

100% Pure Tin Plating Process

Need for the process :

The demand from the semiconductor industry for Green-IC packaging is gaining momentum. In Japan the Japanese Electronic Industry Association (JEIDA), has been formed to monitor its Green progress, and in Europe the European Waste in Electrical and Electronic Equipment (WEEE) taskforce is directed to minimize the environmental impact of electronic waste. Although the US has no pending legislation to ban lead, there has been legislation introduced to encourage recycling of electronic products. As the world turns to Green manufacturing, the next generation of IC assembly service providers must have this option in their portfolio in order to comply with industry legislation and demand. A product is lead-free if it has less than 0.1% lead by weight, and where none has been intentionally added as part of the manufacturing process.

SPEL in order to nurture the nature and to meet the European Commission directives that will be in force by July 1st 2006 has qualified the 100% Tin plating process in a dedicated plating line which will replace lead from all its products.

Why did SPEL choose 100% Pure Tin:

Since the 100% pure tin process is increasingly becoming the most popular and cost effective viable lead-free alternate and is most demanded by Customers, SPEL preferred to choose 100% matte tin process. Also the process was relatively simpler to switch over without any major capital investment (other than a brand new automatic plating line) and technical concerns. There is plenty of plating chemical suppliers for this process worldwide and this is almost the final choice of lead-free plating finish in the semiconductor industry.

The evaluation results are very promising and the other alloy combinations are not fully understood / developed in the industry. SPEL has done extensive testing on a variety of package types, under a variety of stress conditions and there is no abnormal case reported with whisker growth. SPEL adopts the post plate annealing technique (150°C, 1 hour duration bake) to mitigate the whisker growth. 100% pure tin chemistry chosen by SPEL has proven to be stable and resistant to whisker growth. Also SPEL has included the whisker growth study in its regular reliability monitoring plan under various conditions of stress for effective monitoring and control.

Pure Tin plating technique is relatively simple process to control for those who are already involved in Tin-Lead plating process. Pure tin has excellent solderability and is compatible with lead-containing solder pastes. The higher melting point of tin (232° C) allows it to be used for high temperature applications. The metal has a relatively lower costs and the availability is not a concern. Tin has got good solderability and wetting properties. Also it is easy to deposit and no issues prevail on the composition.

However this process is not free from risk factors such as whiskers. Whiskers from Tin plated units are highly dependant on the plating chemistry adopted and mitigations strategies recommended by the chemical suppliers to alleviate the concerns related to whiskers making the process to gain worldwide acceptance.

Of the available pure tin process chemistries in the market SPEL preferred the particular chemistry because it provides a uniform grain structure with a grain size of 3 to 8 Microns. Besides this the process is environment friendly, fluoride free and the deposit gives excellent solderability even after heat ageing at 155 °C for 16 hours. Also the supplier's pre-cleaning chemicals are already in use in SPEL and are compatible with the pure tin process.

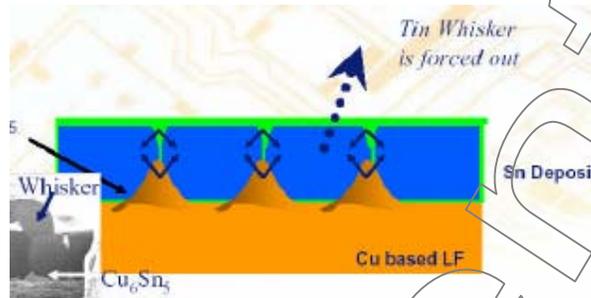
About Whiskers:

The growth mechanism takes by the diffusion of copper from the base material in to the tin deposit over time causing the formation of intermetallics that causes stresses on the remaining pure tin grains. In this process to relieve the internal stresses, whiskers are formed.

Whisker growth mechanism

Mitigation strategies

The driving force for whisker formation is the internal compressive stress, crystal grain structure of the finish, plating chemistry and the plating process parameters. Following are the factors which can induce



compressive stress in the plated deposit.

- Diffusion of Irregular intermetallics
- Surface oxide
- Deposit grain size, shape and orientation
- Substrate
- Plating current density
- Low plating thickness (< than 8 Micron)
- Impurities in the deposits such as carbon and hydrogen
- Excessive mechanical bending and scratches
- Thermal cycling

Following are the universally accepted mitigation strategies which will relieve the compressive stresses in the plated deposit.

- Post plate anneal at 150 °C for 1 hour (within 24hours of plating)
- Nickel under layer plating

Of the above choices SPEL adopts the post plate anneal immediately after plating to relieve the stress.

