

SNIAG

Tin-Silver



MARJAN INCORPORATED

Since 1972

Chicago, IL • Waterbury, CT

Members: IICIT - International Institute of Connector & Interconnect Technology
ACC - American Copper Council

ISO 9001:2000
File# A6711



SINAG

Tin-Silver



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Presented By:



marjan inc

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Why Tin-Silver?

A lower cost structure to 100% Gold or Silver.

Gold

\$4,032.29

* per pound

Silver

\$67.08

* per pound

Tin

\$1.92

* per pound

*Raw material cost as of 1/2/02

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Tin-Silver Saves You Money



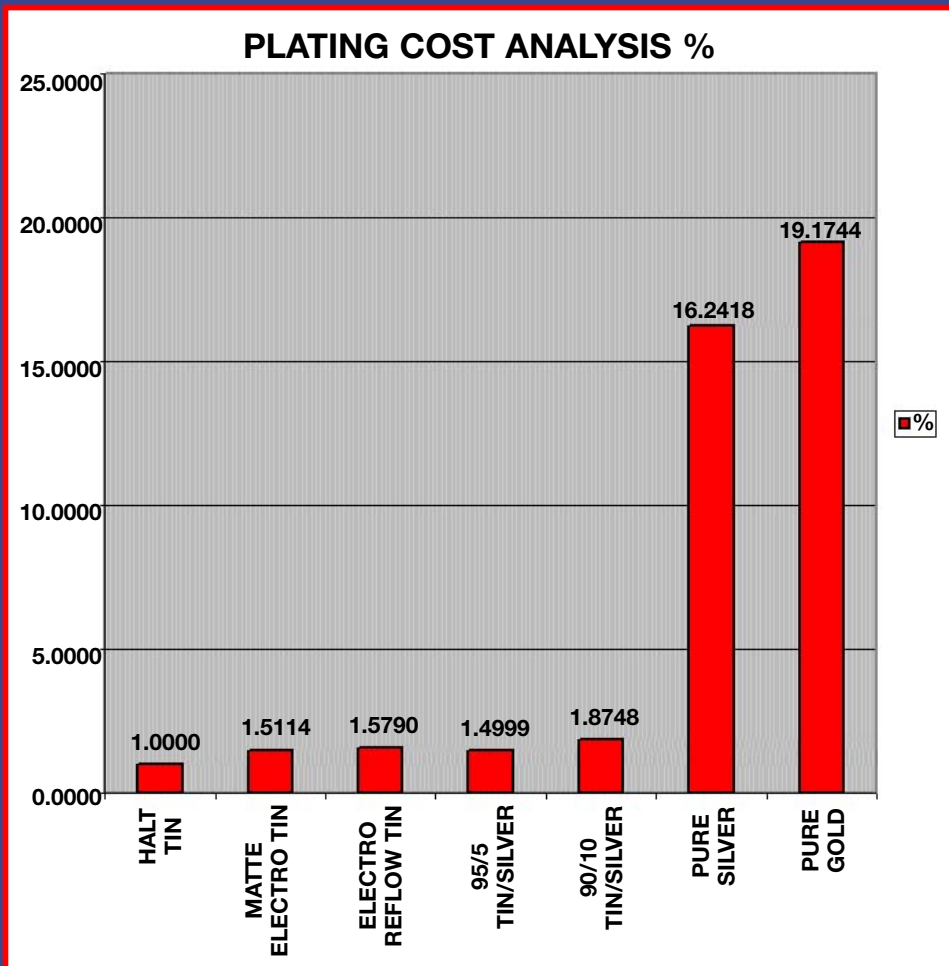
Tin-Silver

\$6.33

*** per pound**

*Raw material cost as of 1/2/02

Tin & Tin-Silver Cost Structure



- HALT (100% Tin) coatings were assigned a value of 1.0000. Other platings reflect cost % from HALT.
- Percentage values based on a cost per pound of base material coated. Prices were gathered based on coating thickness of .00005/.00015" (1.3-3.9 um) per side of strip. Base metal .010 x 6" copper alloy strip.

**** These are value added costs for PLATING ONLY ****

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Marjan produces

the viable alternative for automotive terminals



Class #2



Class #3 & #4

Analytical Techniques: SEM & EDS

Scanning Electron Microscopy (SEM)
Energy Dispersive X-Ray Spectroscopy (EDS)

**Surface Composition:
Plated 95/5 Tin-Silver Strip**

Testing for the silver separation and suspension

Test conclusions

- The as-received surface and plating cross-section was elementally analyzed in twelve (12) locations.

The results are presented in Tables 1 and 2 to follow.

