THE IMPACT OF INTERMETALLIC COMPOUNDS ON RELIABILITY OF SOLDER JOINT

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ABSTRACT

This article deals with the intermetallic compounds and its effect on reliability and strength of solder joint. The reaction of SnPb solder with Cu plated pads is analyzed. Mainly, it is the reaction of Sn from solder with Cu, Cu_6Sn_5 and Cu_3Sn is created. This phenomen is monitored by electron microscope with chemical element analysys.

1. INTRODUCTION

This article deals with problems of creation of intermetallic compounds at soldering and their influence on reliability of solder joint. There is analyzed reaction of solder SnPb with copper surface of basic material. Constitution of separate thicknesses is detected by elementary analyses by electron microscope from micro – grind of solder joint.

During the wetting process of copper surface of the board by liquid solder, the liquid acts like an incrusive solvent and there happens diffusion of tin from solder to basic material. This happens to intermetallic compounds (IMC) Cu_6Sn_5 and Cu_3Sn. Figure 1 shows lay-out of certain thicknesses in solder joint. At the figure there are only intermetallic compounds between solder and copper basic material.

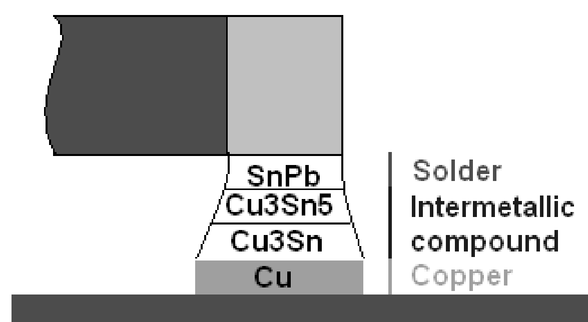

Fig. 1: Lay-out certain thicknesses in solder joint

2. DIFFUSION

At the moment of initiation of wetting process of solid surface by liquid solder, the creation of diffusion zone starts. The concentration gradient causes motive force of this process. Diffusion flow of liquid solder which is diffusing through crosscut A for the duration t from side of lower concentration is proportional to concentration gradient. Diffusion always includes transportation of substance. For thickness of created diffusion layer Z_0 after time of soldering process out of Fick law reads:

$$Z_0 = \sqrt{Dt} \tag{1}$$

Defining: Z_0 thickness of IMC [m]

D coefficient of diffusion [$m^2.s^{-1}$]

t time [s]

Diffusion speed and thickness of created diffusion layer is given by soldering process and by choice of joined materials. Coefficient of diffusion grow up is exponential according to mounting temperature. Excessive growth during the soldering is caused by higher temperature and by longer time of soldering process.

Diffusion process in solid metals generally depends on type and abnormality of construction crystal lattice. Diffusion coefficient grows up by increasing of the density of crystal-lattice defects.

In solderability and wetting view the diffusion is an positive effect. On the other side, lead does not participate on creation of intermetallic compounds. This layer works as a barrier, which gets worse especially mechanical and electrical characteristics of solder joint.

Except above-mentioned diffusion during the soldering process there happens another diffusion on solder joint after soldering. During thermal and current straining happens to next continuation of growth intermetallic thicknesses.

For reliable solder joint is advising temperature reflow (220 – 230)°C for the duration of (2 – 3)sec. Thickness created intermetallic layer is approximately 0,5 µm.

3. DISSOLVING OF METAL

Patterns of dissolving solid phase in liquid phase:

$$\frac{dQ}{dt} = K(C_0 - C)S \tag{2}$$

Defining: $\frac{dQ}{dt}$ quantity of substance dissolution at unit of time[mol.s^{-1}]

K constant of speed dissolution [m.s^{-1}]

C_0 concentration of saturation solid solution [mol.m^{3}]

C real concentration of solid solution at moment [mol.s^{-1}]

S area of solvent solid surface [m^{2}]

For constant of dissolving K is valid:

$$K = \frac{D}{x} \tag{3}$$

Defining: D coefficient of diffusion dissolubility atoms in solder [m^{2}s^{-1}]

x width of diffusion zone [m]

Speed of dissolving is characterized by constant of dissolving speed K, what affect:

- temperature
- material characteristics of solder
- material charakteristics of solid surface

Dissolving of solid material in larger quantity during the soldering process is undesirable effect, especially at thin-walled and plating materials (Au, Sn, etc.). Solubility of solid plated material in solder Sn63Pb37 (250°C) is generally highest at Au (4 mm.s^{-1}) and at Cu is approximately 20x smaller.

Solid material solubility in liquid solder is possible to reduce by these methods:

- lowering of soldering temperature
- shorter soldering time
- by selection of soldering alloys and quantity of solder.

4. INTERMETALLIC COMPOUNDS

Intermetallic layers on interface between substrate material and solder strongly affect reliability of soldered joint. On one hand, it ensures higher fortress characteristics of formalized solder joint. On the other hand, intermetallic compounds are essentially breakable than solder as well as basic material therefore they reduce lifetime of soldered joint.

