

Magn
162x

100 μ m

Effect of Substrate Composition on Sn Whisker Growth in Pure Sn Films

Sarah M. Miller, Uttara Sahaym and M. Grant Norton
School of Mechanical and Materials Engineering
Washington State University, Pullman, WA 99164



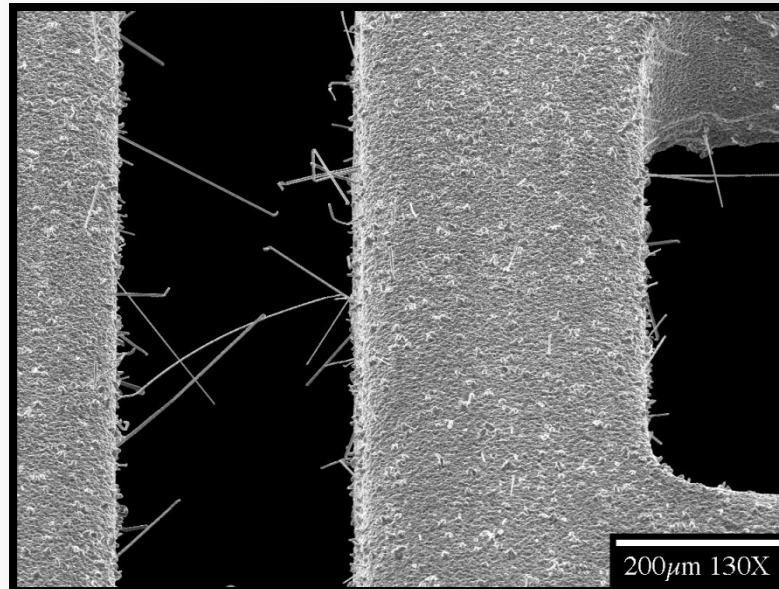
World Class. Face to Face.

Overview

- Introduction
- Experimental Procedures
- Results & Discussions
- Conclusions
- Acknowledgments

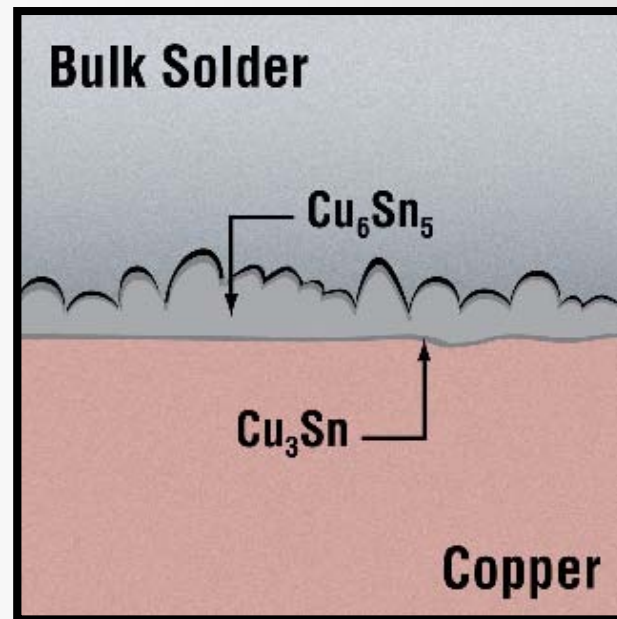
Introduction

- Sn as solder material
 - Prone to whiskers
 - Alloyed with Pb
 - RoHS Legislation, 2003
- Whisker growth mechanism
 - IMC formation, Cu_6Sn_5 , resulting in compressive stresses
 - Formation by diffusion of Cu in Sn grain boundaries



