Inter-metallic copper/ tin phases

1 General

An inter-metallic phase is a homogeneous chemical connection of two or more metals. They show, in contrast to alloy lattice structures, which differ from those of the Constituent distinguished metals. They are formed by diffusion of metals. Diffusion of metals is defined as a naturally occurring physical process, in which the different concentration of pure starting metals are compensated by mixing. For this mixing, defects are used in the metal grids, i.e. the more defects are presented, the greater the diffusion. It starts instantly at the phase boundary of the starting metals and may end with their complete mixing, i.e. if a parent metal has reached the surface of the other parent metal. It runs on one side usually.

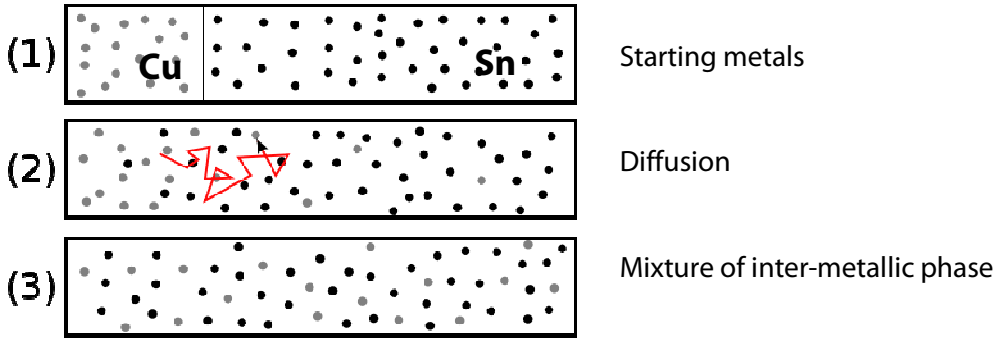

Fig. 1: Schematic representation of diffusion mixing[1]

If printed circuit boards are coated with chemical tin, at the interface of copper/ tin a formation of inter-metallic Cu/ Sn phases starts immediately. **This has the consequence that a very reliable and stable solder connection between pcb and component may occur.** The same mechanism also takes place at pcb with HAL[2] surface.

2 Growth of the inter-metallic phase

The growth of the inter-metallic phase is a function of time and temperature, the temperature affects the growth rate significantly stronger. The growth of the inter-metallic phase can be approximately calculated with the following formula[3]:

$$\text{Growth of the inter-metallic phase [µm/h]} = 0.125e^{-(155-T)/17}$$

Example:

When pcbs with immersion tin surface are transported by sea for four weeks in a container (internal temperature approximately >65 °C), the inter-metallic phase can grow up to 0.42 microns. This value corresponds to a storage period of **12 months at 22 °C**.

[1] JKrieger 27.04.2010 - de.wikipedia

[2] Hot Air Leveling

[3] IPC - 4554/2007

The use of the formula to calculate the growth of the inter-metallic phases gives straight forward the growth curves in relation to time and temperature. However, because the starting metals are not present in the native form, they are exclusively intended to electrodeposited or chemically deposited metal, the real growth during the inter-metallic phase is not straight forward. The growth of inter-metallic copper/ tin phase means the decrease of pure-tin on top. (pure tin is necessary for good soldering)

3 Diffusion system copper/ tin[4]

In the system copper/ tin the copper diffuses into the tin layer. There are formed two primary phases with different compositions and properties.

The 1st phase (less tin) is located at the interface with the copper and contains about 38% Sn. The chemical formulation is Cu_3Sn.

The 2nd phase (more tin) at the interface with the tin and contains about 61% Sn. It has chemical formulation as Cu_6Sn_5.

