Report EL-2004-10-047A CR

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

2005 Aug 16

PURPOSE:

Lead free AIRMAX VS® receptacle 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:

No whiskers were observed on the standard (tin-lead plated) product. No whiskers were observed on the lead free (tin plated) product through three (3) months of treatment. Although a few whiskers were observed on the lead free product after four (4) months of treatment, 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
1	62	AIRMAX VS® Receptacle	10016537-101	04-50	Sn-Pb / Ni	2004 Oct 20
2	127	AIRMAX VS® Receptacle	10016537-101LF	04-58	Sn / Ni	2004 Oct 20

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.

Since growth of tin whiskers is related to stress, this testing was conducted using minimum size plated through holes (which would be expected to yield higher stress levels) 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 Finish	PTH Size
1	Tin-Lead	Minimum
2	Copper / OSP	
3	Immersion Tin	
4	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.

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, whisker measurement 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 many PTHs. This appeared in a variety of forms including flakes, slivers, and 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-Pb plated pins in Ag plated PWBs). The fraction of PTHs showing substantial amounts of such transferred material is given in table 5 for each combination of pin plating and PWB finish.

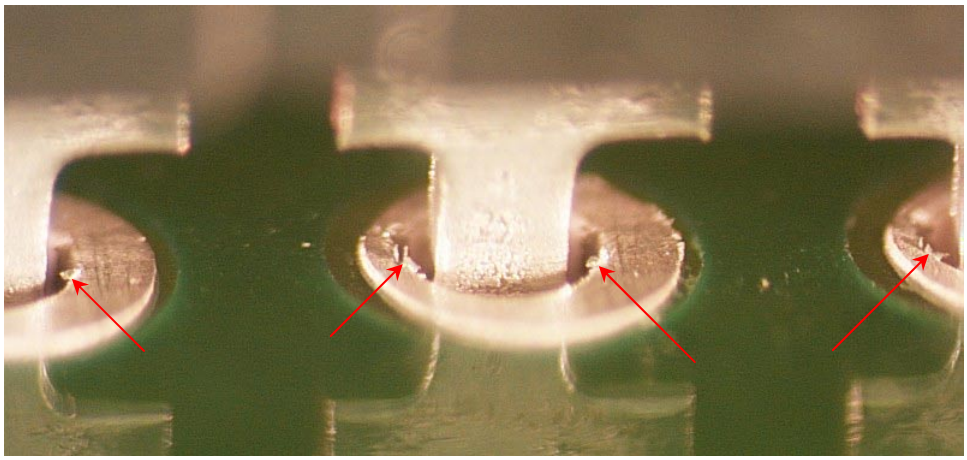

Figure 1. Flakes of Transferred Material at Entry of PTH– 50X

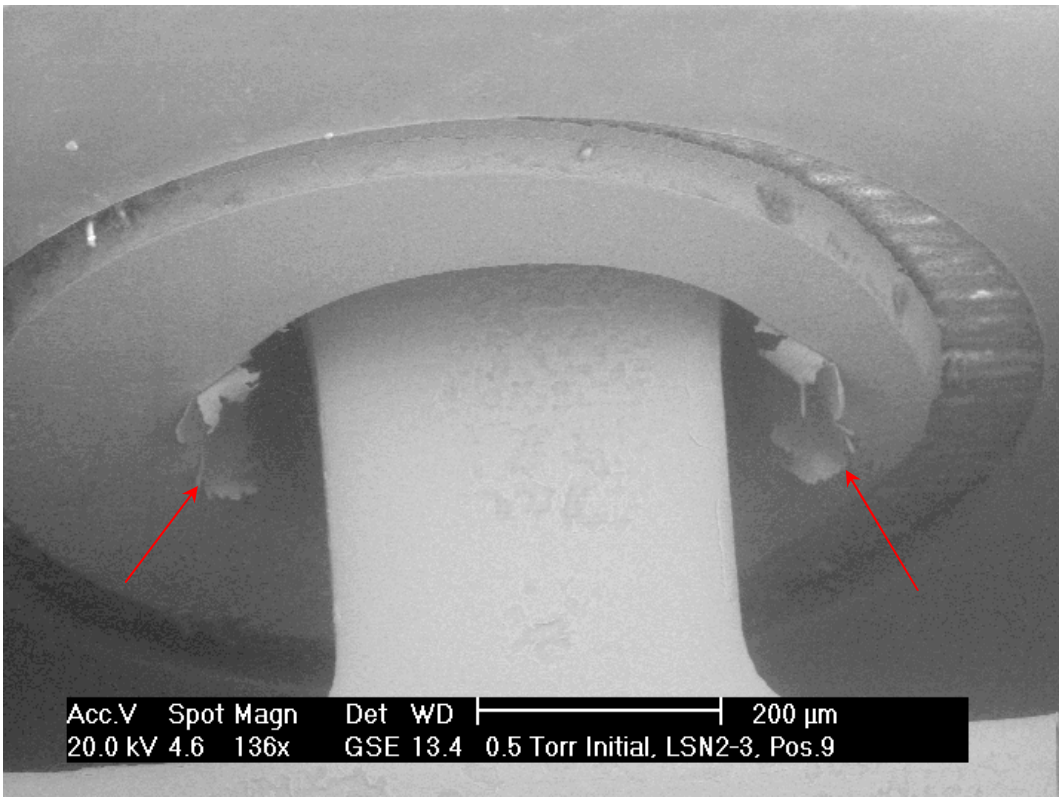

Figure 2. Secondary Electron Image (SEI) Showing Flakes of Transferred Material at Entry of PTH

Table 5. Fraction of PTHs with Substantial Transferred Material

	Fraction of PTHs with Transferred Material			
PTH Size :	**Minimum**			
PWB Finish :	**Sn-Pb**	**Cu/OSP**	**Sn**	**Ag**
Lead Free (Sn Plated) Pins	59%	98%	94%	87%
