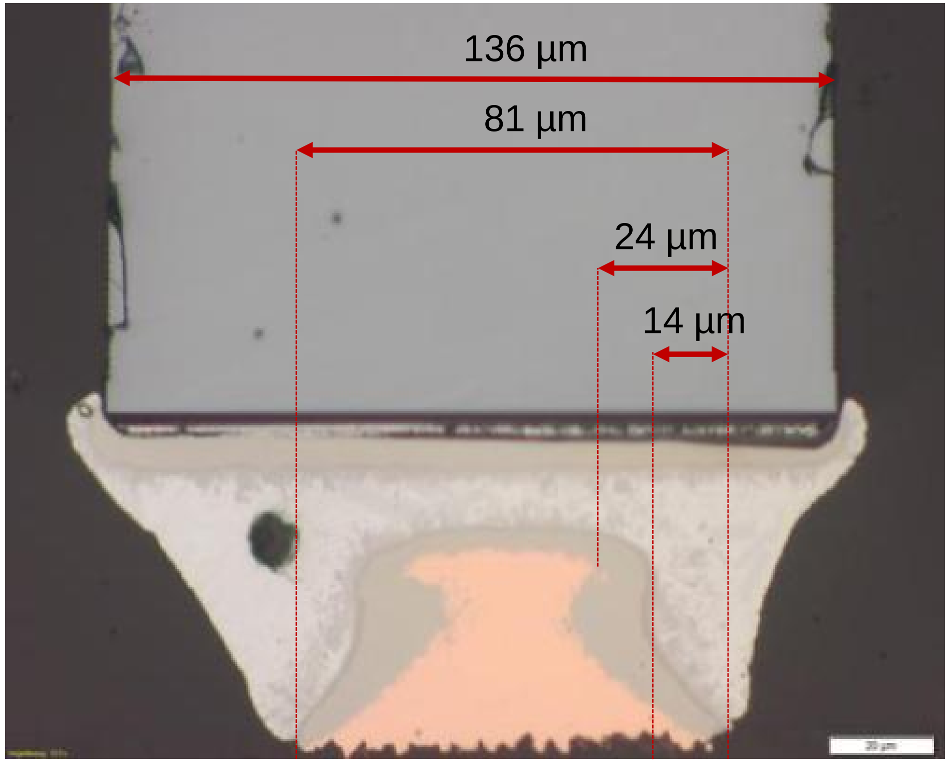


Source: Fraunhofer IZM, Company.

Layout: Desire and reality

Adaptation of PCB layout and of PCB manufacturing process

Cross section of 03015 solder joint



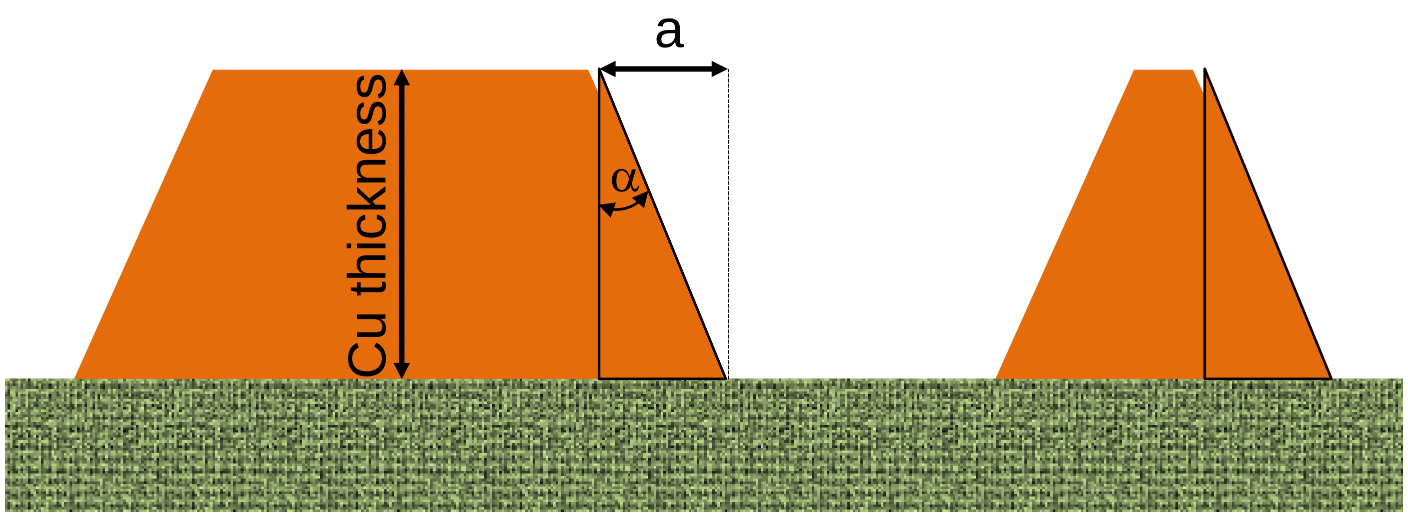
Layout: Desire and reality

Adaptation of PCB layout and PCB manufacturing process

The etch foot “a” is directly dependent on the Cu thickness

> Etch foot “a” = Cu thickness · tan α

$\Rightarrow$ When the interconnections become narrower,
the aspect ratio between upper and bottom side changes

