Report EL-2005-07-046 CR

Evaluation of Tin Whisker Growth, FCI Lead Free AIRMAX VS® Header Connectors

2006 May 16

PURPOSE:

Lead free AIRMAX VS® header connectors were tested to assess the growth of whiskers from the matte tin plating on the compliant pins. Standard AIRMAX VS® connectors (with tin-lead plated terminals) were included as control samples. Testing encompassed exposure to two (2) treatment environments: humid heat aging and room temperature storage. Testing was conducted according to FCI specification GS-19-028, which requires thermal shock preconditioning prior to both aging treatments. Whiskers were identified by visual examination of each tin plated pin in its plated through hole (PTH) in the printed wiring board (PWB) at approximately 100X magnification. Observed tin whiskers were verified by scanning electron microscopy (SEM) and resulting energy dispersive analysis of x-radiation (EDAX). The extent of whisker growth was evaluated by measurement of the projected whisker length in the electron microscope. Results were evaluated by comparison with the requirement for whisker length specified in FCI GS-19-028. These results are applicable to all FCI connectors with eye-of-needle (EON) style compliant sections on press fit (PF) pins.

CONCLUSIONS:

Whiskers were observed starting after two (2) months of treatment duration. This included whiskers on lead free (tin plated) pins (up to 49 micrometers in length) and on standard (tin-lead plated) pins (up to 18 micrometers in length). The lead free test samples met the specified requirement of 50 micrometers maximum whisker length at the end of the six (6) month exposure period.

SAMPLE DESCRIPTION:

Test sample identity is given in table 1.

Table 1. Identity of Submitted Samples

Item	Quantity	Description	Part Number	Lot	PF Plating	Received
1A	50	AIRMAX VS® Header IMLA A	10016529-103LF	Order 4200	Sn / Ni	2005 Feb 21
1B	50	AIRMAX VS® Header IMLA B	10016532-103LF	Order 4201	Sn / Ni	2005 Feb 21
2	115	AIRMAX VS® Header	10016527-101	Y04426	Sn-Pb / Ni	2005 Apr 27

The samples constituting items 1A and 1B were submitted under US Product Laboratory number EL-2005-02-036. Since the compliant sections of the two (2) types of insert molded leadframe assemblies (IMLAs) are equivalent, the distinction of IMLA type was not maintained during testing. The samples constituting item 2 were submitted under US Product Laboratory number EL-2005-04-056; for testing, IMLAs were extracted from the headers by breaking the features of the outer housing that lock the IMLAs in place within the connector assembly.

The plating on the compliant section of the lead free press fit pins was 0.5 micrometer to 1.5 micrometers of pure matte tin over 0.5 micrometer to 3 micrometers of nickel. The plating on the compliant section of the standard press fit pins was 0.5 micrometer to 1.5 micrometers of tin-lead alloy (92 % nominal mass fraction of tin) over 0.3 micrometer minimum of nickel.

This testing was conducted using both minimum size and maximum size plated through holes in printed wiring boards approximately 2.4 mm thick. A variety of board finishes was evaluated as listed in table 2.

Table 2. Identity of Sample Sets

	PWB Part Number	PTH Finish	PWB Size
1	SK10026893-002	Tin-Lead	Minimum
2	SK10026893-102	Copper / OSP	
3	SK10026893-202	Immersion Tin	
4	SK10026893-402	Immersion Silver	
5	SK10026893-001	Tin-Lead	Maximum
6	SK10026893-101	Copper / OSP	
7	SK10026893-201	Immersion Tin	
8	SK10026893-401	Immersion Silver	

REFERENCE DOCUMENTS:

Pertinent documents are listed in table 3.

Table 3. Reference Documents

Document ID	Title	Rev. Level (Date)
FCI GS-19-028	Test Specification, Test Procedure for Tin Whisker Formation in Lead-free Connector Terminal Finishes	A (2004 Feb 09)
FCI GS-20-035	Application Specification, AIRMAX VS® Connector System, press-fit products	A (2004 Oct 08)
FCI EL-2004-01-032C	Test Summary, Thomas D. Moyer, Designed Experiment to Determine the Reliability of Various Commercial Plating Baths and the Key Factors Affecting Whisker Formation	(2004 Nov 24)
ASTM E766	Standard Practice for Calibrating the Magnification of a Scanning Electron Microscope	98 (2003)

TEST SEQUENCE:

The tests were performed in accordance with the humid heat aging and room temperature storage environments specified in FCI GS-19-028 sections 5.4.1.2 and 5.4.1.3, respectively, after preconditioning by thermal shock exposure per FCI GS-19-028 section 5.2.2. Aging in dry heat (FCI GS-19-028 section 5.4.1.1) was not performed since this environment has previously been shown to be benign with respect to whisker growth (FCI test summary EL-2004-01-032C). The applied test sequence is given in table 4

Table 4. Sequence of Applied Tests by Test Group

		Sequence	
		Group C	Group D
		Humid Heat Aging	Room Temperature Storage
Test Description	Condition	45 Terminals	45 Terminals
Terminal Insertion		1	1
Whisker Evaluation	Initial	2	2
Thermal Shock	Preconditioning	3	3
Whisker Evaluation	after T Shock	4	4
Humid Heat Aging	250 hr	5	
Room Temperature Storage	250 hr		5
Whisker Evaluation	at 250 hr	6	6
Humid Heat Aging	+ 480 hr	7	
Room Temperature Storage	+ 480 hr		7
Whisker Evaluation	at 1 Month	8	8
Humid Heat Aging	+ 1 Mo	9	
Room Temperature Storage	+ 1 Mo		9
Whisker Evaluation	at 2 Months	10	10
Humid Heat Aging	+ 1 Mo	11	
Room Temperature Storage	+ 1 Mo		11
Whisker Evaluation	at 3 Months	12	12
Humid Heat Aging	+ 1 Mo	13	
Room Temperature Storage	+ 1 Mo		13
Whisker Evaluation	at 4 Months	14	14
Humid Heat Aging	+ 1 Mo	15	
Room Temperature Storage	+ 1 Mo		15
Whisker Evaluation	at 5 Months	16	16
Humid Heat Aging	+ 1 Mo	17	
Room Temperature Storage	+ 1 Mo		17
Whisker Evaluation	Final (at 6 Mo)	18	18

TEST PROCEDURES:

Terminal Insertion

In normal usage, the AIRMAX VS® receptacle connector is applied to the PWB as a connector assembly, but application of the entire connector precludes observation of the press fit (tin plated) area of the terminal. However, the terminals are not individually repairable; a column of terminals is integrated into an insert molded leadframe assembly (IMLA). Consequently, each IMLA to be tested was removed from the connector and affixed to the moving crosshead of tensile/compression test instrument by clamping the mating end of the IMLA in a vice with the press fit tails projecting downward. The IMLA was applied to the PWB by pressing the entire column of terminals into a series of PTHs in the PWB under machine control to full depth (i.e., until contact between the standoff feature of the IMLA and the top of the PWB) at a rate of 12 millimeters per minute. Each IMLA contained fifteen (15) press fit terminals. Three (3) IMLAs were tested for each combination of test group, terminal plating, PWB finish, and PTH size.

Whisker Evaluation

The presence of whiskers was evaluated by visual observation using a binocular optical microscope at approximately 100X magnification. Samples with possible whiskers identified by visual observation were examined by electron microscopy. Qualitative elemental analysis by electron induced x-ray emission was employed to verify the identity of these features.

Since the press fit tails did not project through the PWB, examination for whisker growth was restricted to the top (component) side of the PWB. Furthermore, since the standoff features of the IMLA obscured one side of the press fit tails, the terminals were examined from one side of the IMLA only. The area of observation included the terminal and PTH from as far down into the PTH as visibly accessible to the bottom of the IMLA.

Examination for whiskers was conducted after terminal insertion, after preconditioning, and monthly during the six (6) month environmental treatments; an examination was also conducted after 250 hours of treatment to check for rapid initial whisker growth.

Whisker Measurement

Verified whiskers were measured for length from secondary electron images obtained by SEM. In case (after 2 months of treatment), the observed whisker was not verified by SEM due to unavailability of the equipment; the length was measured by optical observation.

The geometry of the sample surface being investigated (inside a PTH containing a press fit pin) imposes severe restrictions on the orientation from which a whisker can be viewed, which prevents the use of stereographic imaging. Accordingly, measurement of effective whisker length was performed at the optimal orientation for whisker visibility as adjudged by the operator.

Thermal Shock

The test samples (compliant pins in PWBs) were preconditioned by exposure to repetitive thermal cycling between temperature extremes of –55 °C and 85 °C in accordance with section 5.2.2 of FCI test specification GS-19-028; 500 cycles of 20 minutes each were applied.

Humid Heat Aging

The test samples (compliant pins in PWBs) were subjected to aging under conditions of humid heat at 52 °C ± 5 °C and 90 % ± 5 % relative humidity in accordance with section 5.4.1.2 of FCI test specification GS-19-028.

