Lead-Free Alloy Reliability Testing Information

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Physical Properties of Bulk Solders

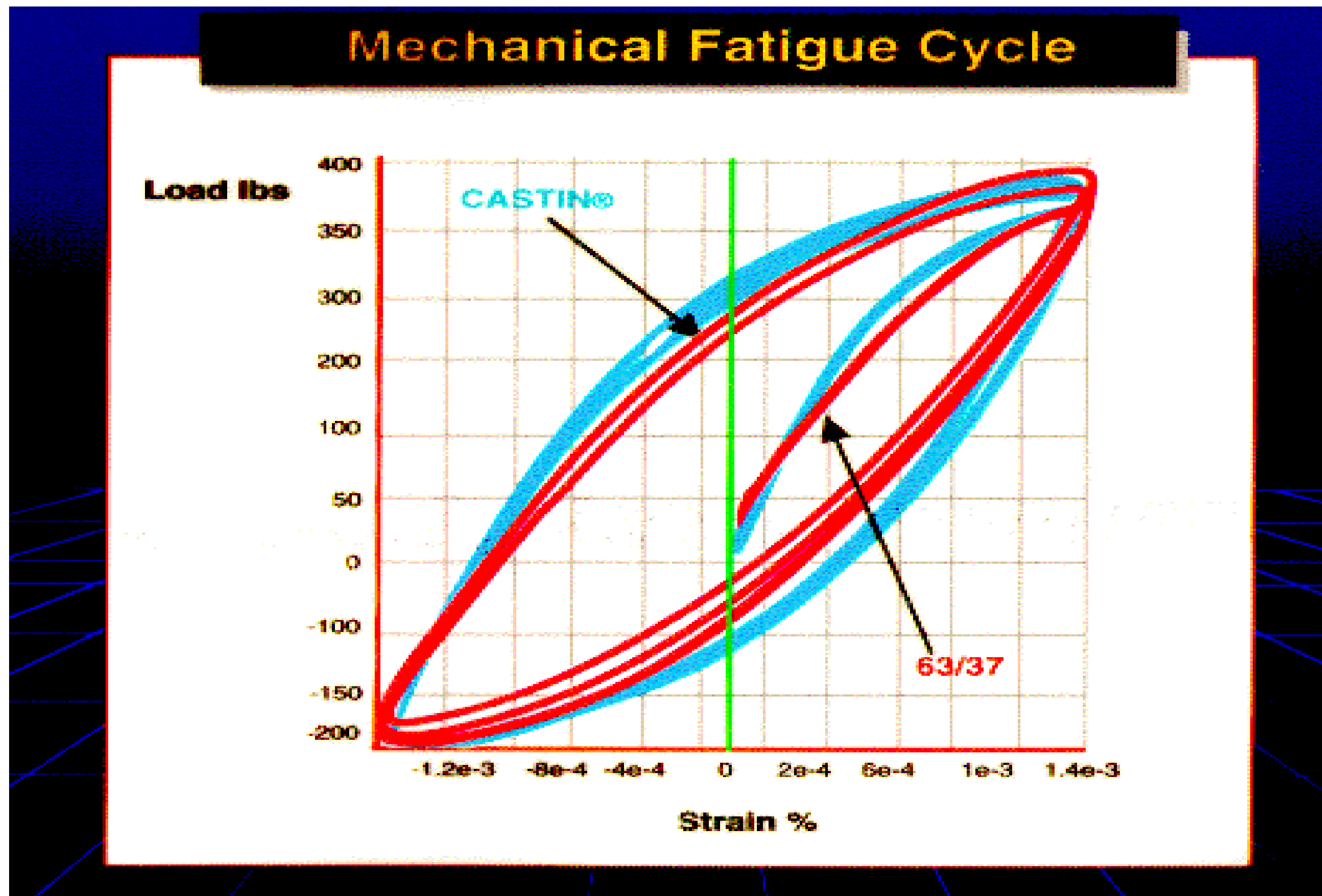
Tensile*	Sn63/Pb37	Sn/Ag/Cu
– UTS (ksi)	4.92	5.73
– Yield Strength (ksi)	4.38	4.86
– Young's Modulus (msi)	4.87	7.42
– % Elongation**	52.87	50.00