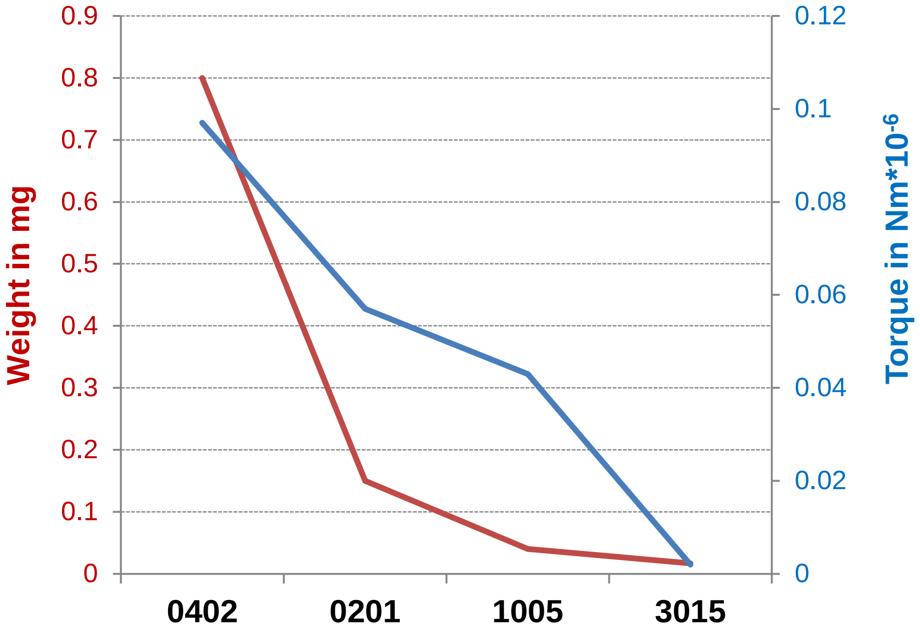


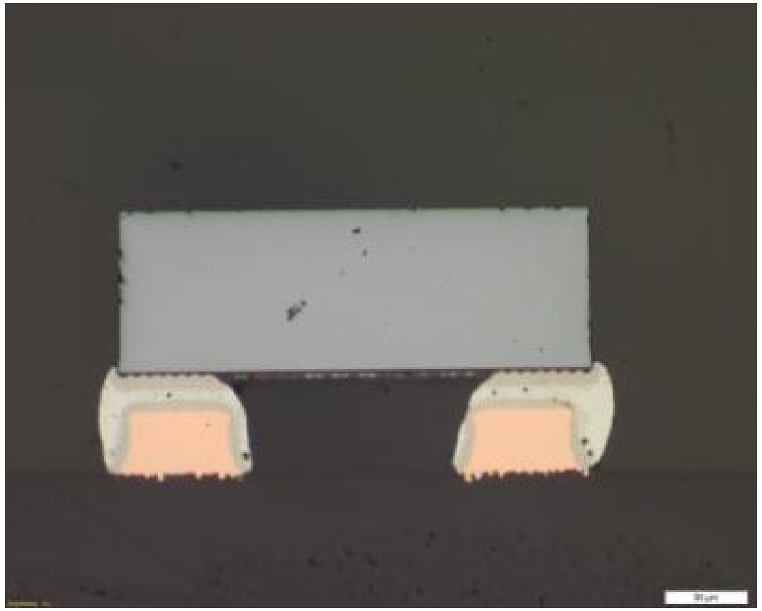
Defect mechanisms during reflow

Tombstones

BE 03015 BTC components

→ No tendency to tombstone



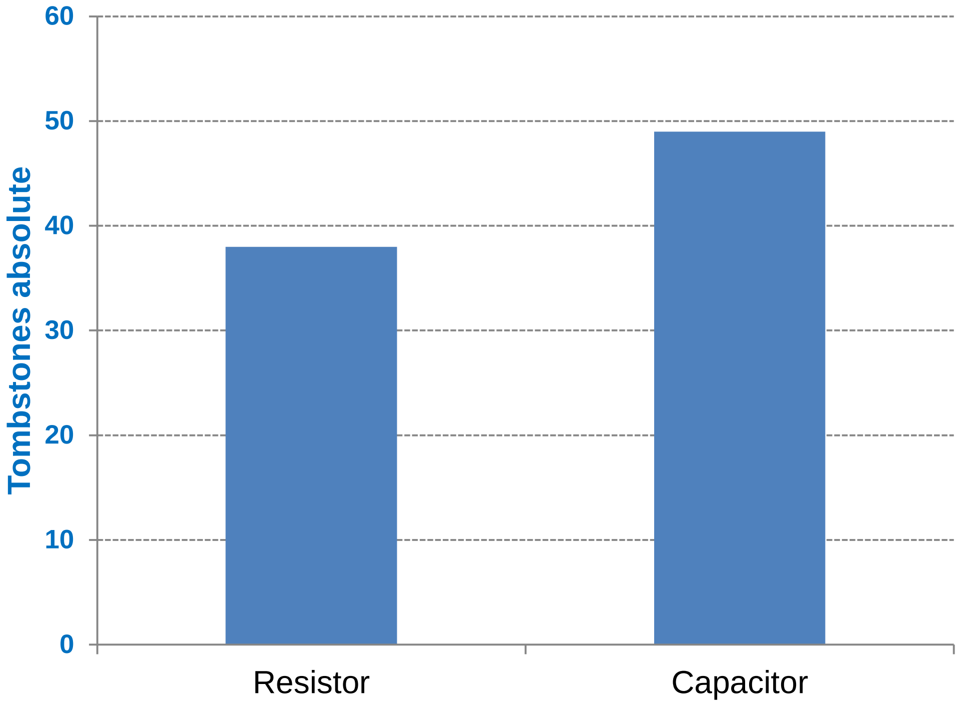


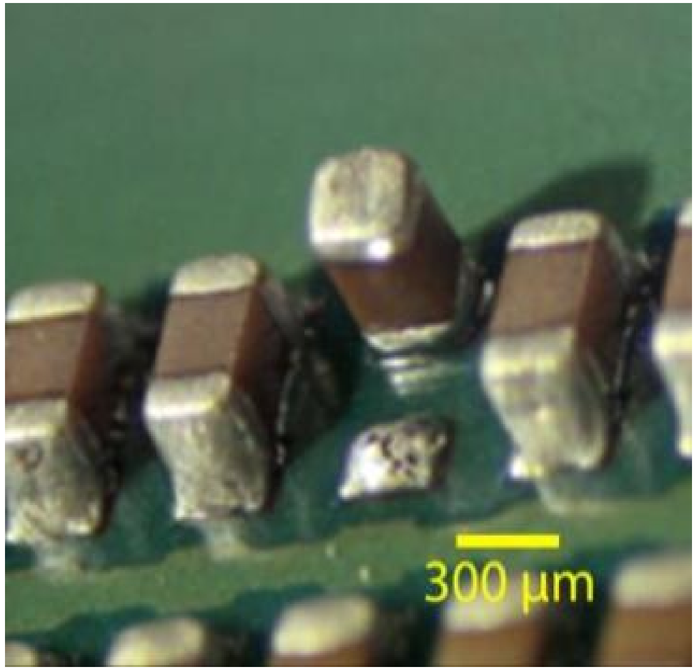
FORWARD THINKING FOR TOMORROW'S TECHNOLOGY

Defect mechanisms during reflow

Tombstones

BE 0402: Resistor versus capacitor



