Effect of Conformal Coating on Tin Whisker Growth

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Abstract
This paper will present the testing performed to date by Lockheed Martin Missiles and Fire Control on Tin Whisker test coupons. Coupons are representative lead materials and are half coated with 3 different conformal coatings in 3 different thicknesses. Testing has been performed over two years at 50/50 temperature/humidity exposure. This paper will also describe the capability of automated conformal coating equipment to provide complete coating coverage of various packages.

Executive Summary
The world wide lead free movement has caused the re-emergence of Tin Whisker reliability risk. It is clear that pure Tin finishes will cause Whisker growth; however, the timetable is unpredictable. The commercial electronic industry is not concerned since their life cycle is six months to a few years and a major part of the electronics market is for non-military applications. It is a major concern for the Aerospace and Defense industries where the product life expectancy is over ten years. Product failures due to tin whiskers have been found after 20 years of operation.

Industry and academic teams have been studying the Tin Whisker growth mechanism for several years. The phenomenon of Tin Whisker growth has been known for over 50 years. Tin/lead (Sn/Pb) historically has been the most common finish on component leads and Printed Wiring Board surfaces. Sn/Pb solder has been the industry standard in circuit board manufacturing throughout the world. Concerns over lead (Pb) contamination seeping into landfills and water supplies from discarded electronic devices (cell phones, computers, telephones, radios, etc.) has forced the industry to evaluate alternate approaches. Current and pending legislation in Europe and Asia has mandated that Pb be removed from all commercial products by July 2006.

Major components manufacturers are switching from plating Sn/Pb leads to tin (Sn) plated leads in an effort to be compliant by July 2006. Resolving the Pb contamination problem has propagated an age-old problem, Tin Whisker growth. Surfaces that are Tin plated have been shown to grow Whiskers, some exceeding ten millimeter in length. Documented failures in fielded hardware (some dating back to the 1980's) have been traced back to the Tin Whiskers bridging between leads and resulting in an electrical short.

The National Electronics Manufacturing Initiative's (NEMI) defines a Tin Whisker as: "A spontaneous columnar or cylindrical filament, which rarely branches, of mono-crystalline Tin emanating from the surface of a plating finish. Furthermore Tin Whiskers may have the following characteristics: a) an aspect ratio (length/width) greater than 2, b) can be kinked, bent, twisted, c) may have striations or rings around it." The agreed factor involved in Tin Whisker growth is the internal stress in the Tin plating. Stress can be caused by many factors (e.g. plating process, formation of intermetallic compound, lead forming after plating, compressive stresses, scratches or nicks in the plating due to mishandling, Coefficient of Thermal Expansion - mis-match between plating material and substrate).

The Tin Whisker growth phenomenon is unknown therefore, at present it is nearly impossible to predict, when and how Whisker formation may occur. However, we are currently forced to address the risk mitigation methods for Tin Whisker growth because it is not possible to completely eliminate the risk.

This test result clearly shows that all of the conformal coating materials (Acrylic, Polyurethane and Parylene) used provides mitigation from tin whisker growth. We did not notice any Whisker penetration of the coating.

Scope
Lockheed Martin Missiles and Fire Control, Orlando-Ocala, FL (LMMFC) conformal coats 99% of all circuit boards using one of three (3) different conformal coating materials: Acrylic, Polyurethane and Parylene. This evaluation was carried out to examine the affects of Tin Whisker growth on three coating materials applied with varying thicknesses to test coupons.

Test coupons consisting of two types of base material (Copper C110 alloy and Alloy 42) were electrodeposited with a layer of 'Bright Tin' plating. After plating and prior to conformal coating a quantity of the plated coupons were 'scratched' to simulate those found during handling and shipping conditions, and another quantity of plated coupons were bent (w/o scratches) in order to induce tensile and compressive stresses on the plating. All of the test coupons were then conformal coated on approximately half of the surface with the other half remaining uncoated. The test coupons were placed in an environmentally controlled temperature/humidity chamber to promote the growth of Tin Whiskers.

At approximately every 1,000 hours time interval, a sample of test coupons were removed from the temperature/humidity chamber and evaluated for Tin Whisker growth on the plated/uncoated surfaces versus the plated/conformal coated surface. Data samples were collected and examined under high magnification, photomicrographs, or SEM photographs. SEM analysis was performed with EDX metallurgy to confirm anomalies were Tin Whiskers. All data collected was documented, logged and charted to show whisker growth and other variations.

Test Objectives

1) Grow Tin Whiskers on the Bright Tin plated test coupons.
2) Provide positive evidence that conformal coating, over a Bright Tin plated coupon protects against Tin Whiskers through growth reduction, abatement or containment.
3) Evaluate different conformal coating materials and thicknesses to determine which material and coating thickness provide the best protection against Tin Whisker growth.

Test Coupon Material and Plating

a) Material: Copper C110	Coupon Dimensions: 1” x 4” x .032” thick	Qty: 99 each
b) Material: Alloy 42	Coupon Dimensions: 1” x 4” x .063” thick	Qty: 99 each

Test coupons were Bright Tin plated, 215 to 225 micro inches thick, applied in accordance with Mil-T-10727, Type I or ASTM-B545. (Supplier of coupons and plating: was the same used by NASA on their Whisker evaluation study: Alexandria Metal Finishers).

Conformal Coating Materials

The coating materials used in this testing was specifically chosen from the current vendors’ materials used in the Ocala manufacturing facility.

a) Acrylic per Mil-C-46058, Type AR
b) Polyurethane per Mil-C-46058, Type UR
c) Parylene per Mil-C-46058, Type XY

Test coupons were conformal coated to the thickness as specified in Table 1 and applied in accordance with documented Manufacturing Procedures. (Coated by: Lockheed Martin, Ocala Division).

Sample Preparation

Copper C110 sheet stock and the Alloy 42 sheet stock was used to cut 1” x 4” test coupons. (see Figure 1), 99 test coupons from each material were used (198 total coupons).

- Copper C110 and Alloy 42 test coupons were plated with Bright Tin plating finish.

Test coupons were plated with the Bright Tin to a thickness of 215 - 225 micro inches.

- After plating, using the procedure described below, random ‘light’ scratches were created on the surface of the Bright Tin plating on 138 coupons as shown in Figure 1. (69 each Copper C110 and 69 each Alloy 42)

Scratch Procedure: Brown paper wrapping material was cut in sheet sizes of approximately 8-1/2” x 11” then wrinkled by ‘balling and crushing’ and then unraveled and flattened. Each coupon was separately wrapped (1 sheet/coupon), then individually laid on a hard surface (i.e., table top) and shuffled around several times on each of its flat sides thus randomly creating ‘light’ scratches on the tin surface. These scratches were intended to simulate those found on the surface of parts as a result of shipping and handling. The typical ‘light’ scratch created by this method was photo documented.

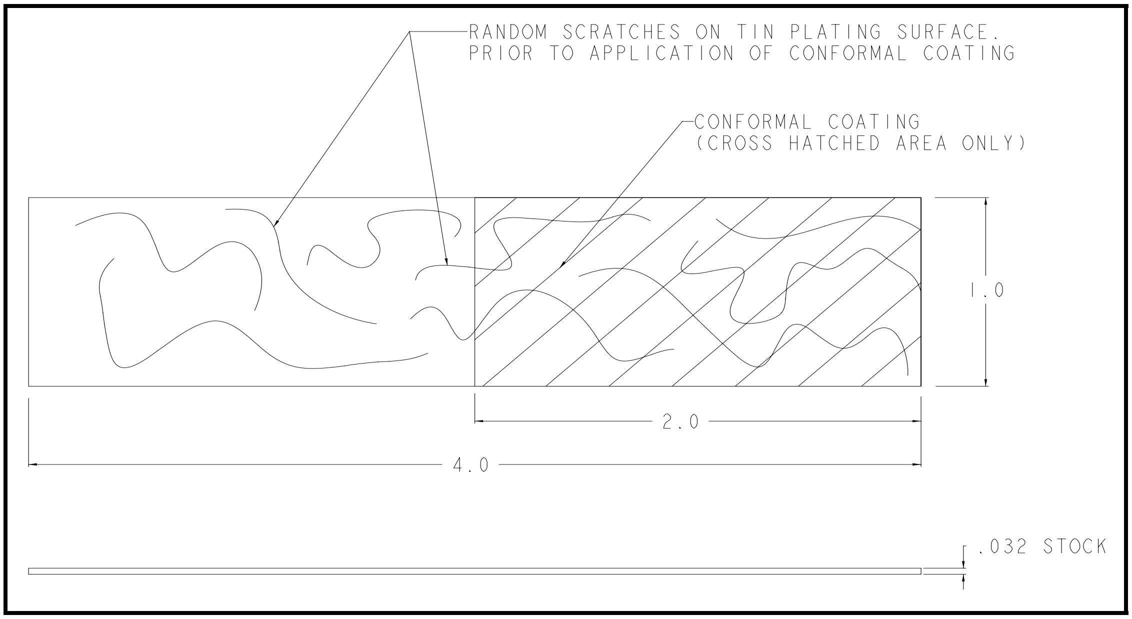


Figure 1 –Individual Test Coupon Dimensions/Scratched Surfaces & Coating Area

- On the other 60 test coupons (30 from Copper C110 and 30 from Alloy 42), 45° bends were made at 2 places as shown in Figure 2 using a machine vise with appropriate protection applied to the jaws of the vise (i.e. Teflon tape or equivalent). This bend was intended to put the Tin plating under stress (i.e., compressive stress on the inside bend and tensile stress on the outer bend). Necessary precautions were taken to protect the transfer of metal to the tin plating during the bending process. Note: These coupons did N<u>OT</u> have scratches in the Tin plated surfaces.

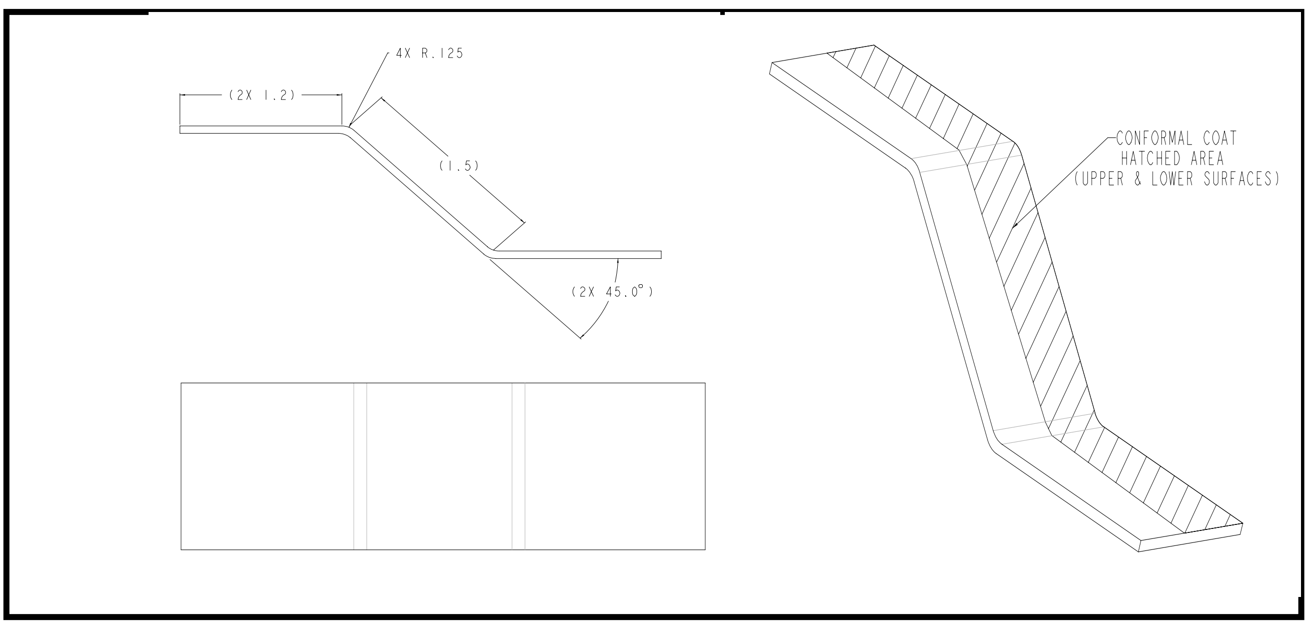


FIGURE 2 – Angled Test Coupon

Identification of Sample Coupons

- Conformal coating material, thickness and the serial number for each coupon, is in accordance with the requirements of Table 1.
  Example: CU-A-1-XX = Cu Coupon, Acrylic Coating, 1 mil thick, Coupons 01, 02,, etc.
  Each test coupon was permanently identified (labels or etching) with the base coupon material, the Example: BCU-U-3-YY = Bent Cu Coupon, Urethane Coating, 3 mils thick, Coupon 01, etc.