* tested per ASTM E-8

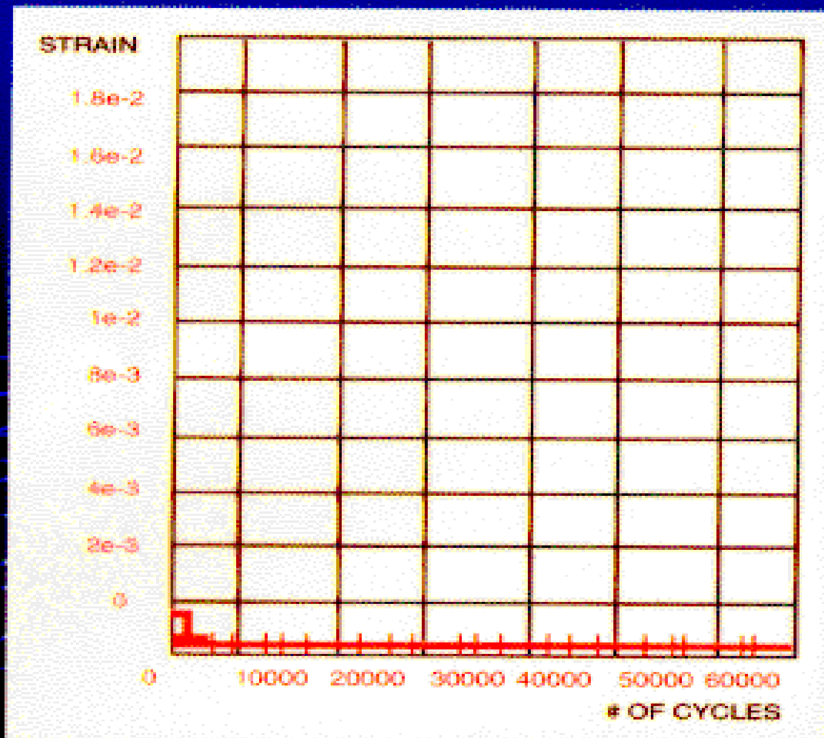
Compression*	Sn63	Sn/Ag/Cu
– Elastic Modulus (msi)	3.99	4.26
– YS (ksi)	4.52	4.33
– Stress 25 °/u (ksi)	7.17	8.54
Hardness**	10.08	13.5

* tested per ASTM E-9
** tested per Rockwell Test, 15W Scale Hardness

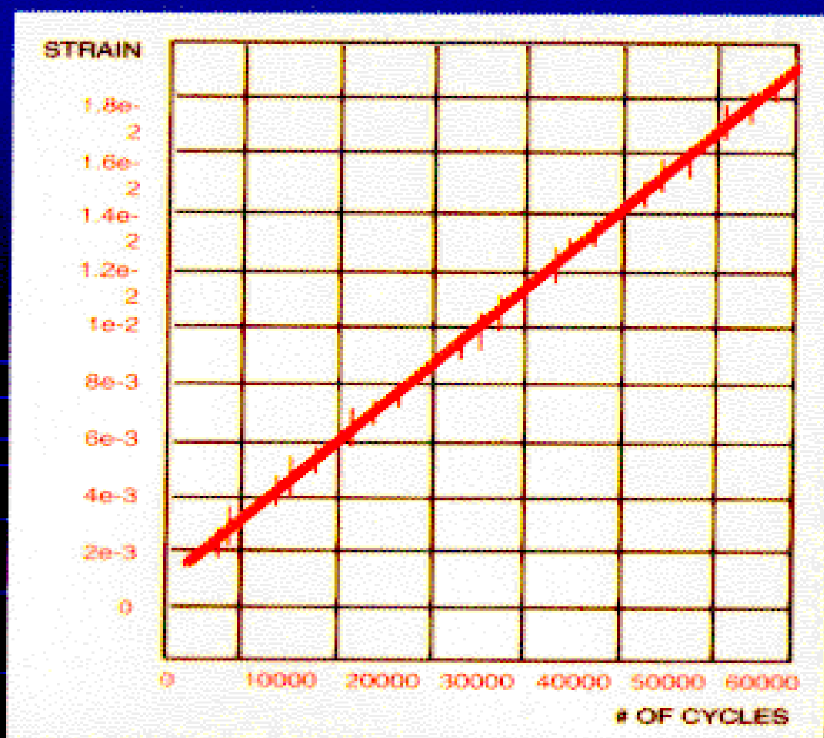
When the curves of mild stresses affected on Sn/Ag/Cu and Sn63/Pb37 are overlaid, they are virtually identical.