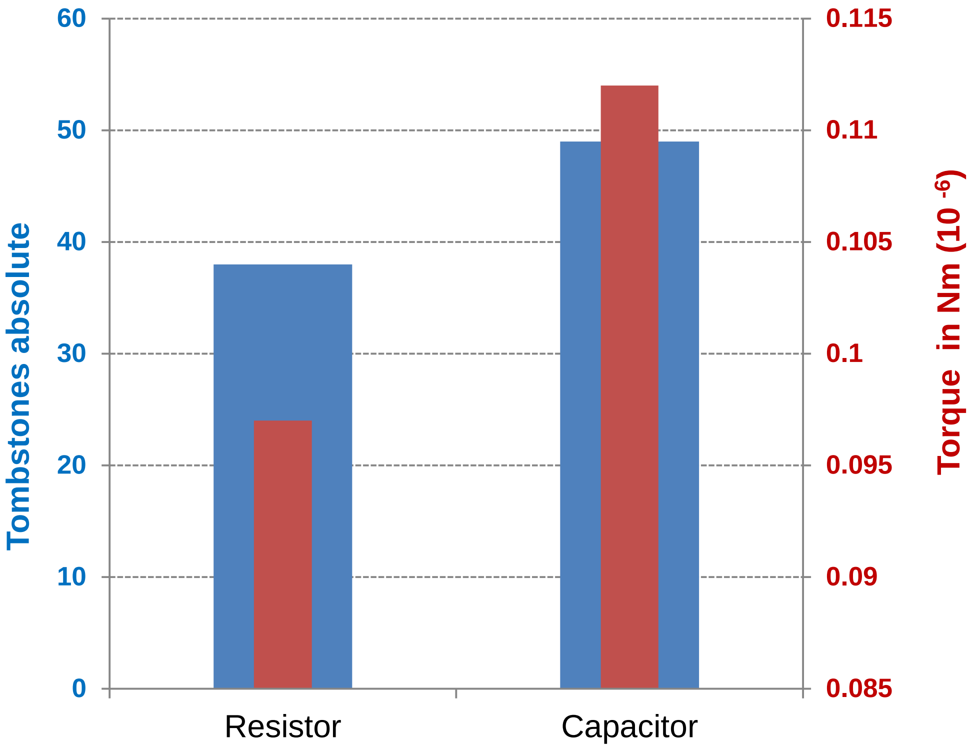


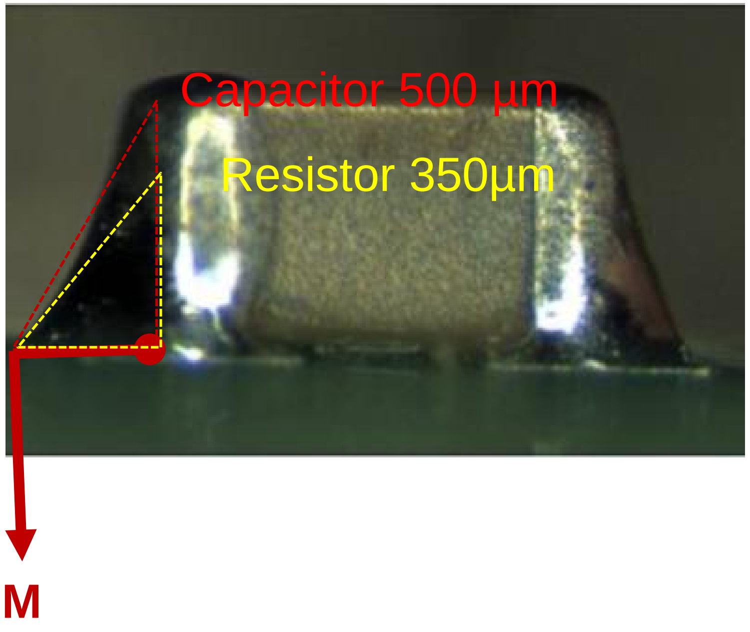
Data: R. Egger, Tombstoning, Zollner March 2014

Defect mechanisms during reflow

Tombstones

BE 0402: Resistor versus capacitor



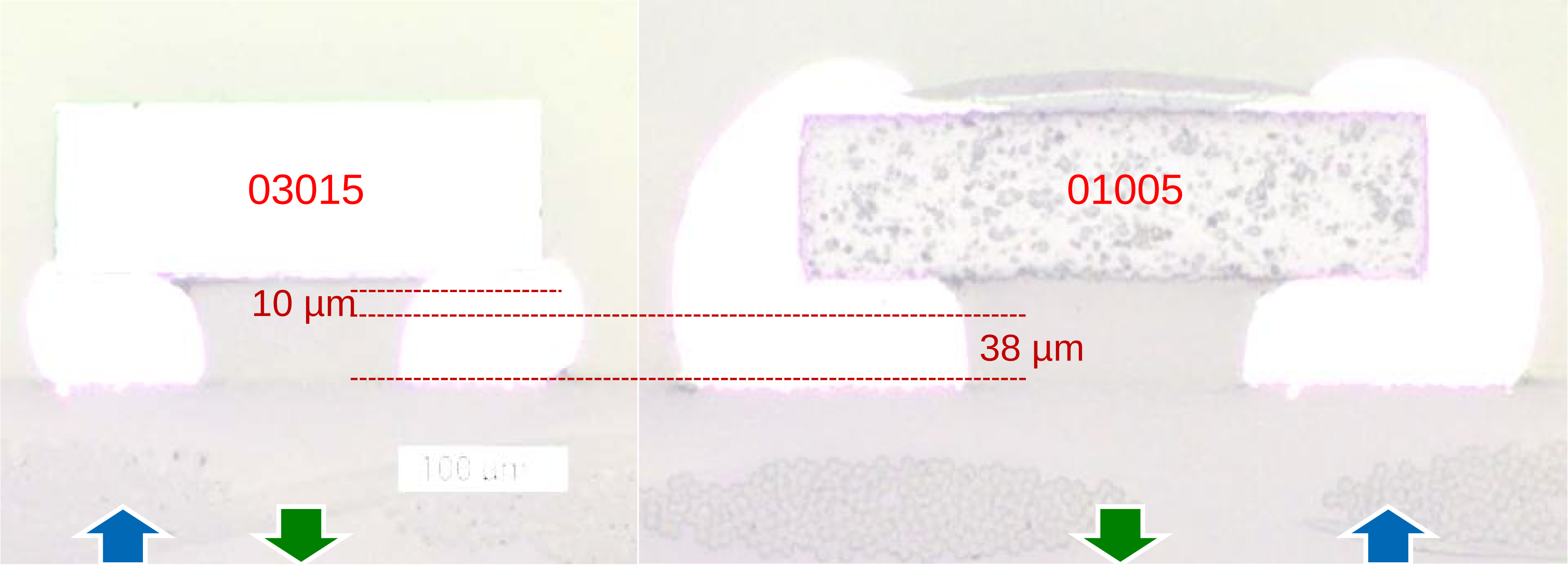


Data: R. Egger, Tombstoning, Zollner March 2014

Physics of Soldering

Gap

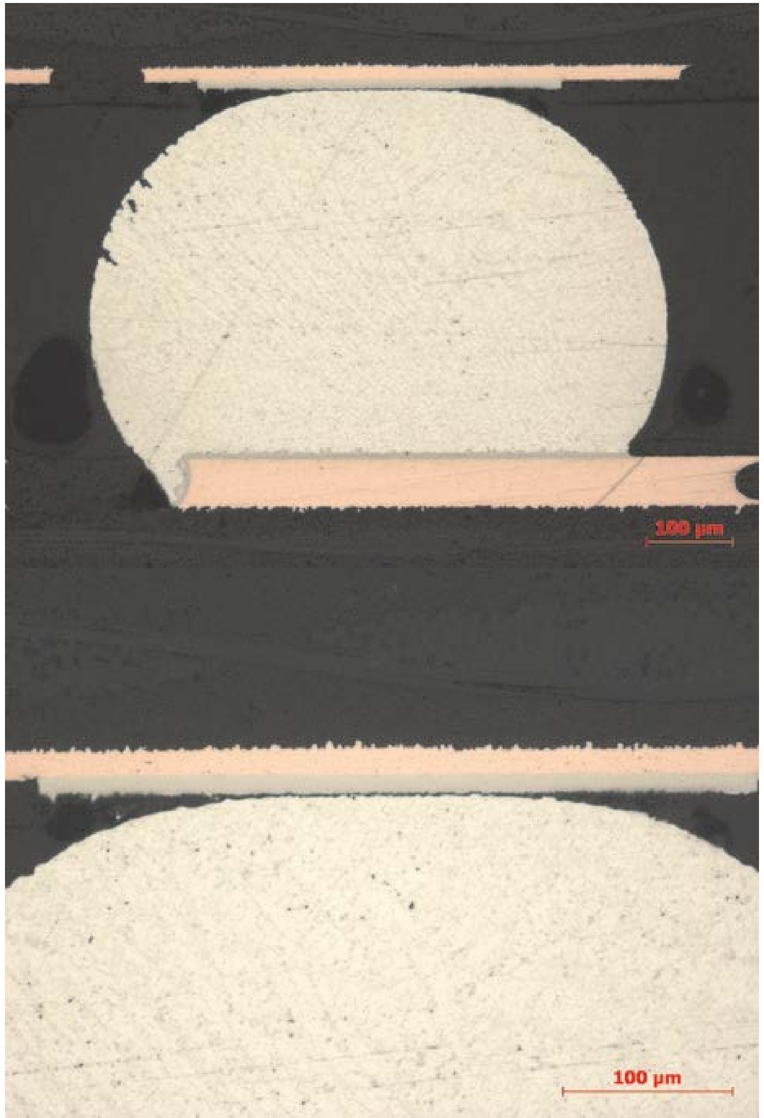
Resulting from geometry, surface tension, buoyancy

