PUBLICLY AVAILABLE SPECIFICATION

IEC PAS 62483

First edition
2006-09

Test method for measuring whisker growth on tin and tin alloy surface finishes

Reference number
IEC/PAS 62483:2006(E)

Publication numbering

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PRICE CODE **U**

For price, see current catalogue

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TEST METHOD FOR MEASURING WHISKER GROWTH ON TIN AND TIN ALLOY SURFACE FINISHES

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IEC-PAS 62483 was submitted by JEDEC and has been processed by IEC technical committee 47: Semiconductor devices.

The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft PAS	**Report on voting**
47/1842/NP	47/1876/RVN

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Test Method for Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes

Introduction

This document contains a suite of recommended tin whisker growth tests. If these common tests are adopted, then the industry can collect common and comparable data that may improve the understanding of the fundamentals of whisker growth and allows comparisons between technologies. Tests in this document may be changed in the future as a better understanding of the mechanisms causing tin whisker growth is developed.

Based on a variety of testing and data review from around the globe, three test conditions have been identified that appear to be suitable for monitoring tin whisker growth. The three test conditions include two isothermal conditions with controlled humidity and a thermal cycling condition. However, these test conditions have not been correlated with longer environmental exposures of components in service. Thus, there is at present no way to quantitatively predict whisker lengths over long time periods based on the lengths measured in the short-term tests described in this document. At the time of writing, the fundamental mechanisms of tin whisker growth are not fully understood and acceleration factors have not been established. Certain applications, e.g., military or aerospace, may require additional and/or different tin whisker tests or evaluations.

The predominant terminal finishes on electronic components have been Sn-Pb alloys. As the industry moves toward Pb-free components and assembly processes, the predominant terminal finish materials will be pure Sn and alloys of Sn, including Sn-Bi and Sn-Ag.

Pure Sn and Sn-based alloy electrodeposits and solder-dipped finishes may grow tin whiskers, which could electrically short across component terminals or break off the component and degrade the performance of electrical or mechanical parts.

Test Method for Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes (TEST METHOD A121)

1 Scope

The methodology presented in this document, see Annex A for process flow, is applicable for studying tin whisker growth from finishes containing a predominance of tin (Sn). This test method may not be sufficient for applications with special requirements, e.g., military or aerospace. Additional requirements may be specified in the appropriate requirements document.

The purpose of this PAS is to:

- Provide an industry-standardized suite of tests for measurement and comparison of whisker propensity for different plating or finish chemistries and processes.
- Provide a consistent inspection protocol for tin whisker examination.
- Provide a standard reporting format.

2 Normative references

JESD22-A104, *Standard for Temperature Cycling*

IPC 7530, *Guidelines for Temperature Profiling for Mass Soldering (Reflow & Wave) Processes*

3 Terms and definitions

3.1 total axial whisker length: The distance between the finish surface and the tip of the whisker that would exist if the whisker were straight and perpendicular to the surface.

NOTE For tin whiskers that bend and change directions, the total axial length can be estimated by adding all of the straight subdivisions of the whisker. (See Figure 5.)

3 Terms and definitions (cont'd)

3.2 whisker: A spontaneous columnar or cylindrical filament, usually of monocrystalline metal, emanating from the surface of a finish. (See Annex C for example pictures of tin whiskers.)

NOTE 1 For the purpose of this document, whiskers have the following characteristics:

- An aspect ratio (length/width) greater than 2
- Can be kinked, bent, or twisted
- Usually have a uniform cross-sectional shape
- Typically consist of a single columnar filament that rarely branches
- May have striations along the length of the column and/or rings around the circumference of the column
- Length of 10 microns or more. Features less than 10 microns may be deemed important for research but are not considered significant for this test method.

NOTE 2 Whiskers are not to be confused with dendrites: fern-like growths on the surface of a material which can be formed as a result of electromigration of an ionic species or produced during solidification. (See Annex D for a picture of a typical solidification dendrite.)

3.3 whisker density: The number of whiskers per unit area on a single lead or coupon area.

3.4 whisker growth: Measurable changes in whisker length and/or whisker density after exposure to a whisker test condition for a certain duration or number of cycles.

3.5 whisker test coupon: A piece of metal of specified size and shape that is plated or dipped with a tin finish for the purpose of measuring the propensity for whisker formation and growth.

