4 P SOLDERING MODEL CONCEPT PROPOSAL

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Abstract: *The reliability of microelectronics components and assemblies it should be considered as expression of solder joints functionality. The functions are in close connection with the microstructure of the solder joints, which are the result of the soldering Process temperature gradient action over the trinomial solder alloy/Paste, electronic components terminals/Pin and PCBs Pads finishes. Consequently the solder joints quality can be correctly evaluated taking into consideration not only the severally intrinsic parameters of the trinomial elements, Pad-Paste-Pin, but also interrelate the complex reaction at the interface between them and interdependence with the soldering Process parameters. Therefore the solder joints can be considered result of a complex function of 4P elements defined before. 4P Soldering Model concept is proposed in order to characterize the solder joints quality, emphasizing dynamics of Pad-Paste-Pin-Process elements synergistically interactions. The different pad finishes (NiAu, ImmAg, ImmSn, HASL, OSP) realized on PCBs having different core material, (FR4, Glass, Al, Cu, Al_2O_3), the components terminals/pins/balls having different finishes, the different solder paste type and the reflow soldering process (infrared-convection/vapour phase/LASER) with their typically parameters are the 4P Soldering Model variables. Practical experiments will be designed in order to study 4P Soldering Model elements, Pad-Paste-Pin-Process, interactions as subject of a Group Project proposed in Working Group 2 of COST MP0602 HISOLD action.*

1. INTRODUCTION

The quality and the reliability of microelectronics components and assemblies it should be considered as expression of solder joints functionality. As very well known, the functions of solder joints in electronic packaging are mechanical, thermal and electrical. The surface mounting assembling technology, typically for level two of electronic packaging hierarchy at board level interconnections, used the reflow soldering process for top side PCBs surface mounted components and the double reflow or the wave soldering process for bottom side PCBs surface mounted components (with glued components for wave bottom side soldering). The functions are in close connection with the microstructure of the solder joints, which are the result of the soldering **P**rocess temperature gradient action over the trinomial solder alloy/**P**aste, electronic components terminals/**P**in and PCBs **P**ads. Consequently the solder joints quality can be correctly evaluated taking into consideration not only the severally intrinsic parameters of the trinomial elements, **P**ad-**P**aste-**P**in, but also interrelate the complex reaction at the interface between them and interdependence with the soldering **P**rocess parameters. Therefore the solder joints can be considered result of a complex function of **4P Soldering Model** whose dynamic elements, **P**ad-**P**aste-**P**in-**P**rocess having synergistically interactions and correlations.

2. 4P SOLDERING MODEL MORPHOLOGICAL STRUCTURE

The modern electronic modules are results of manufacturing process consisting in electronic components interconnected on PCBs support by solder joints using soldering technologies, according with a dedicated project, result of Design for Manufacturing (DfM) process. DfM process can be defined as a space of the possible design solutions Di being conditioned by marketing, business line, manufacturing, test, distribution and after sale requirements (fig. 4).

Corresponding to D_i solutions in the project will be defined the electronic components, and PCBs design where will be defined the pads according with electronic components footprints. Taking into considerations the electronic components terminals as pins can be defined a space of the possible **P**in solutions $\mathbf{P_1}$ being conditioned by the Pin material (copper), finish (Sn, Ni, NiPdAu, SAC) or geometry (thickness, forms: pin, win gull, balls, according with IPC7351). For pads will be two major components:

- metallic surface as support of solder joint, characterized by geometry and finishes (Electroless Nickel Immersion Gold (NiAu); Chemical Tin (ChTin); Hot Air Surface Leveling (HASL - SnCuNi); Organic Solderability Preservative (OSP) Immersion Silver (ImmAg); Copper without finishes);
- substrate, with important contribution over thermal mass and thermal transfer, consisting of different type of PCBs having different core materials and geometry.

As consequence, the space of the possible **P**ad solutions $\mathbf{P_2}$ can be defined, being conditioned by the pad finishes, geometry and substrate.

In the manufacturing area, according with design solution and requirements imposed by **P**in and **P**ad solutions, solder paste will be selected from a typically **P**aste solutions space $\mathbf{P_3}$ determined by solder alloy as basic material, flux and geometry aspects consequences of stencil design.