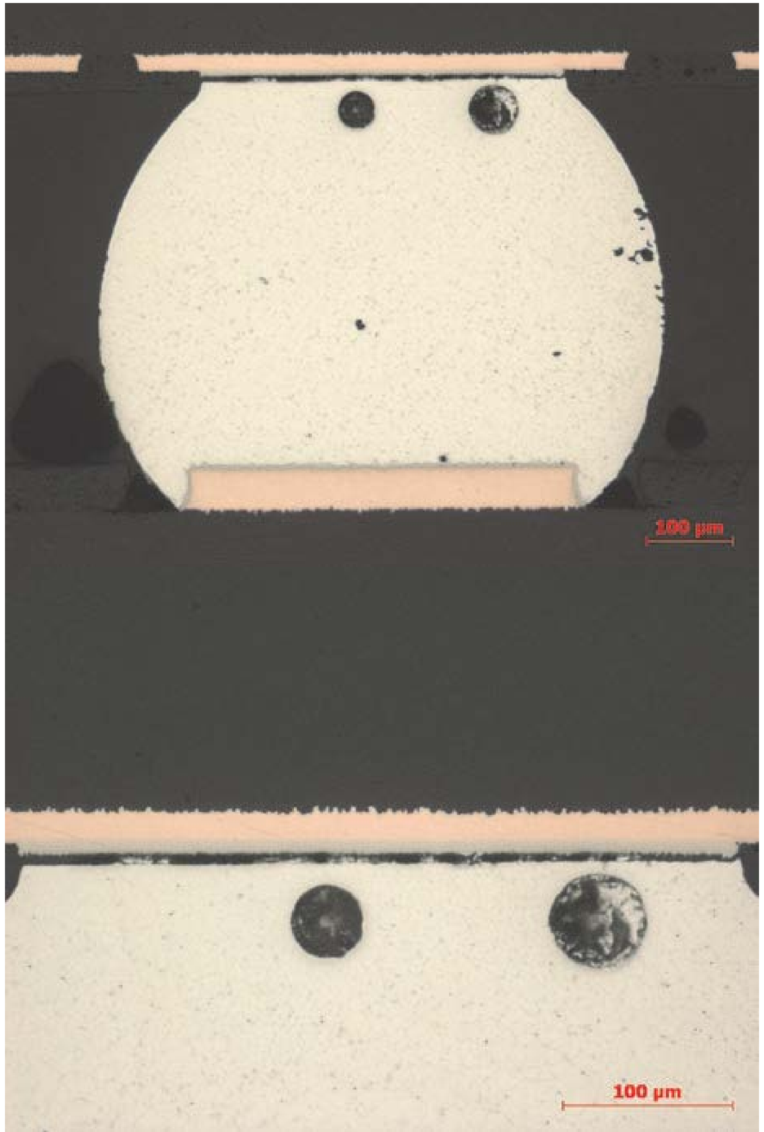


0,17 mN **Weight force** **0,4 mg**

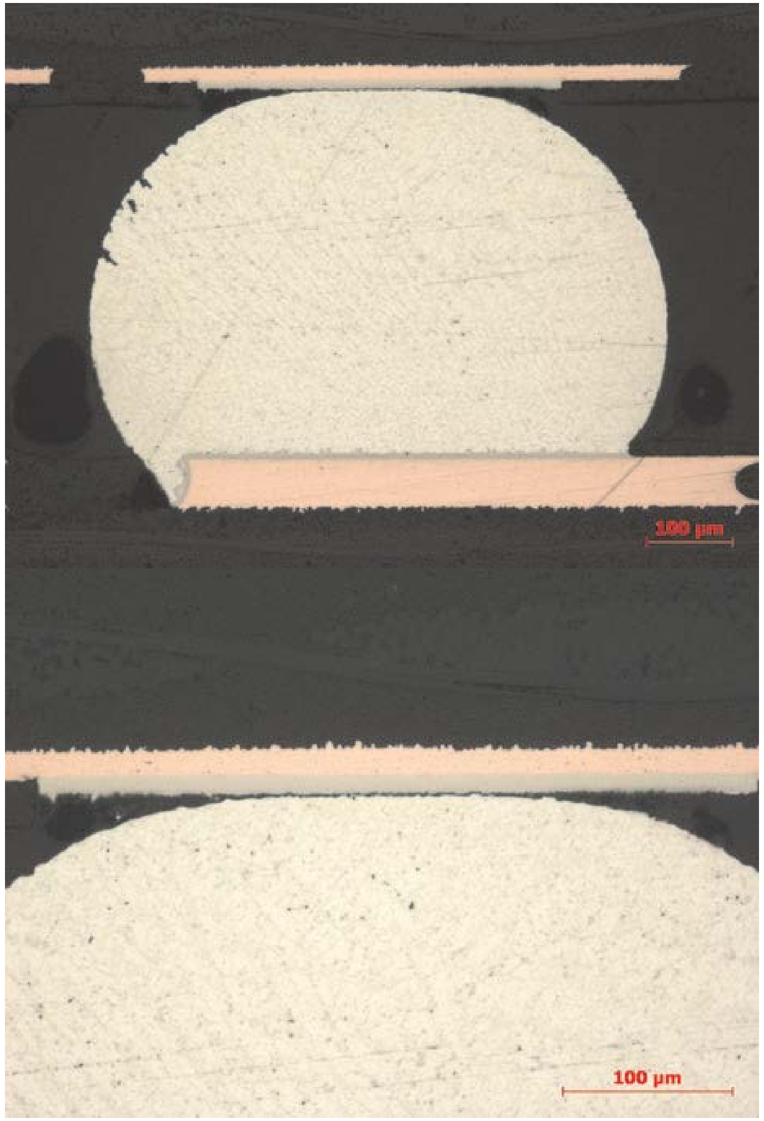
2 x 0,15 mN **Lifting capacity (surface tension 330 mN/m)** **2 x 0,19 mN**