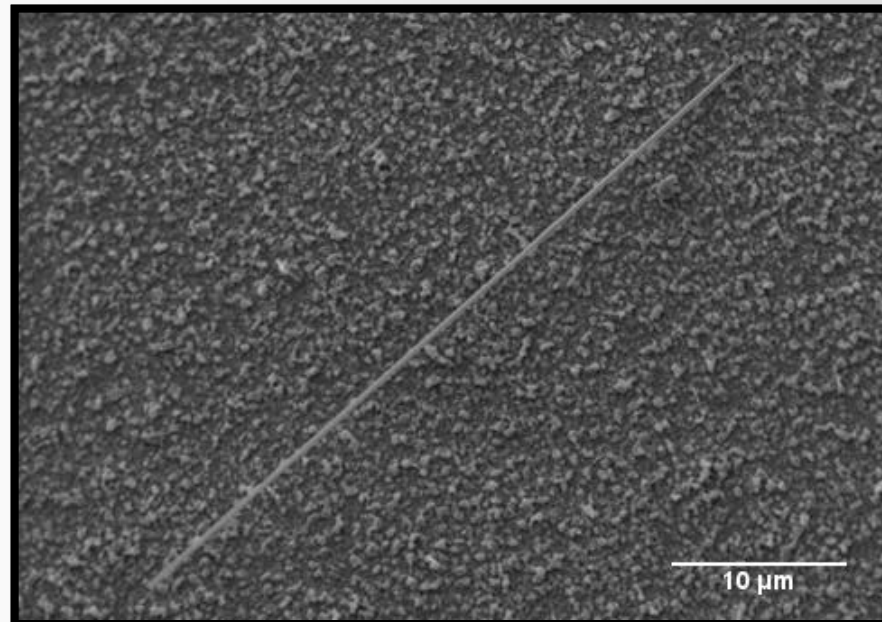
Introduction

- Whisker suppression
 - Post-baking procedures
 - Tensile vs. Compressive stresses
 - IMC type
 - Ni barrier layer
 - Prevents diffusion of Cu



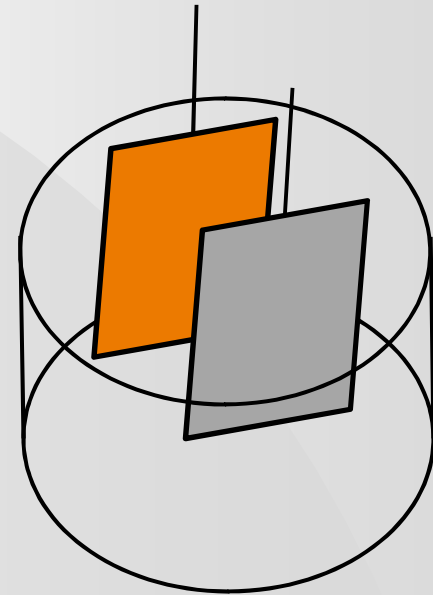
Introduction

- Current study
 - Scope: Effect of substrate composition on tin whisker growth
 - Objective: Determine effect of including Zn in substrate



Experimental Procedures

- Substrate materials
 - Pure Cu
 - 70% Cu – 30% Zn (brass)
- Pre-electroplating preparation
 - Grinding, polishing
 - Cleaning in heated sodium hydroxide
 - Dipping in concentrated sulfuric acid
- Alkaline electrolyte
 - 142.096 g sodium tin (IV) oxide per liter solution
 - 14.960 g sodium hydroxide per liter solution.
- Plating parameters
 - 1 μm or 10 μm thick Sn layer
 - 50 mA/cm^2 current density
 - 85°C to 95°C bath temperature