Table 1 – Identification Of Test Coupons

COUPON IDENTIFICATION CODE	COUPON BASE MATERIAL*	COUPON PLATING**	CONFORMAL COATING(#)	COATING THICKNESS (##) MILS	NO. COUPONS REQUIRED
CU-BASE-YY	COPPER PLATE	BRIGHT TIN	NONE - BARE	N/A	5
CU-A-1-XX	COPPER PLATE	BRIGHT TIN	ACRYLIC	1.0	8
CU-A-2-XX	COPPER PLATE	BRIGHT TIN	ACRYLIC	2.0	8
CU-A-3-XX	COPPER PLATE	BRIGHT TIN	ACRYLIC	3.0	8
CU-U-1-XX	COPPER PLATE	BRIGHT TIN	URETHANE	1.0	10
CU-U-2-XX	COPPER PLATE	BRIGHT TIN	URETHANE	2.0	10
CU-U-3-XX	COPPER PLATE	BRIGHT TIN	URETHANE	3.0	10
CU-P-5-XX	COPPER PLATE	BRIGHT TIN	PARYLENE	0.5	10
					Total of: 69
AL-BASE-YY	ALLOY 42	BRIGHT TIN	NONE - BARE	N/A	5
AL-A-1-XX	ALLOY 42	BRIGHT TIN	ACRYLIC	1.0	8
AL-A-2-XX	ALLOY 42	BRIGHT TIN	ACRYLIC	2.0	8
AL-A-3-XX	ALLOY 42	BRIGHT TIN	ACRYLIC	3.0	8
AL-U-1-XX	ALLOY 42	BRIGHT TIN	URETHANE	1.0	10
AL-U-2-XX	ALLOY 42	BRIGHT TIN	URETHANE	2.0	10
AL-U-3-XX	ALLOY 42	BRIGHT TIN	URETHANE	3.0	10
AL-P-5-XX	ALLOY 42	BRIGHT TIN	PARYLENE	0.5	10
					Total of: 69
SAMPLES BELOW, ANGLED 45° TO STRESS THE BRIGHT TIN PLATING					
BCU-A-1-YY	COPPER PLATE	BRIGHT TIN	ACRYLIC	1.0	5
BCU-A-2-YY	COPPER PLATE	BRIGHT TIN	ACRYLIC	2.0	5
BCU-A-3-YY	COPPER PLATE	BRIGHT TIN	ACRYLIC	3.0	5
BCU-U-1-YY	COPPER PLATE	BRIGHT TIN	URETHANE	1.0	5
BCU-U-2-YY	COPPER PLATE	BRIGHT TIN	URETHANE	2.0	5
BCU-U-3-YY	COPPER PLATE	BRIGHT TIN	URETHANE	3.0	5
BAL-A-1-YY	ALLOY 42	BRIGHT TIN	ACRYLIC	1.0	5
BAL-A-1-YY	ALLOY 42	BRIGHT TIN	ACRYLIC	2.0	5
BAL-A-3-YY	ALLOY 42	BRIGHT TIN	ACRYLIC	3.0	5
BAL-U-1-YY	ALLOY 42	BRIGHT TIN	URETHANE	1.0	5
BAL-U-2-YY	ALLOY 42	BRIGHT TIN	URETHANE	2.0	5
BAL-U-3-YY	ALLOY 42	BRIGHT TIN	URETHANE	3.0	5
					Total of: 60
(XX) = Coupon No. 01 THRU 08 or 10			**OVERALL TOTAL**		**198**
(YY) = Coupon No. 01 thru 05					
*** - Coupon Size 1" x 4" x .032" thick (Before Plating)**					
**** - Plating Thickness, 215 - 225 micro inches, Bright Tin**					
(#)- ACRYLIC = HUMISEAL 1B31 **URETHANE = HUMISEAL 1A33** **PARYLENE = PARYLENE DPX-C**					
(##) – 1 MIL = 0.001 INCH					

Conformal Coating Process

- Each coupon was prepared for conformal coating in accordance with their respective manufacturing procedures.
- Coupons were cleaned in the Inline cleaner
- They were baked @ 85 Deg. C for 2 hours.
- The individual flat test coupons were masked as shown in Figure 1 and the bent test coupons were masked as shown in Figure 2.
- Coupons were coated using automated select coat spray equipment.
- They were de-masked.

- The individual test coupons were coated to the thickness requirements of Table 1 using the "COUPON IDENTIFICATION CODE" on each coupon to control the coupon base material, coating material and coating thickness.

Baseline Analysis

- The "STARTING" condition of the copper and the Alloy 42 samples were photo documented (1 each of the scratched & coated, bent and coated, and BASELINE/uncoated test coupons).
  Total of 6 coupons with the following analysis:
  (1) Scratched Tin surfaces – coated and uncoated sides of coupon
  (2) Bent Tin surfaces (tensile and compressive bends) – coated and uncoated sides of the coupon.
  (3) BASELINE uncoated Tin surface

NOTE: These photographs were used to document the before condition prior to the effects of the environmental conditioning.

- Test coupons were placed into containers that provided for 1 sample from each type of test coupon. Five of the BASELINE coupons were placed on the first 5 trays. The test coupons did not touch metal or other coupons during the environmental conditioning process.

NOTE: At any point thru the completion of all tests, the test coupons were handled with protective gloves and held by the edges and/or outside the region of evaluation. Additionally, the test coupons were transported back and forth from the test chambers to the lab in a manner which did not cause damage to Tin Whiskers which may have developed on the surface.

Test Procedure

- All 198 test coupons were placed in the environmental chamber that was set to 50° ± 10° C and the humidity to 50% 15% RH. Chamber status (Temperature and Humidity), was electronically monitored.
- Approximately every 1,000 hours the test coupons were evaluated for Tin Whisker growth by removing one tray of coupons consisting of one from each of the categories (straight/flat and angled/bent coupons), from each of the material types, and from each of the individual coatings and thicknesses. Evaluation consisted of visual evaluation, photomicrographs, and SEM analysis with photos. See figure 3 for a sample lot.

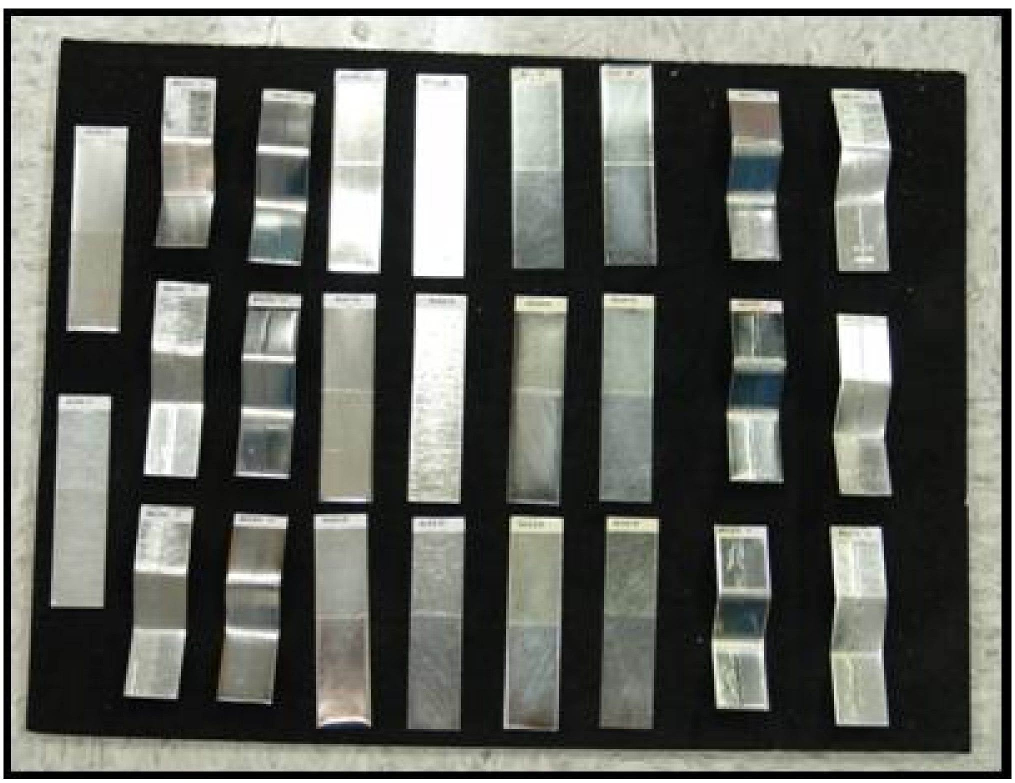


Figure 3 – Sample Lot

- Samples removed from the environmental chamber for inspection were returned back to the temperature/humidity chamber for continued exposure.

- At the completion of the test, remaining samples from the environmental chamber were collected to perform the final photomicrographs along with SEM analysis.
- All findings/documentation were included in a final test report.

Inspection Report

Whisker Inspection Areas

The coupons were inspected using an optical and Scanning Electron Microscope. The entire region of the coupon was observed and any information was recorded. Figure 4 represents JEDEC Standard No. 22A121 on required size and amount of inspection areas needed to be observed on the test coupons. The results obtained in this report were gained through inspection areas smaller and of greater quantity than what is required through the standard published.

Inspection areas as required through JEDEC Standard No. 22A121. "Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes." Pgs. 18-20. JESD22A121. JEDEC Solid State Technology Association. Arlington. 2005.
See figure 4.

Measuring technique for total axial length of tin whiskers. "Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes." Pgs. 18-20. JESD22A121. JEDEC Solid State Technology Association. Arlington. 2005.

Whisker Recording Method.

Tin whiskers that were observed using the Scanning Electron Microscope were estimated and measured using the method below. These lengths include the total axial length of the Tin Whisker. See figure 5.

