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Green Product

Leadframe Packages with Matt Pure Tin Electroplated Surface Finish

Technical Note

Revision 2.1

Infineon Technologies

Never stop thinking

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Green Product

Revision History: 2008-10-23, Revision 2.1

Previous Version: December 2007, Revision 2.0	
Page	**Subjects (major changes since last revision)**
	Applied into the latest Infineon Word template.
	Update chapter 4: Solderability
	Update chapter 6: Special Note (whisker formation)

Table of Contents

List of Figures

Preface

Table 1 Technical Note

Creation	Author: Dr. Marc Dittes Approver: Dr. Robert Hagen
Contact	Department: IFAG BC ES Address: MatQ@infineon.com
Summary	Matt pure tin plated components are compatible to both SnPb and lead-free soldering processes.
Key Words	Lead free plating Matt pure tin Solderability Compatibility Whisker

1 Target

The target of this document is to inform our customers on the properties of tin plated leadframe based components and provide guidelines for our customers to successfully introduce Infineon's leadfree packages into production. This includes the differences to SnPb-plated terminations in terms of thermal and mechanical properties and recommendations for the board assembly process.

2 Background

Based on Infineon´s commitment to environmental responsibility, European legislation (Directive on the **R**estriction of the Use **o**f Certain **H**azardous **s**ubstances, RoHS) [1], and customer requests, Infineon replaces widely used SnPb plating with a pure tin finish for leadframe components. Matt pure tin provides, among others, best compatibility to all existing electronic solders, good resistivity against ageing in natural storage conditions and is the easiest substitute for SnPb from processability point of view [2]. Pure tin has been used for both passive and active components and is known as solderable finish in electronic industry for decades.

3 Specification and General Information

The tin finish of choice is a pure, matt tin electroplated layer. The maximum impurity level of lead (Pb) in the deposit is specified as 1000 ppm (0.1 %). Matt pure tin finish is characterised by a dull, semibright or satinbright appearance, which in contrast to bright tin finishes does not provide mirror like reflectivity, even not on large areas due to its disperse reflectivity. In a more technical manner, matt tin finishes exist of grains with an average size in the range of few microns, whereas bright finishes have an average grain size well below one micron.

Generally Infineon´s matt pure tin finish is a direct replacement of SnPb finishes and is typically applied directly to the leadfame base material, unless a so called preplated thick (> 2 µm) underlayer (NiP or Ag) is applied by the leadframe vendor prior to Infineon´s assembly processes. For whisker mitigation a post plate bake process of 1 h at 150 °C is applied to all Cu based leadframe without allover underlayer (see **Chapter 6.2**). The typical thickness of matt tin finish is 7 µm to 15 µm. The thickness information for individual packages is given in the respective PCN (product change notice) documentation. Both hardness and ductility are very close to SnPb finishes. Thus no difference in bending or abrasion behaviour can be observed. Due to a lower tendency of matt pure tin to smearing, the coverage of unintentional tin on trimmed surfaces (e.g. dambar, lead tip) is usually smaller than the coverage by smeared SnPb. This may result in less wetting of non-electroplated surface and may require an adaptation of optical inspection criteria. However, we like to emphasize that these areas are not specified as solderable per international standards, (e.g. IPC 610, JESD22B102, IEC 60068-2-58) and non-wetting of those areas is not a failure.

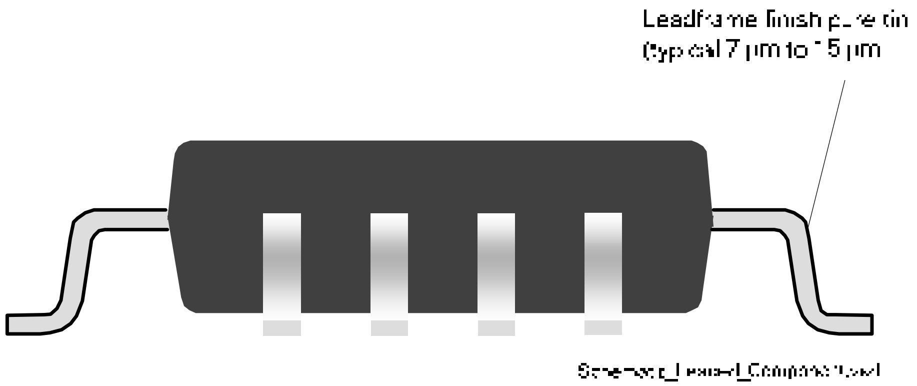

Figure 1 Schematic Drawing of Leaded Component

Table 2 Properties of Tin in Comparison to SnPb

Properties	SnPb	Sn
Composition	SnPb 15	Sn100
Melting range	183 °C – 210 °C	232 °C
Hardness, Ductility	Hardness of matt pure tin is slightly higher than of SnPb15. Ductility of SnPb15 is slightly higher than for matt pure tin, precise values for electroplated layers are not available. The effect on abrasion or cracking behavior is almost negligible.	
Thickness	7 µm - 15 µm (typical)	7 µm - 15 µm (typical)

