LEAD FREE SOLDERING ON CONTACT PADS

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In this article are presented results from the investigations of some peculiarities in the process of soldering on small topological forms in PCBs. The investigation is dedicated to the surface mount technology and deals with lead contained and lead free solder alloy pastes. Attention is paid on the implementation of contact pads with lead free surface finish. For this purpose are used galvanic deposited coatings and different solders. The results are obtained when using temperature profiles of typical production process at regimes, recommended by the solder paste vendors. In the experiments are implemented specially developed test lay outs and samples, manufactured from PCB material. Predominantly are investigated the processes of solder wetting in atmospheric surrounding.

Keywords: soldering, soldering alloys, SMT

Introduction. In the last years in the SMT occurred elements with small and ultra small contact pads [1]. The methods of contact pad surface preparation were developed simultaneously [2]. For obtaining of solder joints in given areas are used the processes of selective deposition with application of protective masks. Some peculiarities in the implementation of protective masks are revealed in [3]. The invasion of lead free technologies stated the demand to proper preparation of the contact pads and knowledge about the soldering processes. Usually the solder paste vendors present basic manuals for the application and process guides [4].

Problem. Determined difficulties in the soldering joint process are the small forms. Such are met in the fine pitch elements; the elements with matrix leads and some microwave devices. We can observe two types of problems – the one connected with the solder paste deposition, the other related to the very soldering process.

The deposition of solder material is done mechanically through printers or dispensers, which are with special construction and regimes for fine pitch elements. In the soldering one must be familiar with the wetting process depending on the topology lay out and the surface finish.

The purpose of the present investigation is the application of lead free coatings on small topology forms and their influence on the solder wetting process. The study must refer to concrete temperature profiles in the production using lead free soldering.

Research method. The investigation of the above mentioned influences could be performed by theoretical analysis, modeling or experimentally. For the choice of a method is necessary evaluation of the parameters, influencing the process. Soldering is result of two technological operations – solder deposition and thermal treatment. The following processes are observed in the thermal treatment:

- The fluid conversion of the flux, change of the form in the printed paste, wetting from the flux and its active co-reaction with solder and substrate. Moreover the wetting is not a pure physical process but is connected with chemical co-reaction.
- The fluid conversion of the solder, pads wetting, at which the process again is not only physical but metallurgical co-reaction (merging of the solder micro-drops ,surface change and volume).

The process of wetting is connected with influence of the flux, gas environment, material, time. The theoretical description of all these elements demands heavy tools and does not reveal visually the effects. The modeling also applies some simplifications; therefore the method of experimental investigation was chosen. For the purpose a program of experimental conduction was developed at the following conditions, fig. 1.

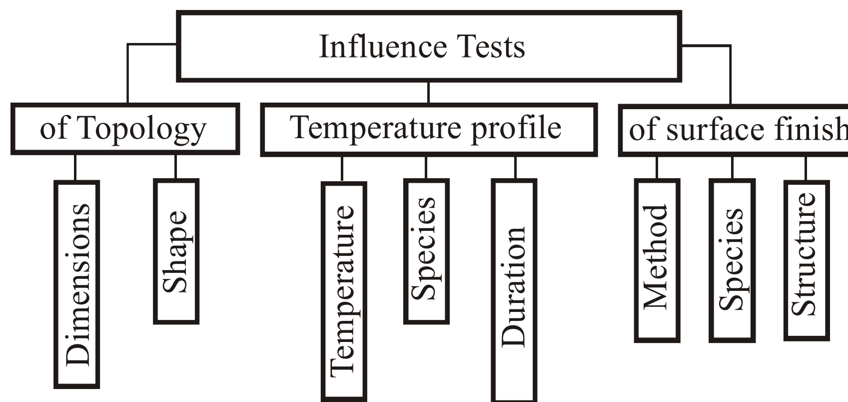


Fig. 1 Tests of wetting conditions

For the development of the wetting process, the horizontal topology influences through trace (pad) width and its shape. In vertical direction the main influence occurs when wetting of holes and vias. The temperature profile influences through its values, speed of change and total time. Usually are used recommended profiles of solder paste manufacturers, matched with the flux and solder. The coatings could be low temperature – solder alloys or high temperature – Ni, Au, Ag. By the method of obtaining they could be chemical, electrochemical, physical.

Test Structures. For the conduction of the experiments are developed test structures with different topological shapes, allowing the application of various methods of surface finish deposition. On fig. 2 are shown sets of photo masks for testing the influence of the horizontal topology.

