Chemistry and Equipment for Electroplating
111 E. Ames Court, Plainview, NY 11803 USA
Tel: 1-516-349-0700 Fax: 1-516-349-0666
atd@technic.com www.technic.com

Suppression of Tin Whisker Growth through Optimized Tin Plating Chemistry Formulation
Technistan EP

Technistan EP is a patented pure tin plating process that produces pure tin electrodeposits with unique properties. Among them is the ability to resist whisker growth[1-4]. This is achieved through a combination of (i) producing a tin deposit with tensile stress; and (ii) producing a tin deposit with certain preferred crystal orientation effects.

It has been clearly demonstrated that compressive stress is the driving force for tin whisker growth, and that a tin deposit which does not exhibit compressive stress will never form tin whiskers. Several factors contribute to compressive stress build-up in the tin deposit, primarily, (i) the internal stress of the deposit itself which is a function of the electrolyte/additives used to electrodeposit the tin; (ii) in the case of tin deposited over copper/copper alloy substrates, grain boundary diffusion of copper into the tin deposit during storage and/or accelerated aging resulting in tin-copper intermetallic compound formation and resultant compressive stress generated on the tin grains during volume transformation from same; and (iii) in the case of tin deposited over Alloy 42, a mismatch of the CTE (coefficient of thermal expansion) between the tin and the substrate which generates compressive stress in the tin deposit during thermal cycling. With the Technistan EP process, the chemistry has been formulated to consistently produce a tensile stress in the tin deposit [1-4]. This tensile stress counter-acts the compressive stress effects mentioned previously and produces a whisker-resistant tin coating.

In terms of crystal orientation, it is well known that electroplated tin deposits are poly-crystals. From the crystal growth perspective, internal stress can be generated if the crystal lattice of the deposited metal as well as its growth direction do not follow certain preferred orientations. During the deposition process, the first few atomic layers are characterized as epitaxial; the crystal lattice of the coating tends to match that of the substrate. However, as layers build, the epitaxial behavior may change to a structure dictated by the electrolyte and additive composition.

In addition, during the deposition process, if the growth direction of the tin coating is completely random, the growth rate would be the same in all the crystallographic facets. However, in practice, the growth directions of the tin crystals are not completely random, they usually exhibit one or more preferred orientations. This means that the growth of the tin grains with the preferred orientation is kinetically more favored (i.e., more stable) compared with other directions. In other words, other orientations eventually are replaced by this preferred orientation during the nucleation and crystal growth process. In general Technistan EP process produces tin coatings with strong preferred orientation(s). Other orientations are relatively weak.

As we know, whisker growth is a phenomenon which is driven by compressive stress in the tin coating. However, if the deposit crystal lattice is orderly and desirable, there will be less stress to initiate whisker growth. Therefore, the growth of whiskers requires the existence of imperfect grains and lattice defects that result in dislocations of the grains. In practice, there are always some crystal defects generated during deposition; however these defects do not necessarily have the crystallographic orientation to influence deposit growth. In the Technistan EP mixed acid technology system, the organic additives preferably suppress certain crystal growth directions, and concurrently, facilitate the crystal growth in other directions.

Experimentally we have found and likewise it has since been reported [1-6] that when tin coatings possess certain strong preferred crystal orientations, the whisker growth propensity is greatly reduced even under the most rigorous accelerated whisker test conditions when compared with tin deposits that do not contain these preferred orientations. Examples of such "beneficial" preferred crystal orientations include <220>, <200>, <420> and others. Similarly, it has been identified that when tin deposits possess certain other types of "detrimental" preferred crystal orientations the whisker growth propensity is increased. Examples of such "detrimental" preferred crystal orientations include <321> and <211>, and others.

We theorize that a tin deposit which contains the "beneficial" preferred crystal orientations, or alternately a tin deposit which lacks the "detrimental" preferred crystal orientations, will have a lower propensity toward tin whisker growth. Conversely, a tin deposit which lacks the "beneficial" preferred crystal orientations that we have identified, or alternately a tin deposit which contains the "detrimental" preferred crystal orientations, will have a higher propensity toward tin whisker growth. Several independent studies have recently confirmed these findings, including a recent synchrotron radiation micro-diffraction study of tin whiskers in which researchers found that the tin whisker growth direction is <100> and the tin deposit which produced the whiskers had a preferred orientation of <321 > [7].

In the Technistan EP mixed acid technology system, the Technistan EP organic additives preferably suppress certain crystal growth directions, and conversely, the Technistan EP plating process facilitates the crystal growth in other crystal growth directions. Please bear in mind that it is the synergetic effect of the mixed acid and the EP additives that results in the desirable whisker resistant behavior. One without the other has shown to not be as nearly as effective. The Technistan EP process has been shown experimentally, both in the laboratory and in production environments, to produce tin deposits which consistently contain the "beneficial" preferred crystal orientations we have identified, and likewise produces tin deposits in which the "detrimental" preferred crystal orientations are absent. This helps to explain the superior whisker resistance of the Technistan EP tin deposits.

It is important to point out at this juncture that although preferred crystal orientation may be a significant secondary factor for explaining the tin whisker growth phenomenon, deposit stress is still the primary factor and more specifically,

compressive stress in the deposit remains the primary driving force for tin whisker growth and Technistan EP tin deposits are proven to consistently possess a tensile-stress.

References

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