Document No. Q2-GE-02007
Date of Issue : March 13, 2003

View on Countermeasures to Sn Whiskers for Lead-free Soldering

Seiichi Okada
Manager of Quality Engineering Section,
Quality Control Department, Murata Mfg., Co., Ltd.

Our view on Sn whiskers is explained as follows :

It is discussed that there are three types of Sn whisker generation mechanisms and their evaluation methods as shown in the table below:

Type	Generation Mechanism	Evaluation Method Example
$\boxed{1}$ Constant Temperature Whisker	Internal stress generated by the diffusion of base metal material into Sn plate film.	50°C, 1000hrs
$\boxed{2}$ Humidity Whisker	Internal stress generated by the oxidization of Sn plate film.	85°C 85%RH, 1000hrs
$\boxed{3}$ Thermal Shock Whisker	Internal stress generated by the difference of thermal expansion coefficient between base metal / under-plating material and Sn plate film.	– 40°C↔85°C, 500cycles

* Terms addressing whisker type in the above table are given according to stress type charged on Sn plate film.

Our general view, countermeasure and evaluation method for each type of the above thermal whiskers are explained as follows :

< Countermeasure to Constant Temperature Whisker >

Sn whiskers of which growth in the market made problems some 20 yeas ago were $\boxed{1}$ Constant Temperature Whisker type. There were cases in which these needle crystal whiskers grew into a size of 1 – 2um diameter with several millimeter length. It has been discussed that the constant temperature whiskers most rapidly grow in 50°C temperature environment. As a countermeasure to this type whiskers, we are giving Ni under-plating between base metal (mainly Cu) and Sn plate in order to prevent the base metal material diffusion into Sn plate film. We have confirmed by our internal evaluations (50°C, 1000 hours) that this design measure prevents the generation of constant temperature whiskers.

< Countermeasure to Humidity Whisker >

In our internal evaluations (85°C 85%RH, 1000 hours), no whiskers have been detected that are generated by the electrode oxidization caused by moisture stress. Therefore, we consider that the humidity whiskers can not be generated on our current design Sn plate film.

< Countermeasure to Thermal Shock Whisker >

We have confirmed that, when a thermal shock stress is charged on an electrode with Ni under-plate + Sn surface plate structure, lint-like Sn whiskers grow crawling on the electrode surface. However, we have been confirming, by performing stress analyses of our key electrode designs, that these thermal shock whiskers make no problem in usual using environments.

Also, we have confirmed that the thermal shock whiskers most rapidly grow in the temperature shift condition of [– 40°C↔85°C]. As for our internal acceptance criteria, we consider that there is no problem in the market if the whisker growth is 50um or less in the test condition of [– 40°C ↔85°C, 500cycles]. Please see “View on Criteria for Sn Whisker Thermal Shock Test” on the next page for our concept of these test criteria.

There are several types of electrode plating structures in our company depending on products applied. We have performed the above countermeasures and evaluations for all of these electrode types and have been confirming that they generate no whiskers or whiskers within the requirements specified above.

Document No. Q2-GE-02007
Date of Issue : March 13, 2003

View on Criteria for Sn Whisker Thermal Shock Test

We have established **"– 40°C ↔ 85°C, 500cycles, whisker length 50um or less"** as our Sn whisker thermal shock test criteria. The technical ground for these criteria is given as follows : (Please see attached paper (published in MATE2000) for the details of research experiments.)

$\boxed{1}$ From the results of our investigation on key electrode structures of our products, we have confirmed that tin whiskers generated by thermal shock stress occur on electrodes with the structure of Sn or Sn-alloy surface plate with Ni under-plating *[1]. From experimental results obtained using an electrode type showing the most intensive whisker growth among the above electrode structures, we have confirmed that **whiskers most rapidly grow under the test condition of – 40°C ↔85°C and, for whiskers on electrodes having Sn surface plate and Ni under-plate, estimated time period for whiskers to grow to 100um is 19100cycles.**

*1 : We have confirmed that whiskers generated by the thermal shock stress occur from the difference of thermal expansion coefficient between under-plating material and surface plating material.

$\boxed{2}$ Further, we calculated the whisker growth speed in [0°C ↔ 85°C] and [25°C ↔ 85°C] temperature shift conditions, and have determined that **the usable life time of products with whiskers follows the below expression** when high side temperature is set to 85°C :

$$\ln L = 16.061 \ln \Delta T + 87.273$$

Where, "L" is a product life time when a whisker reaches 100um and "ΔT" is a temperature difference (however, high side is fixed to 85°C).

$\boxed{3}$ Using this Eyring Model and assuming market use condition to be "maximum temperature difference : 25°C ↔ 85°C, 10 times switch on/off per day" *[2], we have obtained the calculation result that the 100um-reach-life is approximately 600 thousand years. By the way, a test condition in which whiskers reach 100um after 10 years is [–34°C ↔ 85°C]. However, usually, we can not assume an actual use environment in which this extremely severe condition is constantly charged on a product.

*2 : The worst (highest) 85°C and normal 25°C temperatures are assumed as using environmental stress given to devices installed in an automobile passenger room environment. Also, it is assumed that the narrowest distance between mounted component to be 200um, which can be short-circuited when whiskers have grown to 100um length.

$\boxed{4}$ Further, we have confirmed that **the whisker growth saturates at the stage of approximately 2200 cycles** and stops growing after that stage *[3]. For our products, approximate 80um length has been observed as the maximum whisker length and there is no case in which a whisker growing over that length to 100um has been detected.

*3 : As Ni diffusion into Sn film is observed progressing in proportion to the whisker growth saturation phenomenon, we consider that the diffused Ni atoms disturb the migration of Sn atoms. For example, we have confirmed a phenomenon that the growth of thermal shock whiskers are much repressed on the same type samples to which 85 °C high temperature storage has been treated before thermal shock test.

$\boxed{5}$ Also, we have confirmed that this type whiskers are repressed by reflow soldering heat stress. For products pretreated through 240°C reflow soldering, only about 9um length whisker growth has been observed in the test condition of [–40°C ↔ 85°C, 1000cycles].

$\boxed{6}$ From the above observations, we consider that a risk level in which Sn whiskers generated by thermal shock stress **grow to a length that may involve short-circuit problem in the market is extremely low**. However, for various Sn alloy plating technologies that may be developed in the future, we can not say there will be no case in which the whiskers grow longer than those generated on samples used in this survey. Therefore, we have established the abovementioned criteria of [–40°C ↔ 85°C, 500cycles, 50um or less] in order to check whether any new type electrode shows more active whisker growth than the most large grown whiskers in these experiments. For whiskers of which growth level is within the above criteria, we consider that they produce almost nil risk in the aforementioned market environments, even if they keep growing after the test stage of 500cycle.

End of Report