Room Temperature Storage

The test samples (compliant pins in PWBs) were subjected to room temperature storage under ambient conditions (23 °C ± 5 °C with humidity uncontrolled) in accordance with section 5.4.1.3 of FCI test specification GS-19-028.

REQUIREMENTS:

The requirement for whisker length was 50 micrometers maximum in accordance with FCI test specification GS-19-028.

TEST RESULTS:

Initial Observations

Although no whiskers were identified initially, excess material was observed in PTHs, especially those of minimum size. This appeared mainly as material buildup at the entry of the PTH resulting from transfer of the plating from the pin (tin or tin-lead) to the inside surface of the PTH during pin insertion. Examples are shown in figures 1 and 2 (Sn and Sn-Pb plated pins, respectively, in minimum size PTHs on PWBs with Cu/OSP finish). This condition is not unusual for press fit pins.

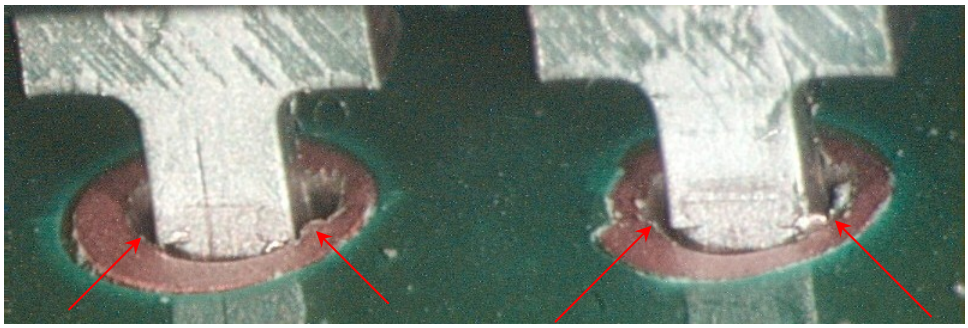

Figure 1. Buildup of Transferred Tin Material at Entry of PTH, Sample DT-CN1 – 50X

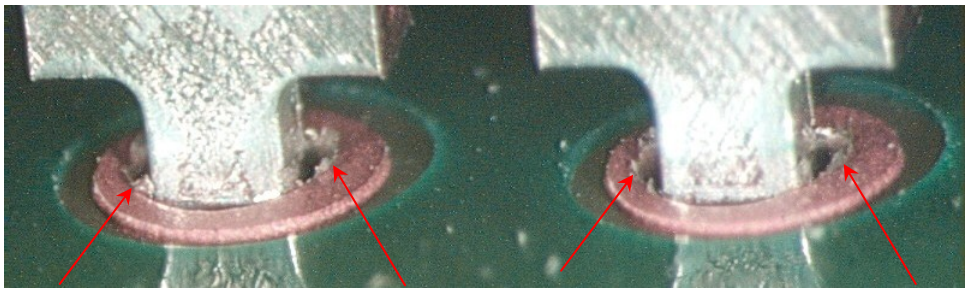

Figure 2. Buildup of Transferred Tin-Lead Material at Entry of PTH, Sample DL-CN2 – 50X

Whisker Evaluation and Measurement

The results of whisker evaluation and measurement are presented in table 5. The expanded relative measurement uncertainty at coverage factor 2 (approximately 95 % confidence level) is estimated to be 6 % for the projected length measurement based on the general tolerance for calibration of SEM magnification per ASTM E766.

Table 5. Listing of Whisker Observations and Measurement Results

Evaluation Condition	Whisker Count	Observed Whisker Details					
		Treatment Type	Pin Plating	PWB Finish	PTH Size	Whisker ID †	Whisker Length / µm
Initial	0						
after T Shock	0						
at 250 hr	0						
at 1 Month	0						
at 2 Months	1	Humid Heat	Sn	Cu / OSP	Max	1	27
at 3 Months	4	Humid Heat	Sn	Cu / OSP	Min	2	16
		Humid Heat	Sn	Cu / OSP	Max	1	22
		Humid Heat	Sn	Sn	Min	3	37
		Humid Heat	Sn-Pb	Sn	Min	4	12
at 4 Months	5	Humid Heat	Sn	Cu / OSP	Min	2	14
		Humid Heat	Sn	Cu / OSP	Min	5	38
		Humid Heat	Sn	Cu / OSP	Min	6	20
		Humid Heat	Sn	Sn	Min	3	37
		Humid Heat	Sn-Pb	Sn	Min	4	13
at 5 Months	4	Humid Heat	Sn	Cu / OSP	Min	6	21
		Humid Heat	Sn	Sn	Min	3	38
		Humid Heat	Sn	Ag	Min	7	34
		Humid Heat	Sn-Pb	Sn	Min	4	13
Final (at 6 Mo)	7	Humid Heat	Sn	Cu / OSP	Min	6	22
		Humid Heat	Sn	Sn	Min	3	38
		Humid Heat	Sn	Sn	Min	8	49
		Humid Heat	Sn	Sn	Min	9	11
		Humid Heat	Sn	Ag	Min	7	31
		Humid Heat	Sn-Pb	Sn	Min	4	13
		Humid Heat	Sn-Pb	Ag	Min	10	18

