

Statement der Firma Philipps (Erik E. de Kluizenaar)

Dear all,

Introduction:

Lead-free solder alloys and soldering processes are becoming known and understood better and better. Lead-free component finishes have not by far been given the attention they require. When WEEE comes into place, lead-free (and preferably also environmentally friendly) solderable component and board finishes have to be available. With nickel and noble metals being extremely environmentally hostile, the obvious direction is tin-based platings, particularly for components. However, there is a long way ahead of us and a lot to be developed/solved before that is mature for the wide range of components applied in electronics.

Together with some colleagues, we at PHILIPS CFT are considering the mysterious phenomenon of whiskering sensitivity of tin-based solderable finishes on components. Lead-free, tin-based solderable component finishes are seen as the environmentally friendly alternative for tin-lead.

Nickel/noble metal finishes are extremely environmentally hostile so, in the framework of lead-free soldering, primarily intended to lower the environmental impact, tin-based finishes should have a strong preference. However, the unexplained phenomenon of tin whisker growth makes many people nervous with respect to reliability of electronic products in particular as applied in satellites, planes, missiles, pacemakers, etceteras. Although we recently have involved some experts already, we would like to involve more people in clarifying possibilities and limitations of tin-based solderable finishes on components by this contribution to the forum. I am sure that there is a lot of experience among the prescribers and I hope that they are willing to share that for the benefit of the environment and the electronic community.

History:

Two decades and longer ago, there were processes (like bright tin plating producing platings with a lot of built-in water, hydrogen and organic brightening agents) that produced platings, which gave tin whiskers, hair-like single crystalline tin crystallites, tens of microns thick and millimeters long. Improved processes do not give this any longer, i.e. Philips Semiconductors' DIL and DIP ICs are Sn100 plated during more than 20 years. Billions of products have been applied and no single whisker has been reported during that period. The stresses produced by bending of the leads and scratches of the test jigs do not produce whiskers either. Further, most leadless ceramic multilayer capacitors are plated with Sn100 on a nickel barrier.

These also are produced by the billions by several suppliers around the world. Again, no whisker problem at all has been reported!

At the time, say 20 years ago, it was reported that small additions of any other metal would largely reduce the whiskering sensitivity. Examples were Pb, Cu, Ag, Bi. Therefore, galvanic finishes of SnCu0.7, SnBi3 and SnAg3.5 are considered as the lead-free alternatives today. In Japan a lot of companies have made a preliminary choice for SnBi3, whereas others are exploring SnCu. However, all these processes are inherently difficult, particularly SnAg, still have problems such as deposition of the added metal on the anodes and have lower deposition rates than Sn100 and SnPb. Further development will be needed to arrive at mature processes.

Discussion:

As the root cause of whisker formation I can only imagine mechanical stresses, which squeeze out the relatively ductile tin. Stresses can originate from various sources, residual stress in the base metal and in the finish, the latter by built-in water, hydrogen and organic brightening agents. Further, the microstructure can vary strongly, from super-fine columnar crystallites (old-fashioned bright tin) to large flat crystals (modern matt tin). Various processes and suppliers produce strongly different finishes, regarding these aspects. Just give it a try by heating tin-plated samples with some solder flux applied and observing these under a

microscope. Some will simply melt showing little to no gas escaping, whereas others will foam like a Dutch glass of beer at the moment of melting. Further, the formation of intermetallic layers between tin and plated metal will change the layer and may induce stresses too after some time. When additional metals are co-deposited with tin, they will be present in different ways:

Ø Copper and silver will be transformed quickly into small, hard intermetallic particles, chemical formulas Cu_6Sn_5 and Ag_3Sn respectively.

Ø Bismuth will be deposited as small, hard polygonal crystallites, mainly present at the grain boundaries of the tin crystallites.

Ø Lead will be present as a reasonably finely dispersed, very soft second phase, particle size comparable to a solidification structure of a soldered joint. At low concentrations it will probably be in solid solution in the tin.

Pb is extremely mobile in tin, and should in principle be able to decrease residual stresses by diffusion to or away from stress points.

Bi, Ag and Cu are not, and these hard particles will block motion of imperfections such as dislocations and vacancies. They will add to the stresses rather than lowering these.

Therefore, I personally have the feeling that Pb is the only addition to tin-platings that may reduce the whiskering sensitivity because, as far as I can see, it is the only metal that is capable to reduce residual stresses simply by diffusion at room temperature. All other contemplated additives (Cu, Ag, Bi) probably will cause higher stresses instead. By the way, also SnPb10 has been reported to produce whiskers if tortured strong enough and, some 20 years ago, I found myself even dense beards of Pb extrusions on SnPb40 finishes on a pre-plated steel plate after deep drawing. Looking into literature, many aspects have been suggested as possible causes for whisker growth. Some even contradicting, such as platings on brass. Some authors state that that is the worst case for whiskering, whereas others declare brass as the obvious cure against whiskers. I think that the situation is as follows. All tin-based finishes are intrinsically prone to whiskering. At the time, the sensitive platings were almost producing whiskers spontaneously. In that case, any effect was able to disrupt this unstable situation and to excite to whiskering mechanism. That is why so many possible causes were reported. It is like a coin standing on its side. Any vibration, air movement etc. can cause it to fall. The fact that it falls, however, lies in the fact that it was standing on its side in an unstable balance. I think of a similar situation for the reported whiskers, where the finishes are in an unstable balance and any influence factor will disrupt that balance.

However, with state of the art processes the situation is different. The finishes apparently are much more stable and the risks are very small. I am afraid that the finishes with Cu, Bi and Ag additives, which were thought to cure the whisker problem twenty years ago, were made in such better processes then, and that the causes have been erroneously mixed up.

Conclusion:

If all this is true, it is highly probable that modern Sn100 finish have a lower whiskering risk than SnCu, SnBi and SnAg. Therefore, next to SnCu and SnBi, Sn100 requires a lot of attention in order to assess this, because it is easy and fast to process, relatively cheap and environmentally friendly.

Urgent problem:

Unfortunately, we are still stuck with the problem of a good whisker sensitivity test. If anyone has a good suggestion there, it would be very helpful indeed.

Looking forward for reactions,
With best regards,
Erik