4 Apparatus

4.1 Temperature cycling chambers

Air to air temperature cycling chamber(s), capable of cycling from -55 (+0/-10) °C to +85(+10/-0) °C or from -40(+0/-10) °C to +85(+10/-0) °C. The temperature cycling chamber(s) must be able to satisfy the cycle conditions defined in Table 4.

4 Apparatus (cont'd)

4.2 Temperature humidity chambers

Temperature–humidity (T&H) chambers capable of non-condensing 60 ±5 °C, 87 +3/-2% RH and 30 ±2 °C, 60 ±3% RH environment.

NOTE 1 The elevated temperature–humidity condition of 60 ±5 °C, 87 +3/-2% RH is close to the condensation point. If water condenses on the tin finish during environmental exposure, the condensed moisture and resulting corrosion may affect the final test results. To prevent condensation in the T & H chamber, the chamber dry-bulb temperature must exceed the wet-bulb temperature at all times by not less than 2.4 °C (or equivalent for electronic sensors). Before opening of the chamber door for loading and unloading, the chamber temperature and humidity should be ramped down sufficiently close to room ambient (recommended within 10 °C and 10% RH) to prevent condensation on the test samples and chamber walls.

NOTE 2 During operation, condensation is most likely to occur on the T & H test chamber walls and ceiling; therefore, it is recommended that the test samples be sufficiently shielded from any condensed water that may drip from the chamber ceiling and/or walls onto the samples.

NOTE 3 When loading the test samples into the T & H test chamber, the sample temperature must be sufficiently higher than the chamber ambient temperature to avoid condensation on the test samples. It is recommended that the test samples and all sample trays or holders be preheated (to a temperature equal to the test temperature of the T & H test chamber) in a dry-bake oven prior to loading them into the T & H test chamber.

NOTE 4 Frequent wet-bulb maintenance is required for proper control of this test condition.

4.3 Optical stereomicroscope (Optional)

Optical stereomicroscope with adequate lighting capable of 50X to 150X magnification and capable of detecting whiskers with a minimum axial length of 10 microns, per Annex B. If tin whiskers are measured with an optical system, then the system must have a stage that is able to move in three dimensions and rotate, such that whiskers can be positioned perpendicular to the viewing direction for measurement.

4.4 Optical microscope (Optional)

Optical microscope with adequate lighting capable of 100X to 300X magnification and capable of measuring whiskers with a minimum axial length of 10 microns, per Annex B. For tin whisker measurements, the optical system must have a stage that is able to move in three dimensions and rotate, such that whiskers can be positioned perpendicular to the viewing direction for measurement.

4.5 Scanning electron microscope

Scanning electron microscope (SEM) capable of at least 250X magnification. An SEM fitted with an X-ray detector is recommended for elemental identification.

4 Apparatus (cont'd)

4.6 Convection reflow oven (Optional)

A convection reflow system capable of achieving the reflow profiles of Table 3.

5 Sample requirements and optional preconditioning

For specific requirements of tin finishes, the relevant test conditions, read points, and durations shall be described in a test plan agreed upon by the supplier and user. For comparing various finishes for whisker propensity, it is recommended that all three conditions defined in Table 4 be used and that sufficient test time be allocated to allow for the tin whisker incubation period to expire (typically up to 3000 hours). In addition, each test condition is to be performed independently on separate samples.

5.1 Test samples

Any test samples with tin-based finishes may be studied, including Sn-Pb finishes. Sample types may include experimentally plated or tin-finished coupons or components, or production-plated/finished electronic components. However, coupons may not be representative of final product because of processes, such as lead trim and form.

5.1.1 Sample size

The measurement of maximum whisker length may be significantly influenced by the amount of surface examined because whisker appearance and length are distributed over a range. Examination of large areas may result in a larger maximum whisker length than would be detected by examining a small area. In fact, whiskers may not occur on a particular sample or termination even though other samples and terminations from the same plating or finish lot exhibit significant whisker growth. Therefore, if the total area inspected is not held constant, data will not be directly comparable among different experiments.