† The whisker ID numbers are arbitrarily assigned in order of observation to facilitate tracking of specific whiskers through time.
Note: All whiskers grew on material transferred from the pin to the inside surface of the PTH.

The first whisker was observed at 2 months of treatment duration. Although generation of additional whiskers continued throughout the test, the length of a specific observed whisker did not vary more than the expected measurement uncertainty at subsequent treatment duration. In some cases, previously identified whiskers were not observed at subsequent treatment durations presumably due to mechanical damage during sample handling. Although whiskers occurred in both PTH sizes, most observed whiskers were in minimum size PTHs. Whiskers occurred on PWBs with all tested finish types except tin-lead. The final examination at 6 months of treatment duration revealed an additional whisker that was near the specified maximum in length; this is depicted in figure 3. In addition to tin whiskers, two (2) short whiskers (less than 20 micrometers in length) were observed with standard (tin-lead plated) pins in tin and silver coated PWBs. All observed whiskers were growing from the inside surface of the PTH on material that had been transferred from the press fit feature of the pin to the PTH during pin insertion.

The trend of whisker length with time is illustrated in figure 4. Both average and maximum whisker lengths were nearly stable by 3 months of treatment duration. Specific whiskers appear suddenly with no subsequent change in length (see table 5). This behavior is not indicative of linear growth but tends to imply a segmented growth mechanism comprising an initial quiescent phase, an episode of whisker formation and rapid growth, and a subsequent period of stability.

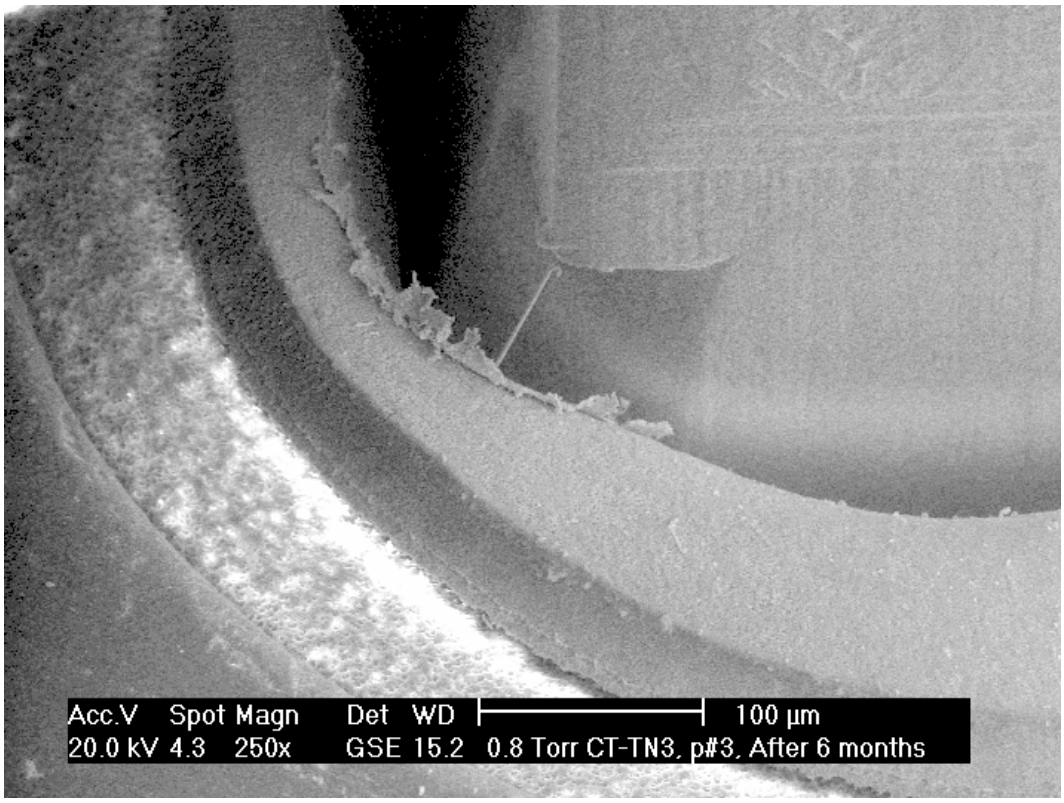

Figure 3. Secondary Electron Image (SEI) of Longest Whisker (ID 8, 49 µm Long) at End of Test