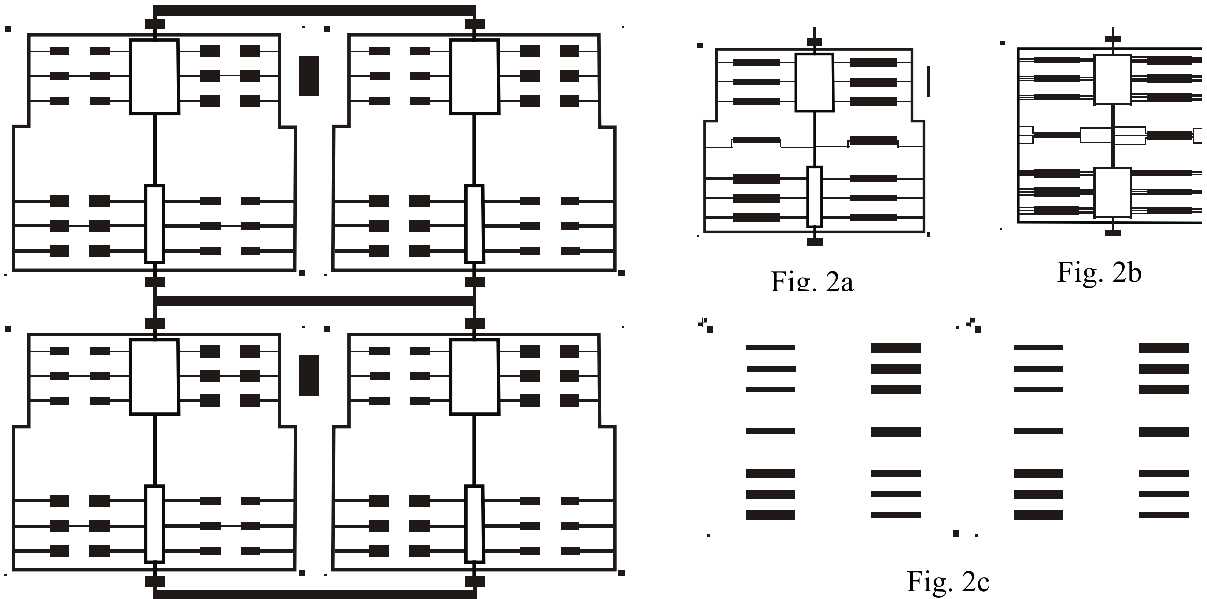


Fig. 2a Fig. 2b Fig. 2c

Fig. 2 Test masks for testing of solder wetting

The test elements are contact pads with different sizes, allowing the print of different paste quantities. From the contact pad exit traces with different widths on which flows the melted solder. The widths of the traces are in range of 100÷350 um and cover practically the fine pitch sizes. The stencil consists of four structures with axis symmetry allowing the use of different print combinations by rotating it – fig. 2c. All topologies are designed with possibility for applying chemical and electrochemical deposition of coating, while the set of masks permits implementation of selective growth or coating of the structured substrate.

Experimental Results. The manufacturing of the test samples is conducted in the department laboratory. The metal stencils are produced in "Micron 20" and two thickness of the material are used – 120 and 150 um. The experiments of paste deposition are done at the department KTPPME and in the premises of foundry "EPIC 2 EA", Botevgrad.

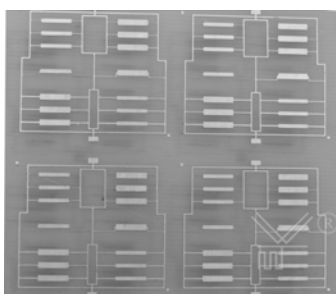


Fig. 3a

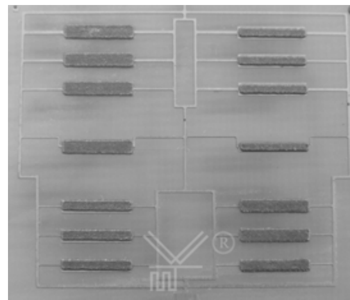


Fig. 3b

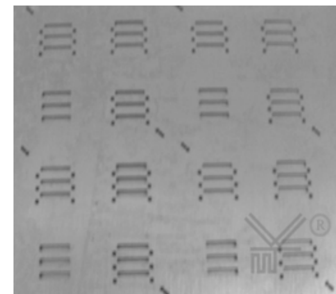


Fig. 3c

Fig. 3 Experimental samples for wetting investigation

On fig. 3a is shown one experimental sample of test PCB, while on fig. 3c the corresponding stencil for solder paste deposition. On fig. 3b is shown deposited paste at the first variant and is seen that half of the pads are with narrower footprint. When rotating the stencil, the footprints exchange and the pads with narrower footprints become normal.

