RELIABILITY IMPROVEMENTS BY THE CREATION OF INTERMETALLIC CONNECTIONS

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ABSTRACT

Especially for the SMT new trends like miniaturization 0201, 01005, 0201 (metrics) for passive components, as well as new devices for actives like LGA or QFN, it requires a lot of investigation for researching, developing, questioning about application, product/component mix, and finally about reliability. One major challenge is the combination of small, medium and large components in one production step. For example, large components need more solder paste, based on a thicker stencil than small components. Several studies have shown, that properties for reliability at a temperature cycle e.g. -40/+125 prolonged its lifetime by increasing an intermetallic phase (IMP) between substrates and component finishes (e.g. Papers Trodler SMTAi 2012-14). This paper will show and discuss the possibilities by application to combine small and large passive components, and new devices for active components with an increase in reliability, especially for automotive/industry requirements by an IMP formation.

Key words: Reliability, Lead Free, IMC

INTRODUCTION

Since many years, the quality of assembled printed circuit boards are mostly specified according the IPC-A-610 standard [1]. Especially the solder joints have a description about the meniscus for an acceptance criterion. Based on several investigations about reliability, it seems there is an increase of live cycles as well as temperature stability when Intermetallic Phases (IMC) are between substrate surface and component finish especially in the gap, where some cracks mostly starts. Therefore, that paper will show and discuss results of reliability based on different solder paste quantity and consequently a minimized solder joint with a creation on IMCs by a combination of SAC lead free solder and passive components. Additional it will show possibilities to make it possible for various component sizes. By creating those IMCs, it changed also the physics of failures means and that will discuss as well.

BASIC RESULTS OF ASSEMBLED BOADDS

Reliability acc. Automotive Standard

Several projects describes the state of the art for reliability results especially for Temperature Cycle/Shock Test (TCT) from -40/125°C. As one of the last German founded project, LiVe [2], there had been described an increase of reliability on one hand by reduction of the component size but also on the other hand due to creating intermetallic phases inside the interconnection gap between substrate and component, Figures 1 and 2.

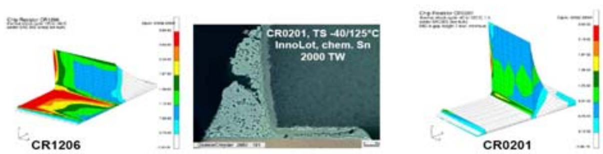

Figure 1. Creep Strain for different passive components by -40/+125°C TCT, Solder Innolot [2]

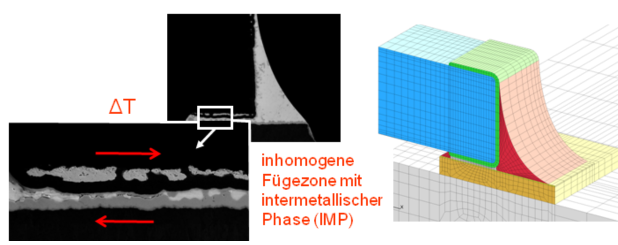

Figure 2. Cross section for Chip R 0201, Gap 6-7 µm and FE-Model [2]

During several tests, it showed that one of the criteria, a possible reduction as failure criteria by 50% shear stress from initial, were more than doubled compared of 1206 and 0201.

Reliability of different Alloys

In addition to the live project [2] there different alloy for long-term stability were also analyzed [3]. The condition of the long-term field-test was 22/93°C with a soak of 6 hours.

For SAC alloys same or similar failures were detected, figure 3 and 4, compared to TCT e.g. -40/125°C.

