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April 19, 2005

Paul Hebert
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Re: GIDEP FV5-P-05-01, Final updated version of April 13 Report.

Hello Paul,

We have supplied answers to the four questions asked and have included them following the background, investigations and test results sections. Please review and let us know if you need any additional information.

Background

Novacap provides a full range of termination compositions and has been providing 90%Sn/10%Pb electroplated terminations on ceramic capacitors for space applications for over twenty years. We have not had any reported failures of Novacap capacitors for tin whiskers. Novacap part number suffixes define the termination finish; "Y" indicates 90Sn/10Pb and "N" indicates 100% Sn.

We have participated with other customers in discussions and analysis of the variables that reduce tin whiskers. Working closely with Boeing/JPL/NASA we duplicated the NASA tin whiskers study and correlated with their results. Both studies identified parameters that minimize the length and quantity of tin whiskers resulting from **thermal cycling**. The use of **Ag termination** versus Cu reduces whiskers. **Higher plating thicknesses** of nickel and tin or tin/lead alloys reduce whiskers. The **addition of Pb** in Sn plating reduces whiskers. Use of **matte** Sn/Pb chemistry versus bright chemistry reduces whiskers. The use of **annealing** process after plating reduces whiskers. The process of **reflow** reduces whiskers. We are aware that **Tin/Antimony and Tin/Bismuth** have been determined to not grow whiskers. The other test conditions run in both studies did not produce whiskers.

Novacap has historically controlled the plated composition by maintaining chemistry of the plating bath solutions, according to the vendor specifications. Furthermore, the plating bath contains 90Sn/10Pb metal anodes, which directly dissolve and maintain the metal content at all times. Bath titrations are done at Novacap on a regular basis as well as samples verified at an outside lab to assure 90Sn/10Pb chemistry. NASA/Boeing and MIL-PRF-38534 require a minimum of 3% Pb to prevent tin whiskers. Novacap's X-Ray Fluorescence (XRF) is calibrated with Veeco certified standards and is used to measure the compositions and plated thicknesses to assure we meet this minimum Pb content.

International Rectifier instituted an EDS-measured verification of composition to assure the Pb content. IR reported two lots both measuring 1.4% Pb and one lot measuring 7.37% Pb. Novacap's XRF results indicate all three in excess of 5% Pb. IR indicated that EDS was their measurement of choice and that lots must meet their measured limits or be rejected. Novacap accepted returns for lots that measured acceptable on XRF at Novacap and began investigations to assess measurement techniques.

Investigation

We interviewed a variety of individuals with various backgrounds in an attempt to gain a better understanding of the EDS capability versus XRF:

Cyrus Razmara, American Environmental Testing Laboratory

- ICP expert/PhD in Chemistry from Empirical College University of London/30 yrs in chemical and compositional analysis.

Ron Barauskas, Rohm/Haas Electronic Materials

- Beta backscatter/EDS/XRF/plating chemical expert.