The contact pads and traces used in the investigation of the wetting are bare copper or standard coated – hot coating, electroless deposited Ni/Au layer, and electrochemical deposited lead free surface finish. From a practical point of view, the last coating variant is something new. Here is tried the system SnSb, where initially are deposited layers directly onto the copper surface and then are applied barrier Ni layers. The barrier layer is deposited electrochemically also.

On fig. 4 are shown microscopic pictures of SnSb coating, at different deposition regimes.

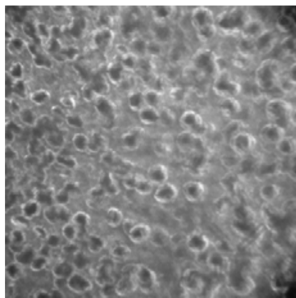


Fig 4a – direct current

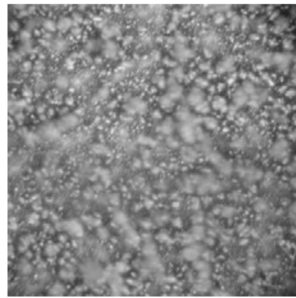


Fig. 4b – impulse 50%

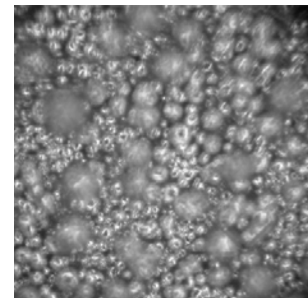


Fig. 4c – impulse, rev.

Fig. 4 Structure of SnSb layers, deposited at different regimes – x250

The deposition velocity dependence of current density and regime is investigated, taking for parameters of the layer structure and Sb concentration. Direct current regimes, impulse and such with reverse are used, while varying the duty cycle to 25 % and the duration of the reverse pulses are from 20 to 300 ms.

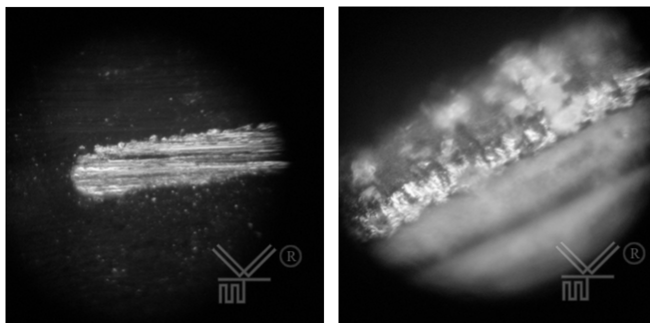
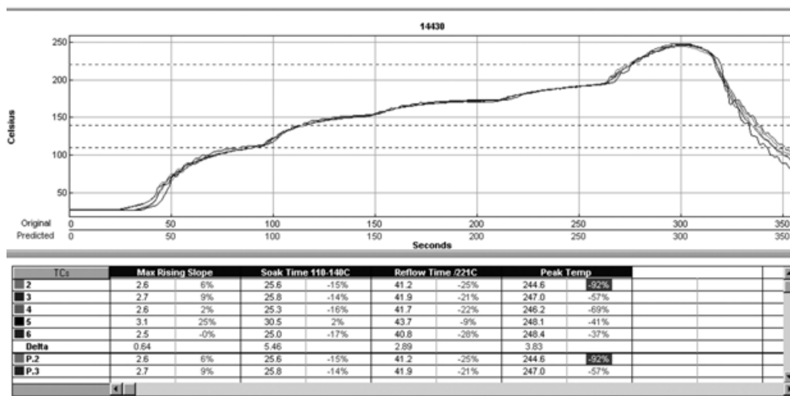


Fig. 5 Cross-section of SnSb on Cu - x100

The deposited layers are observed at different topological dimensions. For determination of the layer structure in vertical direction and at the periphery of the traces, cut cross-sections are prepared – fig. 5. At the preparation of the soldering, solder paste deposition onto trace with coating and without is applied on one sample, aiming the creation of same experimental conditions. Analogically when checking the self-soldering (melting) of the coating on one and the same sample, a zone with flux and without is created.

The soldering is performed by convection and conduction through the substrate. The gas surrounding is air and at the conductive soldering the heating velocity is not defined. One typical profile of the conducted experiments with lead free soldering by convection is depicted on fig. 6. The results of test PCBs and control samples of layers are shown on fig. 7. In order to check the melting of the layer, selective deposition onto the traces is performed.