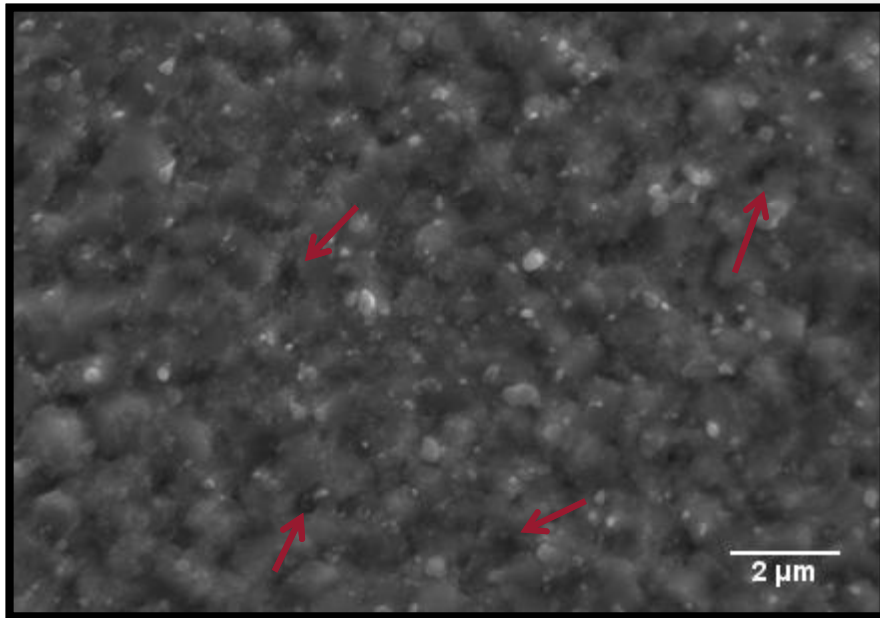


Experimental Procedures

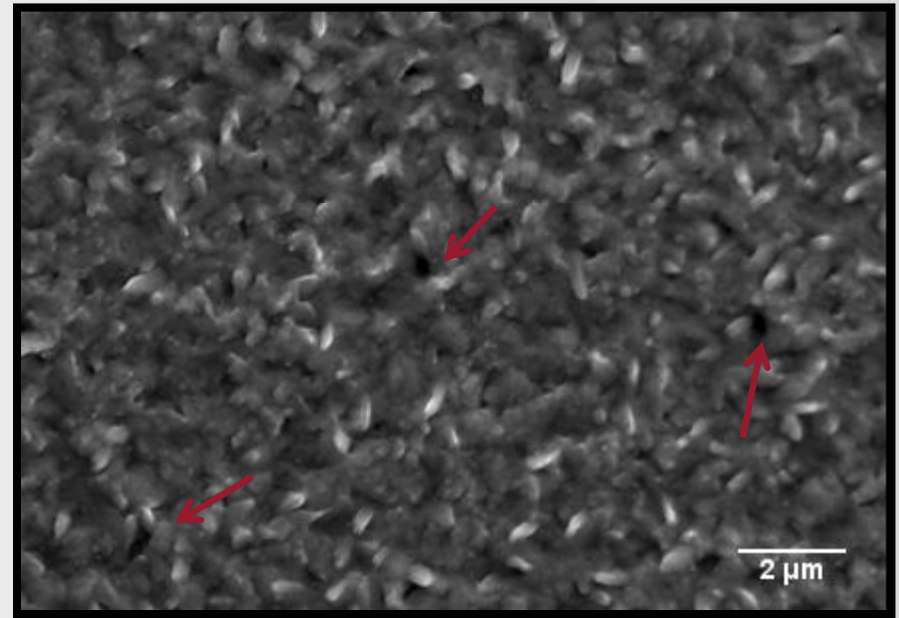
- Aged at RT in air
- Equipment:
 - FESEM for imaging
 - EDM for cross-sectioning
 - EDS for composition

Results & Discussion: Comparing Surface Morphology

- 1 μm thick Sn layers (24 hrs after plating)