Another effect known associated with tin is the so called tin pest. This describes the mechanical destruction of bulk tin or tin layers by transformation of β-Sn to α-Sn. The speed of transformation reaches a maximum in the region of -40 °C, but is usually supressed by smallest amounts of contaminations and requires inoculation by either α-Sn or other crystals of diamond type [3]. The appearance of tin pest has never been observed and is regarded as not relevant.

4 Solderability

For better understanding some general statements and information shall be given prior to the results:

In this paper solderability describes the ability of a surface to be wetted by a relevant solder material and to form a reliable solder joint with the base material.

The melting point of pure tin is 232 °C and thus almost 50 °C above the solidus temperature of SnPb finishes. But it must kept in mind that a surface does not have to melt in order to be wetted (e.g. water on glass, NiPd with melting point of palladium T_{sol} = 1552 °C and nickel T_{sol} = 1453 °C). However, for typical SnPb soldering processes the solder mechanism with matt pure tin surface changes compared to that with a SnPb surface. Using SnPb solder the solder and the component finish have the same solidus temperature and the finish starts melting at the same time as the solder (in reflow soldering) or when getting in contact with the molten solder (flow soldering). The solder joint interface is formed between the base metal and the solder. In the case of copper base material this joint formation is associated with the formation of CuSn intermetallic. With FeNi leadframes or Ni plated components NiSn intermetallics are built.

When soldering matt pure tin plated components with SnPb solder in a typical reflow process the solder temperature does not exceed the melting temperature of the tin finish. Thus an initial wetting of the tin surface must take place followed by a rapid dissolution of the few micron thin layer into the molten solder. Finally the solder joint is formed in the same way as with SnPb plated components. This two step process (wetting, dissolution) is very fast and will not be noticed in typical processes, but should be kept in mind when comparing solderability of SnPb plated and tin plated components. When using a lead-free solder (e.g. SnAgCu) usually the soldering temperature is close or above the melting temperature of tin and the soldering process is similar to the one described for the SnPb finish / SnPb solder combination. Based on this general difference tin plated components can never meet the solderability of a component with SnPb finish. However solderability of pure tin plated components is excellent and meets all requirements for electronic soldering.

Typically the dip&look test conditions used for SnPb plated components (in accordance with IEC 60068-2-58 [5]) will also be passed with matt pure tin plated components.

Additionally to the SnPb test solder a lead-free solder (SnAgCu) with a dipping temperature of 245 °C [6] is used for the testing of the solderability of matt pure tin plated components. This test is passed as well.

Wetting balance test reveal the good solderability of tin plated components (Figure 2 and Figure 3), whereas ageing has a somewhat stronger effect on the solderability for tin plated terminations compared to SnPb plated ones.