Also SPEL has done extensive reliability stress test in the pure tin plated products to study the whisker growth. Mild whisker growth to the maximum length of 0.53 mils was observed in the temperature cycled devices alone which is well below the NEMI accepted limit of 3 mils for the particular type of package.

Alternative lead-free lead finish materials

Alternative "lead-free" lead finish materials for use in the solder plating shall have a stringent visual, mechanical, electrical, and chemical requirements similar to that of Tin/Lead. These requirements include acceptable melting point, good wettability / solderability, high adhesion/mechanical strength, excellent conductivity and compatibility with the Lead free and Tin/ Lead solder pastes. The solder must also allow high volume production, inspection, and if necessary, rework, while remaining to be reliable and cheap.

Some possible options and their pros and cons are described below.

Tin – Zinc:

Sn – 9%Zn has a melting temperature of 198°C, making it a close alternative to eutectic Sn-Pb solder. Once solidified, it exhibits large grains with a fine and uniform two-phase eutectic colony. Also it has higher strength and fatigue resistance. However it has got high drossing and corrosion potential. The wetting characteristics are poor on Copper or Nickel substrates.

Tin – Copper:

Sn-0.7%Cu is the eutectic composition of the Sn-Cu binary system. This solder alloy is relatively cheap, has fine grains, and exhibits good solderability. However, due to the high percentage of Sn, it is also prone to tin whiskers and tin pest. It melts at 227°C. Although copper has a higher strength and has sufficient supply all around the world, the metal alloy is brittle and has poor wetting characteristics. Tight alloy control is required during the plating process as slight change in alloy composition results in a great change in eutectic temperature. This process is not compatible for

Alloy 42 leadframes and aggravates whisker growth. The presence of copper alloy on copper substrate makes it difficult for plating thickness and composition measurements in the X-ray fluorescence machine.

Tin – Bismuth :

Sn and Bi form a eutectic alloy at 42%Sn and 58% Bi, which melts at an excessively low temperature of 138°C. However, at 3% Bi the melting temperature is about 215-220°C. Also this alloy composition has gained major acceptance in Japan. The key issues with this chemistry is that Bismuth forms a low melting phase (96°C) with tin-lead pastes and the ternary Sn-Bi-Pb phase formed is very brittle and prone to fracture. Any deviations in the Bismuth composition (in excess of 4-5%) is likely to fracture the plated layer covering the leads exposing the base metal. This alloy composition has a relatively poor wetting characteristics and due to huge difference in the electrode potential between tin and bismuth, bismuth cementation occurs in the anodes. This process requires tighter process control techniques for maintaining the bismuth concentration in the plating bath that could affect the bismuth composition on the plated units. This process has a higher maintenance, material and labor costs and this is again not whisker free.

However due to the demand from the Japanese customers SPEL has developed Tin (97%) – Bismuth (3%) plating also as an lead free alternative. Following counter measures are adopted by SPEL to mitigate the above problems encountered in the Tin-Bismuth process.

- In order to have a tight control over the deposit composition, bismuth composition is controlled by frequent analysis of Bismuth in AAS.
- The general problem of immersion of Bismuth on the plated surface by interruptions of the current is minimized by a special formulation of the additives by the supplier.
- SPEL also adopts a post plate annealing at 150°C for 1 hour immediately after plating to mitigate the whisker growth.

Sn-3.5%Ag exhibits good solderability and mechanical properties and has the longest history of reliable usage as a lead-free solder. However, it is expensive, prone to tin whiskers due to the high Sn content. Increasing Ag% to > 5% will result in drastically higher melting temperatures. Also this alloy composition has acceptable wetting characteristics. However this alloy composition need to be tightly controlled as any slight changes in silver composition could change the eutectic temperature. Use of silver, a precious metal increases the assembly cost and the process complicates waste treatment leading to environmental concerns. The deposition rate of this alloy is also very low. Typical alloy composition is 97% Tin and 3% silver.

Tin – silver – Copper :

Sn-Ag-Cu solder, which is eutectic at 3.9% Ag and 0.6% Cu, exhibits a melting temperature of about 217 deg C. Copper may be difficult to stabilize in this alloy.

Pre-Plated leadframes (Ni/Pd/Au)

The pre-plated lead-finish is also adopted by most of the subcontractors and it simplifies the assembly process as no post-assembly plating process is required leading to shorter assembly cycle time.

The key issues such as solderability, bondability and moldability in this leadframes have been taken care and is gaining acceptance. Spel ensures adequate precautions in forming and singulation process to avoid the cracking of Ni/Pd/Au layer