If we reflect using SnPb solder and Cu basic material, the creation of intermetallic compounds Cu_6Sn_5 (melting temperature 415°C) and Cu_3Sn (melting temperature 670°C) is happening. Lead does not participate these reactions. Figure 2 shows basic characteristics of intermetallic compounds as compared to copper.

Property	Cu_6Sn_5	Cu_3Sn	Ni_3Sn_4	Cu
Vickers Hardness (Kg/mm^2)	378 (+/- 55)	343 (+/- 47)	365 (+/-7)	50
Mechanical Character	Brittle	Brittle	Brittle	Ductile
Poisson Ratio	0.309	0.299	0.330	.34
Thermal Expansion (ppm/c)	16.3	19.0	13.7	16
Thermal Conductivity (W/m-K)	34.1	70.4	19.6	385
Resistivity (micro-ohm-cm)	17.5	8.93	28.5	1.7
Density (g/cc)	8.3	8.9	8.65	8.9

Fig. 2: *Basic characteristics of intermetallic compounds as compared to copper [2]*

After solidification of solder the creation of intermetallic layer is stopped by mechanism dissolving and continuous by mechanism of diffusion in solid – the diffusion is significantly stronger by higher temperatures. Figure 3 shows thickness growth by different temperatures in depending on time.

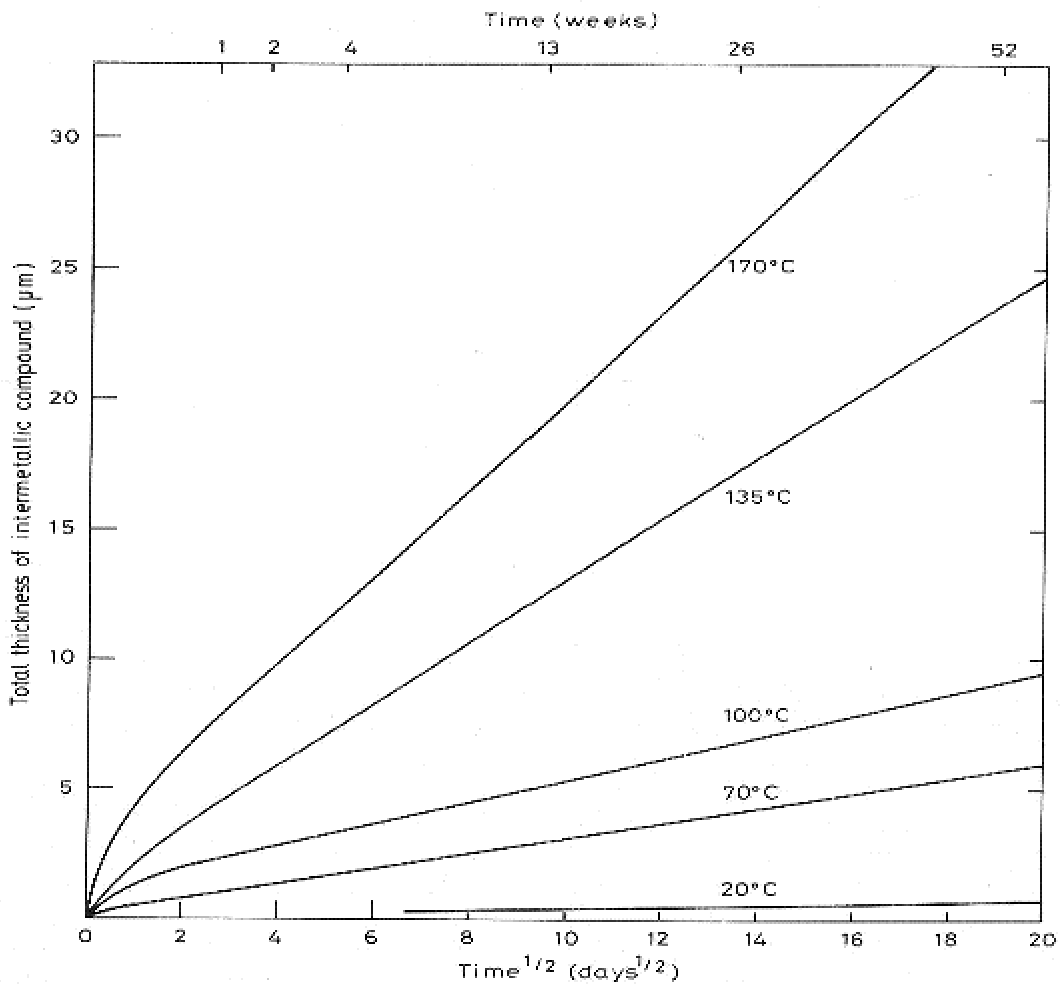

Fig. 3: *Thicknes growth by different temperatures in depending on time [1]*

5. CONCLUSION

As a result of above mention facts, the preposition of serious affect cost by intermetallic layers of reliability in surface mount technology, could be confirm. In the future I will concentrate myself on intermetallic compounds which origins by different combinations of used solders and used adjustments.

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