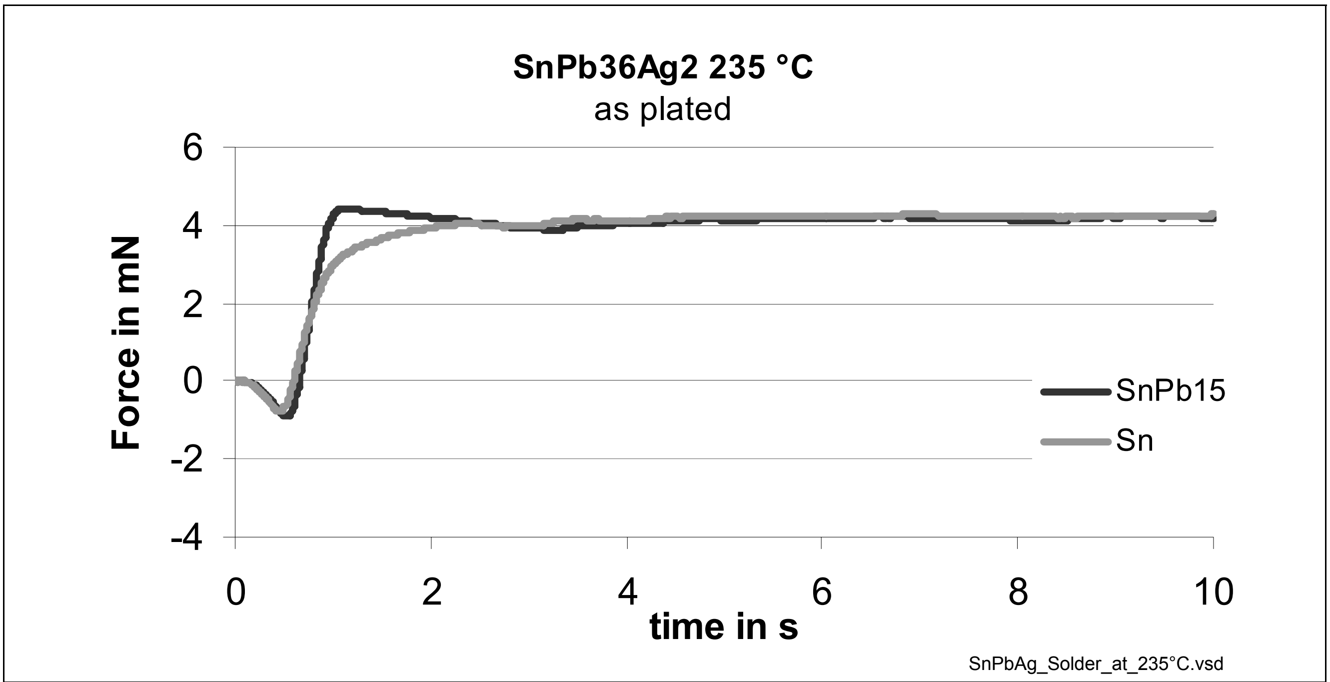

Figure 2 Wetting Balance Result with SnPbAg as Test Solder

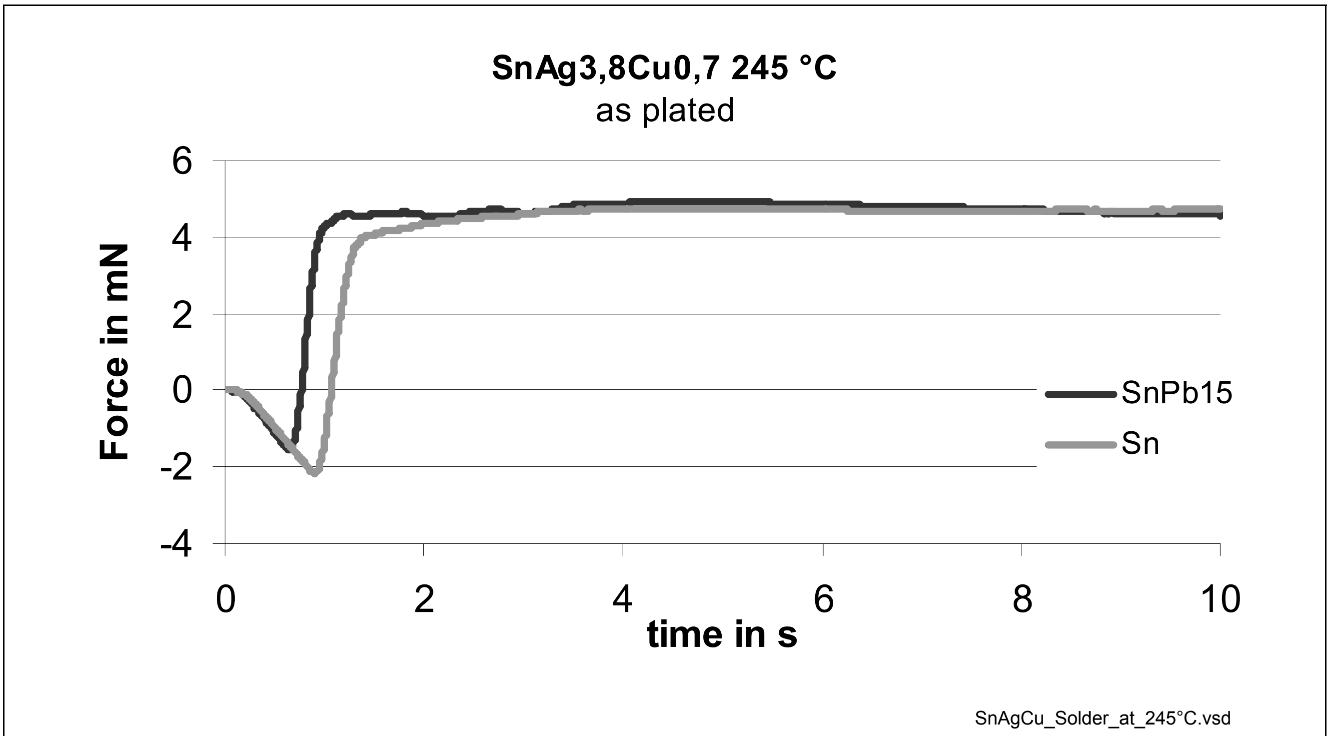

Figure 3 Wetting Balance Result with SnAgCu as Test Solder

However, long time storage tests for more than 3 years in uncontrolled ambient atmosphere have shown that matt pure tin plated components are capable to pass solderability requirements after 2 year storage in non dry packed storage conditions. And a systematic investigation of ageing bahaviour of matt tin plated components shows that tin oxidation related solderability fails will not occur within any relevant storage time [7].

5 Compatibility & Board Level Reliability

Tin is the base metal for typical SnPb and lead-free electronic solders. Thus no additional metal will be introduced in the solder joint. Usually the amount of solder exceeds the amount of plating on a component by far. Hence, the only effect of soldering matt pure tin plated components is a slight variation of the composition in the joint in advantage to tin. A full metallurgical compatibility is given for both tin-lead and lead-free soldering.

Also from processability point of view compatibility is given and usually no adaptation of the soldering process is necessary due to the change of the termination plating from tin-lead to matt pure tin. This becomes obvious with the above results and statements for solderability. An individual verification of processability for each printed circuit board however is recommended as the overall performance is mainly determined by other factors (e.g. the solder paste, the soldering equipment, the thermal mass distribution on the printed circuit board). The choice of solder alloy composition determines the appropriate process conditions, whereas matt pure tin plated components are fully compatible to both SnPb and lead-free solder processes.

Based on above conclusion for the compatibility no adverse effect of matt pure tin plated components on the solder joint reliability is to be expected. No reports on such effects can be found despite tin plated components are used for decades. Furthermore this has been confirmed by own investigation done inhouse and performed by an independent institute. These show not a single failure for leaded components (DSO-12 and TQFP-100) up to 4000 cycles (-40 °C / +125 °C) for both SnPbAg and SnAgCu solder joints and first failures well above 2000 cycles for leadless components (VQFN-48).