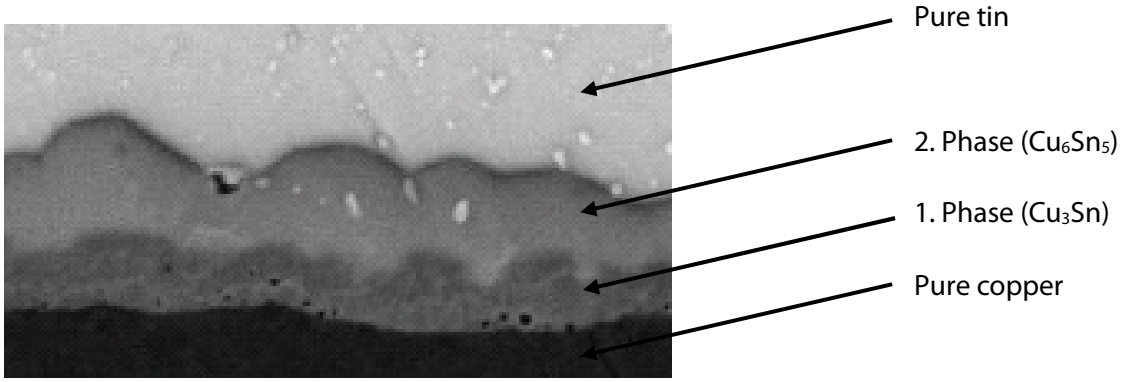

Fig. 2: Layer structure Cu/ immersion tin[5]

The forming of inter-metallic phase interfere each other with the increasing layer thickness in their growth. They act very similar as diffusion barriers, which counter-acts a further growth of the inter-metallic phases.

4 smarttin® coating

Are printed circuit boards coated with immersion tin, the inter-metallic phases are formed directly during the coating process. Their initial thickness depends on:

- the nature of the copper substrate
- the purity of the deposited tins

In order to keep the thickness of the inter-metallic phases initially formed as low as possible, APL uses a copper pretreatment specially adapted to smarttin®. In addition, the chemical-tin electrolyte all inter-fering substances will be kept at very low concentrations (below the specification limits). Therefore, the occurrence of defects is minimized in the metal lattice, as well as the formation of the diffusion layer. The

[4] Copper electrodeposited, tin deposited on charge exchange

[5] Dr. Hans Bell, Rehm Thermal Systems, 01.10.2009 - Hamburger Lötzirkel (influence of the temperature profile of the reflow quality)

initial thickness of the inter-metallic phase at smarttin® process is approximately from 0.2 to 0.25 microns[6].

5 Real growth of inter-metallic copper/ tin phase

The inter-metallic copper/ tin phases grow as a function of time and temperature, not straight forward. Immediately after the depositing it can be 0.2 to 0.25 microns. During a 1/2-year storage (standard ambient conditions[7]) an increase of inter-metallic phases of 0.18 microns can be determined (computationally it would be 0.195 - be 0.261 microns depending on the temperature), so there would be also only ca . 0.02 .µm after 6 month additional storage.

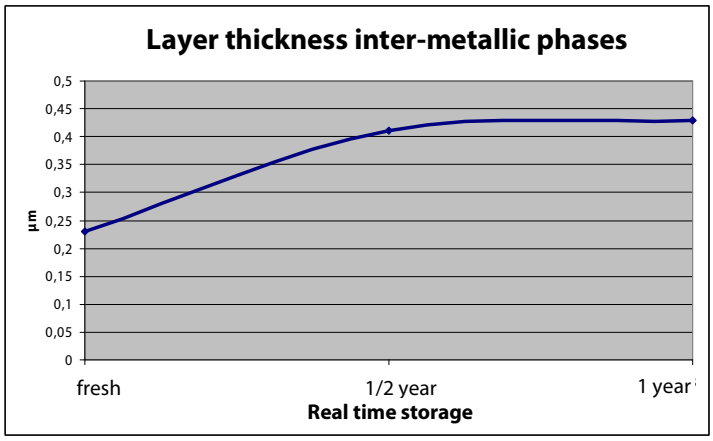

Fig. 3: Growth of inter-metallic phase/ real time storage[8]

A significantly higher growth of the inter-metallic phases is observed by the thermal processes. In a reflow process (default values for lead-free soldering with 245 °C peak and 480 s profile length), depending on the initial thickness of the inter-metallic phases, which may mean an increase from 0.37 to 0.5 microns. In a second reflow process, however, the increase amounts to only 0.04 to 0.07 microns. Extremely clear these values show, if real-time overlays with thermal loads considered combined.