Figure 3a. Cross section for Chip 1206, SAC, N=6500 field cycles 22/93 (4 ½ years) [3]

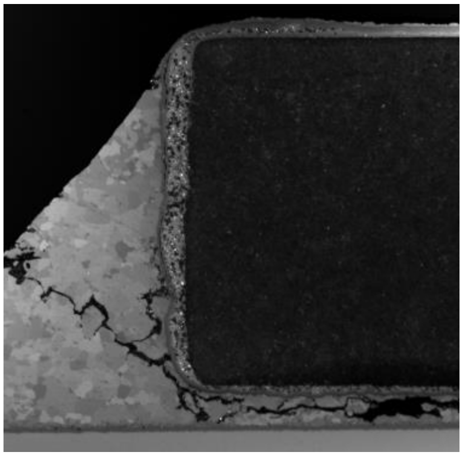

Figure 3b. Cross section, SAC N=6500 field cycles 22/93 (4 ½ years), recrystallized microstructure, intergranular crack path [3]

After the 6500 cycles app. 80-90% of the R1206 shows complete cracking. Means between test cycles and field cycles there are no significant differences because of the failure mode itself.

By using high temperature alloys like Innolot, the results between field and test seems to be different, Figure 4 and 5.

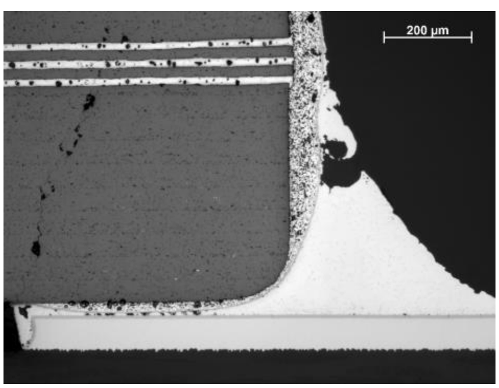

Figure 4. Cross section, Innolot N=1000 test cycles TCT -40/150, Crack of the ceramic, starting by the metallization [3]

This type of reliability issues have also been monitored by some analyses with different types of assembled boards after several working conditions. Means there could be an issue, when the solder/interface/interconnection is not the necessary reason for failures because of stiff connection due to IMCs or other alloy like Innolot.

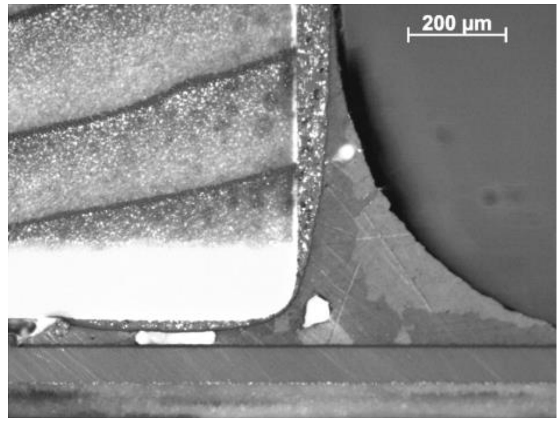

Figure 5. Cross section, SAC N=6500 field cycles 22/93 (4 ½ years), recrystallized microstructure, intergranular crack path [3]

After those conditions, it does not show any failures based of the Innolot alloy. Means when the field-conditions are similar or same it could be no issue for some well-known reliability problems. On the other hand, the failure mode, detected by the TCT condition, changed into the component body or can change into the pcb, means that requires more investigation for an improvement of the reliability.

Reliability acc. Avionic

Another project has done an investigation of 14 different lead free alloys as well as an interaction for several types of passive components, different size of pad geometries and also different surface finishes [4, 4a]. The interested part were results of fixed components with a bigger pad length, Figure 6.

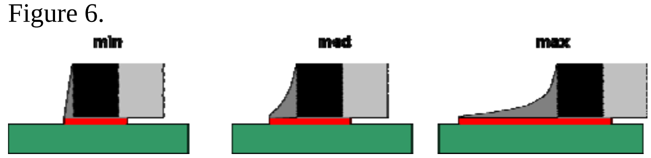

Figure 6. Combination of pad geometry/size for passive components

After soldering, it shows that the pad geometry changed the interconnection in the gap, Figure 7, probably because of the surface tension based on the solder paste. Figure 8 shows, that there is also an influence from the type of the surface finish. The thesis is, those changes, especially because of different structures/type of interconnect in the gap, shows also different results for the lifetime by TCT.

