A Study of Lead-Free Surface Mount Technologies

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Abstract – **The paper describes problems concerning the application of lead–free solder inks for SMT (surface mounting technology), as well as lead–free solder alloys for conventional PCB (printed circuit board) technology. Comparative technological and design tests of test SMT printed circuit boards with different final plating have been carried out. Destructive tests for peeling and shearing strength determining, combined with thermal cycles have been implemented also.**

Keywords – **Lead–free solder alloys, test printed circuit board, peeling strength, shearing strength.**

I. Introduction

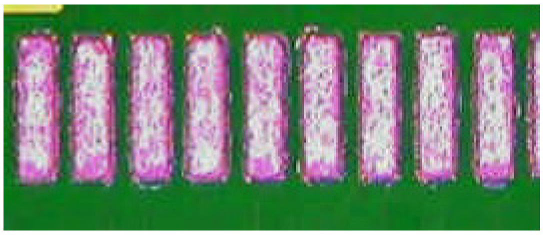
Abandoning lead as an essential material in electronic manufacturing is an inevitable process. Proof is the EU directive RoHS which requires the restriction of dangerous substances from electronic and electrical equipment. In accordance with the latter lead should be eliminated from electronic products put on the market after July 1, 2006. It is therefore essential for the electronic products manufacturers to be informed about the possible choice of lead–free solder alloys, used for soldering, printed circuit board and electronic components pin plating. They should possess similar features in comparison with the most commonly used nowadays tin–lead (SnPb) solder alloys. Literature study shows, that possibilities for lead–free solder alloy choice is not very wide. Most serious pretenders for substituting tin-lead alloys are tin and copper, as well as tin, copper and silver alloys [1,2].

Subject of a comparative investigation of this paper are tin, copper and silver alloys, as well as tin–lead alloy. The aim is to examine solder stability and reliability in cases of SMT and conventional technology.

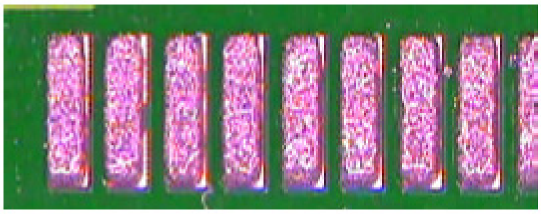
II. Experiments

Lead–free solder inks for SMT are being prepared from the most common Sn–Ag–Cu alloys: Sn96,5-Ag3,0-Cu0,5; Sn95,5-Ag3,8-Cu0,7; Sn95,5-Ag4,0-Cu0,5. Evaluation of solder inks is being carried out in accordance with the following criteria: availability, price, printing, melting, temperature ageing, and reliability characteristics of solders [3]. Examined solder inks show very good similar printing characteristics Fig.1.

Melting temperatures of the three inks lie between 218°C and 220 °C (219,77 °C, 218,8 °C and 220,23 °C, appropriately). These values are very close to each other, but Sn95,5–Ag3,8–Cu0,7 solder ink has the lowest melting temperature [4].



Sn96.5/Ag3.0/Cu0.5



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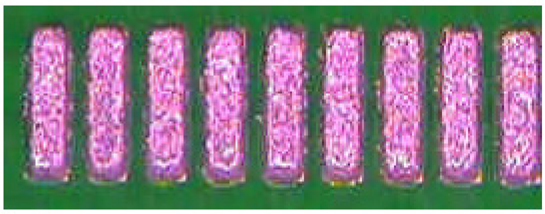

Sn95.5/Ag4.0/Cu0.5

Fig. 1

For experimental needs a test SMT printed circuit board has been implemented. Fig. 2 shows its topology. Pads for mounting the most common footprints are provided: FLAT – 1206, 0805 and 0603; MELF; SOT 23 and SOT 89; SO; PLCC and TOFP. Hence all commonly used standard surface mounting devices are being used in our experiment – resistors, capacitors, transistors and integrated circuits. Printed circuit boards are produced in accordance with the conventional subtractive technology. Some of the PCBs are with final tin-lead plating, the rest – with a gold one. Although gold final plating is more often being used, the percent of Sn–Pb plated PCBs is relative high in the transition period and it is possible to combine Sn–Pb plated PCBs with lead–free soldering materials.

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A lead–free solder ink type TCS552 – 1 with the following ingredients: Sn 95,5; Ag 3,8; Cu 0,7 and melting temperature 217 °C has been chosen for our experimental purposes. Soldering is being carried out in a four – zone REFLOW oven with infrared heating and air convection. For comparison, another test PCB has been mounted with a lead solder ink type R256 (Sn 62; Pb 36; Ag 2) with a melting temperature 183 °C.

For pads mechanical strength and reliability evaluation a destructive test method has been used, wherein strength for peeling the pad from the test board has been measured. The test boards have been passed through temperature cycles with a given duration.