Sn/Ag/Cu has demonstrated the ability to be more adaptable to a wide range of stresses than Sn63/Pb37.



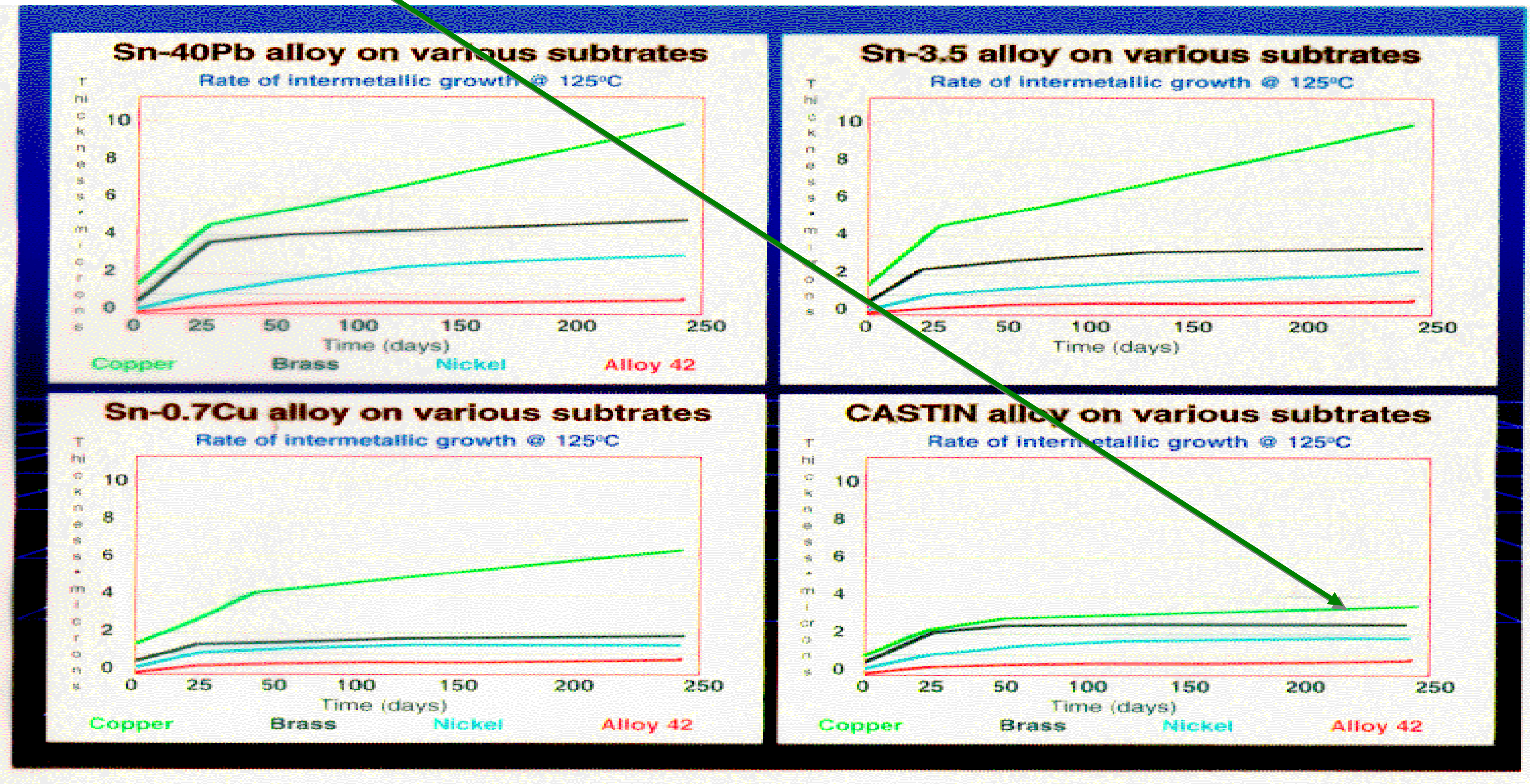
Sn/Ag/Cu



Sn/Pb

Intermetallic Growth Rates Comparison

- Sn/Ag/Cu is more resistant to Cu intermetallic growth than other alloys.