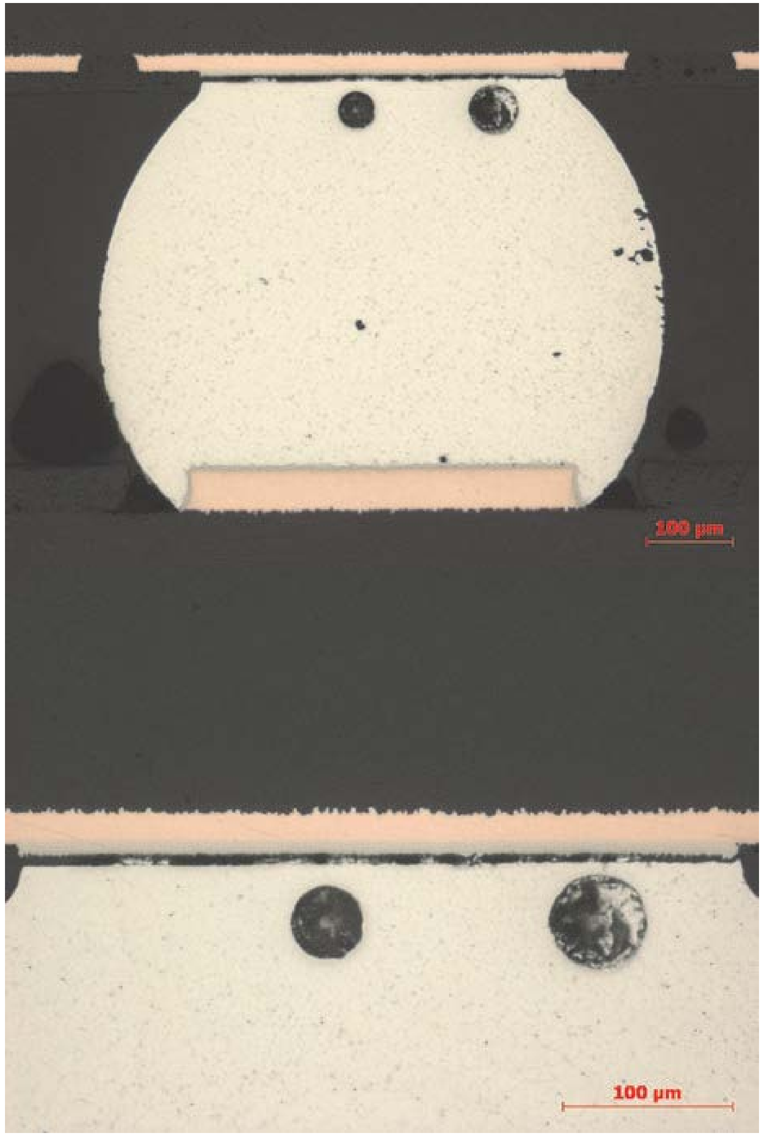
Troubles besides miniaturization





Trouble with component quality

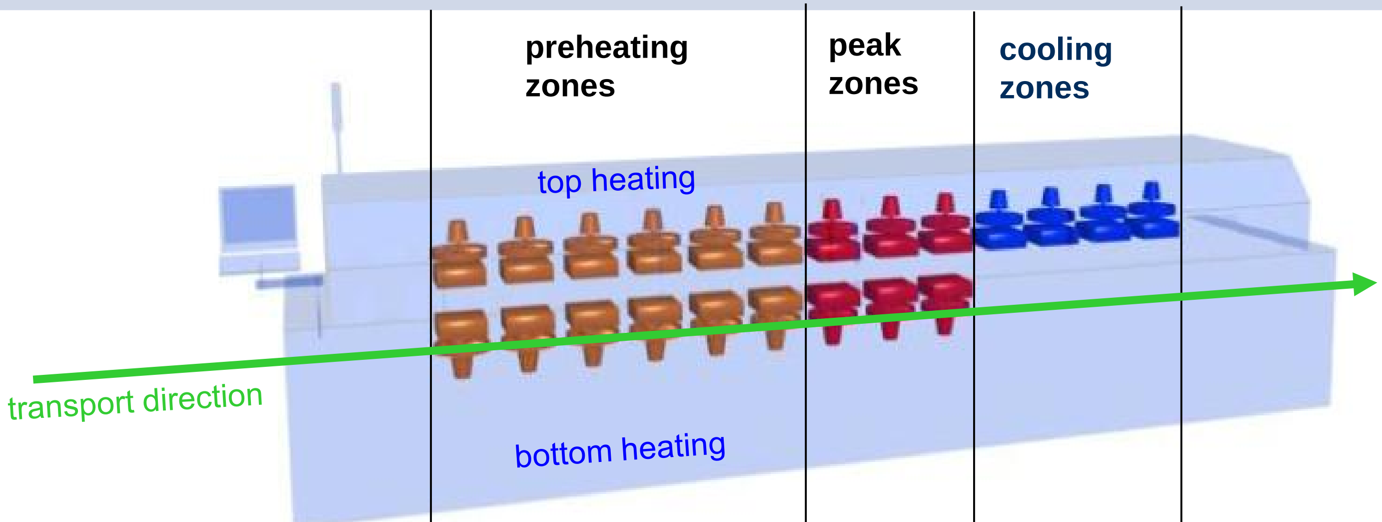




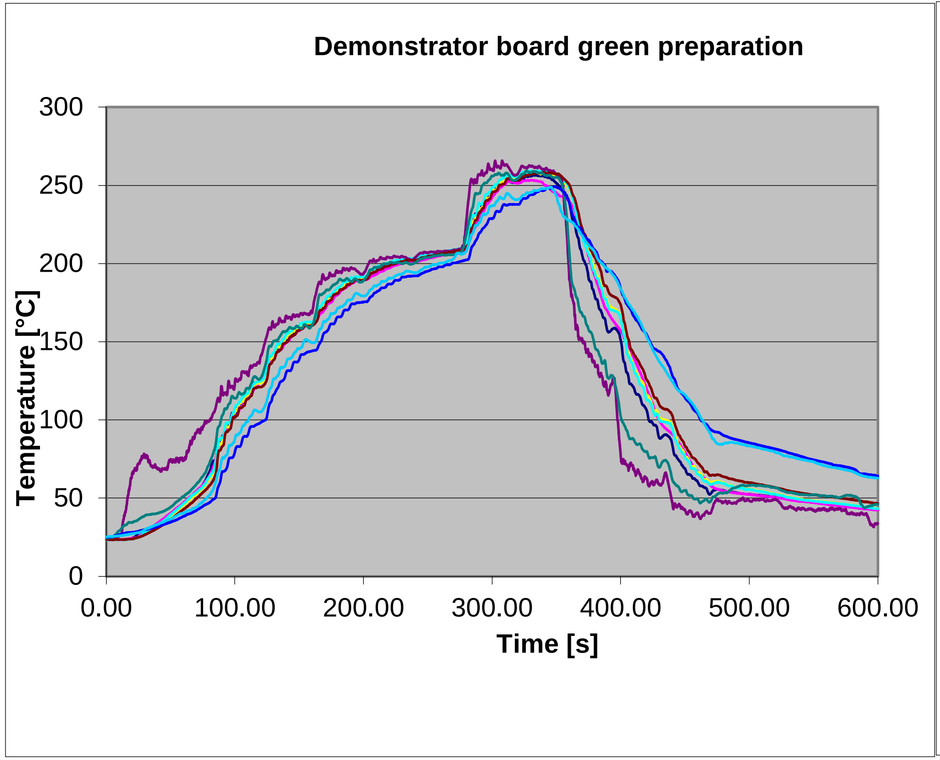
Settings for an optimal reflow profile

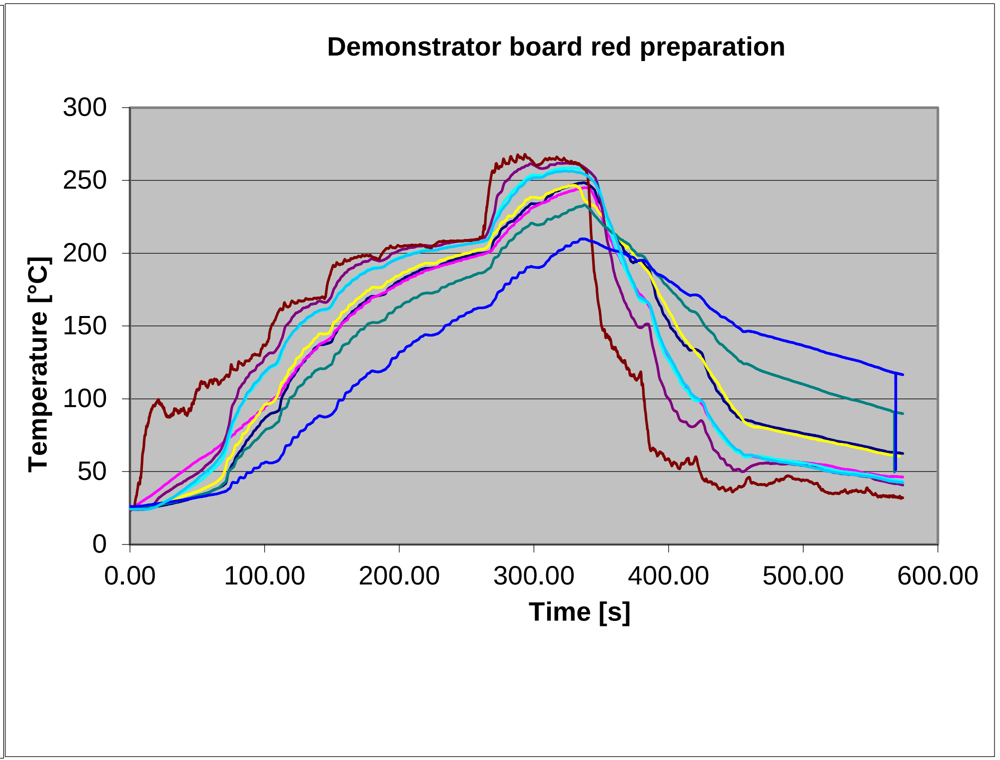
Convection oven **A**

	PH1	PH2	PH3	PH4	PH5	P1	P2	C1	C2	C3
top	145	175	205	210	210	280	275	95	35	25
bottom	145	175	205	210	210	280	275			
Transport speed: 530 mm/min										



Convection:





	PCB top front	PCB btm front	01005	03015	Atmosphere	Switch body	LED lense	PCB top bck.	PCB btm bck.		Delta T / board	Delta T
Green			258.3	259.4		258.3					1.1	26.3
Red	248.8	245	246,6	258,5			233.1		256.4		25.4	
	Connector	Connector body	Connector Pin	Shielding	Shielding top	Atmosphere	Transformer	Transformer top	0201			

Reflow Soldering

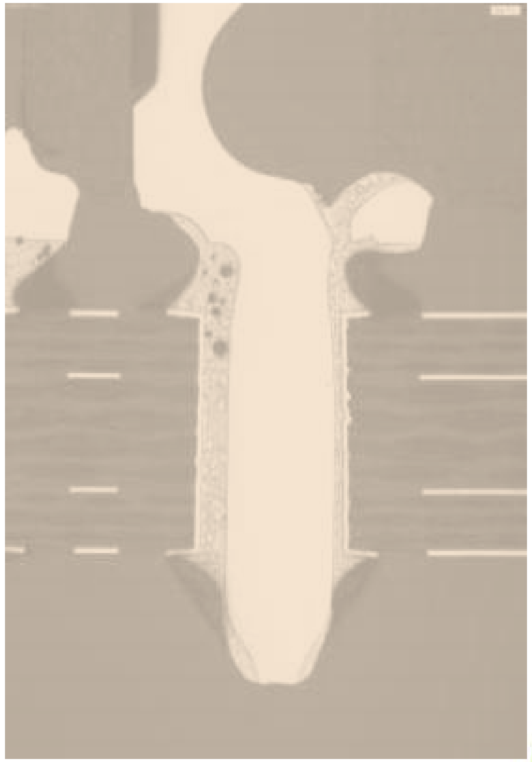
Pin-in-Paste

Opens

T_{max} = 229 ° C
t_L = 16 s
⇒ Adapt the reflow profile!