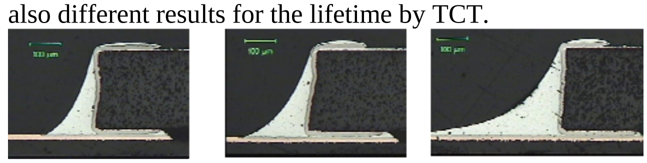

Figure 7. Cross section passive components R0402 solder SAC305 on NiAu PCB surface [4, 4a]

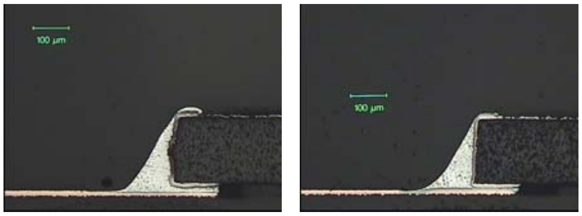

Figure 8. Cross section passive components R0402, solder SAC305 left on chem.Sn right on NiAu PCB surface [4, 4a]

The reliability has been tested by a thermal shock -55/+125°C and analyzed of the electrical resistance of Zero Ohm resistors. Figure 9 shows the results of the characteristic failure rate and table 1 the characteristic lifetime (statistical results) for the component R1206 based on SnAg3.5 alloy.

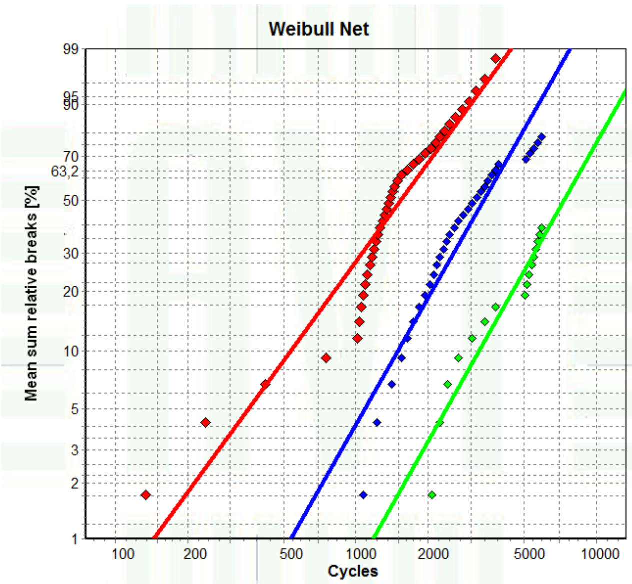

Figure 9. Failure rate (sum), R1206, SnAg3.5, NiAu, different pad geometry (red=min, blue=med, green=max) [4]

Table 1. Statistical results of the reliability data R1206, SnAg3.5, NiAu, different pad geometry (red=min, blue=med, green=max)

	Minimum	Medium	Maximum
Char. Life time N_f	1889	3987	8556
Shape parameter β	1,79	2,288	2,32
Est. life time 0,1 %	40	195	436
Est. life time 1 %	145	534	1178

As the results shows there is a strong correlation between reliability data and pad geometry. It is not 100% clear whether that effect has gotten by the solder deposit especially outside of the components because of the meniscus or is there also an influence due to changing the structure in the gap between pad surface and component.

Reliability acc. Diffusion Soldering

Additional results of another public project had been presented in [5]. Therefore one part of this project were the assembly of SMD on pcbs by creating of intermetallic phases and whose reliability [6]. Therefore, it had created IMCs during the reflow process by a two paste printing process (Cu-paste and Lead Free paste). The results about 1206 components shows Figure 10.

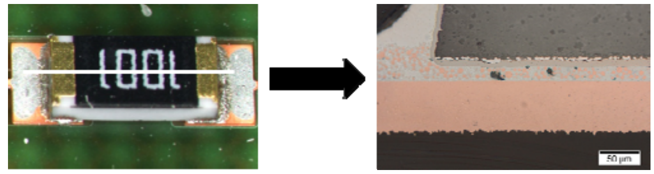

Figure 10. Result of 1206 by the HPC process (diffusion soldering with two-paste process)

The active reliability test gave after 1000 cycles no failure at TCT -40/+200°C as well as 125 cycles at -40/240°C, Figure 11.