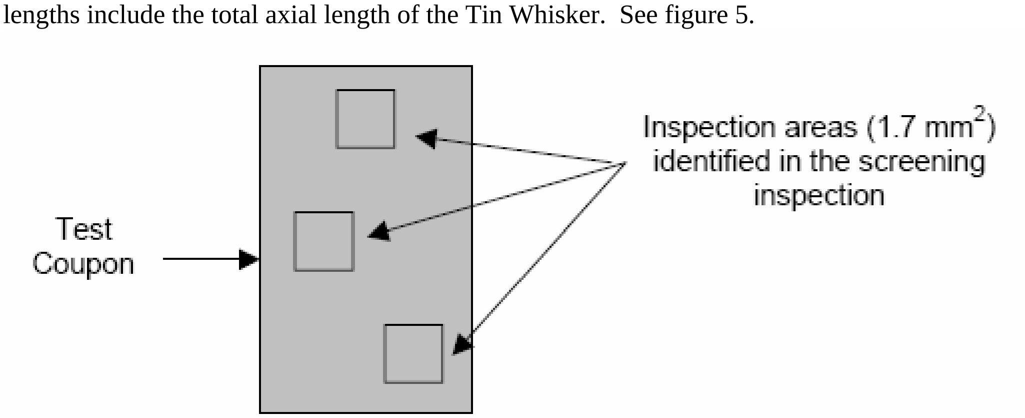


Figure 4

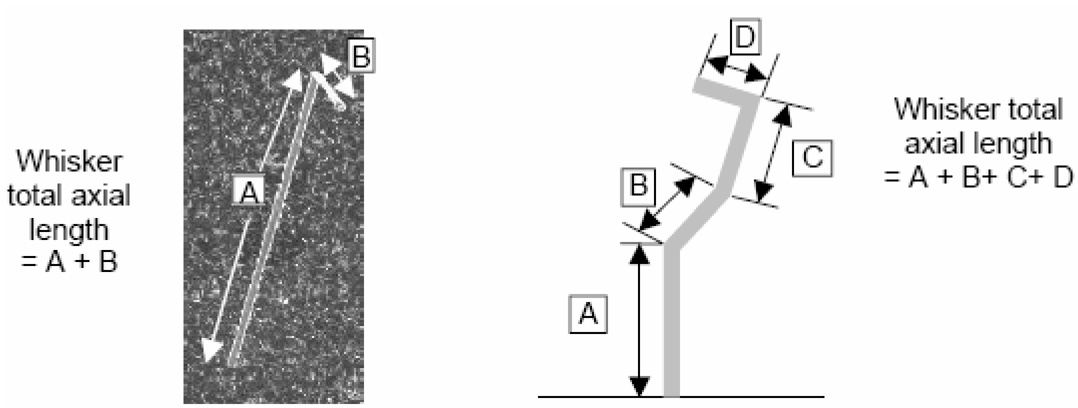


Figure 5

Whisker Density Measurement Method

The amount of tin whiskers that were present in a specified area of interest on the coupon represented the density of tin whiskers. Table 2 (below) was used to determine the range of each specified observation area.

Table 2 – Tin Whisker Density

Maximum Whisker Density Range	Total Number of Whiskers per Lead, Termination, or Inspected Coupon Area	Lead, Termination, or Coupon Inspection Area
Low	< 10 whiskers	**(mm^2)**
Medium	10 – 45 whiskers	**(mm^2)**
High	> 45 whiskers	**(mm^2)**

Test Results – see Appendix A for photos

The first six identified sample lots have been pulled and analyzed for tin whisker growth. Sample lot #3 was insignificant (no differences in data beyond what had been collected in lots 1 and 2) and was placed back into the chamber. Detailed observations of lot 6 are listed below in Table 3. Whisker densities, axial length of whiskers, and whisker features were noted. Information gathered from the table shows a higher probability for copper samples to grow whiskers compared with alloy 42. See test plan for description – each lot contains samples of both materials (alloy 42 and copper), 3 conformal coatings (acrylic, urethane, parylene) with 3 thicknesses (1, 2, and 3 mils), scratched surfaces, and bent surfaces.

Table 3 - Detailed Observations Of Tin Whiskers On Coupons (Non-Coated Sections)

Sample information	Detailed Observations (non-coated region):		
	Whisker Density (Low, Medium, or High)	Axial length of longest whisker (micrometers)	Whisker Features (e.g., corrosion, scratches, etc.)
CU-A-1-06	Low	50	-Near other Hillocks -Near edge of sample -Hillocks
CU-A-2-06	Low		Nothing Noticeable
CU-A-3-06	Low	130	-On edge of sample -Hillocks
CU-U-1-06	Low		-Hillocks
CU-U-2-06	Low		-Hillocks
CU-U-3-06	Low	60	-On scratched region -Hillocks
CU-P-5-06	Low	68	-Sharp 90 deg bend -Irritated surface -Hillocks
AL-A-1-06	Low		-Nothing Noticeable
AL-A-2-06	Low		-Hillocks
AL-A-3-06	Low		-Nothing Noticeable
AL-U-1-06	Low	20	-3-way branched whisker -Hillocks
AL-U-2-06	Low		-Small Hillocks
AL-U-3-06	Low		-Hillocks
AL-P-5-06	Low		-Nothing Noticeable

CONCLUSIONS

- Heat and humidity accelerated the growth of intermetallics at the interface of the substrate and plating.
- Tin Whisker growth may be due to the compressive stress that was caused by irregular growth of intermetallics. Other theories are not ruled out.
- Tin Whiskers did not grow through any coating on samples through pull six.
- Lot six was in excess of 10,000 hours and the whiskers observed were low in density throughout the coupons.
- There was a medium density of hillocks forming rather than actual whiskers, so further pulls are expected to have additional Whiskers.
- Verification of coating coverage indicates automated select coat process is capable of providing complete coverage of chip packages and complete coverage of sides of leads. See Appendix B for photos/data.

Lot #1

Removed after 1,000 hrs. in the temperature/humidity chamber.
Total samples removed = 26 coupons
Total whiskers identified = 1 coupon with multiple verified Tin whiskers

- bent copper with urethane 1 mil thick coating
- 3 measured confirmed Tin whiskers and multiple areas of "proto" whiskers

Summary of Lot #1

- Tin Whisker growth initiated after 1,000 hrs. of exposure to 50/50 temperature/humidity
- Determination made that it's impossible to find the same whiskers in later analysis (no way to mark coupons)
- No Whiskers have been identified to date on the coated surface areas.
- All identified whisker growth was found in the straight non-coated areas of the bent coupon

Lot #2

Removed after 2,000-hrs. in the temperature/humidity chamber.
Total samples removed = 25 coupons
Total whiskers identified = 7 coupons with multiple verified Tin Whiskers

- Both Cu and Alloy 42 – 6 bent coupons and 1 scratched
- Multiple areas of "proto" whiskers

Summary of Lot #2

- Multiple coupons found to contain tin whisker growth after 2,000 hours of exposure to 50/50 humidity/temperature conditions. Many "proto" Whiskers have begun to form. It is difficult to measure the whiskers at this point in the acceleration process.
- All Whiskers were identified on non-coated surfaces only.

Lot #3, 4, 5

- Whiskers were identified on uncoated surfaces only
- No Whiskers have been identified to date on the coated surface areas.

Lot #6 – see table 3 and Appendix A for details
Removed after >10,000 hrs. in the temperature/humidity chamber.

- Whiskers were identified on uncoated surfaces only
- No Whiskers have been identified to date on the coated surface areas

This test data presents validation of three different specific vendor conformal coating materials to contain/abate Tin Whisker growth on representative lead materials (Cu and Alloy 42). Data also validates the automated select coat process is capable of providing adequate coating coverage in critical areas.

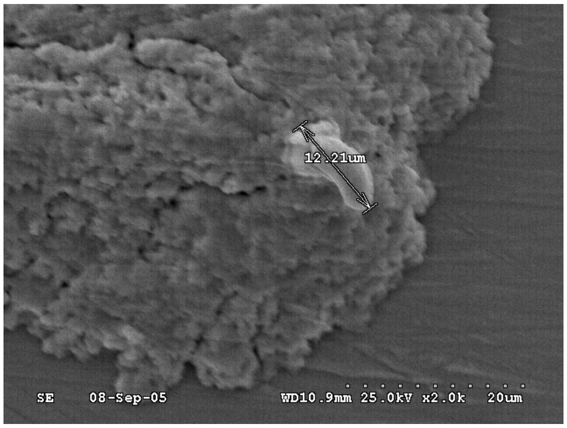
Note that these results are from coupons with platings that are typically seen on leads of standard packages. The results are only relevant to the specific coatings tested with the specific coating process that was utilized.

References

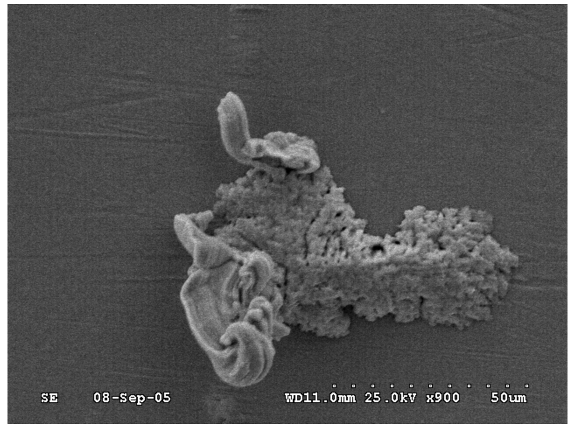
1. JEDEC Standard No. 22A121. "Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes." Pgs. 18-20. JESD22A121. JEDEC Solid State Technology Association. Arlington. 2005.
2. "Evaluation Of Conformal Coatings As A Tin Whisker Mitigation Strategy, Part II"
Thomas A. Woodrow, PHD. And Eugene A. Ledbury, The Boeing Company, Seattle, WA, USA

3. J.A. Brusse, G.J. Ewell, and J.P. Siplon, “Tin Whiskers: Attributes and Mitigation”, 22nd Capacitor and Resistor Technology Symposium Proceedings, March 25-29, 2002.
4. Tom Woodrow, Bill Rollins, Pat Nalley and Bob Ogden, “Tin Whisker Mitigation Study: Phase I. Evaluation of Environments for Growing Tin Whiskers”, Electronic Material and Processes (EM/P) Report – 576, The Boeing Company, August 1, 2003 (prepared by the Tin Whisker Alert Group).

Appendix A – Tin Whiskers



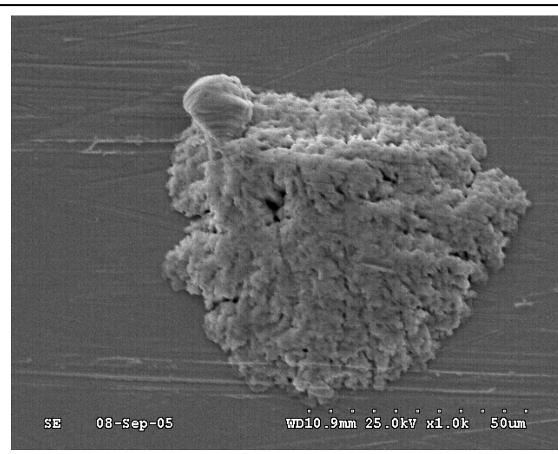
CU-U-3 06 (Copper w/Urethane 3mil thick)
Whisker forming from hillock surface
- 12 um in length



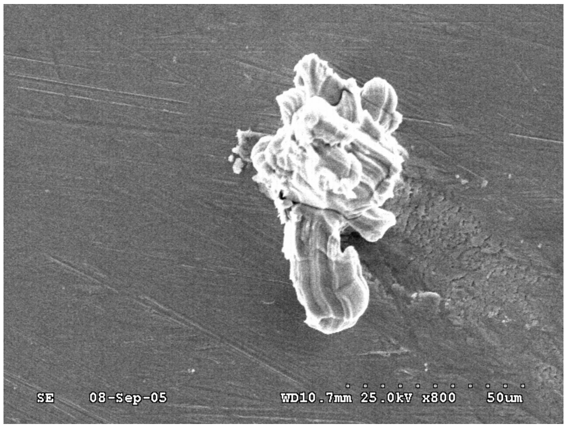
CU-U-3 06
Whisker forming from hillock surface

Pull #6 Sample Photos – all photos from uncoated surfaces

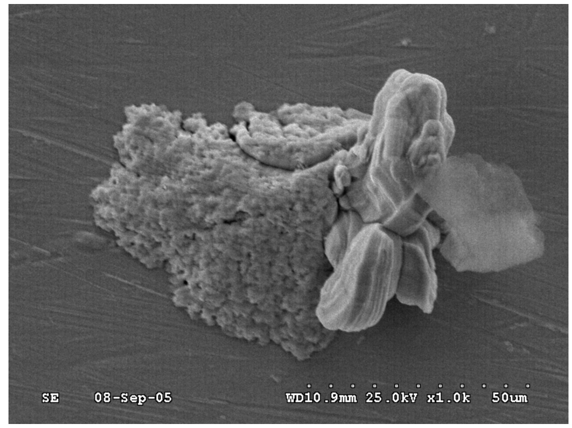
CU-U-3 06
Whisker forming from hillock surface
- 48 um in length