5.1.1.1 Electronic components with leads

For research and comparison of finished components, plating baths, processes, etc, regarding propensity for whisker growth, a minimum of 96 terminations/leads on at least six samples, for each test condition at each inspection read out, are required to attain a meaningful detection level. The number of samples may need to be adjusted in order to obtain a total of 96 terminations/leads. Components should have completed all manufacturing operations. For consistency and traceability, if applicable to package type, choosing corner leads is recommended. For finished components with large terminations, Table 1 may be used to reduce the number of terminations that are recommended for inspection.

5.1.1 Sample size (cont'd)

5.1.1.2 Test coupons

For comparison purposes, if using coupons, a total inspection area of at least 75 mm^2 on at least 3 coupons is required for each test condition. For small coupons, it is recommended that there be sufficient coupons so that the total area inspected adds up to a minimum of 75 mm^2, as described in Table 1.

Table 1 — Details on the number of test samples and terminations required for comparison of screening inspection data. The number of terminations required for inspection depends on the tin-finished area of each termination.

Sample Type	Tin Finished Area [1]	Minimum Number of Samples	Minimum Total Inspection Area for Screening Inspection	Minimum Inspection Surface Area per Sample for Screening Inspection	Minimum Total Number of Inspection Areas for Screening Inspection [2]
Coupons	< 25 mm^2	3	75 mm^2	Top and two sides of coupon	75 mm^2 $\div$ (Plated area on top and 2 sides of coupon)
Coupons	$\geq$ 25 mm^2	3	75 mm^2	Top and two sides up to a total of 25 mm^2	3
Components	< 0.85 mm^2	6	75 mm^2	Top and 2-3 sides of termination	96
Components	$\geq$ 0.85 mm^2	6	75 mm^2	Top and 2-3 sides of termination	75 mm^2 $\div$ (Plated area on top and 2-3 sides of termination)

NOTE 1 See Figures 2, 3, and 4 for detailed definition of the plated/finished area for inspection.

NOTE 2 For large terminations, more than one inspection area may exist on the same termination.

The same 6 components or 3 coupons for each test condition may be evaluated at all sequential read outs, including the final readout. Hence, to study a single finish, 18 component or 9 coupon samples are required to complete the three test conditions. Alternatively, the test may be started with sufficient test samples to inspect 6 different component or 3 coupon samples at each read out. In this case, the number of test samples required will be a minimum of 18 component or 9 coupon samples times the number of read out points during the test. (For example, if a finish is studied in temperature cycling for 2000 cycles with read outs performed at 500, 1000, 1500, and 2000 cycles, then 24 component samples are required just for this test condition.) If a more accurate determination of growth kinetics is needed, it is recommended that the same test samples be used for each sequential read out instead of using re-populated samples.

5.1 Test samples (cont'd)

5.1.2 Optional test sample preconditioning

Table 2 lists optional test sample preconditioning treatments that are recommended prior to all subsequent Sn whisker growth tests. If the test method described in this standard is used as part of a tin finish qualification, then the user and supplier must agree on the precondition requirements before commencement of testing.

Table 2 — Optional Preconditioning Treatments for Tin Whisker Test Samples

Condition	Preconditioning Temperature Exposure	Thermal Profile Exposure	Use Guidelines
A	None	Normal ambient exposure	Intended to test for whisker growth under ambient temperature/humidity storage.
B	Room temperature storage for a minimum of 4 weeks after the finish is applied	15 -30 °C 30 – 80% RH	Intended for samples without under-plating or post bake mitigation before exposure to high temperature/humidity storage, temperature cycling or preconditioning per conditions C or D.
C	Sn-Pb Temperature Preconditioning	Sn-Pb profile per clause 5.1.2.1	Intended to test for whisker growth after thermal exposure to Sn-Pb SMT assembly temperatures (backward compatibility).
D	Pb-free Temperature Preconditioning	Pb-free profile per clause 5.1.2.1	Intended to test for whisker growth after thermal exposure to Pb-free SMT assembly temperatures (Pb-free compatibility).

5.1.2.1 Optional test sample preconditioning profiles

Test sample preconditioning profile information is shown in Table 3 and Figure 1. All profile criteria reference either the lead or solder joint temperature for components or the surface temperature for coupons. For the profile and the preconditioning process itself, it is recommended that non-metallized carriers or printed circuit boards are used to hold the samples during the reflow process. For components with leads, the orientation of the component shall be in the "live bug" configuration (i.e., leads down touching the carrier or board).