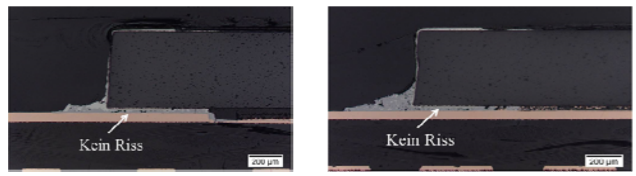

Figure 11. Cross Section after TCT -40/200°C N=1000 left, -40/+240 N=125

After the TCT there is no crack inside the gap but in both cases there was a fatigue inside of the meniscus of the soft solder alloy, which was not infiltrated and didn't crate intermetallic. Means the meniscus itself does not have any influence for the reliability itself. Based on this results there FEM models were made, which compared the stress with and without IMCs [5, 6], figures 12 and 13.

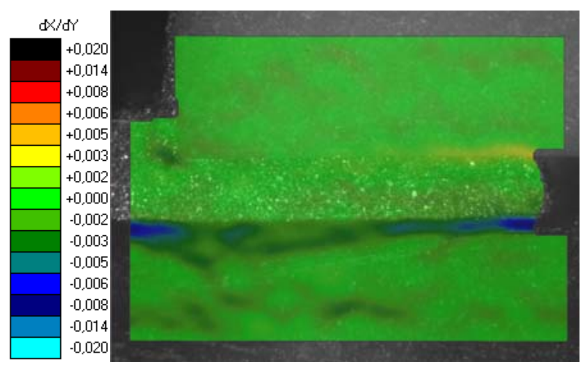

Figure 12. Local shear strain HPC at 210°C [5, 6]

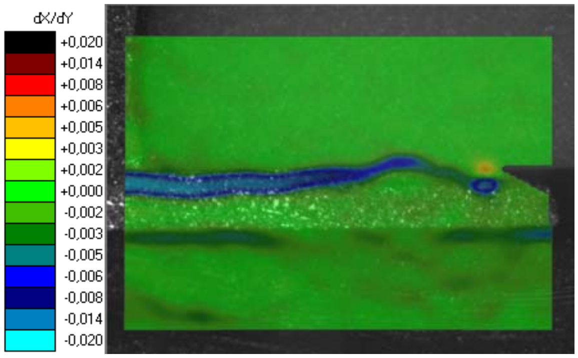

Figure 13. Local shear strain SAC at 210°C [5, 6]

The result shows significant differences of deformation or movements while heating between SAC and HPC. This means the deformation of SAC is nearly three times more than HPC [6]. The reason is the intermetallic at HPC, which is harder than SAC. By analyzing the localization of the stress, it can retain that HPC, in figure 11, has just local stress between pad and pcb laminate and SAC, in figure 12, as usual between component and soft solder, in the direction of cracks after reliability tests.

Complex Board

Due to decrease passive and active component size, a compendium has been published to find answers for a high mix of several components [7] and describes the possibilities about the assembling process. Based on several impotent properties like pcb, stencil, solder resist, pick and place and so on is one part the solder paste especially the particle size. By using multiple printing process with a step stencil, it can use two powder types e.g. 3 and 5. The reason, for smaller particles the stencil size (thickness) is limited. Means, based on the necessary particles type 5 for finest pitch and components smaller than 0201 needs as maximum stencil thickness 100µm or better 75µm. By using that application with one stencil it will change the solder joint or for all bigger components.

OUTLOOK

Based on the positive results for reliability and the challenge for more complex boards without using different types of paste (powder size) and stencils, more assembly steps, a project has been started for harmonizing and searching the limits with solder paste and one stencil thickness as well as different openings in the stencil. With those results, the process flow can be described and additional reliability test could be follow to proof an increasing for bigger component as well.

LITERATURE

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