TCs	Max Rising Slope		Soak Time 110-140C		Reflow Time /221C		Peak Temp	
2	2.6	6%	25.6	-15%	41.2	-25%	244.6	-92%
3	2.7	9%	25.8	-14%	41.9	-21%	247.0	-57%
4	2.6	2%	25.3	-16%	41.7	-22%	246.2	-69%
5	3.1	25%	30.5	2%	43.7	-9%	248.1	-41%
6	2.5	-0%	25.0	-17%	40.8	-28%	248.4	-37%
Delta	0.64		5.46		2.89		3.83	
P.2	2.6	6%	25.6	-15%	41.2	-25%	244.6	-92%
P.3	2.7	9%	25.8	-14%	41.9	-21%	247.0	-57%

Fig. 6 Typical profile of lead free soldering
(courtesy of EPIC EA)

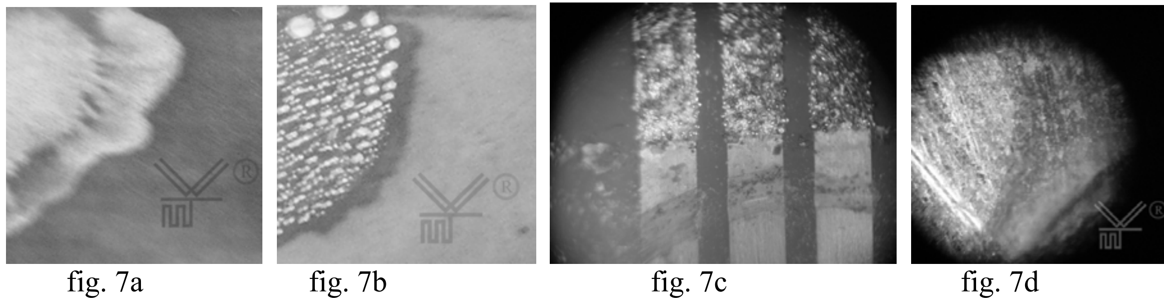


fig. 7a fig. 7b fig. 7c fig. 7d

Fig. 7 Microphotography of samples after convection soldering

On fig. 7a and 7b is shown the front of wetting, when using flux type RM for the case of DC deposition and impulse at 50 % duty cycle. Fig. 7c and 7d refer to the traces wetting.

When implementing lead free pastes, the wetting is investigated at different trace widths. On fig. 8 are depicted such cases.

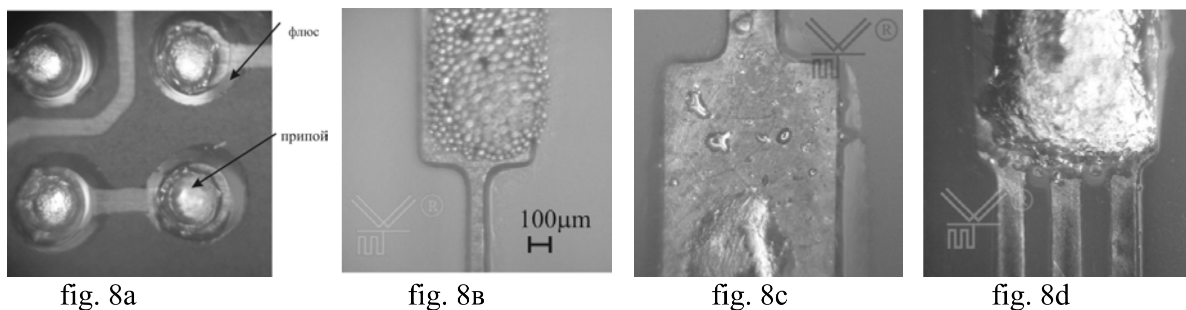


fig. 8a fig. 8в fig. 8c fig. 8d

Fig. 8 Wetting at soldering with lead free pastes

Fig. 8a depicts a case of direct paste deposition on cleaned pads, while fig. 8b presents deposited paste near thin trace. On fig. 8c is shown the result of wide contact

pad soldering. Fig. 8d presents the result of fine pitch trace soldering. All cases are without using of protective masks.

Conclusions: The conducted experiments proved the lower wetting of metal surfaces when applying lead free solder pastes. The effect of strong solder drop and spherical-like shaping on large contact pads is observed. The same is not observed on pads with dimensions less than 400 um. On traces less than 200 um, nevertheless they are alone or in clusters, for the time of soldering (40 –70 sec.), entering of the solder is not observed. This circumstance allows not using thermal bridge lets.

Additional investigation of the flux excess and influence of oxygen free soldering atmosphere is necessary.

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