III. Experimental Results

TABLE 1

PCB#	Technological characteristics	Melting temperature, °C	Solder outer appearance	Defects
01	SnPb plating SnPbAg ink	225	Proportional, smooth, shining solders; excellent pad wetting.	Not observed
02	SnPb plating SnAgCu ink	242	Incomplete ink melting, rough mat solders; unburned flux traces round pads outlines	Cold solders
03	SnPb plating SnAgCu ink	245	Incomplete ink melting, rough mat solders; unburned flux traces round pads outlines	Cold solders
04, 05	SnPb plating SnAgCu ink	250	Complete ink melting; good pad wetting; smooth shining solders	Not observed
06	Au plating SnAgCu ink	250	Complete ink melting; good pad wetting	Areas without ink are not observed
07, 08, 09	Au plating SnAgCu ink	250	Complete ink melting; good pad wetting; smooth shining solders	Not observed

Seven PCBs with different final plating and different soldering temperatures have been examined. The overall results are given in Table 1.

Pads mechanical properties have been examined by means of destructive peeling strength measurement. There are three possible cases - pad destruction, solder peeling from pad, pad peeling from PCB. Tests have been done after applied

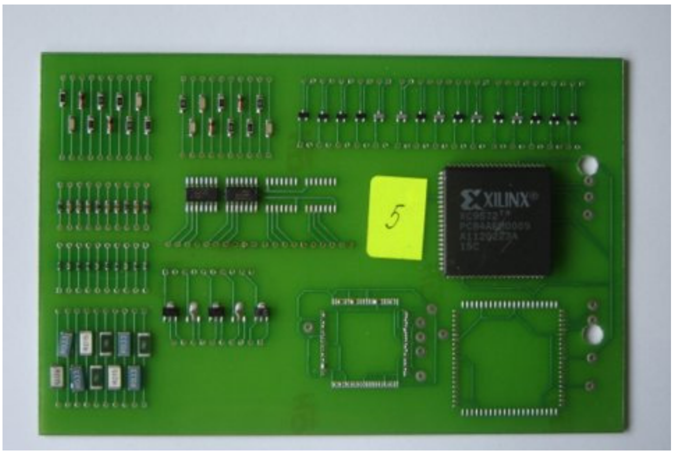

Fig. 2

temperature cycles with the following parameters: +85 °C (25 min), ambient temperature equalization (5 min), -25 °C (25 min), ambient temperature equalization (5 min). Peeling strength measurements have been done at regular cycle intervals - 0, 5 and 10 by means of a four - channel measuring bridge type MK from "HOTTINGER - BALDWIN - MESSTECHNIK", with the following parameters: matching range ± 26000; 1 scale count = 1 μm/m for a typical strain gauge; carrier frequency 180 Hz; precision 0,1 %. Each measurement comprises 10 pads per test cycle. Corresponding results (peeling strength mean value) are shown in Fig. 3. Series 1 (blue) data are the results (mean value) from a tin-lead solder alloy (SLT 60) strength test, whereas Series 2 (red) - these (mean value) from a lead-free alloy. Peeling strength of lead-free alloy solders is about 20% higher than tin-lead alloy solders strength. More important, no pad destruction was observed, at all.

IV. Conclusion

Comparative examinations of lead-free (TCS 552-1 type) and tin-lead (R256 type) solder inks, as well as lead-free and tin-lead solder alloys reveal very good technological and mechanical properties of the examined lead-free solder ink and alloy. Lead-free solder alloys are technologically compatible with golden plated PCBs.

Products proposed from the solder producer are appropriate for substituting the lead solders and inks for conventional and surface mount printed circuits. The only requirement for using lead-free materials is the higher temperature of the REFLOW process and of the solder iron used.

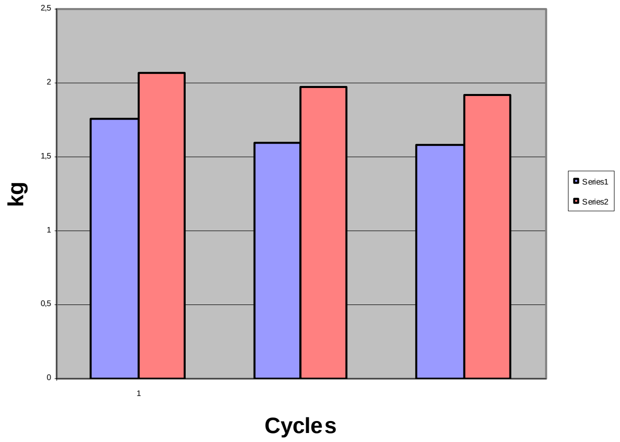

Fig. 3

References

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