6 Special Note (Whisker formation)

6.1 Fundamentals

Whisker formation is a well known phenomenon for electroplated tin layers. Whiskers are spontaneous protrusions of some micron up to several millimetres of length and a few microns in diameter. Whisker growth is a diffusion controlled mechanism and they can grow over years. They develop under the influence of mechanical stress in the layer and are not to be mixed up with dendrites or migration products, which grow in electric fields and / or under the influence of humidity and ionic contaminations. Various shapes of whiskers exist. They can be straight, kinked, bended or of irregular, nodule like shape.

Three major mechanism for whisker growth are identified. Each of them has to be addressed by appropriate countermeasures The growth of whiskers can be understood as follows and based on some proven premises. These are:

- The driving force for whisker formation is a compressive stress in the tin layer
- Matt tin finishes are almost stress free in the state as plated
- Copper based leadframe material: Compressive stress development is related to the irregular growth of intermetallics at the substrate / tin plating interface.
- Relevant irregular growth of intermetallics can be found on copper-based materials only, whereas Cu_6Sn_5 grows preferentially in the tin grain boundaries
- FeNi42 leadframe: Compressive stress is induced by temperature cycling only (due to the mismatch in the coefficient of thermal expansion for tin and FeNi42). The growth is influenced by the rate of temperature change and the temperature limits. These kind of whiskers are state of the art and present on actual SnPb plated components, too. They typically achieve a maximum length in the range of a few ten microns. Thus FeNi42 leadframes plated with matt pure tin are regarded as safe and do not require special treatment. The cte mismatch between copper and tin is minor and does not result in whiskers of concern.
- Another mechanism for stress generation is a corrosion of the tin layer, which is associated with a volume increase due to the formation of oxides / hydroxides throughout the entire thickness of the finish. Corrosion may occur especially under high temperature (e.g. 50 °C and above) and high humidity (e.g. 85 % R.H.) and is not restricted to one of the above base materials [8].