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Analytical Techniques: SEM & EDS

Table 1

Surface Elemental Composition (Weight %)

<u>LOCATION</u>	<u>SILVER</u>	<u>TIN</u>
1	4.90	95.01
2	4.05	95.95
3	4.98	95.02
4	4.41	95.59
5	5.10	94.90
6	4.73	95.27
7	6.17	93.83
8	5.46	94.54
9	3.84	96.16
10	5.41	94.59
11	4.70	95.30
12	4.52	95.48

Table 2

Cross-Section Elemental Composition (Weight %)

<u>LOCATION</u>	<u>SILVER</u>	<u>TIN</u>
1	4.97	95.03
2	3.90	96.10
3	4.75	95.25
4	5.90	94.10
5	3.74	96.26
6	4.41	95.59
7	3.89	96.11
8	3.52	96.48
9	4.79	95.21
10	3.30	96.70
11	4.93	95.07
12	4.19	95.81

**Plated
95/5
Tin-Silver
Strip**

Analytical Techniques: SEM & EDS

Scanning Electron Microscopy (SEM)
Energy Dispersive X-Ray Spectroscopy (EDS)

**Surface Composition:
Plated 90/10 Tin-Silver Strip**

Examination of surface

- The as-received surfaces were examined by SEM/EDS.

Test conclusions

- Both surfaces showed a smooth, plated structure with no sulfur or other contamination.

The results are presented in Table I to follow.

Analytical Techniques: SEM & EDS

Table 1

**Plated
90/10
Tin-Silver
Strip**

Elemental Composition (Weight %)			
<u>SIDE/AREA</u>	<u>COPPER</u>	<u>SILVER</u>	<u>TIN</u>
1-1	2.44	8.62	88.93
1-2	2.88	7.44	89.63
1-3	2.28	9.06	88.66
1-4	2.05	9.10	88.85
1-5	2.25	9.09	88.66
2-1	1.84	6.68	91.48
2-2	2.47	7.44	90.09
2-3	2.23	7.46	90.31
2-4	2.36	6.44	91.19
2-5	2.57	7.79	89.64

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Coating Hardness

*Tests prove by adding Silver to the Tin bath, we increase the hardness of the coating by

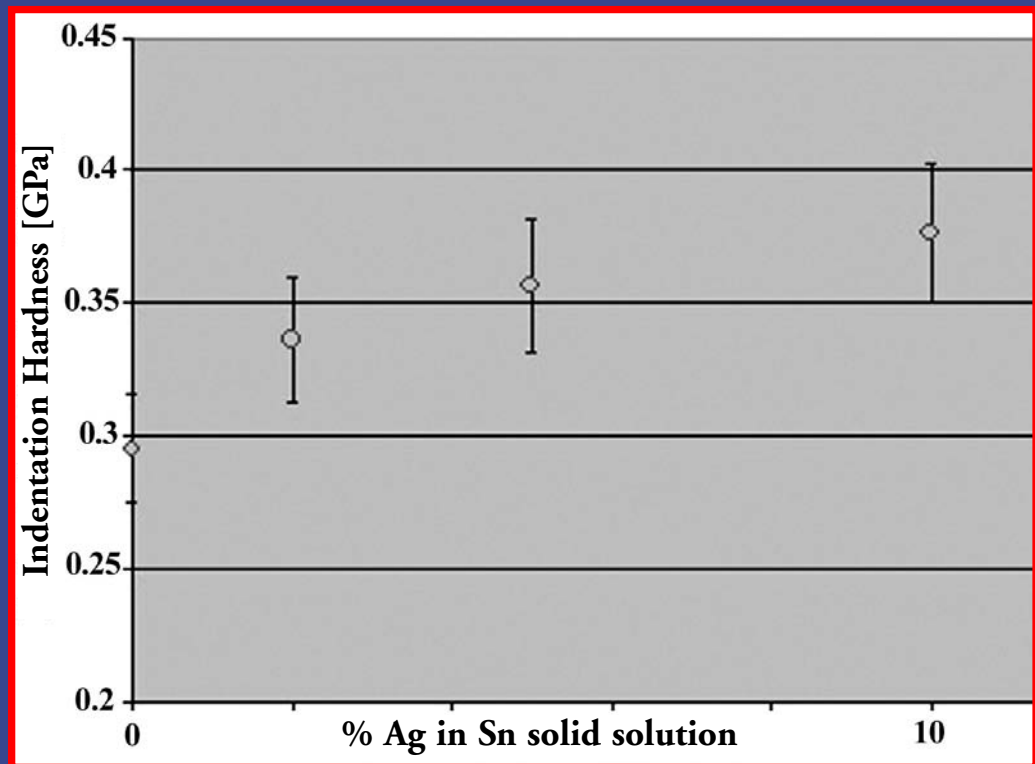
27%

* Lexcom Tests 8/21/01

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Lexcom Tests:

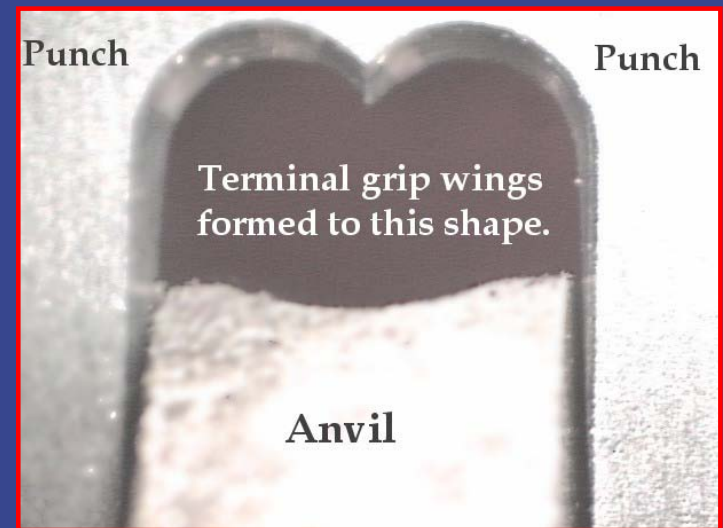
Increased hardness is evident with increase of Ag content



Indentation hardness of Sn-based films as a function of %Ag.