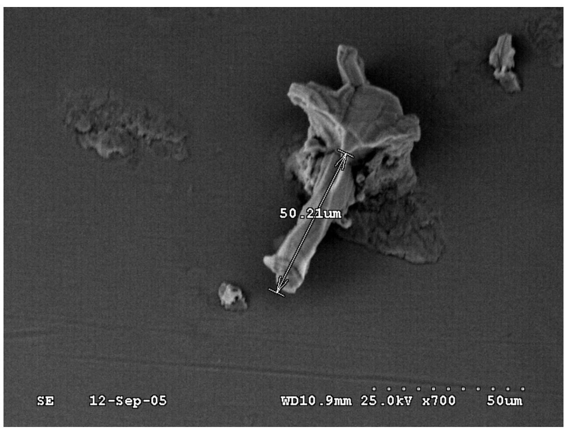
CU-U-3 06
Whisker forming from hillock surface



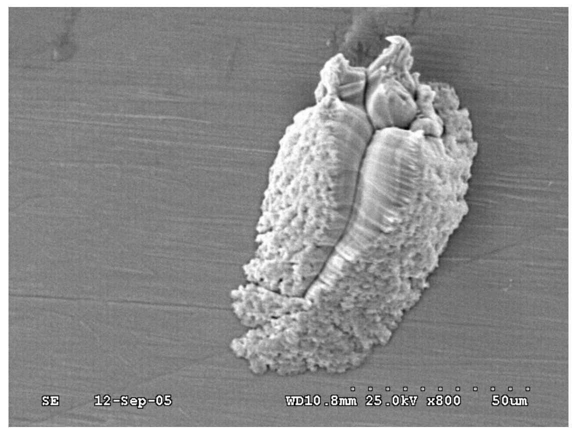
CU-U-3 06
Whisker formation



CU-U-3 06
Whisker forming from hillock surface



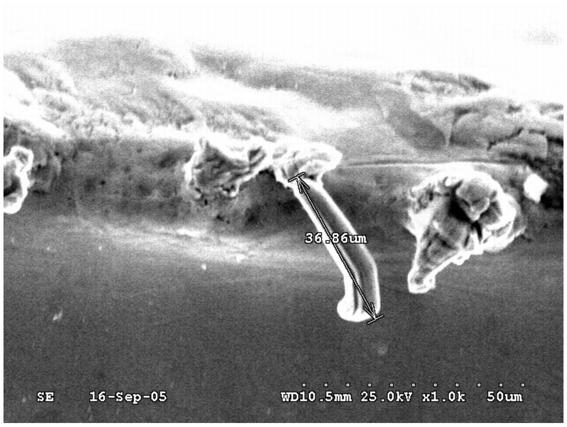
CU-A-1 06
Straight whisker formation from a hillock surface – Protruding 50.2 um



CU-A-1 06
Whisker forming from hillock surface

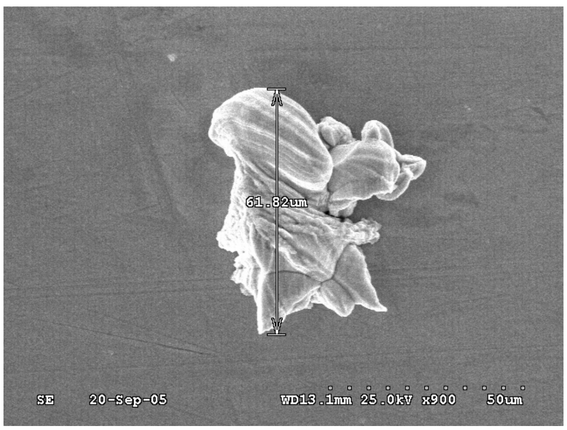
CU-A-1 06
Whisker formation

CU-A-2 06
Whisker formation

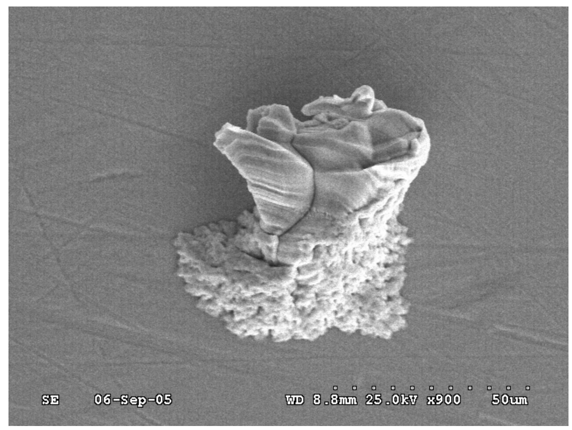


NO I.D. CU
Straight whisker forming from hillock surface
- Protruding 37 um

NO I.D. CU
Curved whisker forming from hillock surface
- Protruding 55 um with a 7.6 um diameter

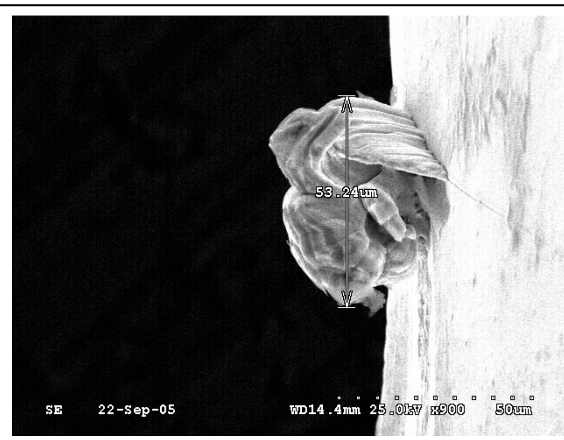


CU-U-1 06
Whisker formation on hillock surface
- 62 um in length



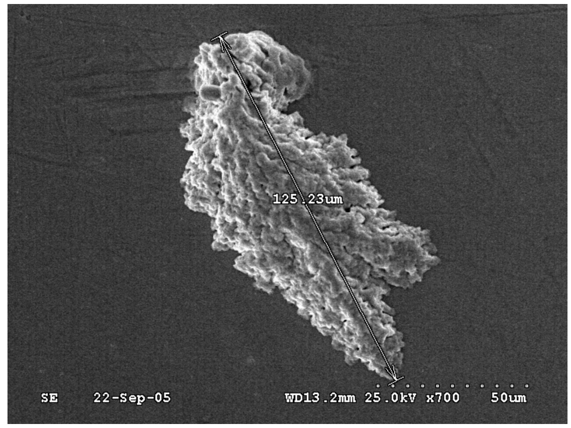
AL-P-5 06
Whisker formation from hillock surface

AL-U-1 06
Three-way branched whisker forming from hillock surface - Protruding 20 um from hillock surface on three sides

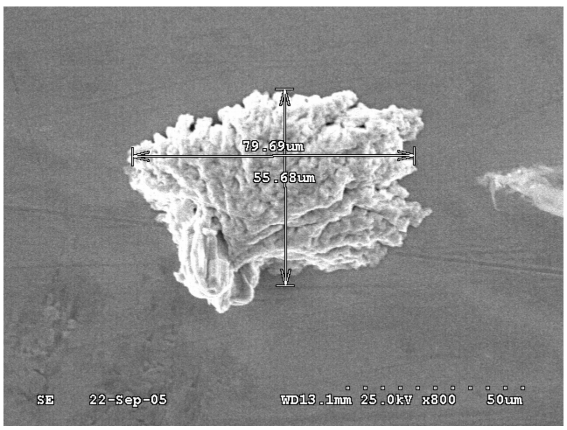


CU-U-2 06
Hillock surface – 53 um diameter

CU-U-2 06
Whisker forming from hillock surface
- Protruding 60 um diameter hillock

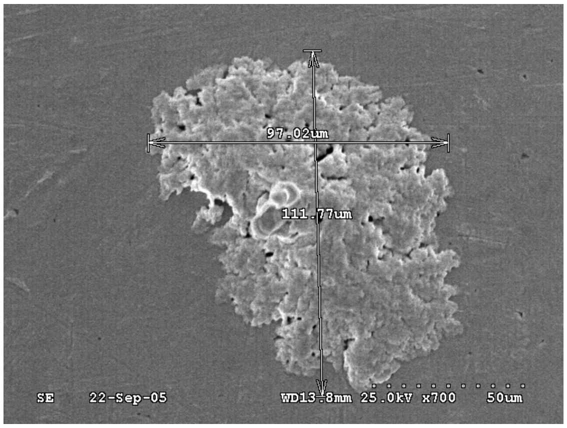


CU-U-2 06
Hillock surface – 125 um length

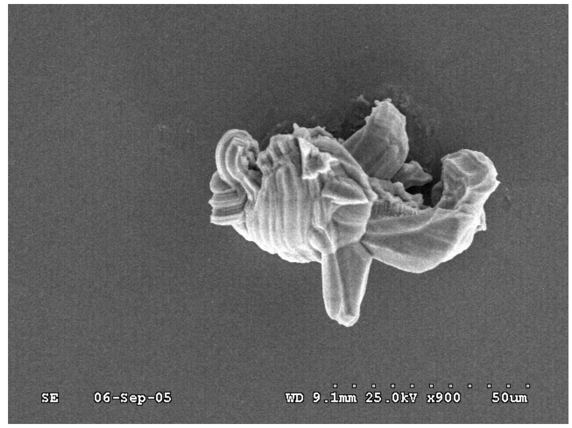


CU-U-2 06
Hillock surface – 4480 um^2 area

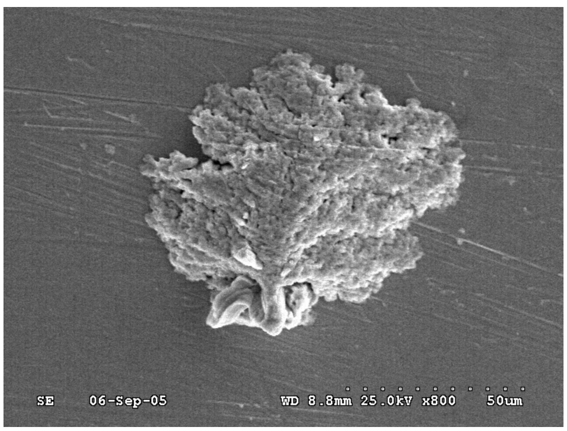
CU-U-2 06
Hillock surface – 50 um diameter



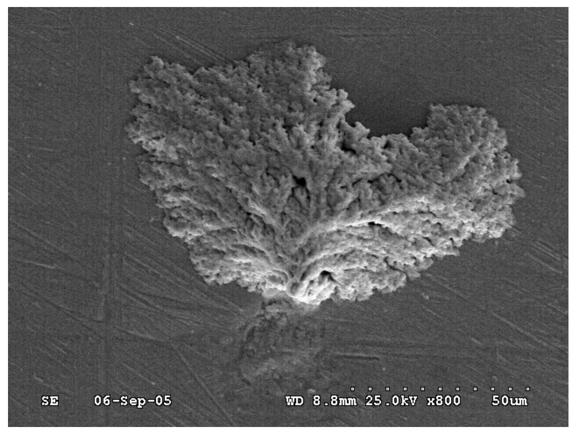
CU-U-2 06
Hillock surface – 112 um length and 97 um width