Standard (Sn-Pb Plated) Pins	78%	87%	99%	93%

The effect of PWB finish is statistically significant at the 95 % confidence level mainly due to the inclusion of tin-lead coated PWBs (with a thick and relatively soft final coating layer). Neither the main effect of pin plating type nor the interaction of pin plating and PWB finish is statistically insignificant.

Whisker Evaluation and Measurement

The results of whisker evaluation and measurement are presented in table 6. 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 6. 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	0						
at 3 Months	0						
at 4 Months	2	Humid Heat	Sn	Cu / OSP	Min	1	33
		Room Temp.	Sn	Cu / OSP	Min	2	41
at 5 Months	3	Humid Heat	Sn	Cu / OSP	Min	1	33
		Room Temp.	Sn	Cu / OSP	Min	2	41
		Room Temp.	Sn	Cu / OSP	Min	3	6
Final (at 6 Mo)	3	Humid Heat	Sn	Cu / OSP	Min	1	35
		Room Temp.	Sn	Cu / OSP	Min	2	40
		Humid Heat	Sn	Cu / OSP	Min	4	51

† The whisker ID numbers are arbitrarily assigned in order of observation to facilitate tracking of specific whiskers through time.

The first whiskers were observed at 4 months of treatment duration; these two (2) whiskers (IDs 1 and 2) continued to be observed through the remainder of the test without change in length. At 5 months of treatment duration, one (1) additional whisker (ID 3) was identified, but it was very small; it was not found in the subsequent (final) examination. The final examination at 6 months of treatment duration revealed one (1) additional whisker (ID 4), which had not been previously identified; although the measured length was slightly in excess of the specified maximum, it was within the measurement uncertainty of the specified limit; consequently, this is not considered to be in violation of the requirement for maximum whisker length.

The trend of whisker length with time implies that the growth is relatively rapid in the fourth (4^{th}) month of treatment with little growth before or afterward, as illustrated in figure 3.