6.2 Countermeasures

Based on this knowledge various countermeasures for copper based leadframe materials can be applied to effectively suppress the intermetallic formation related whisker formation [4]. These are:

- Application of dense underlayer as a diffusion barrier for copper diffusion into tin. Such layers can be
  - Nickel
  - Silver
- Heat treatment (baking) of the electrodeposited matt tin layer (this leads to the formation of a dense and regular intermetallic layer, which acts as a diffusion barrier as well)

The countermeasures selected by Infineon are:

- Baking of 150 °C / 1 h (first choice and applied to the majority of packages)
- Ag-underlayer of > 2 µm (limited to very few package types)

At least one of the above countermeasures will be applied to all of our matt pure tin plated products built on copper based leadframe material. The selection of the appropriate technology is based on the assembly concept and costs and logistic issues, whereas each technology guarantees whisker safety according to below criterion.

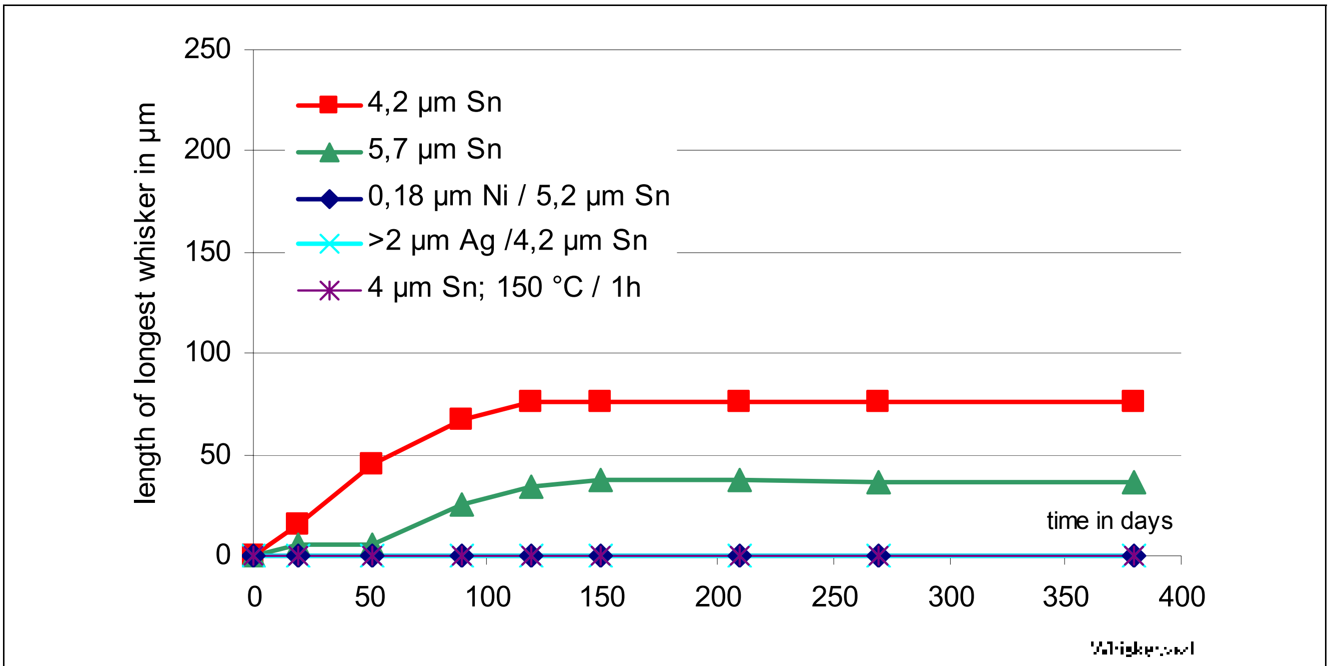

Figure 4 Whisker Growth with and without Countermeasures

To reduce corrosion related whisker growth an important factor appears to be the cleanliness of the finish (absence of mobile ions). This can be achieved by proper cleaning after the plating. However, also any contamination with mobile ions during board assembly or service life may have an adverse effect on the corrosion resistance of tin. Safety critical applications in an environment providing high temperature and humidity may thus require special measures to prevent corrosion.

6.3 Qualification

Infineon Technologies applies the procedures per JESD201 for qualification. For the selection of test parameters, durations and acceptance criteria, class 2 of JESD 201 is applied.

6.4 Disclaimer

Since the correlation of the tests per JESD 201 to field life conditions are not known, Infineon Technologies makes no representation, warranty or guarantee of any kind with respect to the field performance, quality or freedom from whisker-related failures, of any package tested by Infineon using these procedures.

7 References

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