SNAC 27% Increase in Hardness =

- enhances the coefficient of friction values
- improves engage-disengage forces
- no galling detected after crimping on either the crimp or crimping tool



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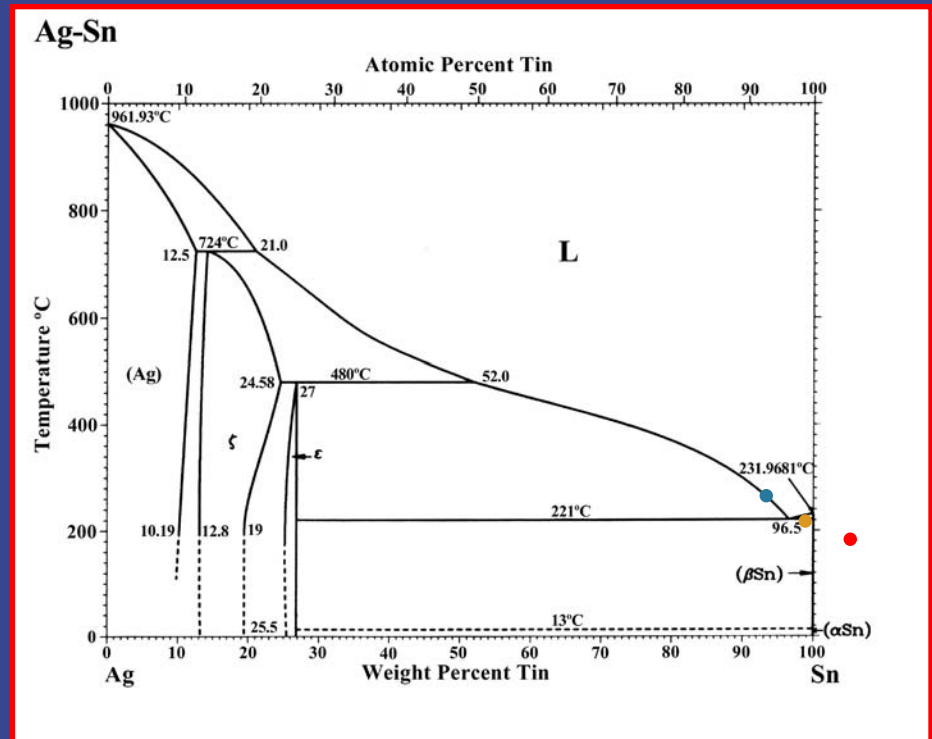
Melting Points:

Binary Alloy Phase Diagram

100% Pure Tin 231° Celsius

95% Tin - 5% Silver 255° Celsius

90% Tin - 10% Silver 315° Celsius



MELTING POINTS:

100% Pure Tin: 231.9681 Degrees Celsius

Silver: 961.93 Degrees Celsius

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Lab Tests Performed:

USCAR Performance Standards

Automotive Electrical Connector Systems Revision #3

- temperature/humidity cycling
- 1008 hour current cycling (one of the tests that simulates 10-year or 100,000-mile life expectancy for a terminal)
- dry circuit resistance, etc...

- Test conclusions**
- the temperature/humidity tests show the Tin-Silver, electrically, to perform as well as 100% Silver
 - cosmetically, Tin-Silver looked much better

These are some examples of the many tests performed that conform to the USCAR Performance Standard for Automotive Electrical Connectors

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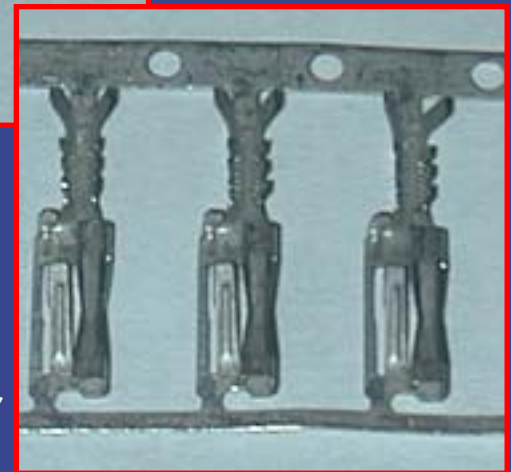
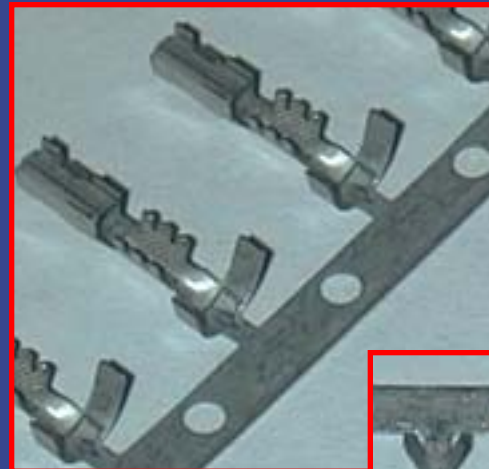
Lab Tests Performed:

Ammonium Sulfide Soak

100 hour soak at a Ph 5.8 level with both mated and unmated terminals

Test conclusions

- the test showed that after the 100 hour soak the Tin-Silver to be well acceptable with comparison to 100% Silver



These are some examples of the many tests performed that conform to the USCAR Performance Standard for Automotive Electrical Connectors

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Lab Tests Performed:

High Temperature Exposure

Thermal aging may cause changes in metal and plastic materials, including stress relaxation in important flexing members of the terminal or its connector. These changes may be detrimental to electrical and physical performance.

- Test conclusions**
- the combination of Tin-Silver coating survives high temperature exposure
 - ideal coating option for pure Silver and pure Gold applications, as well as an upgrade for 100% Tin applications

These are some examples of the many tests performed that conform to the USCAR Performance Standard for Automotive Electrical Connectors



Lab Tests Performed:

Temperature Classifications

Class	Ambient Temperature Range	Potential Peak Temperature (Ambient + Rise)
1	-40° C to + 85° C	+105°
2	-40° C to +100° C	+120° C
3	-40° C to +125° C	+145° C
4	-40° C to +155° C	+175° C

FIGURE 5.1.4: Component Temperature Classes

Reference section 5.1.4 of the USCAR/EWCAP Testing

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Lab Tests Performed:

Examination of Grain Structure

test

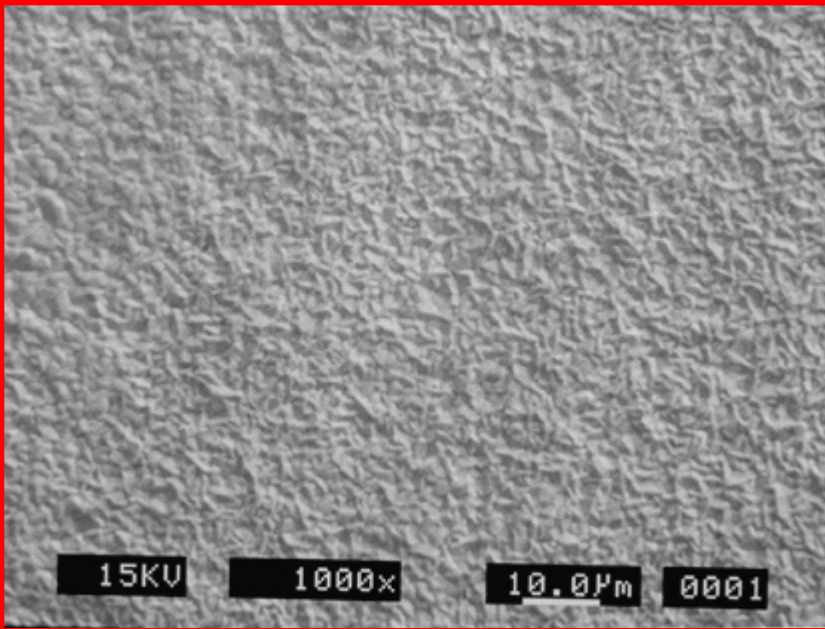
Samples examined by **Optical Microscopy (OM)** and **Scanning Electron Microscopy (SEM)**

- #1 Electro Plated Tin - Matte, was examined in the as-received condition
- Samples #2, #3 and #4 were etched with: 2% HC, 5% HNO (sub3), and 90% Alcohol