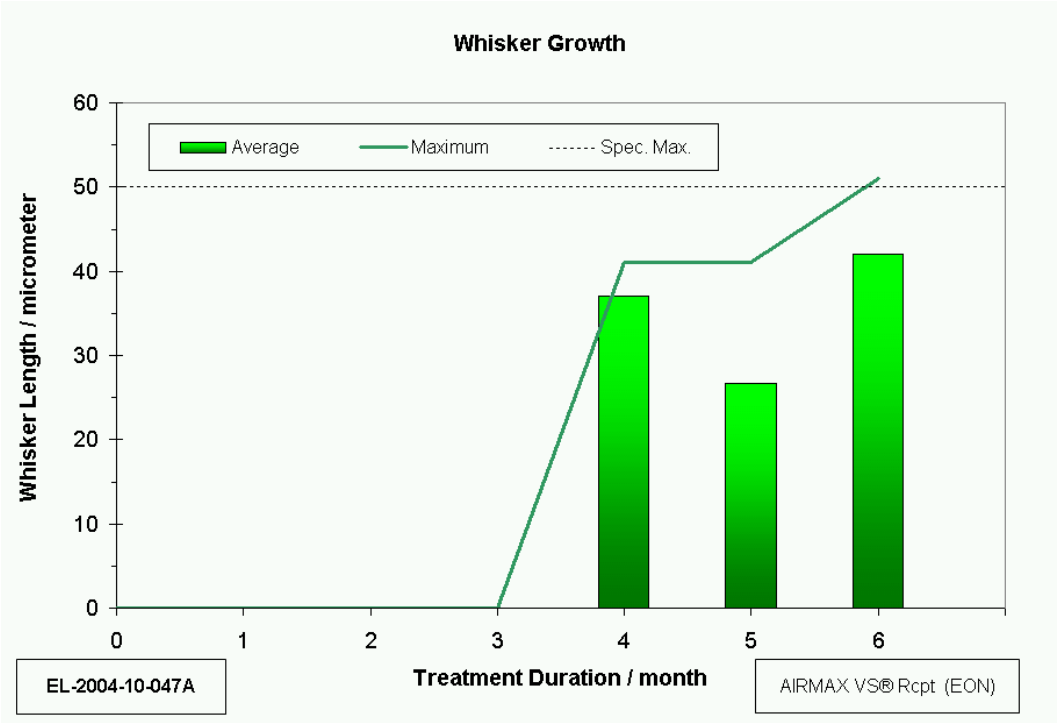

Figure 3. Whisker Growth with Treatment Duration

All identified whiskers were observed to protrude from tin material on the interior surface of the PTH that had been transferred from the compliant section during terminal insertion. In all cases, the whiskers were observed on samples with lead free (tin plated) pins in copper (OSP) PTHs. Figures 4 through 6 show secondary electron images of the three (3) whiskers observed at the end of testing (after 6 months of treatment).