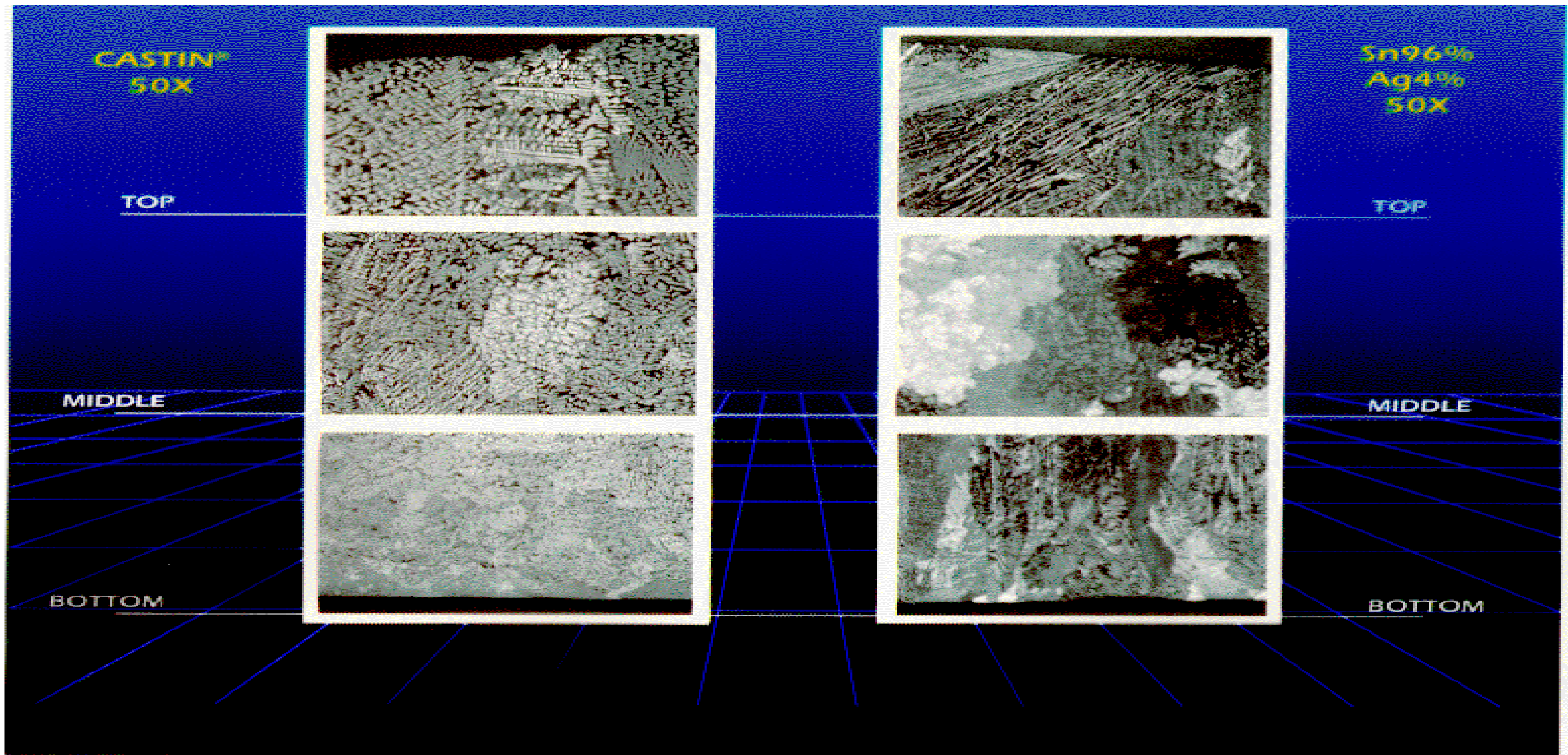
Physical Comparison

During fatigue testing Sn96.5/Ag3.5 failed one run and passed the others only marginally, whereas Sn/Ag/Cu passed all tests easily. (10,000 cycles constituted a passing mark)

Fatigue Test	Sn/Ag/Cu	Sn96.5/Ag3.5
– # Cycles to Failure	11,194	10,003
–	26,921	6,267*
–	24,527	11,329

- *Failure, Load Amplitude dropped >20%
- According to ASTME 606, 1Hz triangular waveform oscillated between .15% strain and -.15% strain.