SNAG Grain Structure

Sample 1

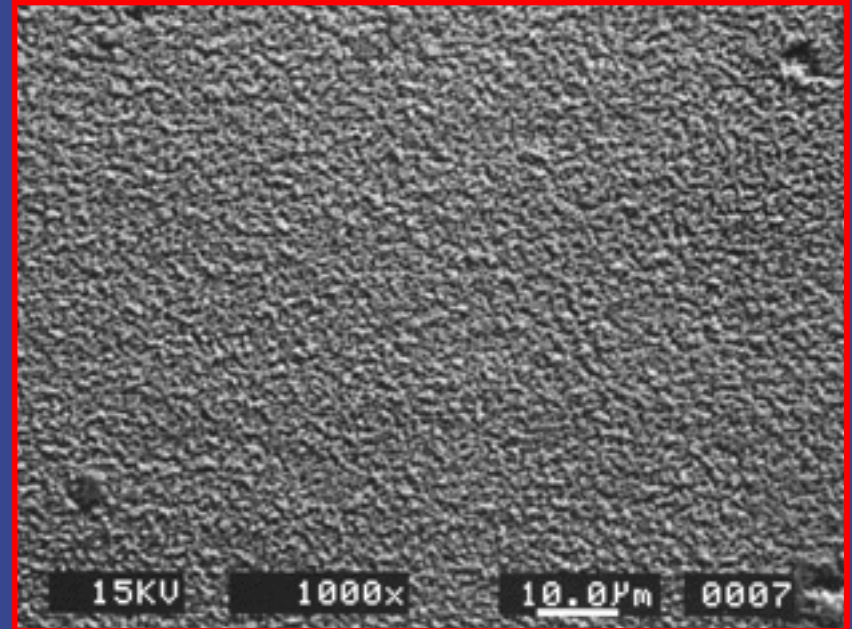
**Electro Plated Tin
- Matte**



M-5 EP TIN-MATTE SEM-1000x

Sample 2

**Electro Plated Tin
- Bright**

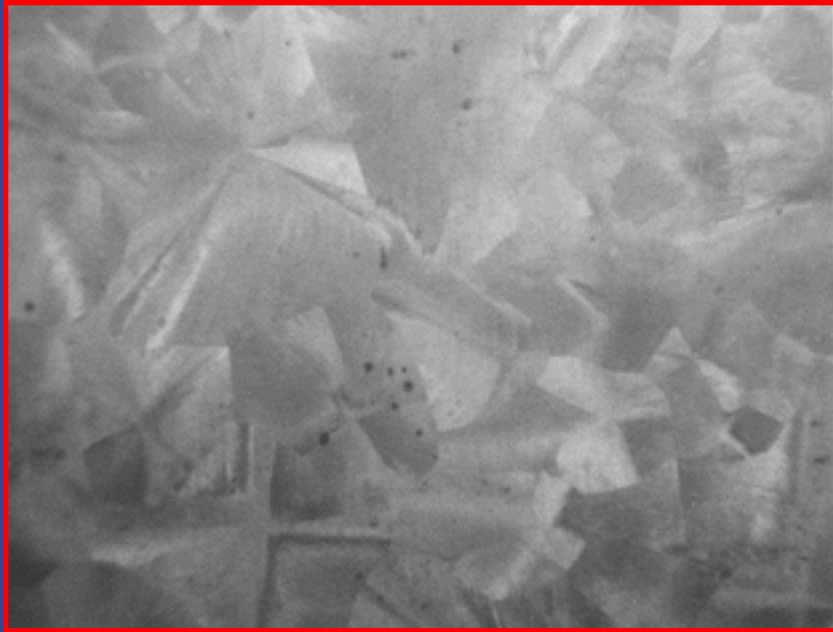


M-10 EP TIN-BRIGHT SEM-1000x

SNAG

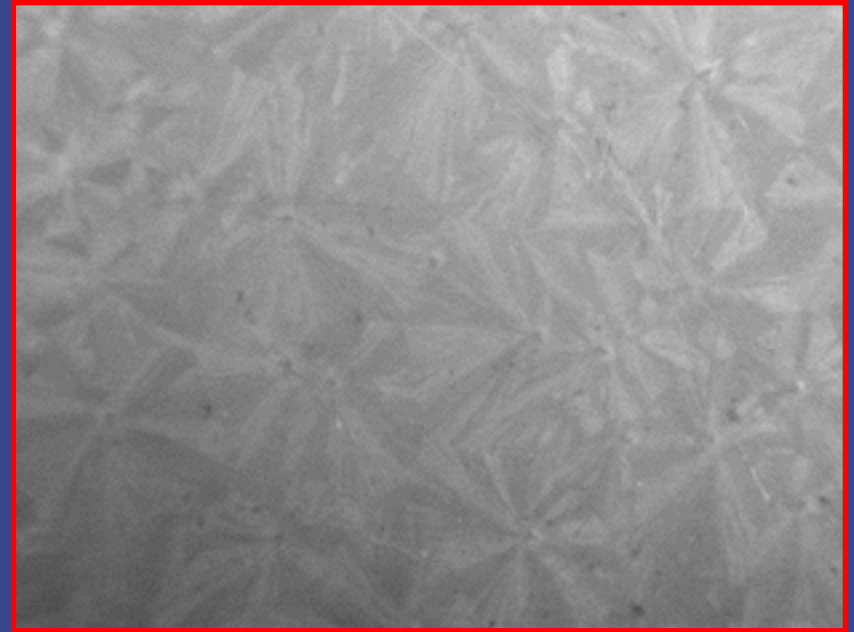
Grain Structure

Sample 3 95/5 - Sn/Ag



M-11 95/5 - Sn/Ag OM-10x

Sample 4 90/10 - Sn/Ag



M-14 90/10 - Sn/Ag OM-10x

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Solderability

test followed the Military Standard/ MIL-STD-202B Method 208

result With our Tin-Silver alloys both 95-5 and 90-10 performed exceptionally well.