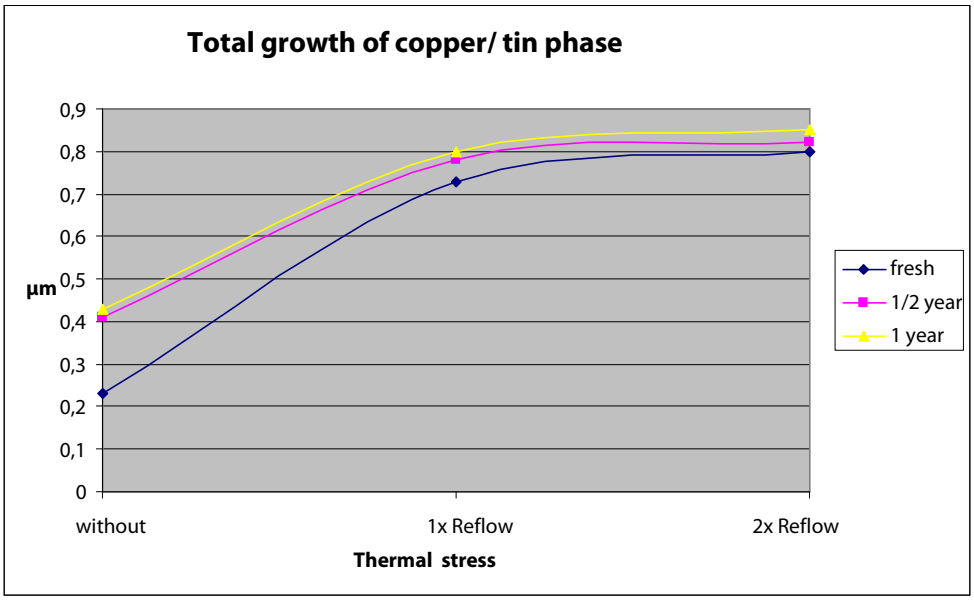

Fig. 4: Growth of diffusion layer / real time storage / thermal stress[8]

[6] Mario Reiter, Fraunhofer ISIT Itzehoe, 02.11.2009 - project 294956

[7] ZVEI storage recommendation - 28.02.2008

[8] A. Krieger, FEM Schwäbisch Gmünd 11.12.2014 - project 3E14336

Notes:
All Values were measured with middle X-Ray/ COULOSCOPE according to IPC-4554/ DIN EN ISO 2177.

6 Problems that the inter-metallic phase may cause

Because of its the behavior, the inter-metallic phases a grow through of the pure tin layer can happen. The atmospheric oxygen then to oxidizes the located copper value on the surface. "Through growing" and oxidized inter-metallic phases can not, or can only made solderable again with very strongly activated Fluxers . No Clean Fluxer can perform with such situations.

Main causes for poor solderability:

- Insufficient tin layer (layer thickness not matching to/ the soldering process)
- Pcb's were too long and/ or not stored according to the recommendations from the ZVEI.
- Improper handling before placement e.g. to temper for too long at too high temperature
- Inadequate purity of the chemical tin layer or poorly rinsing the chemical tin surface

Corrective action:

If it comes to solder problems caused by inter-metallic phases due to long storage times etc., **the affected circuit boards can be refreshed very effectively by smarttin® refresh process again.** The copper contents are removed at the surface and replaced by pure tin. Further processing should then be carried out promptly.