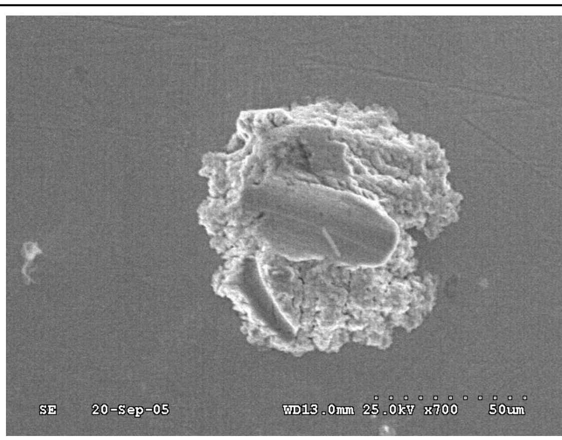
CU-P-5 06
Curved long whisker formation on hillock surface – Protruding 40 um



CU-P-5 06
Hillock surface

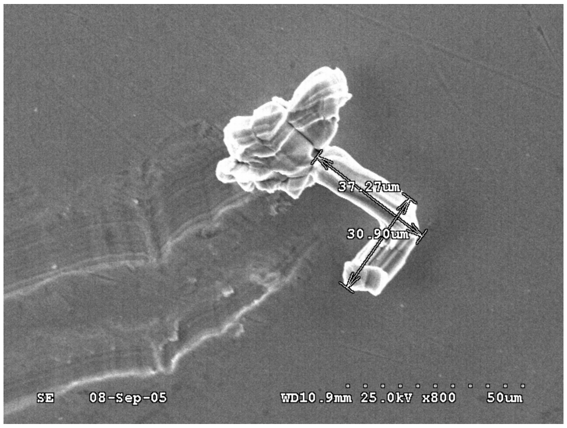


CU-P-5 06
Hillock surface

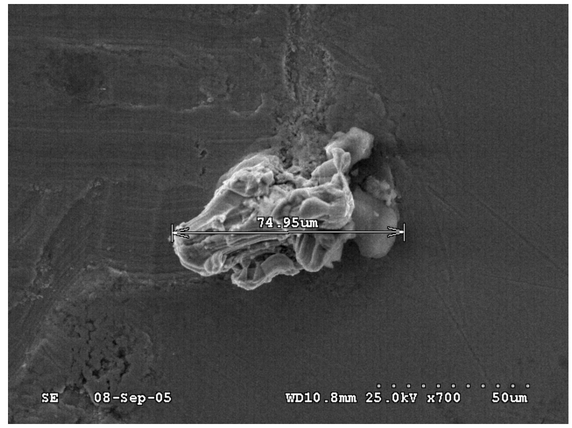


CU-U-1 06
Hillock surface

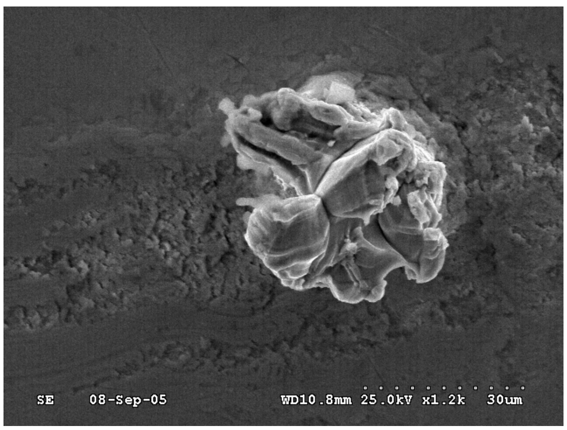
CU-A-2 06
Whisker formation



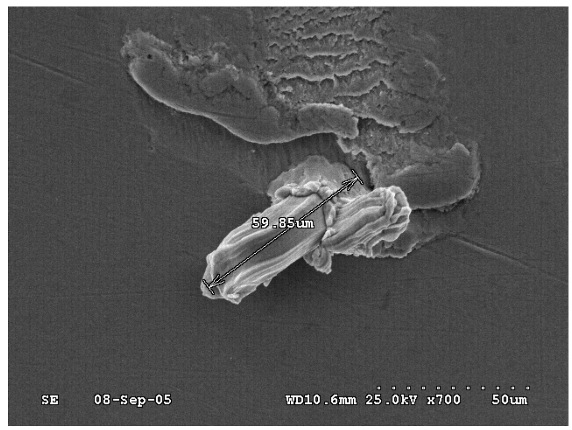
CU-P-5 06
Kinked whisker protrusion – 68 um axial length



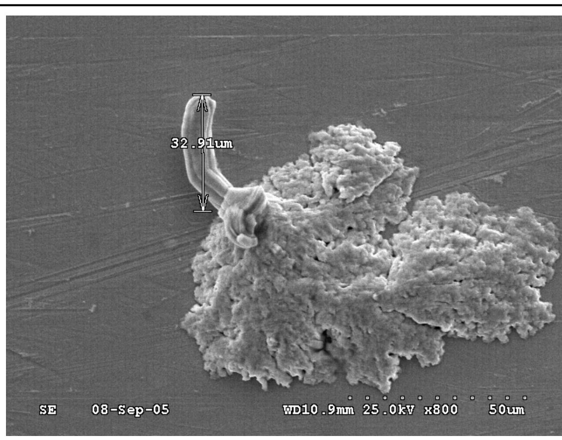
CU-U-3 06
Hillock surface – 75 um in length



CU-P-5 06
Hillock surface



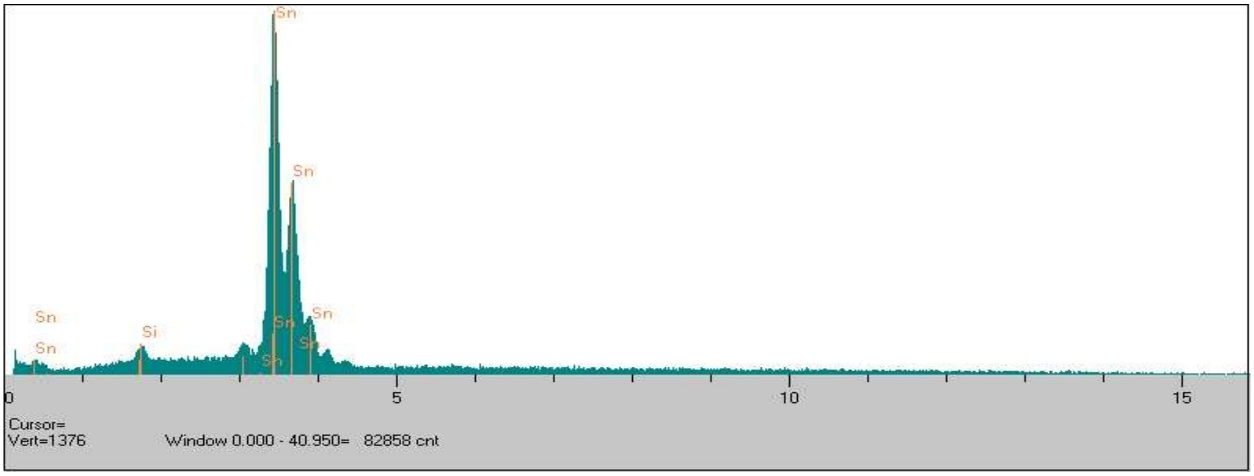
CU-U-3 06
Straight whisker protrusion – 60um axial length



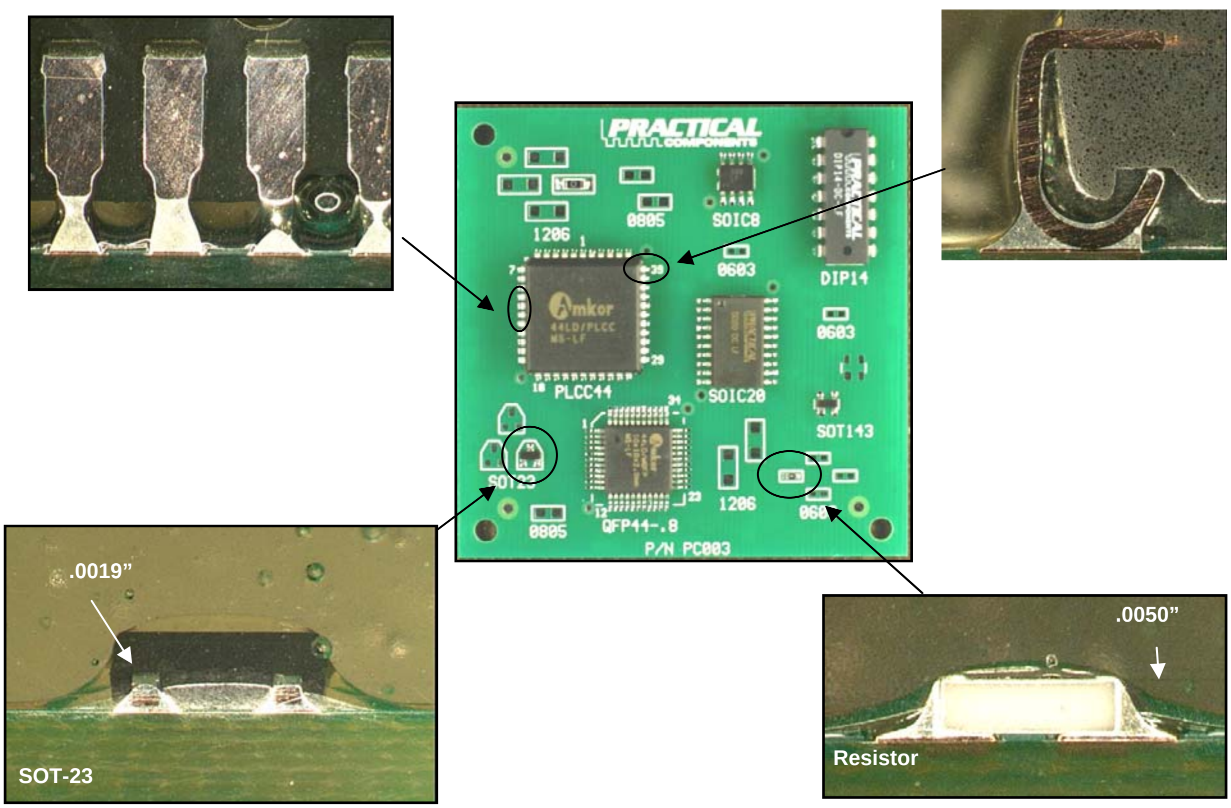
CU-U-3 06
Curved whisker protrusion from hillock – 35 um axial length

CU-A-3 06
Kinked long whisker – 130um in length

This representative EDX spectrum is verification of “Proto-whiskers to be made up of Tin (Sn).



Appendix B – Coating Coverage



Coating thickness application, 3.0 to 5.0 MILS (test coupon averaged 4.6 MILS)

Effect Of Conformal Coating On Tin Whisker Growth

ANALYSIS OF CONFORMAL COATINGS FOR MITIGATING TIN WHISKER GROWTH
2004 – 2007 Test Data

Authors:
Vijay Kumar and Linda Woody
Lockheed Martin Missiles and Fire Control

OCALA OPERATIONS

TEST OBJECTIVES

This test has three primary objectives.