Sample 1



Ambient Temperature (90-10 SnAg)

Sample 2



24 Hour Steam Age (95-5 SnAg)

Sample 3



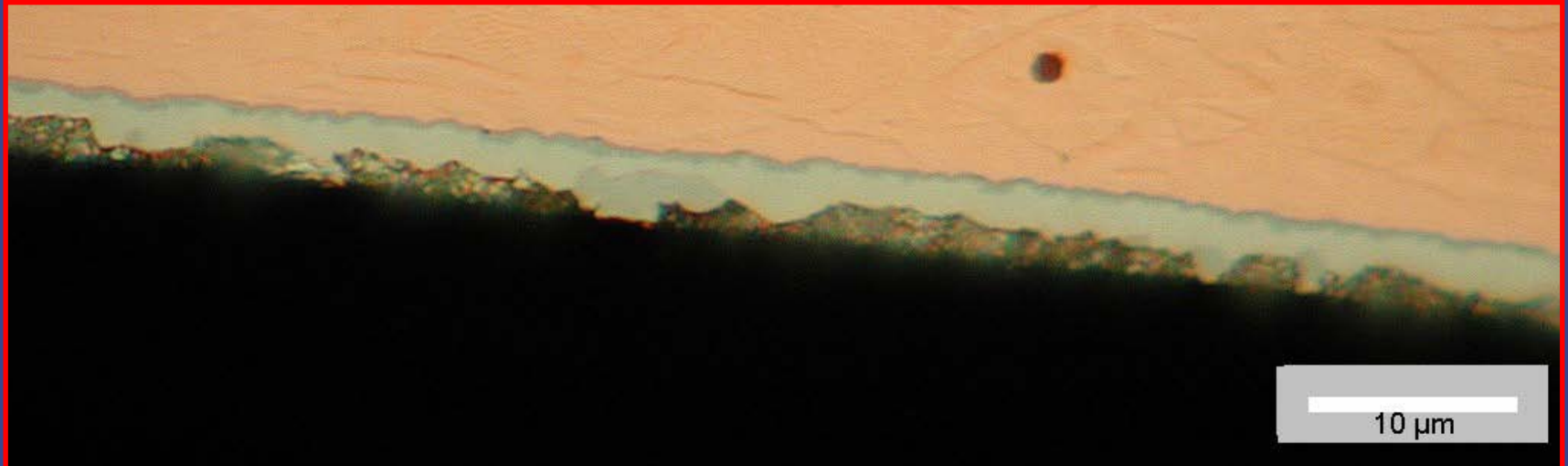
8 hour bake 160° Celsius (95-5 SnAg)