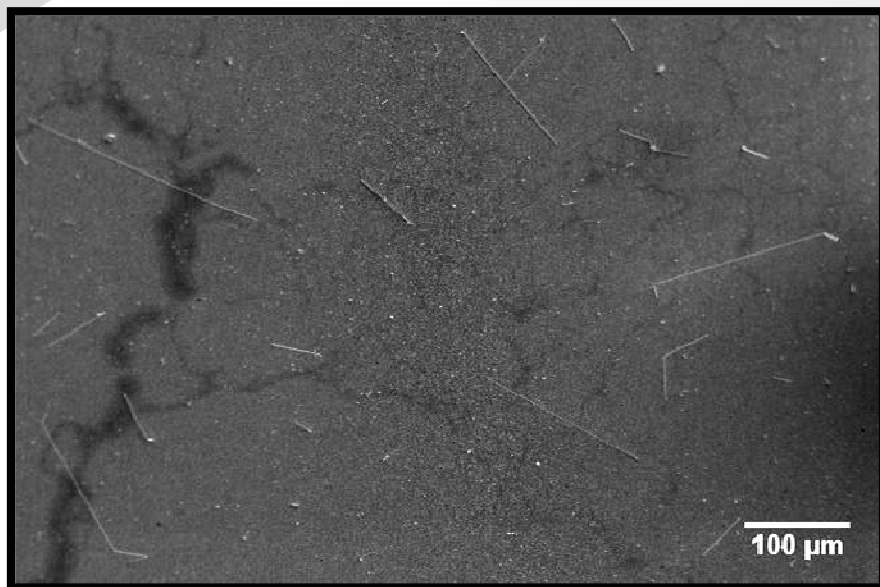


Copper



Brass

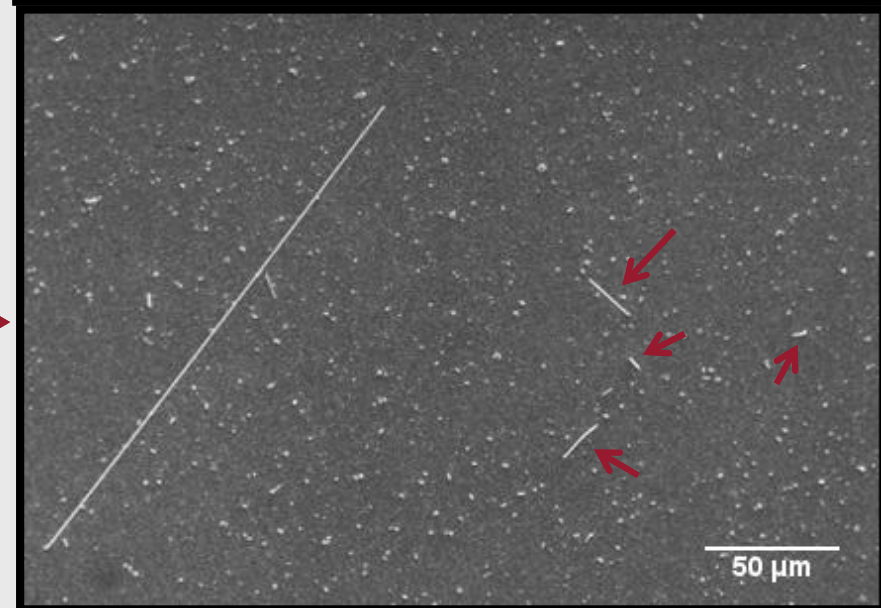
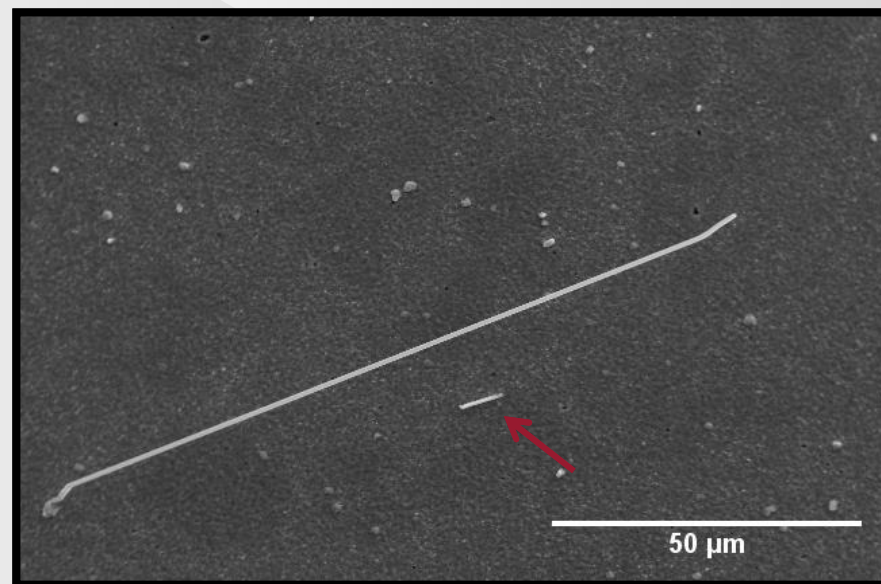
Results & Discussion: Cu Substrate Features