In cases of assembling in reflow soldering processes, typically for Surface Mount Technology (SMT), analyzes regarding thermal profiles are based on recommendations of IPC/JEDEC:J-STD-020C standard. For different soldering processes can be defined a space temperature / time, for assembling **P**rocess solutions $\mathbf{P_4}$ (fig. 4), corresponding to D_i (DfM solution) and defining a particular process thermal profile. The different soldering process, are characterized by different thermal profiles with variation in practical range presented in Fig. 1, comparative Lead / Lead-Free technologies for **I**nfra**R**ed/**C**onvection (IRC) soldering process, in figure 2 for **V**apour **P**hase **S**oldering (VPS) or in figure 3 for LASER Soldering Technology (LST). The **P**ads having different finishes (NiAu, ImmAg, ImmSn, HASL, OSP) and geometry, realized on PCBs having different core material, (FR4, glass, Al, Cu, Al2O3), the components terminals/**P**ins/balls having different finishes, material and geometry, the different solder **P**aste type, having different solder material, flux and geometry, the reflow soldering **P**rocess (Infrared-Convection/Vapour Phase/LASER) with their typically thermal profiles are the **4P Soldering Model** variables.

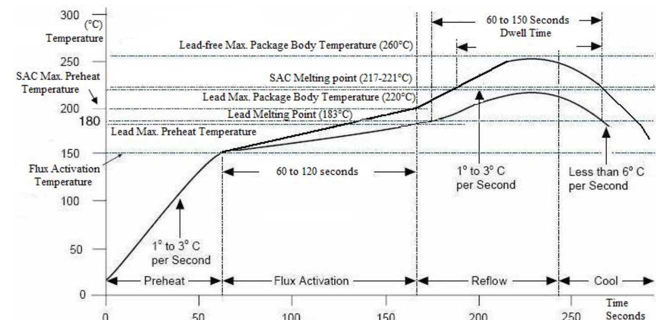

Fig. 1. The comparative Lead / Lead-Free thermal profile

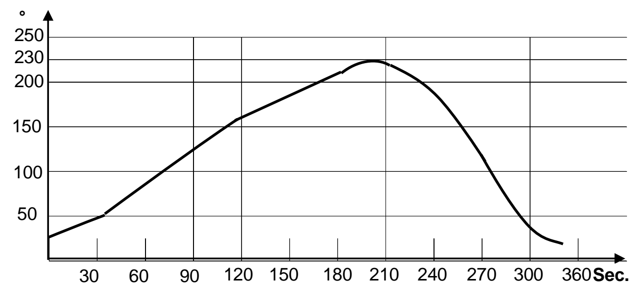

Fig. 2. The Lead-Free VPS thermal profile

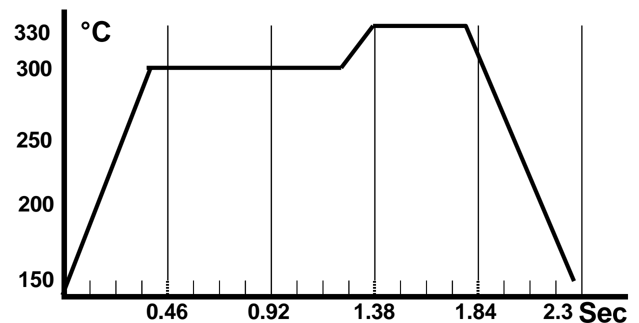

Fig. 3. LASER Soldering Technology thermal profile

The **P**in-**P**ad-**P**aste-**P**rocess will be considerate as Key Process Input Variables (**KPIV**) for the **4P Soldering Model** (Fig. 4). The projections of D_i (DfM proposed solution) to **P**in-**P**ad-**P**aste-**P**rocess possible solutions spaces will generate proposed solutions for each of KPIV. Defining **The Pad-Paste-Pin-Process Correlations Space**, as a space of synergistically interactions and correlations between KPIV proposed solutions projections, the result will be final solutions for **P**in-**P**ad-**P**aste-**P**rocess as **4P Soldering Model KPIV**, having as univoque application in **The Solder**

Joints Reliability Results Space, the reliability function:

$\mathbf{R=R_i(P_{1i},P_{2i},P_{3i},P_{4i})}$ [1]

Where,

$\mathbf{P_1 = P_{1i}(\mathit{g_i\, f_i\, m_i})}$ [2]

$\mathbf{P_2 = P_{2i}(\mathit{g_i\, f_i\, s_i})}$ [3]

$\mathbf{P_3 = P_{3i}(\mathit{g_i\, f_{xi}\, m_i})}$ [4]

$\mathbf{P_4 = P_{4i}(\mathit{T,t})}$ [5]

P_1 = Pin functions, P_2 = Pad function,
P_3 = Paste function, P_4 = Process function
g_i = geometry, f_i = finish, m_i = material,
s_i = substrate, f_{xi} = flux, T = temperature, t = time.