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Photomicrographs

Sample 1 - Baked at 175° Celsius for 10 hours

ALLOY 1453

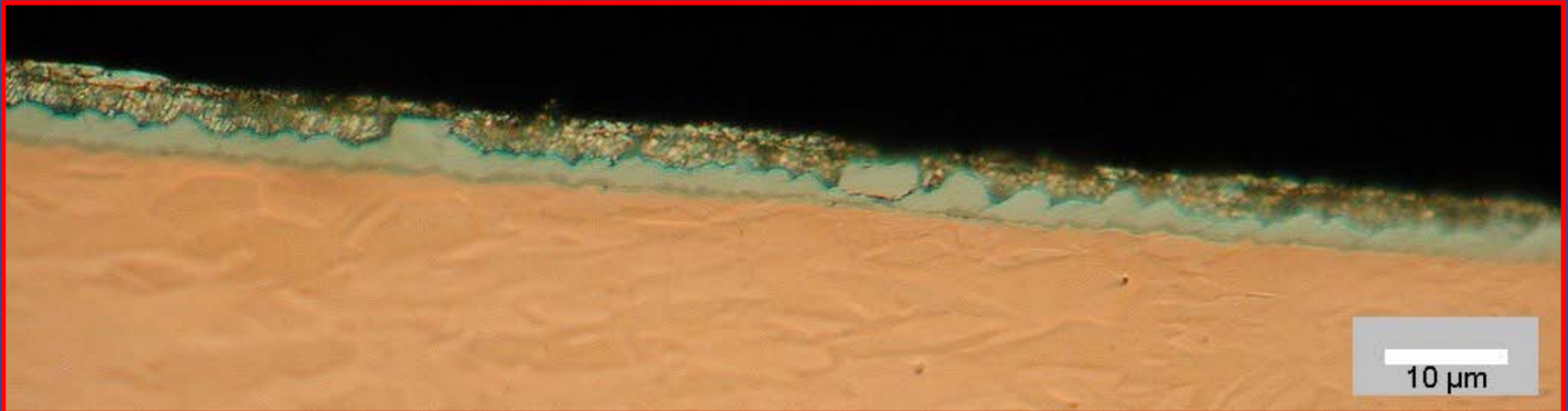


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Photomicrographs

Sample 2 - Baked at 150° Celsius for 100 hours

ALLOY 1453

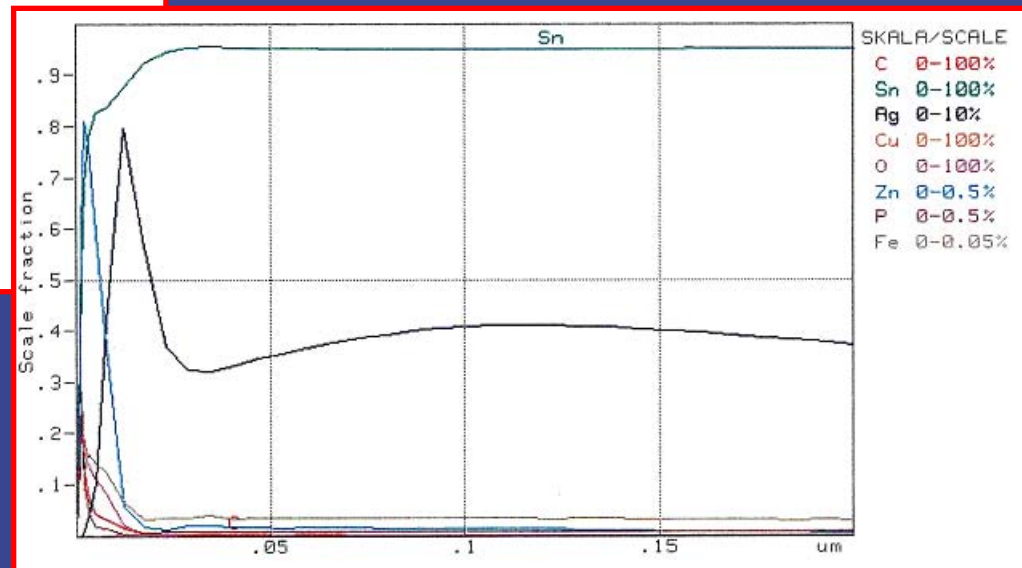
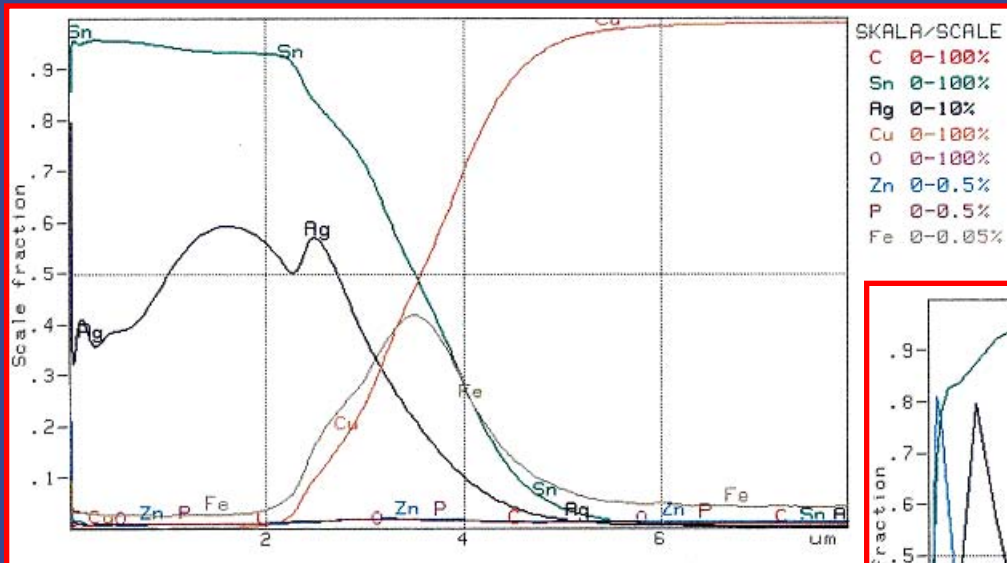


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Surface Analysis

Depth Profile - 150° Celsius for 100 hours

Coating thickness 2.8 um (110 microinches)



Surface analysis/Depth Profile
Datum 17 Aug 2001
Test by: Outokumpu Copper Products

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Thank you for your time.



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The following information
is reference material to be used in support
of the Tin-Silver presentation.

Should you need any further documentation
or have questions please call:

Richard Strobel @ 203-573-1742

or

William C. Strobel @ 630-906-0053



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==Laboratory for Experimental and Computational Micromechanics
Massachusetts Institute of Technology
Cambridge, MA 02139

August 21, 2001

To: Richard Strobel
Metalslitting

From: Krystyn J. Van Vliet
Ph.D. Student

Re: Nanoindentation study of Sn and Au films

Dear Mr. Strobel,

Enclosed, please find our report of the nanoindentation studies conducted on the tin (Sn) and gold (Au) thin films you provided. Please feel free to contact me with any questions you may have regarding this report or future testing of these systems. These tests required four days of testing, due largely to the fact that little was known about their mechanical properties prior to testing.

Thank you,

Krystyn J. Van Vliet

Objectives

1. To use nanoindentation to determine whether the indentation hardness of Sn-based films was affected by the addition of Ag.
2. To use nanoindentation to determine the indentation hardness of Au films.

Experimental Procedure

A. *Sn-based films*

Sn-based films were of approximately 3000 nm thickness. In order to eliminate interference from the substrate during nanoindentation experiments of relatively soft metals, the maximum indentation depth should be less than 33% of the film thickness. Each film was indented in load control at a loading rate of 0.02 mN/s to a final load of 5 mN, resulting in a maximum depth of ~750 nm (25% of film thickness). At least three indentation tests were conducted in each sample. Spurious data due to surface roughness often necessitated additional testing.