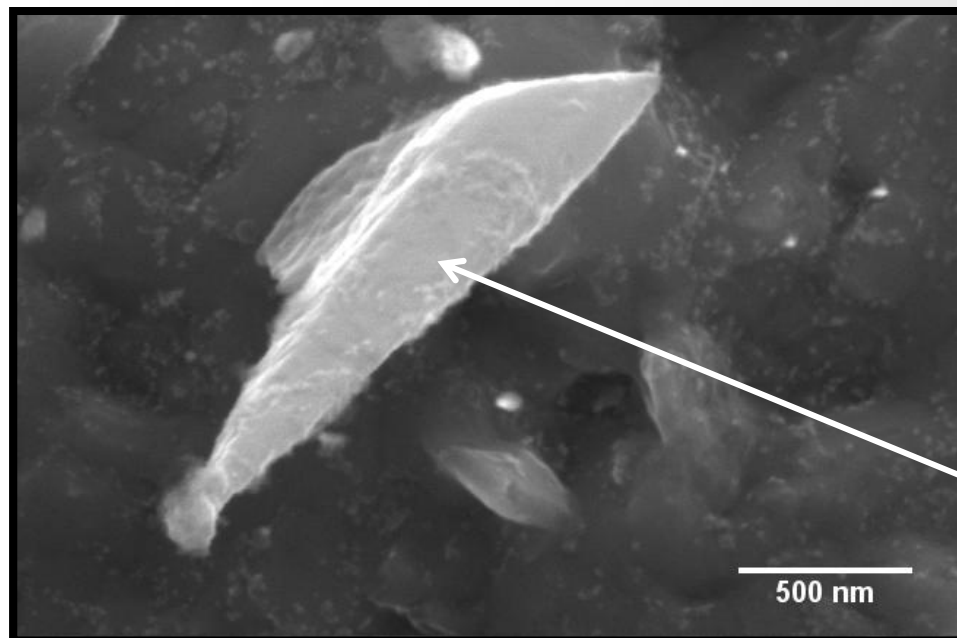
11 days

1 μm thick
Sn layer

140 days

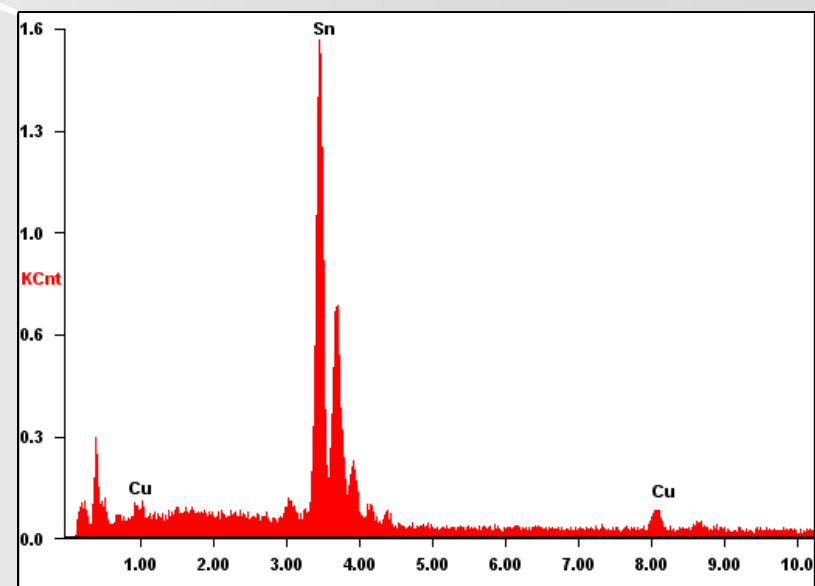


Results & Discussion: Brass Substrate Features



24 hours

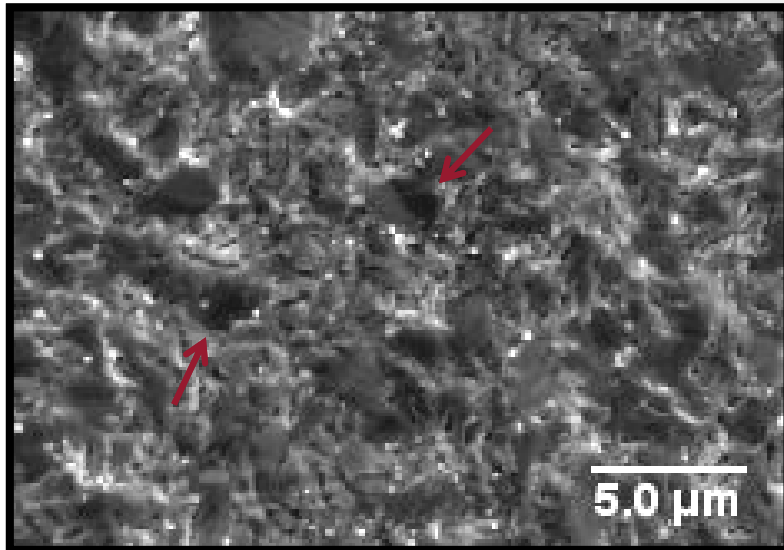
1 μm thick
Sn layer



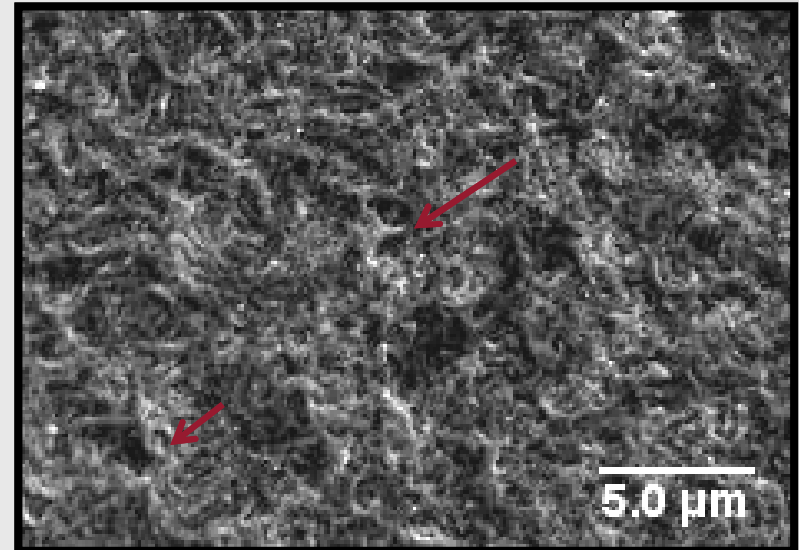
Results & Discussion: Comparing Surface Morphology