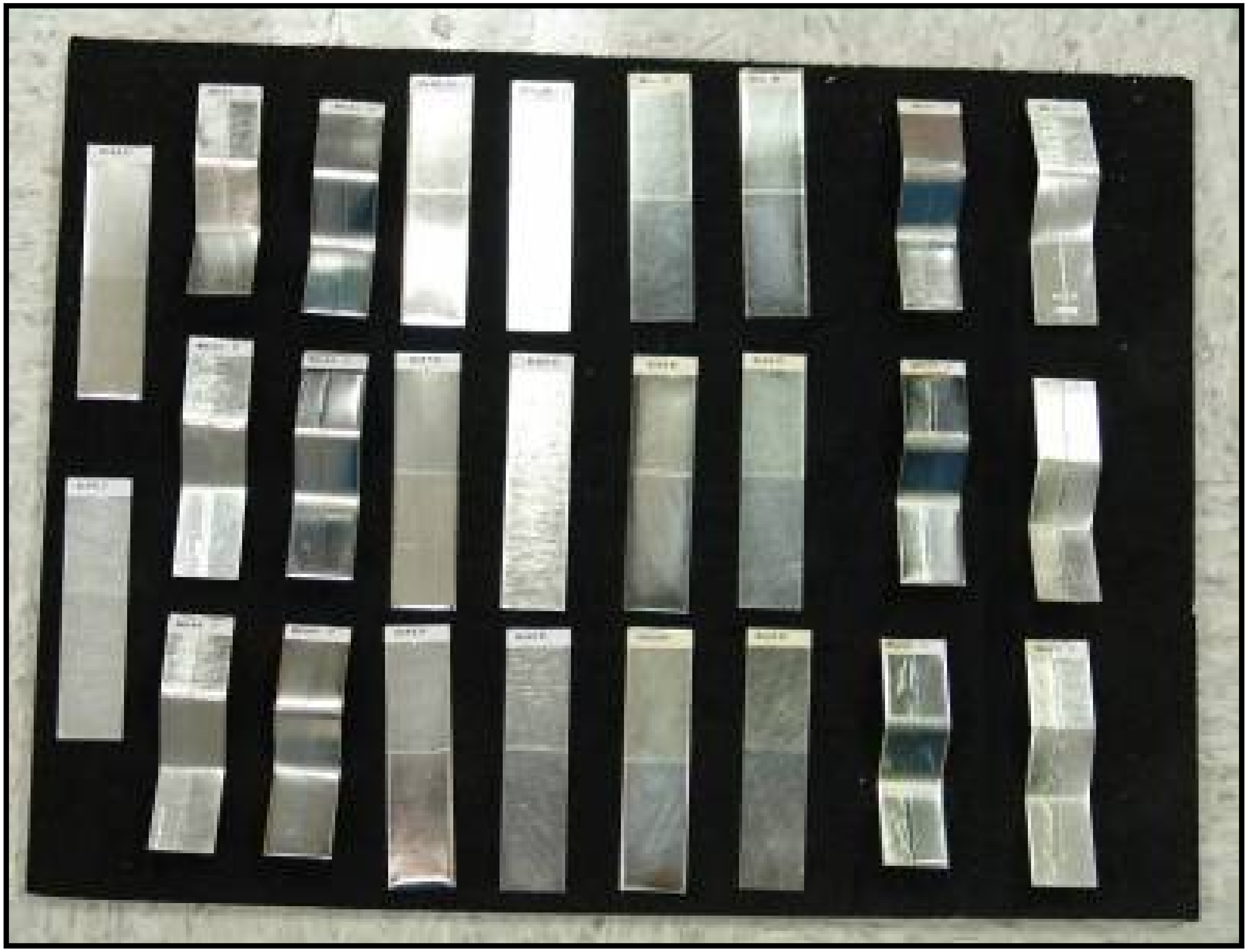
1) Grow Tin Whiskers on the Bright Tin plated test coupons.
2) Provide positive evidence that conformal coating, over a Bright Tin plated coupon protects against Tin Whiskers through growth reduction, abatement or containment.
3) Determine which conformal coating materials and thicknesses provide the best protection against Tin Whisker growth.

Tin Whisker Coupon Testing

- 198 coupons – stressed by bending and scratching
- Copper C110 & Alloy 42 – typical component lead base metals
- Plating vendor same as NASA and CALCE testing
- Bright tin plated with no nickel barrier – worse case scenario intended to promote whisker growth
- 3 coating materials
  - Humiseal 1B31 (type AR)
  - Humiseal 1A33 (type UR)
  - Parylene DPX-C (type XY)
- 3 thicknesses for each coating/coupon combination
  - 1, 2, and 3 mils for type AR&UR
  - 0.5 mils for type XY

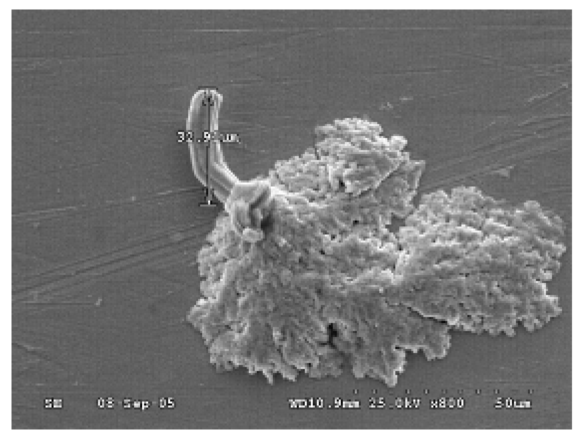
Sample Lot of Coupons

- Copper Baseline
- Alloy 42 Baseline
- Bent coupons
- Scratched coupons
- UR coating 1,2,3 mil
- AR coating 1,2,3 mil
- XY coating .5 mil



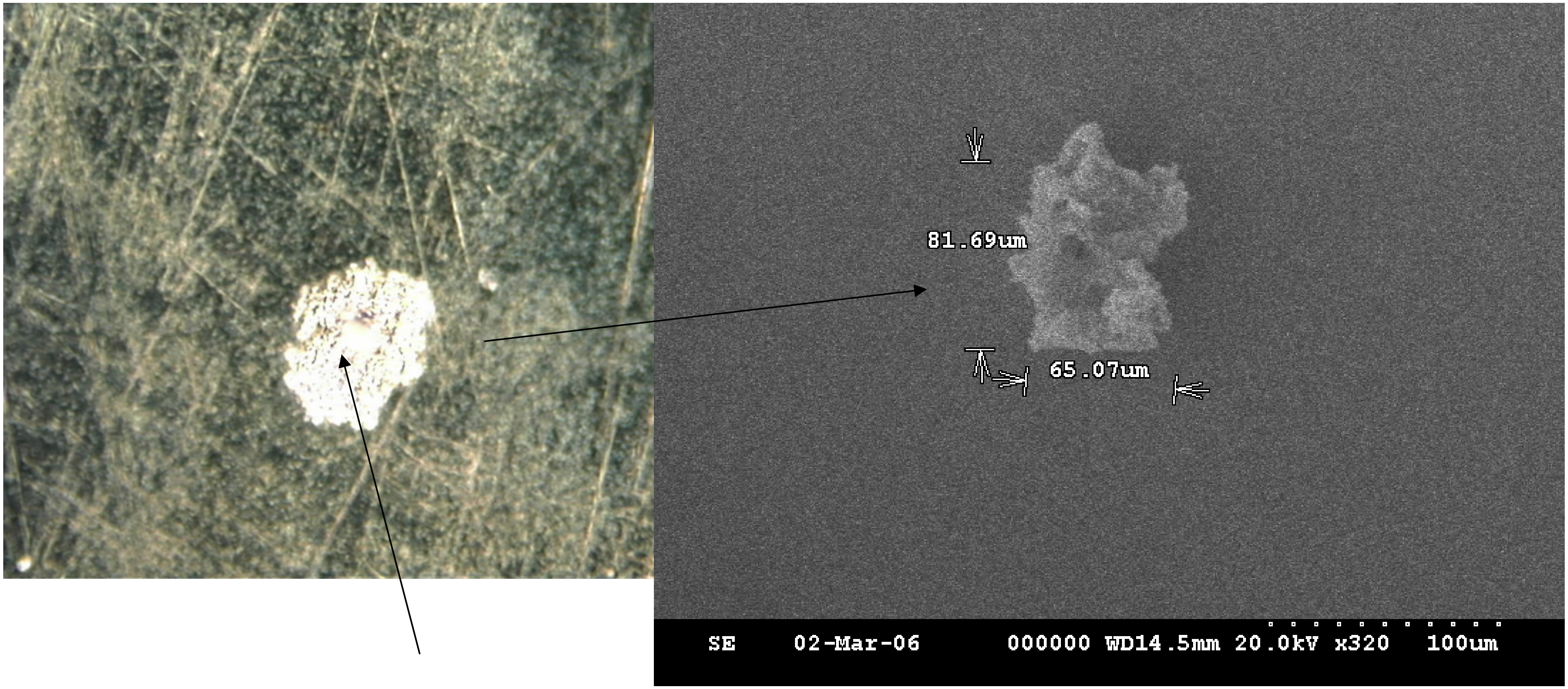
Tin Whisker Coupon Testing

- Results after > 13,000 hours of 50/50 temperature/humidity exposure
  - Whisker growth observed on uncoated areas of numerous coupons
  - No whiskers observed on coated areas



Tin Whisker Coupon Testing

- Results after 15,021 hrs
- 646 hrs in chamber @ 80degC 80%Humidity
- All other hours @ 50degC 50%Humidity
- Sample lot of 14 coupons analyzed
- SEM performed
- Several coated areas appear to contain “fibers” (debris which historically has not been tin whiskers)
- EDS in process



Protrusion

*** Could be a true whisker Hillock – EDS analysis in process**

CU-U-1 07 Un-Coated

*** Probably a fiber (debris) – EDS analysis in process**

AL-U-3 07 coated

Tin Whisker Coupon Test Conclusions

- Heat and humidity accelerated the growth of intermetallics at the interface of the substrate and plating.
- Tin Whisker growth may be due to the compressive stress that was caused by irregular growth of intermetallics. Other theories are not ruled out.
- Tin Whiskers did not grow through any coating on samples through pull six.
- Lot six was in excess of 10,000 hours and the whiskers observed were low in density throughout the coupons.
- There was a medium density of hillocks forming rather than actual whiskers, so further pulls are expected to have additional Whiskers.
- Verification of coating coverage indicates automated select coat process is capable of providing complete coverage of chip packages and complete coverage of sides of leads.

L

Coating Thickness Coverage on Components Process Validation

SELECT COATING COVERAGE PROCESS FOR SMT AND PTH COMPONENTS

OCALA OPERATIONS

Scope:

The scope of the validation task is to assess the conformal coating coverage and thickness on SMT and PTH components, including the sides of the component leads using Urethane (type UR) Humiseal 1A33 coating. At present the requirement per * 79P020004 section 3.3.9.3 is as follows; "-Thickness.- Application shall be such as to obtain a uniform dry film thickness of 0.003 ± 0.002 inches on flat unencumbered surfaces for coating types AR, ER, and UR. For Type SR coatings, thickness shall be .005 ± .003 (see 4.5.2). For application to assemblies other than printed wiring assemblies, the thickness requirement shall not apply but coverage shall be complete." The bases of this testing is tin whisker growth prevention.