Pin not soldered

Pin soldered



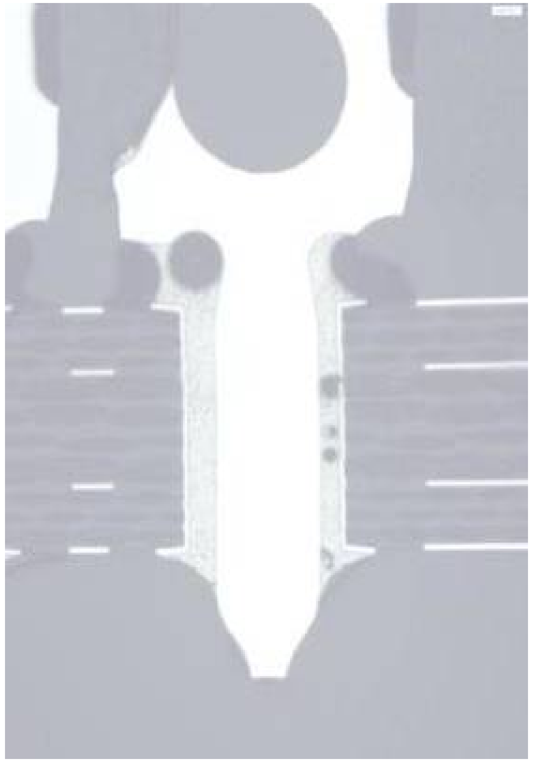
Reflow Soldering

Pin-in-Paste

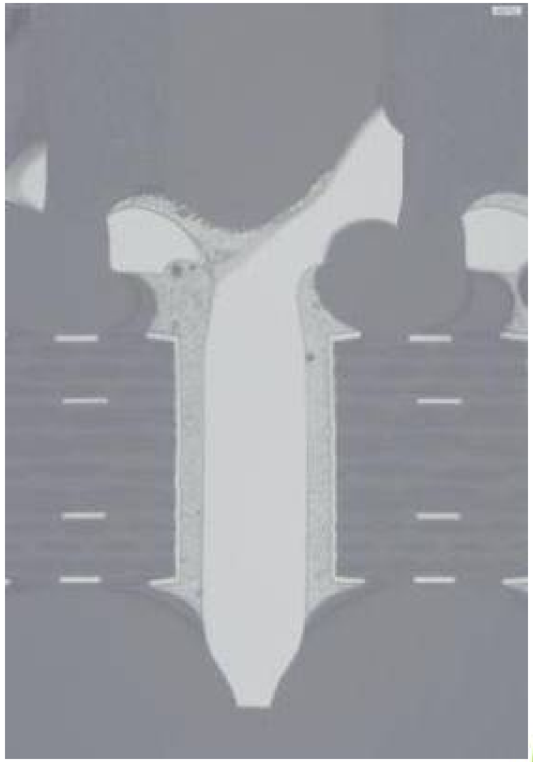
Good solder joints

T_{max} = 247 ° C
t_L = 83 s
⇒ Optimal reflow profile

Pin soldered



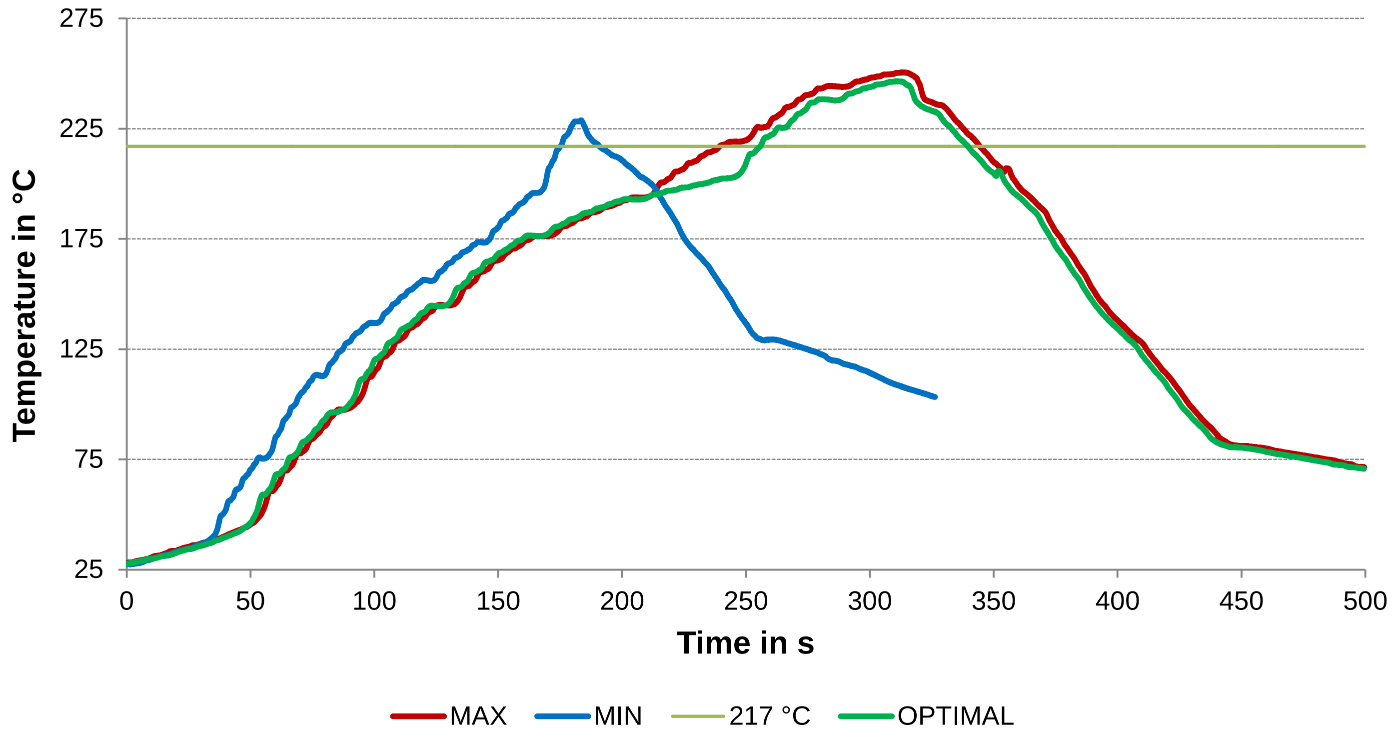
Pin soldered



Reflow Soldering

Pin-in-Paste Reflow profiles

Reflow profile	MIN	MAX	OPTIMAL
T_{max} in °C	229	251	247
t_L in s	16	105	83



Soldering process vapour phase

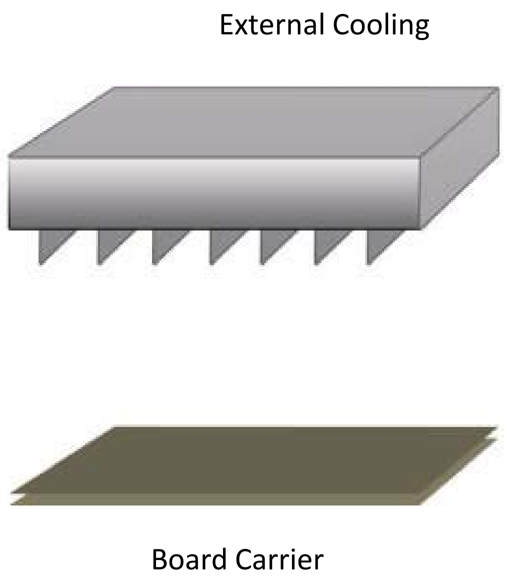
3-Step-Soldering

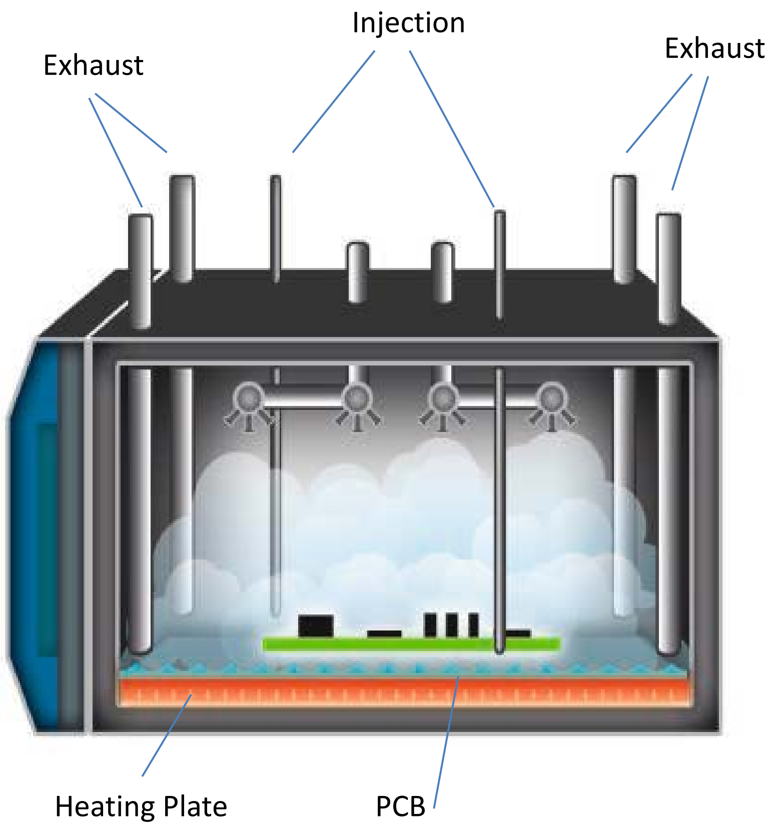
→ Injection of inert medium

→ Horizontal transport