- 10 μm thick Sn layers

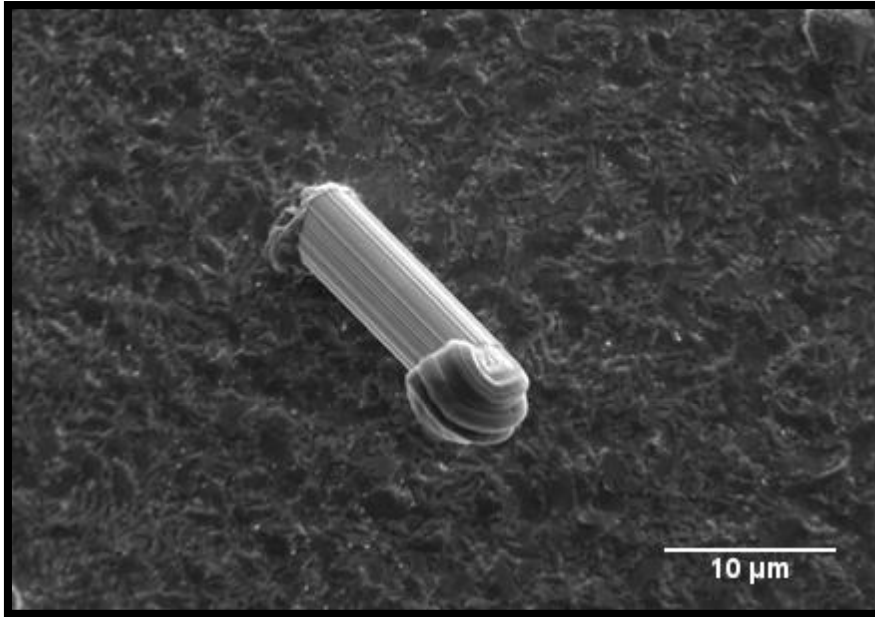
Copper



Brass

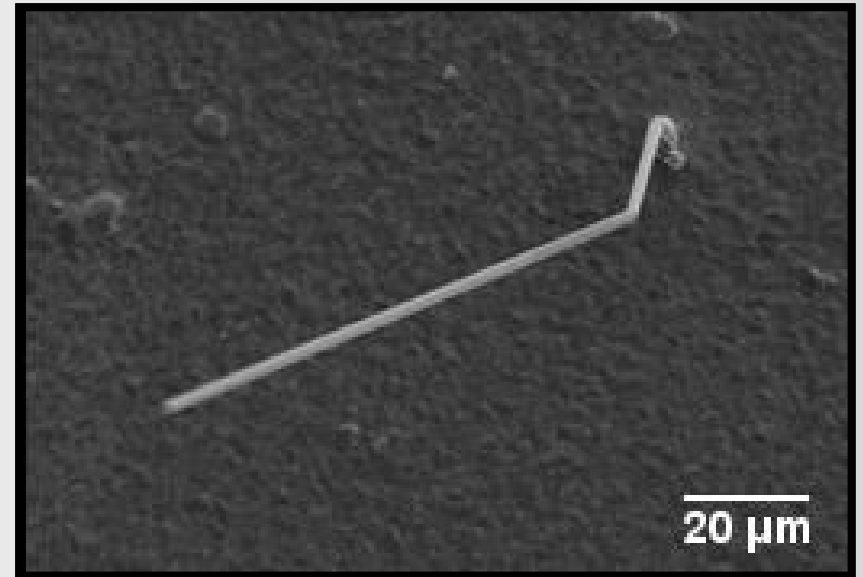


Results & Discussion: Cu Substrate Features



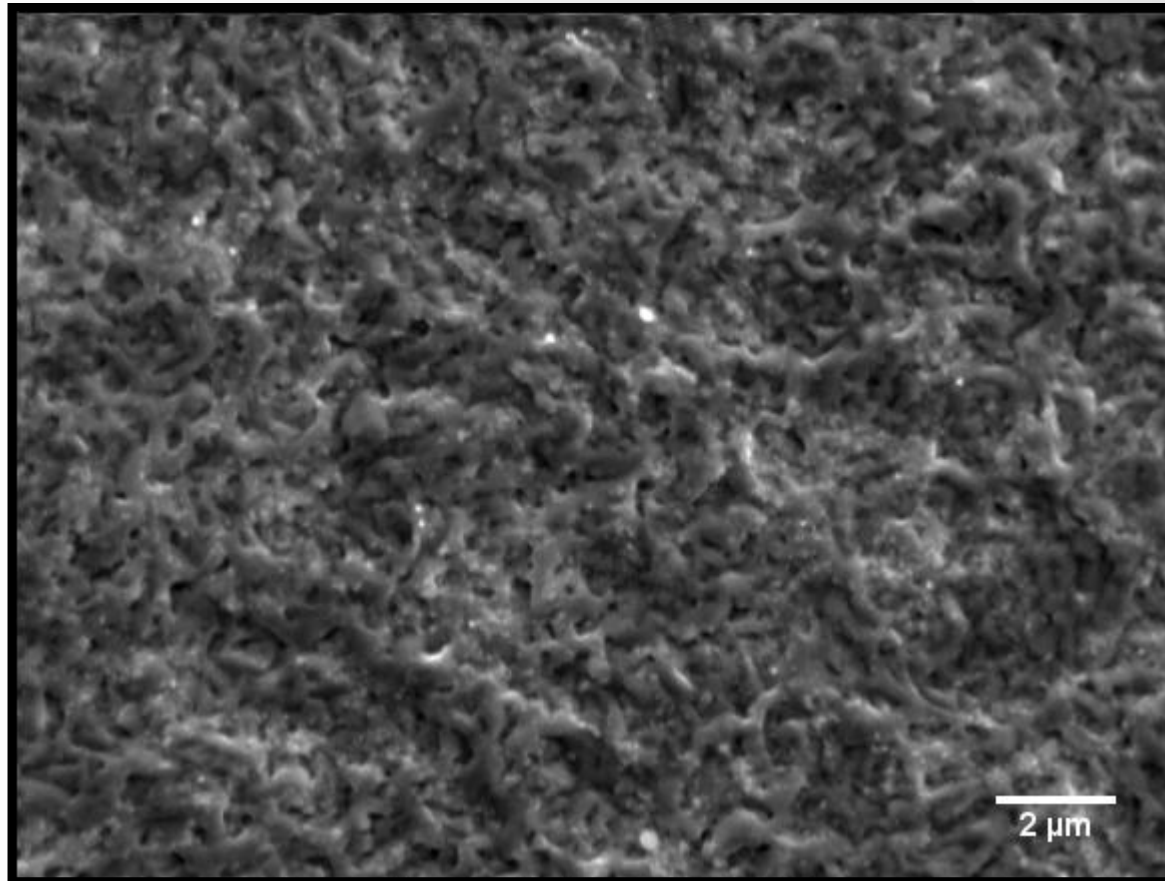
21 days

10 μm thick
Sn layer



28 days

Results & Discussion: Brass Substrate Features



10 μm thick
Sn layer

57 days

Results & Discussion: Specific Molar Volume Values for IMCs

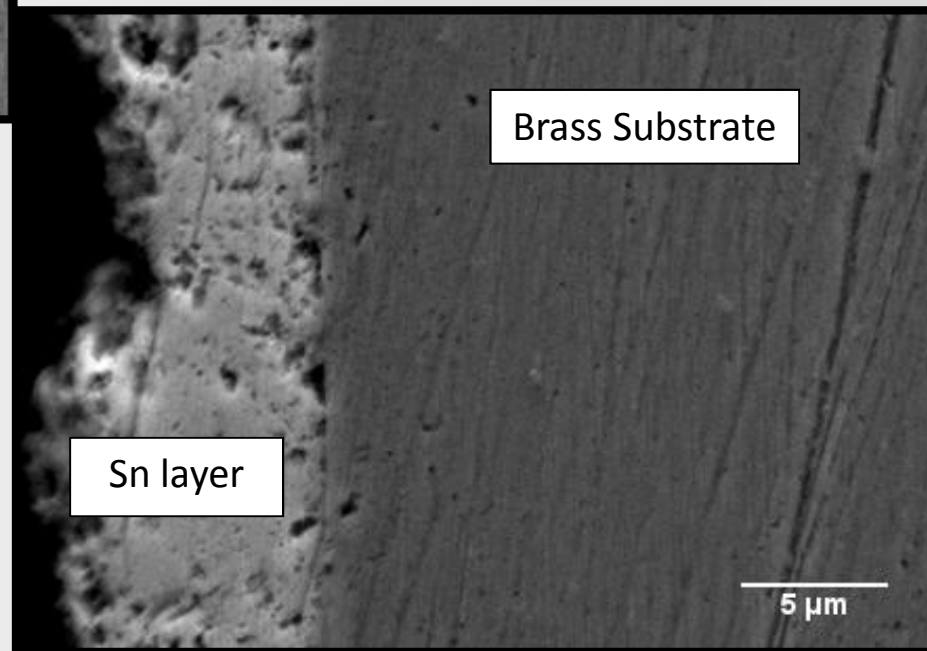
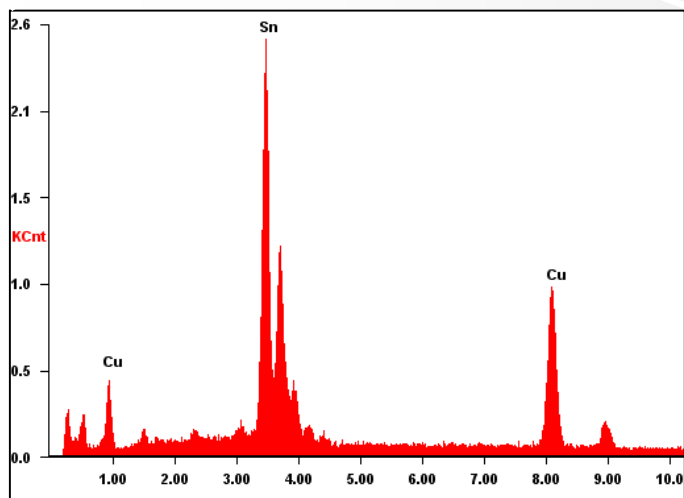
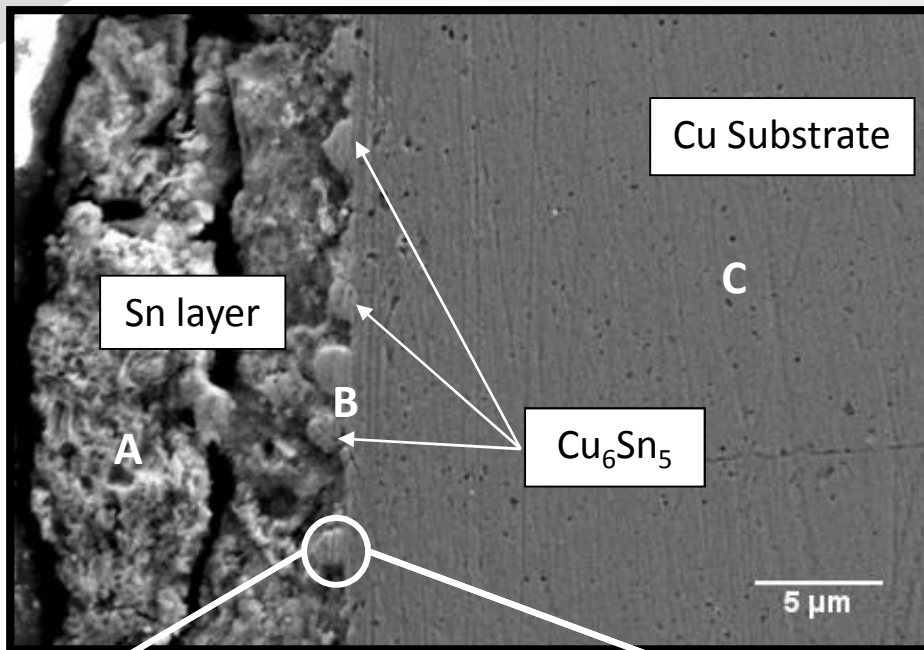
IMC	Molar weight (g/mol)	Density (g/ cm ³)	Molar volume (cm ³ /mol)
Sn	118.71	7.365	16.23
Cu ₆ Sn ₅	974.69	8.28	117.71