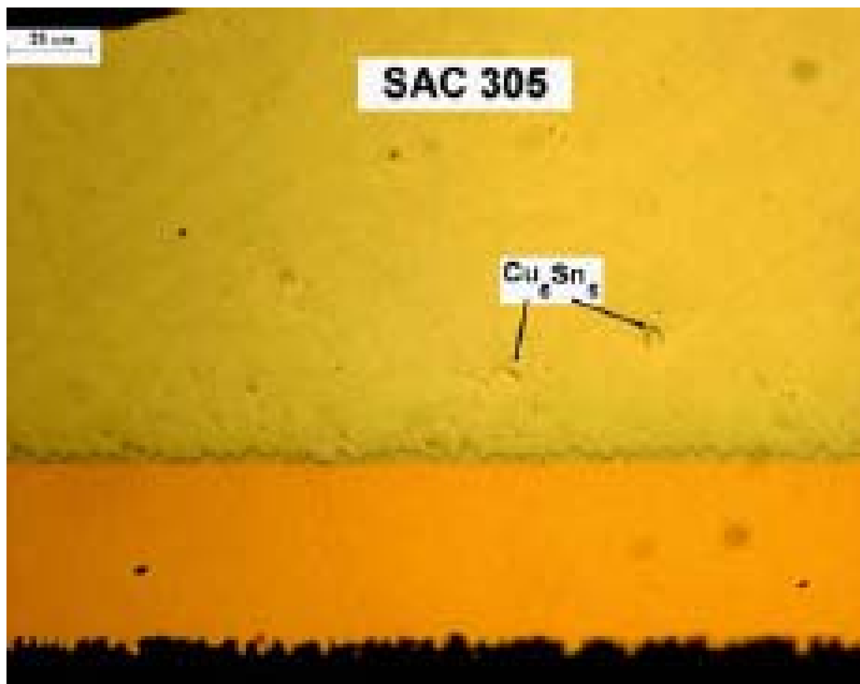
Microstructures Testing



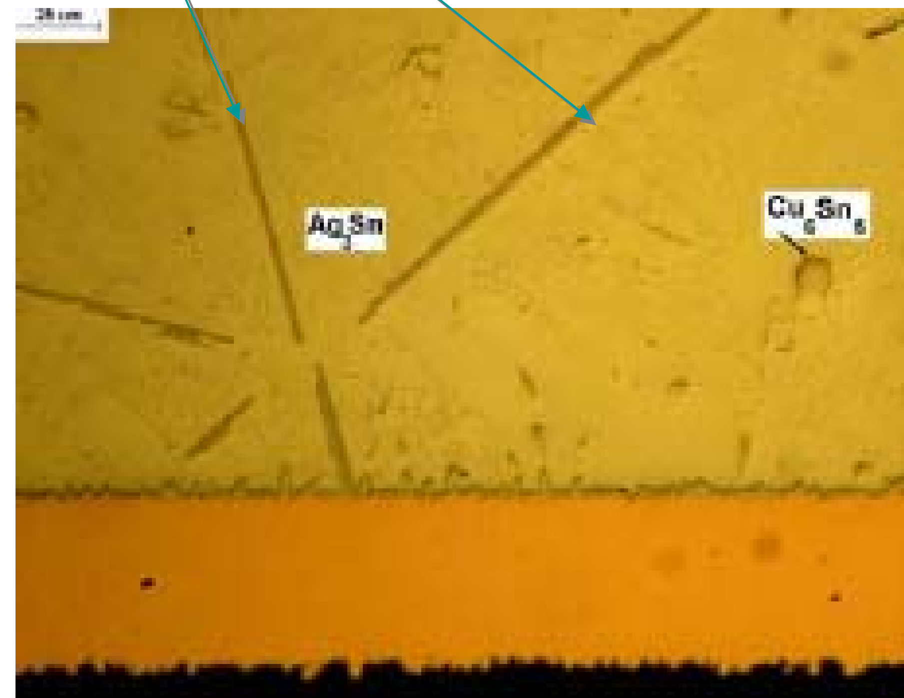
- One bar each of Sn/Ag/Cu and Sn96.5/Ag3.5 were melted and subjected to different cooling rates.
- The Sn/Ag/Cu alloy shows a consistent, leafy, dendritic structure. However, the Sn96.5/Ag alloy went through three different phases, depending upon the cooling rate. This