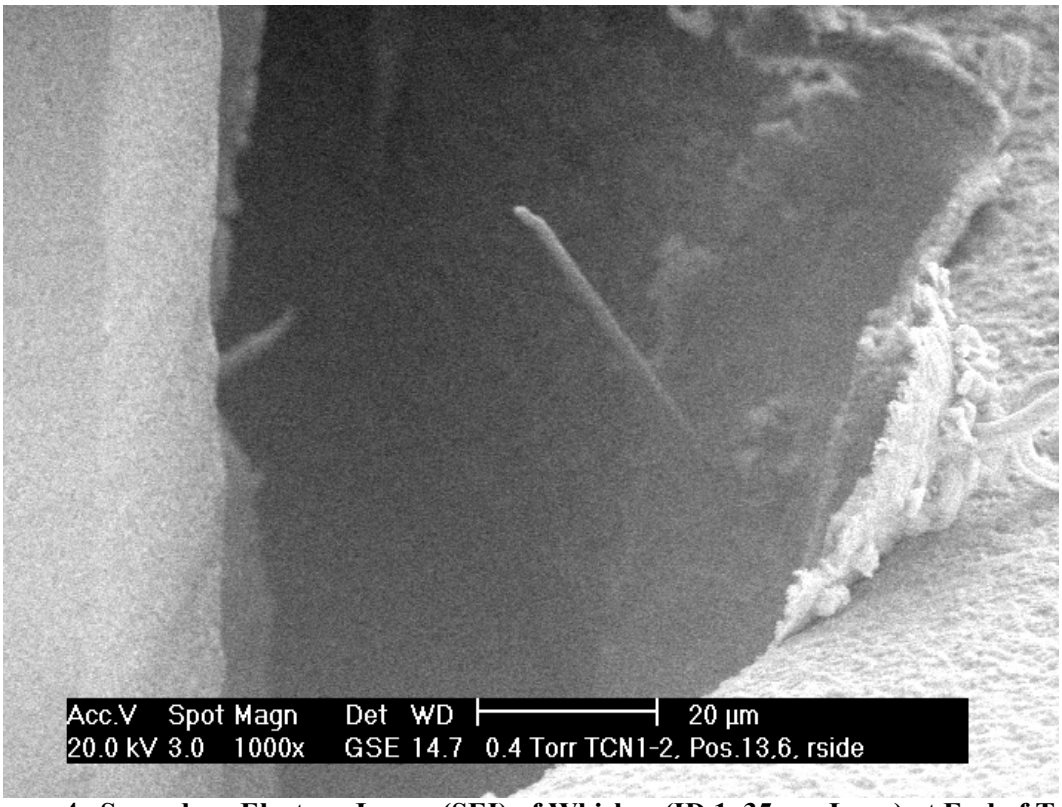

Figure 4. Secondary Electron Image (SEI) of Whisker (ID 1, 35 µm Long) at End of Test

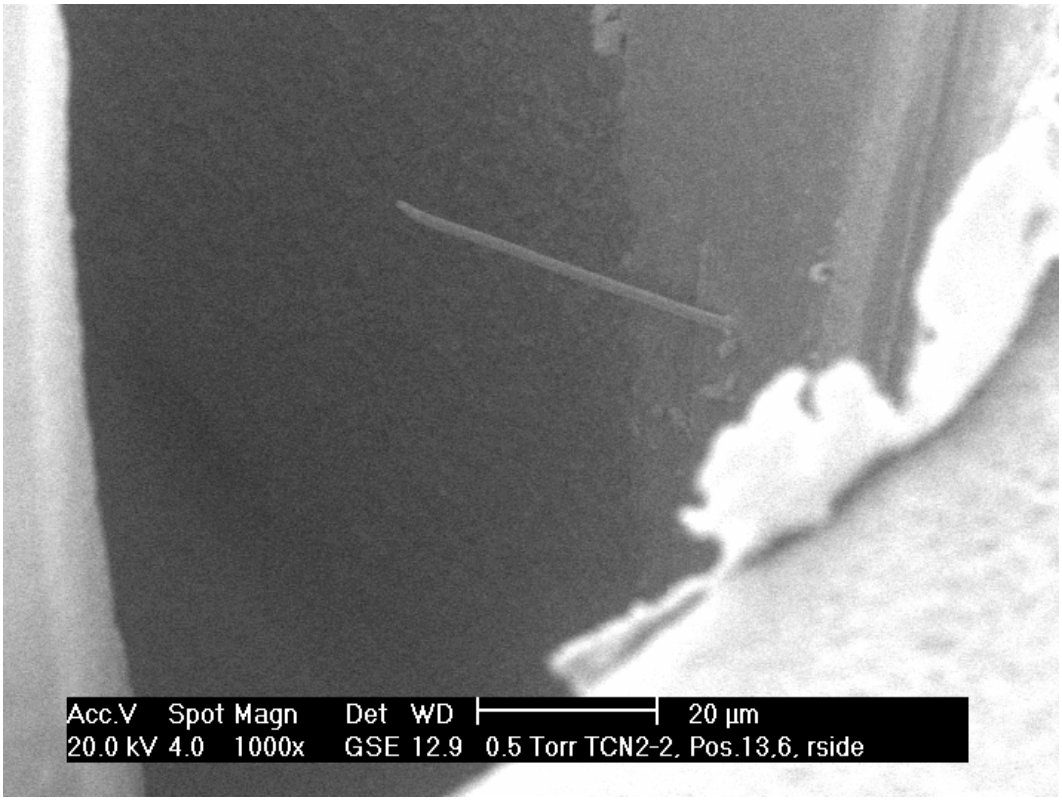

Figure 5. Secondary Electron Image (SEI) of Whisker (ID 2, 40 µm Long) at End of Test