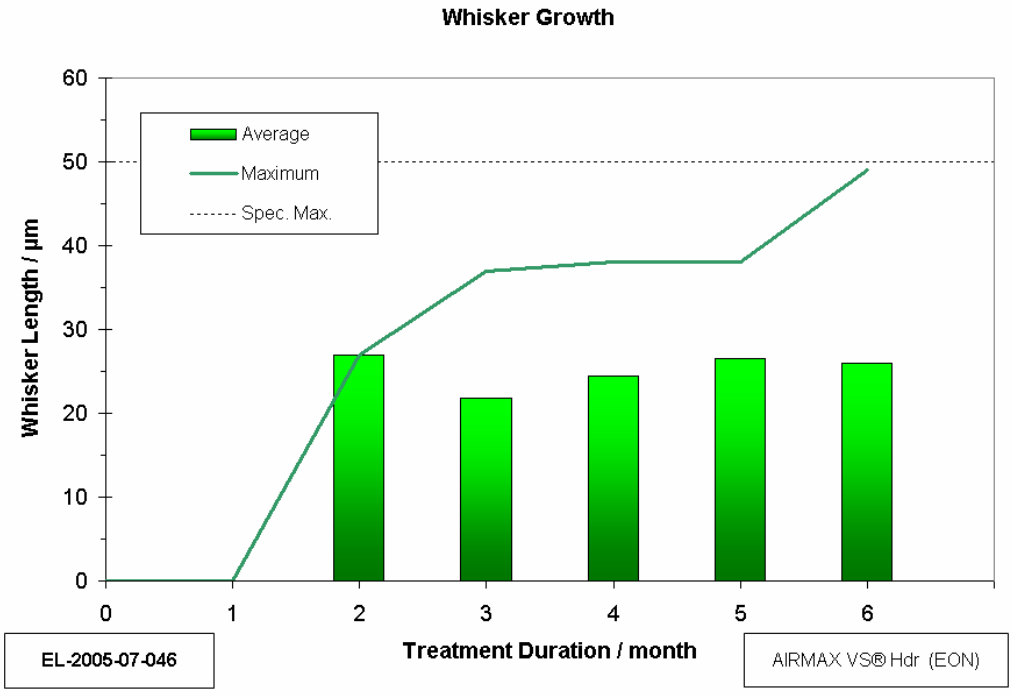

Figure 4. Whisker Growth with Treatment Duration

EQUIPMENT:

Item Description	Manufacturer (Model)	Equip. ID	Cal. Date	Cal. Due
Microscope	Wild (M8)	VG7088	Not Calibrated	NA
Tensile/Compression Tester	Instron (Model 1122, SN 4471)	VG7171	2005 Aug 02	2006 Aug
Load Cell	Instron (1000 lb, SN 1281)	VG6460	2005 Aug 04	2006 Aug
Calibration Mass	Instron (10 av lb #1)	VG6253	2005 Sep 02	2006 Sep
Calibration Mass	Instron (10 av lb #2)	VG6254	2005 Sep 02	2006 Sep
Thermal Shock Chamber	Cincinnati Sub-Zero (VTS-1.5-105-105-S/AC)	VG7403	2005 May 11	2006 May
Humidity Chamber	Espec (PRA-3GP, SN 00119002)	S56130	2005 Apr 27	2006 Apr
Optical Comparator	OGP (XL-14C, SN 140535)	FO0936	2005 Dec 05	2006 Jun
Microscope	Nikon (Measurescope 10 & MC-102)	VG5949	2005 Dec 06	2006 Jun
Scanning Electron Microscope X-ray Analyzer	Philips (XL30 ESEM TMP, SN E159/D6886) EDAX (SUTW PV7760/77 ME, SN 8837-60770 ME)	VG7782	Cal. Before Use	NA
Cu and Al Reference Sample	Ernest F. Fullam (10800)	VG7943	Not Calibrated	NA
SEM Magnification Sample	NIST (SRM 484a, SN JY-55-3L)	VG7955	1978 Dec 05	2028 Dec

REVISION RECORD

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