→ No movement of PCB during the process

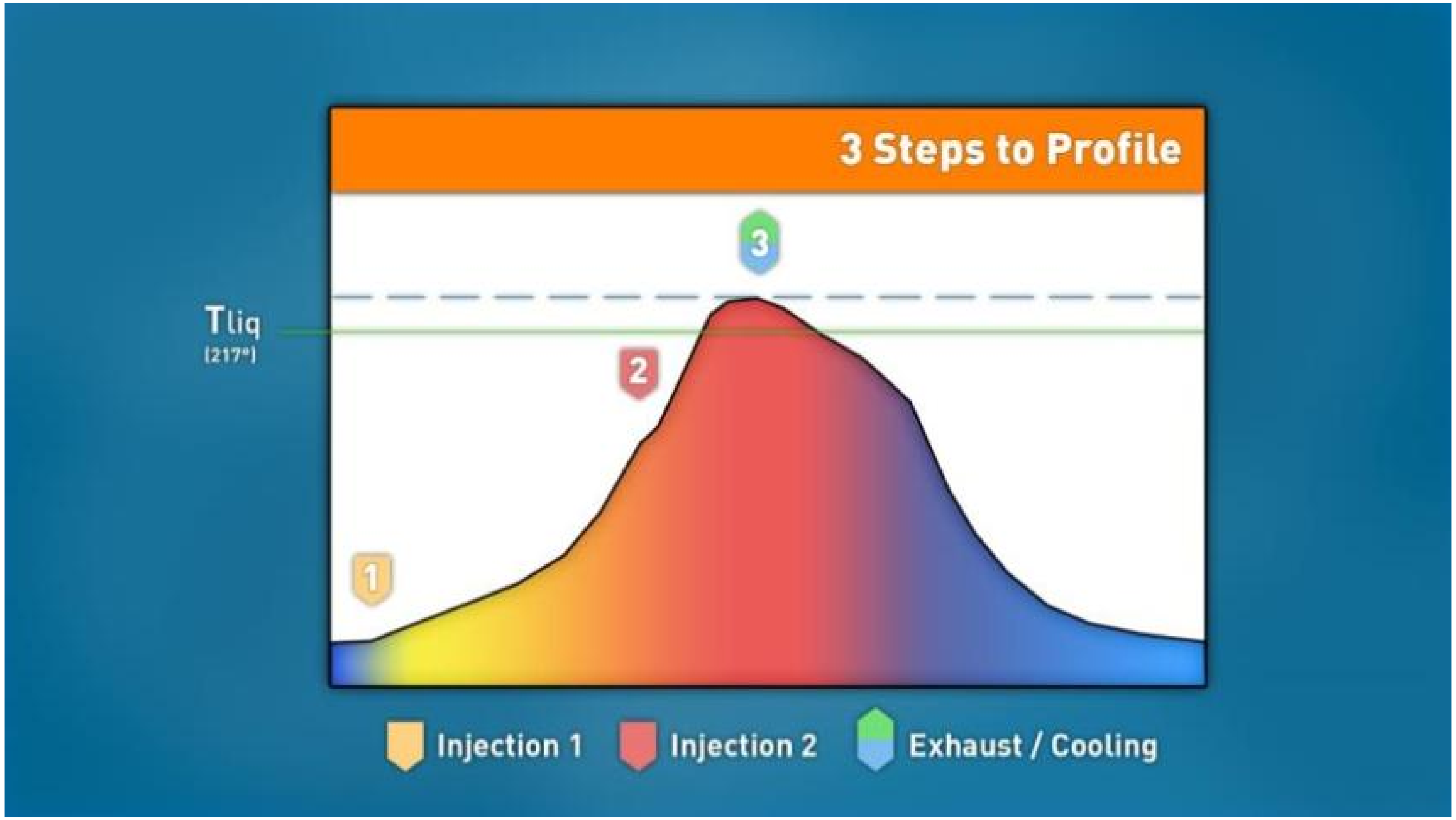
→ Vacuum option



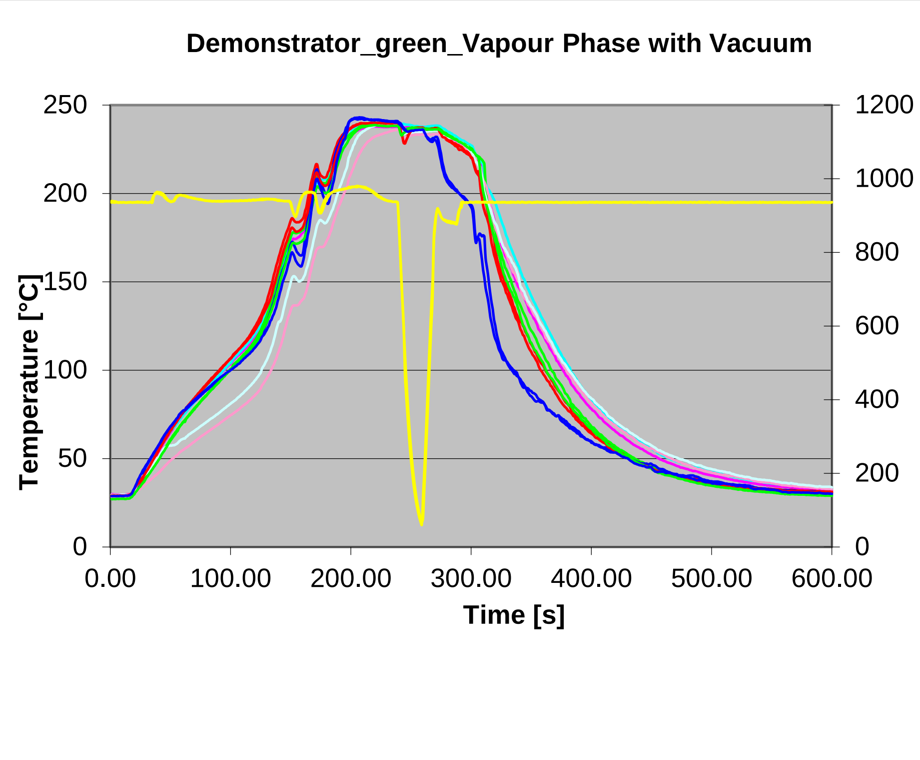


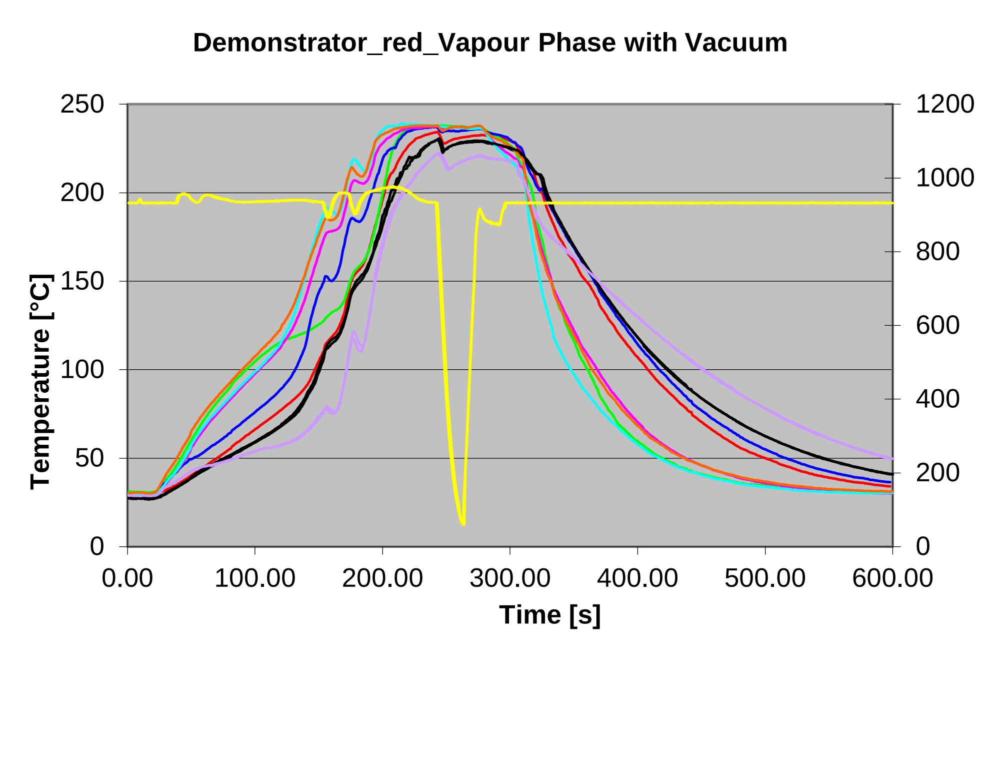
Temperature Profiling

3 Steps to Profile



Condensation soldering with Vacuum





	PCB top front	PCB btm front	01005	03015	Atmosphere	Switch body	LED lense	PCB top bck.	PCB btm bck.		Delta T / board	Delta T
Green			239.9	240		239.8					0.2	10.2
Red	237.4	238.1	237.2	229.8			230.6		238		8.3	
	Connector	Connector body	Connector Pin	Shielding	Shielding top	Atmosphere	Transformer	Transformer top	0201			

… and keep the right balance with miniaturization!