Edward Li, AEM Inc

- EDS/XRF/plating expert

Joe Brady, Fischer Technology

- XRF expert

Hans Shin, Pacific Testing Laboratories

- EDS expert

Frank Ferrandino, Matrix Technologies

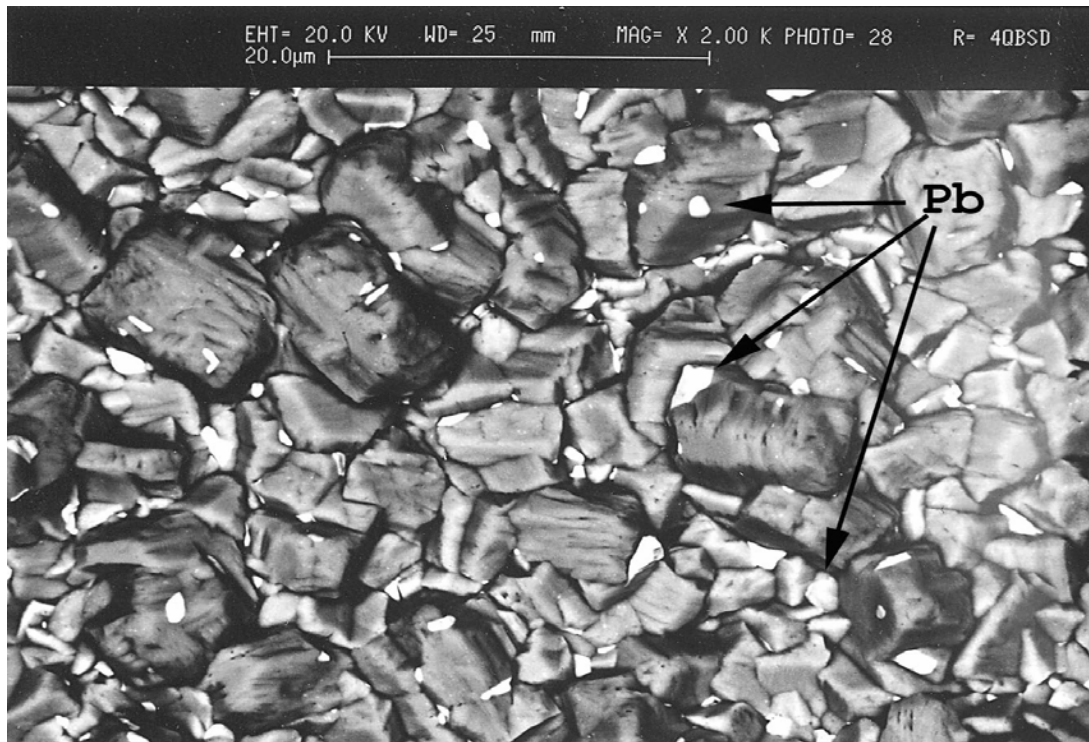
- XRF/EDS expert

All these industry experts indicated a similar experience of different %Pb composition readings when using EDAX vs. XRF measurements, and that XRF should be more accurate than EDAX based on the larger area and depth of measurement performed by XRF.

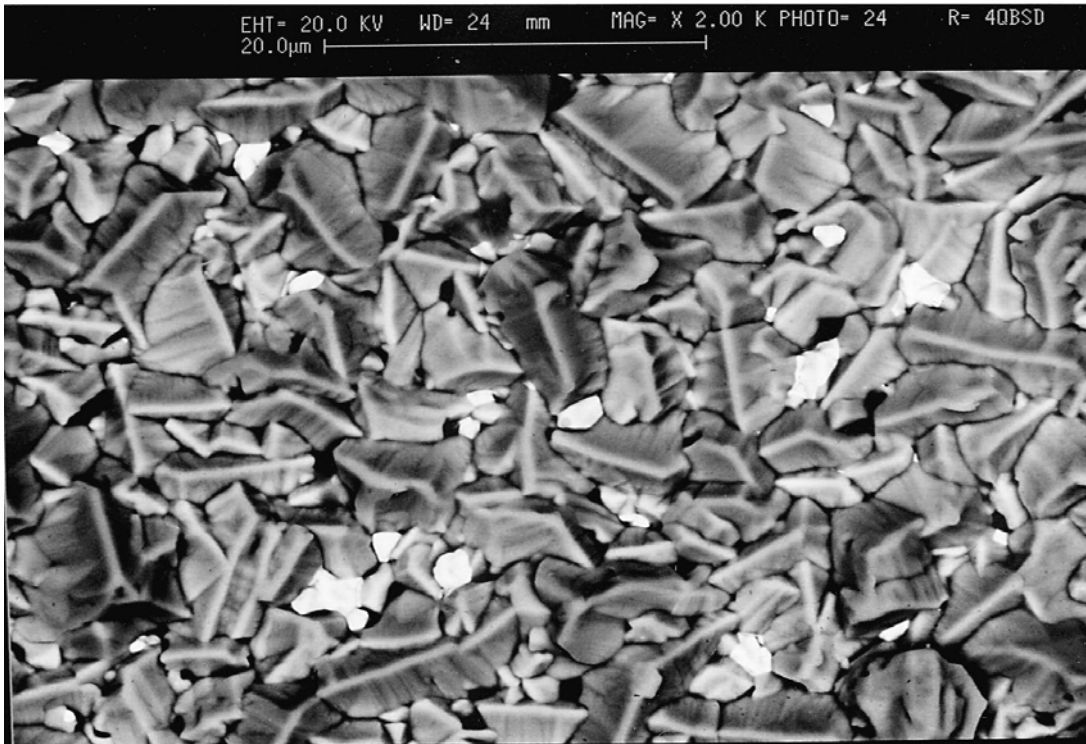
XRF uses certified standards for calibration, uses highest energy lines to determine elements and has the capability of measuring a depth up to 3,000 micro-inches.

According to the experts, SEM/EDS is a semi-quantitative standard-less test, which uses lowest energy lines to determine elements and measures a depth of approximately 40 -120 micro-inches.

Sn-Pb plating is typically non-homogenous in appearance, whereas the Pb appears like pepper scattered throughout the Sn crystals, as seen under SEM magnification (the white particles are Pb and the other areas are Sn). If the sample area measured happens to be an area of low lead concentration, this can contribute to error in an EDS measurement. This photo is of 7% Pb in composition:



This photo is of 10% Pb composition.