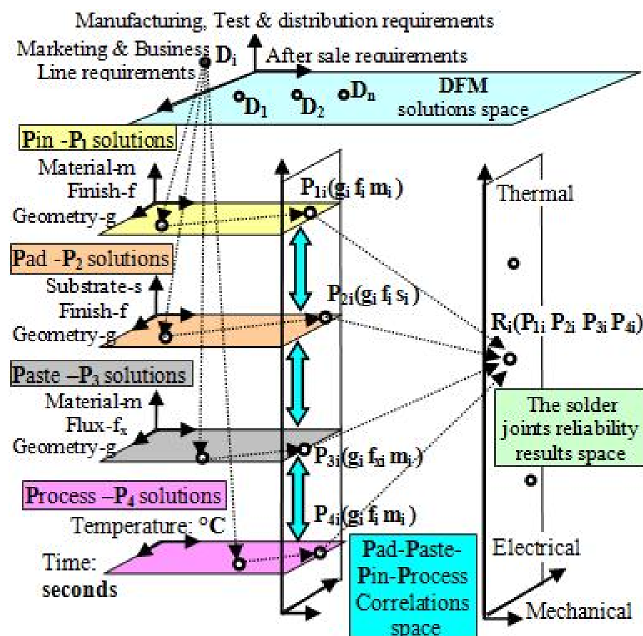

Fig. 4. 4P Soldering Model morfological structure

3. Conclusion and Proposals

The solder joints electrical and thermal parameters depend by all P "actors" of the **4P Soldering Model** concept. The **P**ads having different finishes (NiAu, ImmAg, ImmSn, HASL, OSP) and geometry, realized on PCBs having different core material, (FR4, glass, Al, Cu, Al2O3), the components terminals/**P**ins/balls having different finishes, material and geometry, the different solder **P**aste type, having different solder material, flux and geometry, the reflow soldering **P**rocess (Infrared-Convection/Vapour Phase/LASER) with their typically thermal profiles are the **4P Soldering Model** variables. The **P**in-**P**ad-**P**aste-**P**rocess will be considerate as Key Process Input Variables (**KPIV**) for the **4P Soldering Model.** The KPIV influences over solder joints functionality were verified by the experiments and confirm theirs right selection.

The practical experiments will be necessary to be developed in order to characterize the solder joints quality and reliability, taking into considerations properties, interactions and correlations of **P**ad-**P**aste-**P**in-**P**rocess defined as **KPIV** of the **4P Soldering Model**. KPIV influences will be verified for theirs right selection confirmation. In principal the folowing issues for experiment are proposed:

- the **P**ad influences over solder joints quality having as constants the Pin-Paste-Process elements of **4P Soldering Model** and consist in assembling of PCBs with different core material using the same type of components, solder pastes in the same process;

- the **P**aste influences over solder joints quality having as constants the Pin-Pad-Process elements of **4P Soldering Model**. The works will be focus on analyzes the quality of solder joints realized on special designed test PCBs using different solder paste types and qualities in the same conditions of reflow soldering processes (same thermal profile);

- the **P**rocess influences over solder joints quality having as constants the Pin-Pad-Paste elements of **4P Soldering Model**. Considering the quality and reliability of solder joints as function of the microstructure composition, in order to characterize the solder joints microstructures and parameters dependency only of the process thermal profile there were used the same input elements for the trinomial solder Paste, electronic components terminals–Pin and metallic substrate on PCBs-Pad.

The results of the proposed experiments will be used to improve methods and future experiments in order to study the correlations between functionality and microstructure of solder joints as function of **4P Soldering Model KPIV**. The purpose will be to set up a data base that will offer information for improvement of the thermal profile of reflow process depending on the solder microstructure, in volume and at the interface with the metallic layer. This specialized data base will offer the mean to assure functionality of solder joints at a higher quality and reliability level and the reduction of the validation time for other new lead-free solder alloys.

The **4P Soldering Model** concept was developed as subject of a Group Project proposed in Working

Group 2 of COST MP0602 HISOLD action.

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