B. *Au-based films*

Au-based films were of approximately 770 nm thickness. Thus, this film was indented to a maximum depth of 150 nm (20% of film thickness). Ten indentation tests were conducted in each sample.

Data Analysis

Indentation data consists of applied load P and resulting indentation depth into the sample h . This indentation P - h response can be analyzed by several published methods to calculate properties including hardness and Young's (elastic) modulus. These data were analyzed by three methods of analysis: (1) Oliver/Pharr; (2) Giannakopoulos/Suresh; and (3) Dao et al., as referenced below. The latter two analytical methods utilize data during indentation loading and unloading, whereas the first method utilizes only the unloading data. Averages of all of these calculations are reported below for values of indentation hardness p_{avg} and Young's modulus E .

Indentation hardness is calculated in units of pressure, and represents the average pressure which the sample can sustain beneath the indenter. Traditional hardness numbers such as Vickers hardness HV do not have physical units, and are not explicitly related to indentation hardness as calculated above. However, if one is more familiar with HV calculations of hardness, a rough relationship between these two values is:

$$HV \sim 0.94p_{\text{avg}} \quad (1)$$

Results

A. Sn-based films

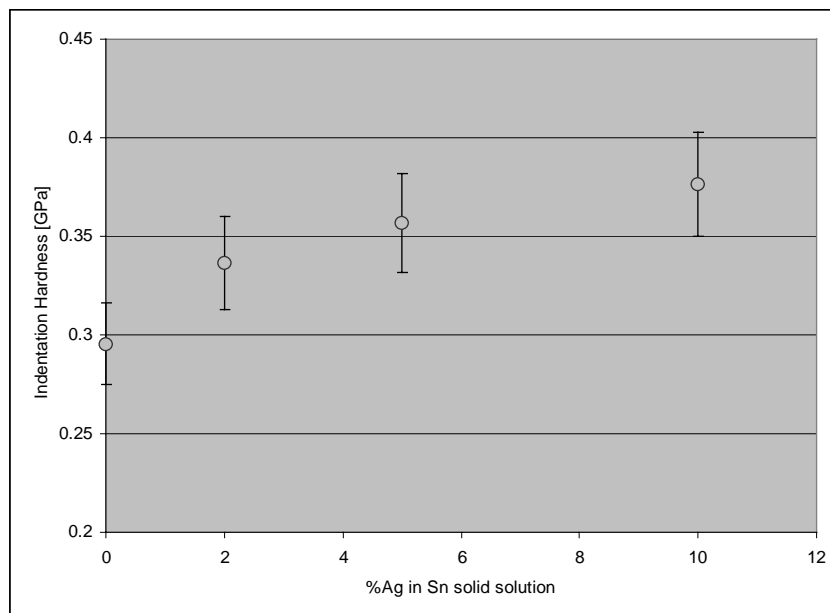
Figure 1 shows the variation of indentation hardness with %Ag. Although there exists a standard deviation of 7% among the tests for each sample, a trend of increasing hardness with increasing Ag content is quite clear. For an addition of 10%Ag, the indentation hardness increases by 27%. The indentation hardness value calculated for 0%Ag (100%Sn) was 0.30 GPa, or approximately 30 HV. No literature value of HV hardness was available, but the literature value of Brinell hardness in pure Sn is 3.9, or approximately 4.0 HV. At this time, the discrepancy between these values is unexplained, but may be due to processing-induced strengthening of the film or surface roughness.

The calculation of Young's modulus was a weak function of %Ag, averaging to a value of 30 GPa for all samples tested. This value is 30% lower than the literature value for pure Sn (<http://www.matweb.com/>).

B. Au-based films

Indentation hardness and Young's modulus of the Au films was calculated to be approximately 2.5 GPa and 113 GPa, respectively. Although the chemical content of the Au-based film is undocumented, the value of E compares well to literature values for alloyed films of 70Au-30Pt (~114 GPa). The literature value of pure Au is considerably lower (77 GPa), so alloying of these films was assumed to be a reasonable. However, the value of p_{avg} is 50% greater than that cited for the 70Au-30Pt alloy. This discrepancy may be due to processing/alloying differences between the cited example and the actual film, and also to surface roughness. Nanoindentation of these Au-based films exhibited considerable variation from test to test, most likely due to the roughness of the film surface on the nanometer scale.

Figure 1. Indentation hardness of Sn-based films as a function of %Ag.



Published methods of indentation data analysis

1. Oliver, W.C. and Pharr, G.M. "An improved technique for determination of hardness and elastic modulus using load and displacement sensing indentation experiments", *Journal of Materials Research*, Vol. 7, No. 6, June 1992.
2. Giannakopoulos, A.E. and Suresh, S. "Determination Of Elastoplastic Properties By Instrumented Sharp Indentation", *Scripta Materialia*, Vol. 40, No. 10, pp. 1191-1198, 1999.
2. Dao, M., Chollacoop, N., Van Vliet, K.J., Venkatesh, T.A. and Suresh, S. "Computational modeling of the forward and reverse problems in instrumented indentation", Accepted, *Acta Materialia*, 2001.



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