We think the minimal depth and area capability of the EDS combined with the typical non-homogenous Sn/Pb plating may result in inaccurate and inconsistent measurements. The XRF, with greater depth of field will measure a much larger volume sample, resulting in a more consistent and accurate measurement. We believe the data from the three lots mentioned above indicates the possible inconsistency in the reported EDS tests.

It was decided to verify controlled samples on XRF, EDS and ICP. ICP stands for Inductively Coupled Plasma and utilizes an acid digestion process to completely dissolve the sample and provide quantitative element results. Our thought is that ICP will remove measurement and sample variations and give us the most accurate result.

Test Results

Two of the test groups consisted of 85Sn/15Pb plated onto brass plates and copper strips, to remove any possible substrate effect (the ceramic capacitor material) from the ICP analysis. The Sn/Pb was scraped off some brass plates, and the scrapings analyzed separately, as an additional group to help eliminate any substrate effects in ICP. The Sn/Pb plating bath was certified at 11.7% Pb during the plating of these 3 plating tests. The results of ICP on the copper strips, brass plates and 85Sn/15Pb scrapings correlate with XRF much more closely than EDS. ICP showed the pure Sn/Pb scrapings as 15.8% Pb. The following shows the % Pb measured by each test method:

	<u>XRF</u>	<u>EDS</u>	<u>ICP</u>
Copper Strips 85/15	17.6 – 22.6	12.56-27.44	24.6
Brass Plates 85/15	12.5-20.7	31.73-60.45	20.8
Brass Scrapings 85/15	11.5-22	17.5-39.8	15.8

We sent two capacitor samples (one of which was returned from IR for low Pb from lot # 200330067) for ICP testing. The results of ICP and XRF appear much more similar than the EDS results. We believe this data gives an indication that the EDS method may not be the most accurate method.

	<u>XRF</u>	<u>EDS</u>	<u>ICP</u>
0402N101K500Y Lot 200330067	6.5-8.1	1.4	10.8
0805B471M101Y Lot 200402089	3.1-4.3	0.3-2.9	3.8

A final additional test performed solely at Novacap, was to measure the %Pb of various Pb composition platings by XRF. The composition 85Sn/15Pb, plated directly over nickel-plating, was found to give the expected 15% Pb content. However, when this same plating solution was plated over the top of a previously plated 100Sn/Ni part, the resultant XRF reading measured only 8% Pb, confirming that the XRF indeed penetrated through the entire thickness of Sn and Sn/Pb plating, and came up with an averaged %Pb for the two levels of plating. Once again, the XRF confirmed its depth of measurement and accuracy.

Root Cause

We believe the root cause of this issue at Novacap is due to the implementation of the EDS measurement at IR. It is stated in the problem description that “an investigation at Novacap revealed that the plating line chemistry did not produce the required amount of Pb” and further attributed Novacap with inadequate testing and analysis methods. We think the statement is not clear, and should instead state that the EDS results do not correlate to our plating line chemistry and we believe there is no information presented that confirms inadequate testing and analysis methods. Based on the data generated and information shared above, we believe our measurements are more accurate than the EDS implemented at IR. Additionally, we have not had any issues of failure reported to us, which reinforces our position that the controls of chemistry and XRF have produced conforming products for over 20 years.

Additionally, tin whiskers are known to grow even in verified 90Sn/10Pb plated compositions. The NASA study, as well as our own, verified presence of a small quantity of whiskers in the 5-10 um ranges with Sn/Pb plating. One large US-based electronics company has developed classifications based on the length of whisker grown under defined conditions. Our components have been classified as acceptable criteria A-2, passing their most stringent whisker length criteria with our 90Sn/10Pb and also passing their acceptable criteria A-1 with 100% Sn.

Corrective Actions

We implemented a change to our Pb targets in order to comply with the EDS measurements at IR. Our Pb range of the bath solution changed from 9-15% to 15-20%. Our specification of measured Pb content by XRF on finished parts has been increased to a minimum of 10%.

What lots or date codes are affected?

Returns were accepted on all parts identified by IR as not meeting their EDS measurement. Once we were informed of the EDS requirement and observed the poor offset correlation, the CA was implemented to assure we complied. We have systems in place to assure all outgoing product is verified prior to release. We do not believe there are any other lots affected.

Are there possible similar issues to other products at Novacap?

No, we do not see any correlation to other items.

Could this problem be systemic to other manufacturers?

We cannot answer with certainty. We are a specialty supplier that offers a variety of compositions and will continue to do so. Much of the world is trying to eliminate Pb and some suppliers may no longer offer 90/10. Each manufacturer will have to be addressed individually at the time of purchase to assure the customer and supplier has a clear understanding and agreement on the requirements.

Please let us know if you need any additional information.

Sincerely,

Brian D. Crowley
QA Manager