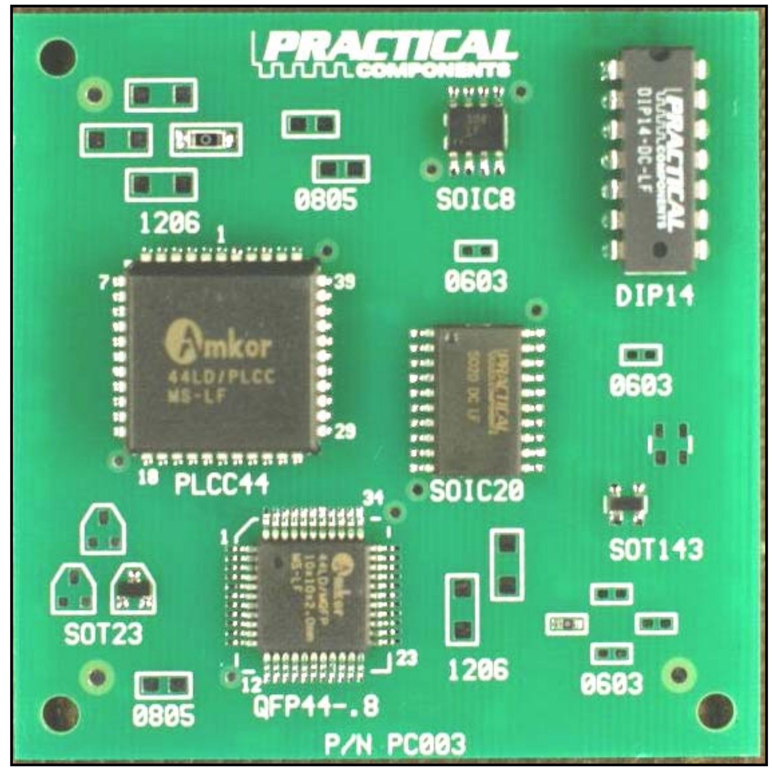
Procedure
Describe procedure for validation task:

1. Build 12 test boards (PC08); qty. 6 with QFP208 and QFP100 (bottom side) and qty. 6 with DIP 14, SOIC8, PLCC44, SOT23, QFP44 - .8, 0603, SOT143, SOIC20, and1206 (top side), by hand soldering all components to PWB's.
2. Clean all test boards using the Triton inline cleaner EQ 798296.
3. Wearing gloves remove boards from cleaner.
4. Place in air-circulating oven for 4hrs. @ 250º F.
5. Photograph for baseline.
6. Label boards for identification, a set of boards consisting of one A side and one B side qty of 2 boards per test:
    a. A/ 1-3 mils (x 2 for all labels)
    b. B/ 1-3 mils
    c. A/ 3-5 mils
    d. B/ 3-5 mils
    e. A/ 5-7 mils
    f. B/ 5-7 mils.
7. Conformal coat both sides of each sample, qty. of 2 sample boards per test, one A side and one B side. Use the Asymtek select coat machine with the swirl head nozzle and atomized. Use material Urethane (type UR) Humiseal 1A33 .
8. Cure coating @ 225º F. for 4hrs. in air-circulating oven.
9. Photograph coated boards.
10. Visual inspection of coating coverage and thickness.
11. Using a micrometer measure coating thickness and coverage photograph and document.
12. Section boards for detailed cross sections.
13. Cut samples into cross sections using saw EQ 733976.
14. Place cut sections in ultrasonic cleaner with water to clean residue.
15. Using mounting materials, mount cross sections.
16. Polish mounts using polishing table wheels EQ 795687 and polishing materials.
17. Using Unitron scope EQ 796058 analysis coating thickness and coverage.
18. Photograph using Nikon scope EQ 796058 and document findings.
19. Optimize coating process: follow above process with the adjustments to coating process.
20. Photograph and document findings.
21. Final report.

Build 12 test boards (PC08);

- qty. 6 with QFP208 and QFP100 (bottom side)
- qty. 6 with DIP 14, SOIC8, PLCC44, SOT23, QFP44 - .8,
- 0603, SOT143, SOIC20, and1206 (top side)

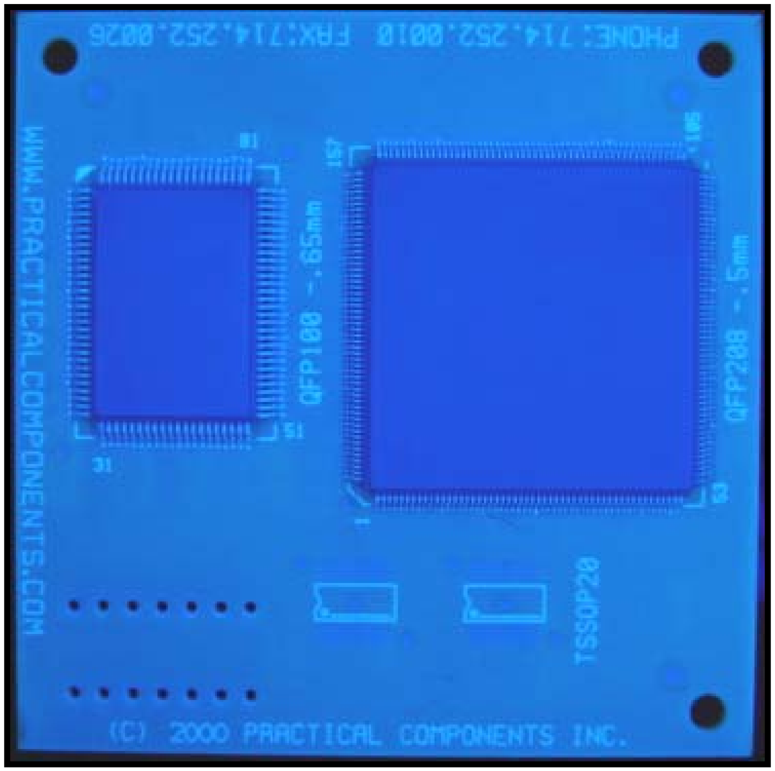
Side A



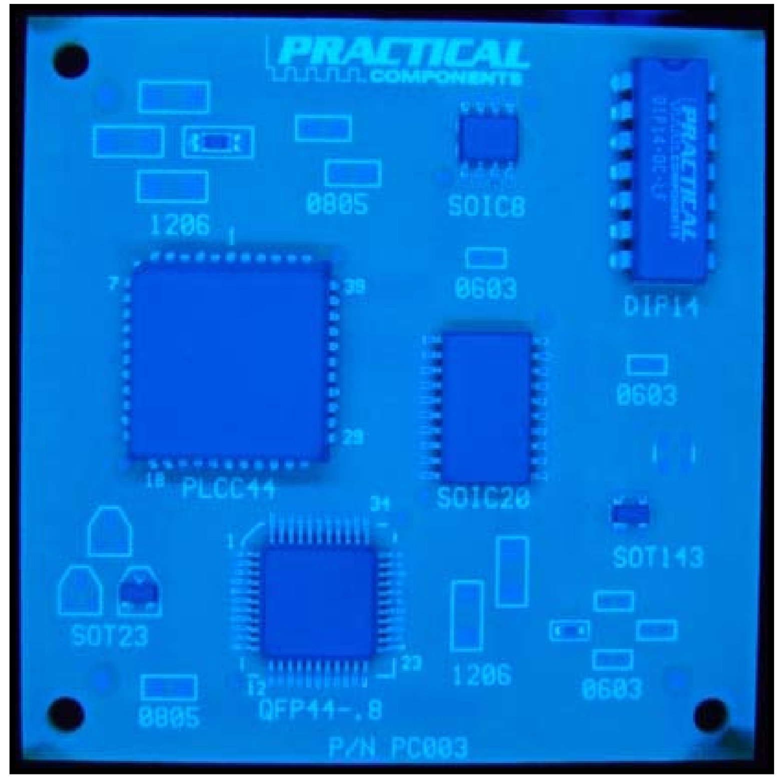
Side B

Overall thickness of boards before coating is 0.061” thick

After conformal coating with 1A33



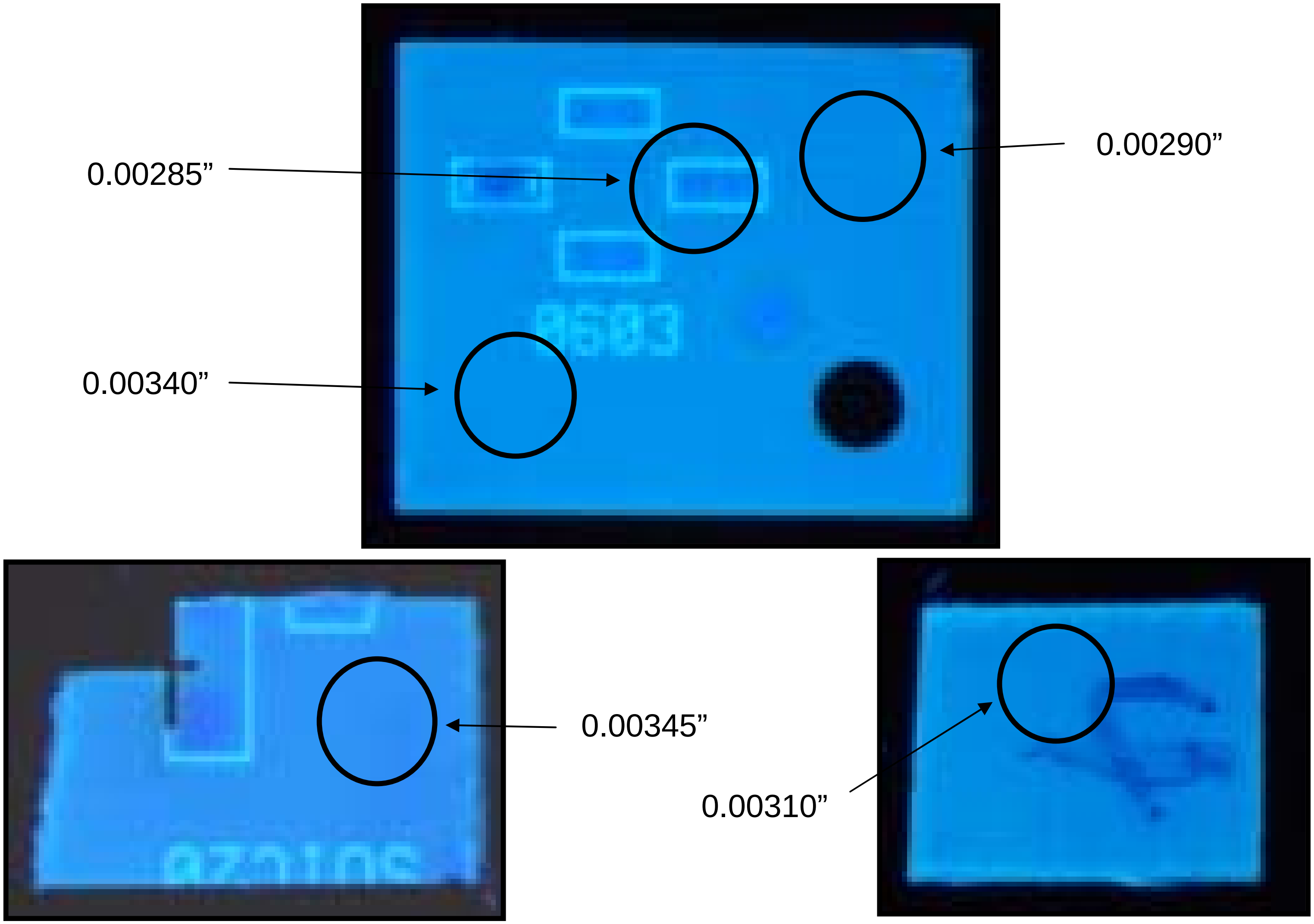
A side



B side

Each set of boards were coated with a different thickness, a set of boards consisting of one A side and one B side board. The coating thicknesses were, 1 to 3 mils, 3 to 5 mils, and 5 to 7 mils.

Surface Measurements with Micrometer on Boards Coated with 1 to 3 mils.

