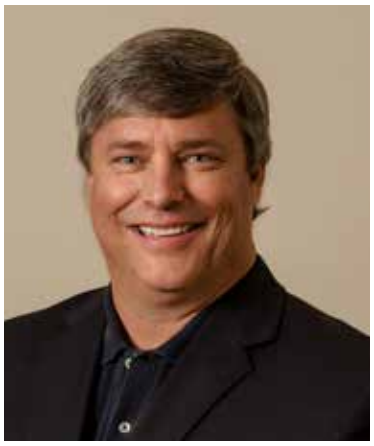
What is a Tin Copper Intermetallic Compound and when is it a problem?



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What is a Tin Copper Intermetallic Compound (IMC) and when is it a problem?

I have been asked this question over the last two months by two different clients. What is IMC (Intermetallic Compound)? And when does brittleness occur? IMC Intermetallic Compound is an interesting topic and is required to form a good solder joint. IMC is formed between the solder alloy (63/37 tin lead eutectic solder) and the pcb copper pad. Depending on its solder surface or pad surface finish will dictate which chemical formation occurs. If the solder pad is copper with an organic surface protectant such as OSP+ then the resultant IMC layer is cu6sn5 and cu3sn. The cu3sn will be near the copper source itself and then the cu6sn5 forms on top of it. The cu3sn is usually very thin and difficult to see initially because the cu6sn5 is the prominent intermetallic formation. As the solder joint ages (Time and Temperature) and thickens over time then the cu3sn will grow and become visible and the cu6sn5 becomes consumed into the cu3sn. The visible intermetallic formation is usually called the IMC formation or intermetallic compound. Initially the IMC formation for tin copper intermetallic formations are 1 to 2.5 microns or 39 to 97 microinches thick and is made up of both cu6sn5 and cu3sn. As the solder joint ages or has multiple thermal cycle excursions then the IMC can grow to 2 to 4 microns or 78 to 156 microinches in thickness. When IMC grows to 5 to 7 microns or 195 to 273 microinches then the potential for excessive brittleness can occur and this thickness is vulnerable to fractures or microfractures inside the IMC structure itself. One needs some level and thickness of IMC (1 to 2.5 microns) for there to be a good solder joint but once one crosses the 4 micron / 156 microinches threshold then one is becoming susceptible to IMC brittleness issues. The forces which propagate intermetallic formation fractures are constant strain forces in excess of 500 – 600 microstrains and or sudden mechanical forces of 1000 to 1500 microstrains. One can also see intermetallic formation fractures when thermal cycling or thermal shock cycles are applied to thicker than normal IMC thicknesses; which indicates that temperature changes from hot to cold can induce coefficient of thermal expansion (CTE) movement on this region of the solder joint and cause fracturing within that IMC region. The last known obvious variable influence is vibrational forces whereby the energy is applied into this region of the solder joint and it propagates a micro fracture first followed by a standard fracture throughout the solder joint IMC region. These different force variables all weaken or manifest itself on thicker than normal IMC structures. Thus we now know IMC is a needed component of a good solder joint but when it grows excessively then it becomes a liability to the solder joint. IMC brittleness is a direct function of the z axis thickness of the IMC structure and one becomes concerned when it approaches or exceeds 5 microns or 195 microinches. This is for reference only because every situation is different due to its environmental operating environment and thus if one has a harsh operating environment then having a thinner IMC layer is desired to prevent fracturing thru the IMC region which is brittle in nature but becomes really vulnerable as it approaches 5 microns or 195 microinches.

DIFFERENT SOLDER PAD PLATING FINISH

If the underlying solder joint pad solder surface is nickel such as with Electroless Nickel Immersion Gold (ENIG) then the corresponding initial IMC thickness will be .4 to .8 microns or 15 microinches to 31 microinches thick. This drop in thickness is because the nickel barrier is slower to dissolve into the IMC itself and thus it forms a thinner IMC zone initially but it will continue to grow overtime. ENIG

is preferred by some customers for lead free soldering because the reflow temperature for Lead free solder alloys is higher than the 63/37 eutectic leaded solder alloys which promotes more copper dissolution into the IMC layer when soldering to copper pads. This is why we are starting to see alternate plating finish materials being tested and used for lead free solder applications. Note copper pad dissolution is another topic and it is an issue when wave soldering / selective soldering is performed and the copper pad dissolves into the solder pot itself, this is a different topic all together than the dissolution of copper into the tin copper IMC region. It is sometimes confused as a the same topic but it is a different topic for a different day.

LEAD FREE SOLDER ARE MORE PRONE TO BRITTLE FRACTURES?

Lead free solders such as SAC 305 solders are more prone to brittleness fractures for two reasons over using 63/37 leaded solders. First reason, the higher elastic modulus of lead free solders are less ductile or compliant and are more prone to shear fracturing or putting the strain at the weakest point which is the intermetallic compound zone. Second reason, the IMC layer or zone is thicker because the reflow temperatures are higher with longer dwell times and they are more complex because you now have a more complex solder chemistry. We now get ternary intermetallic phase with lead free solders such as (ni,cu)3sn4 and(cu,ni)6sn5 when soldering a copper containing lead free solder to a nickel plated pad surface. These intermetallic compounds (IMC) are thinner in nature but due to their low ductility or compliant nature they are more prone to brittle fractures. Again it all depends on their operating environment and one should take these thickness recommendations as reference points and make the best decision based on your fielded application. There are a number of studies going on to determine the ideal thickness for range for lead free solders but again thinner is better provided that there is enough present initially to warrant a good solder joint during the initial fabrication and reflow function.

The answer to the questions is quite interesting because most people believe more is better does not apply in this application; we want to see good IMC present but we do not want to see too much which then it becomes a liability.

Please email or call if you have any questions as it relates to IMC and when does it become brittle. Remember IMC is always brittle as it relates to the adjoining bulk solder alloy region but it becomes to brittle when it crosses the 4 microns thickness for tin copper intermetallic compounds. As always thanks for your questions and feedback and hopefully these short articles are beneficial to our followers.

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for any comments or questions.

Reference photos of different intermetallic compounds - notice the different grain structures and sizes – this is what is inside the solder joint you cannot see from the outside. This is the weakest non compliant region of a solder joint – the IMC (Intermetallic Compound zone)