Cu ₃ Sn	309.31	8.9	34.75
Cu ₅ Zn ₈	840.74	7.98	105.35

Results & Discussion: Energy of Formation Values: Cu/Sn & Cu/Sn/Zn Systems

IMC	X _{cu}	ΔH (kJ/mol)	ΔS (J/mol*K)	ΔG at 298 K (kJ/mol)
Cu ₅ Zn ₈	0.4	-11.41	1.62	-11.89
CuZn	0.5	-11.12	0.69	-11.33
Cu ₃ Sn	0.7	-3.91	6.75	-5.75
Cu ₃ Sn	0.8	-4.10	5.55	-5.92
Cu ₆ Sn ₅	0.6	-2.99	7.73	-5.29
Cu ₆ Sn ₅	0.5	-1.99	8.05	-4.39

- Cu-Zn IMCs more thermodynamically favorable in Sn-Cu-Zn system

Results & Discussion: Cross-sectional Images



Conclusions

Cu Substrate

- Whiskers observed
- IMC formation
- Including Zn at Sn-Cu interface can mitigate growth of Sn whiskers
- Future Work: Plate pure copper with two layers
 - Zn & Sn

Brass Substrate

- No whiskers observed
- No IMC formation

Acknowledgments

- Hi-Rel Laboratories, Spokane for financial support
- *National Aeronautics and Space Administration* (NASA) for the Space Grant Science Opportunity Scholarship
- Washington State University for the Auvil Undergraduate Scholars Fellowship
- Gerald A. Soffen Memorial Fund Travel Grant Committee for the 2009 Soffen Fund Travel Grant, allowing attendance at MS&T 2009
- Stephanie Miller for preparing the cross section samples, NSF sponsored REU program at Washington State University (DMR 0755055)