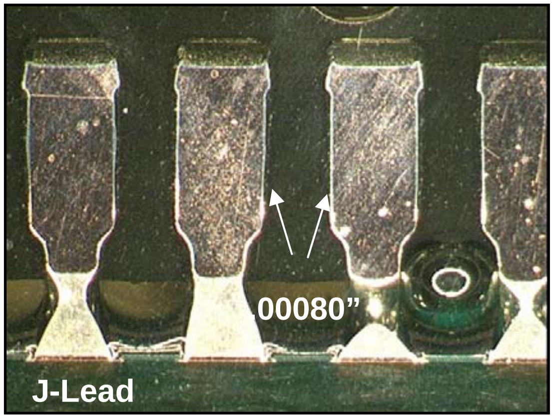


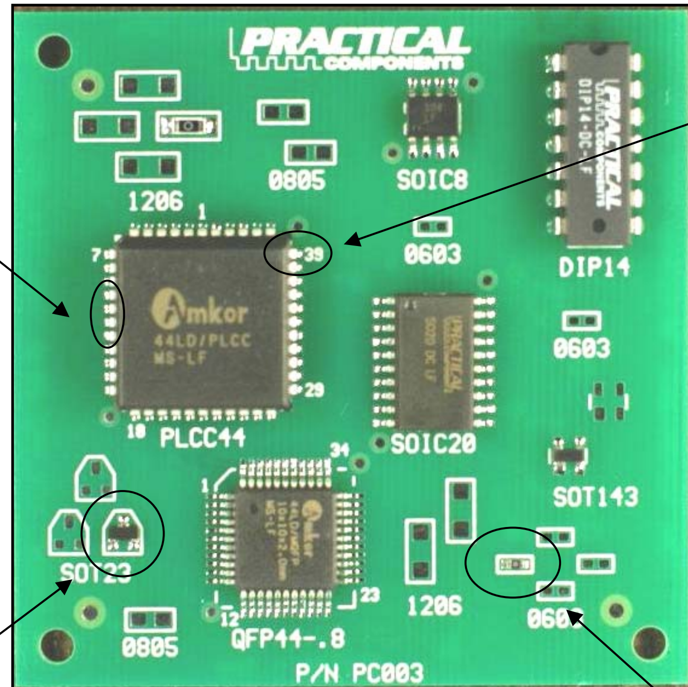
Overall thickness of boards before coating is 0.061” thick. Coating was removed from one side to enable correct measurements / Avg. thickness of coating minus the board =.00 314”

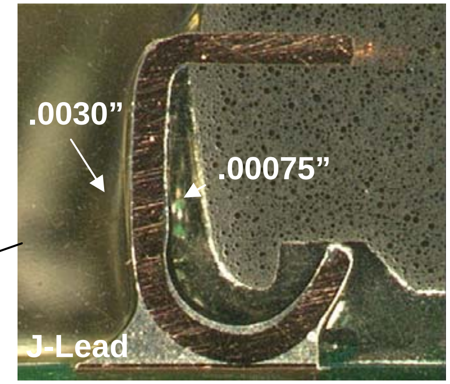
Coating Thickness Measurements Before Mounts

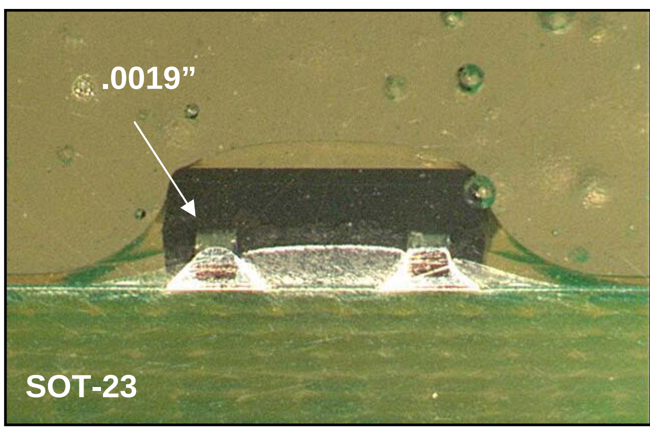
A/1-3	B/1-3	A/3-5	B/3-5	A/5-7	B/5-7
0.00295	0.00285	0.0055	0.00555	0.0045	0.0073
0.0034	0.0029	0.00735	0.00585	0.008	0.0071
	0.0034			0.00546	
	0.0031			0.0055	
	0.00345				
avg.=	avg. =	avg. =	avg. =	avg. =	avg. =
0.003175	0.00314	0.00642	0.0057	0.00586	0.0072

Coating thickness application, 3.0 to 5.0 MILS
(test coupon averaged 4.6 MILS)

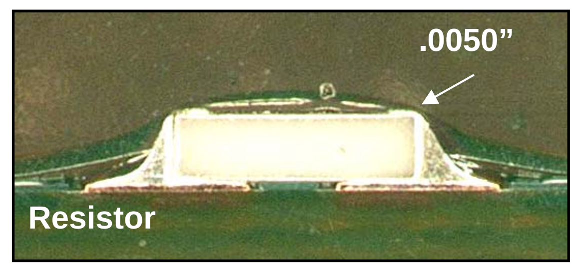








Dimensions are averaged and vary from lead to lead



Coating thickness application, 3.0 to 5.0 MILS
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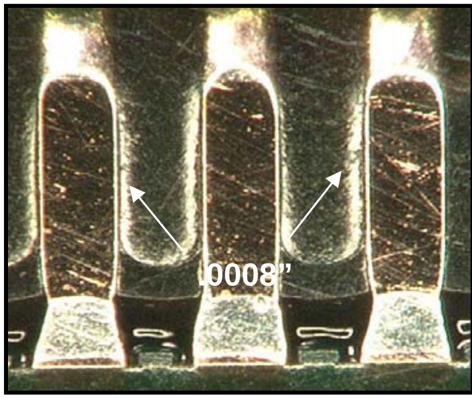
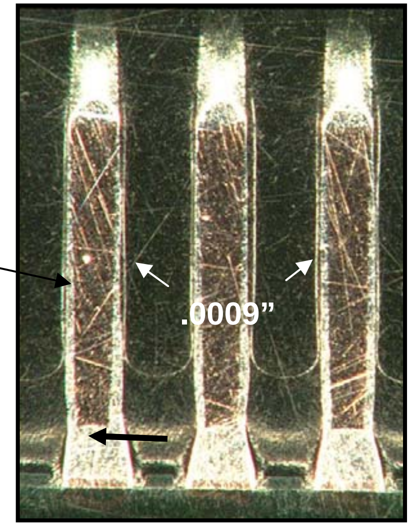
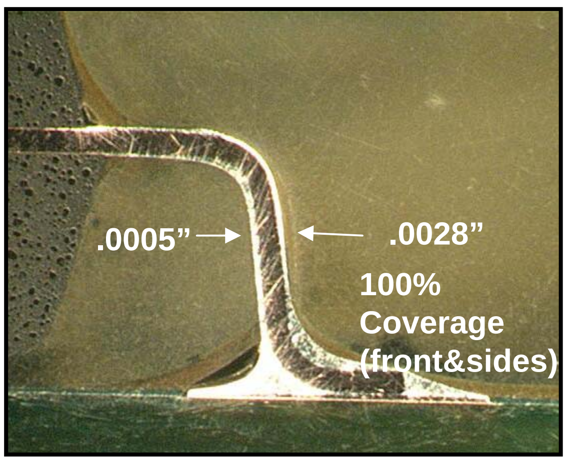


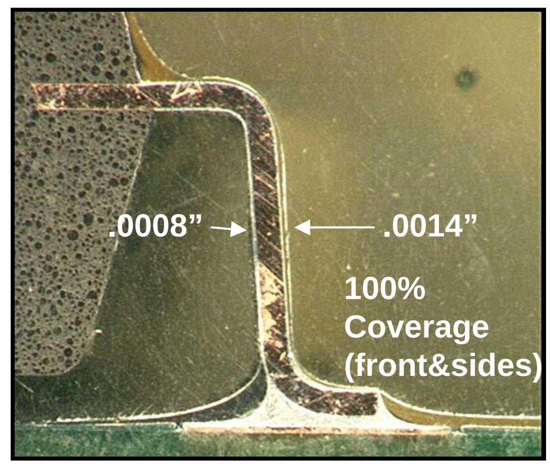
25 mil pitch

20 mil pitch

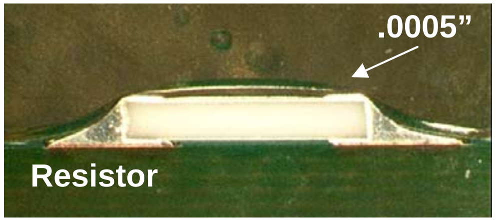


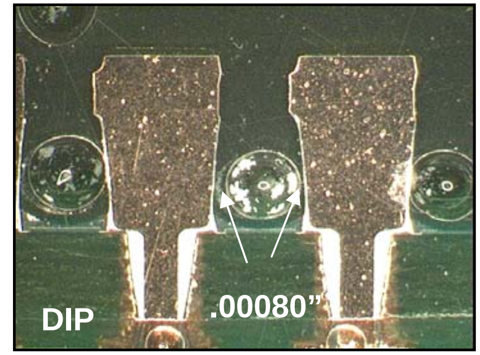


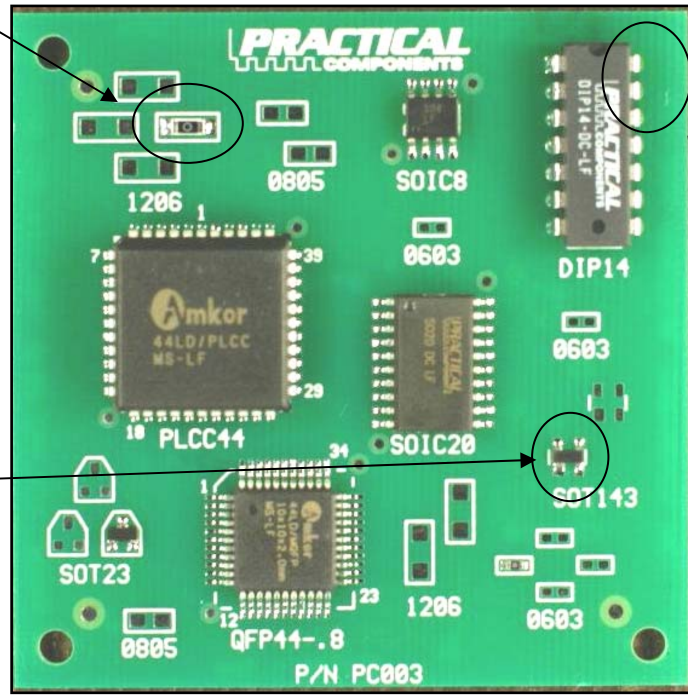
Dimensions are averaged
and vary from lead to lead

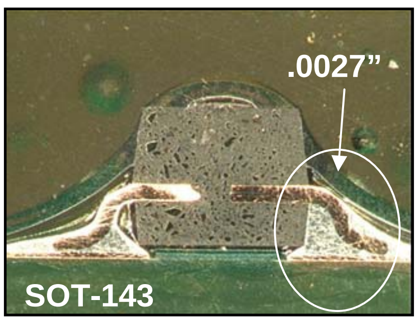


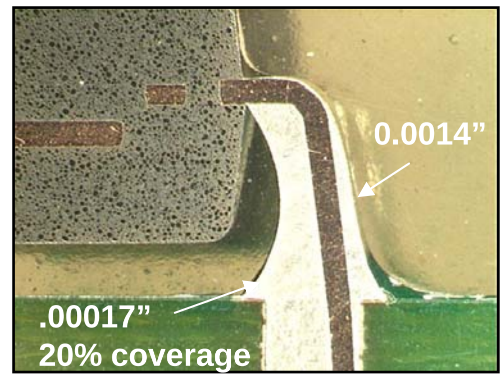
Coating thickness application, 3.0 to 5.0 MILS
(test coupon averaged 4.6 MILS)











Dimensions are averaged and vary from lead to lead

Coat Coverage Test Conclusions

- 3-5 mil samples had 100% coverage with an average of 1 mil of coating on the sides of fine pitch leaded packages
- Other packages (ie. passives, SOT-23, etc.) also exhibit 100% coverage of the exposed conductive surfaces
- 5-7 mils exhibit excessive coating bridging between leads of fine pitch leads
- 5-7 mils type UR is not recommended per the vendor due to cracking during operational life