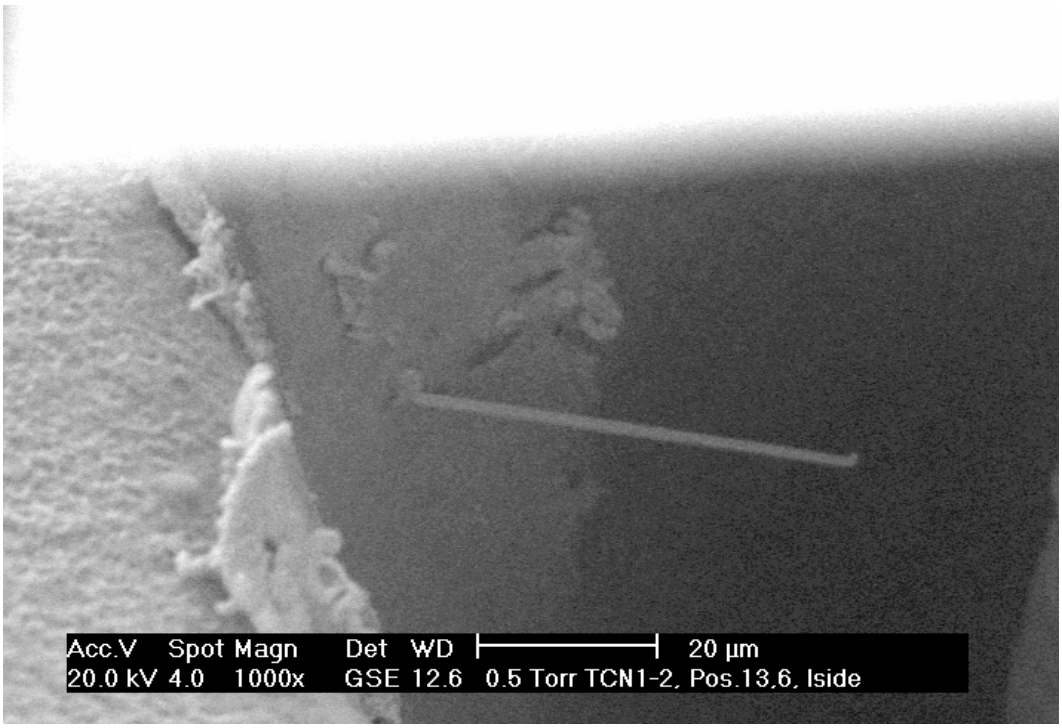

Figure 6. Secondary Electron Image (SEI) of Whisker (ID 4, 51 µm Long) at End of Test

EQUIPMENT:

Item Description	Manufacturer (Model)	Equip. ID #	Cal. Due Date
Microscope	Wild (M8)	VG7088	Not Calibrated
Microscope	Olympus (SZH)	VG7399	Not Calibrated
Digital Camera	Polaroid (DMC Ie)	VG7555	Not Calibrated
Climate Monitor	Fischer Scientific (SN 230011267)	VG7314	2005 Apr
Tensile/Compression Tester	Instron (Model 1122, SN 4471)	VG7171	2005 Jul
Thermal Shock Chamber	Thermotron (Model AT5-320-V-10-705-LN)	VG6931	2005 May
Humidity Chamber	Thermotron (Model SE-300-2, SN 31938)	VG7888	2005 May 2006 May
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
Cu and Al Reference Sample	Ernest F. Fullam (10800)	VG7943	Cal. Not Required
SEM Magnification Standard	NIST (SRM 484e, ID # JY-55-3L)	VG7955	2028 Dec

REVISION RECORD

Rev. #	Revision Date	Page(s)	Description
–	2005 Aug 16	All	Original Issue