led to concerns that structural weakness similar to these could occur in a solder interconnect, potentially leading to a field failure.

Sn/Ag/Cu Alloys Microstructure Comparison

- There is concern about Ag_3Sn needles ("platelets") found in the microstructure of Sn/Ag3.8/Cu0.7 and Sn/Ag4.0/Cu0.5
- Not found in Sn/Ag3.0/Cu0.5

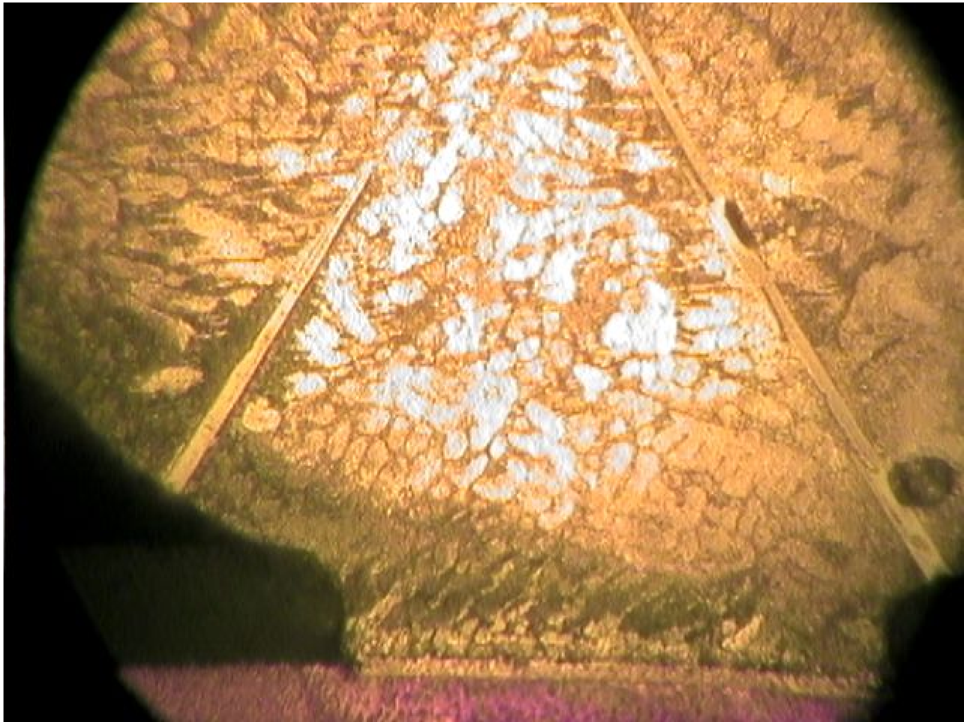


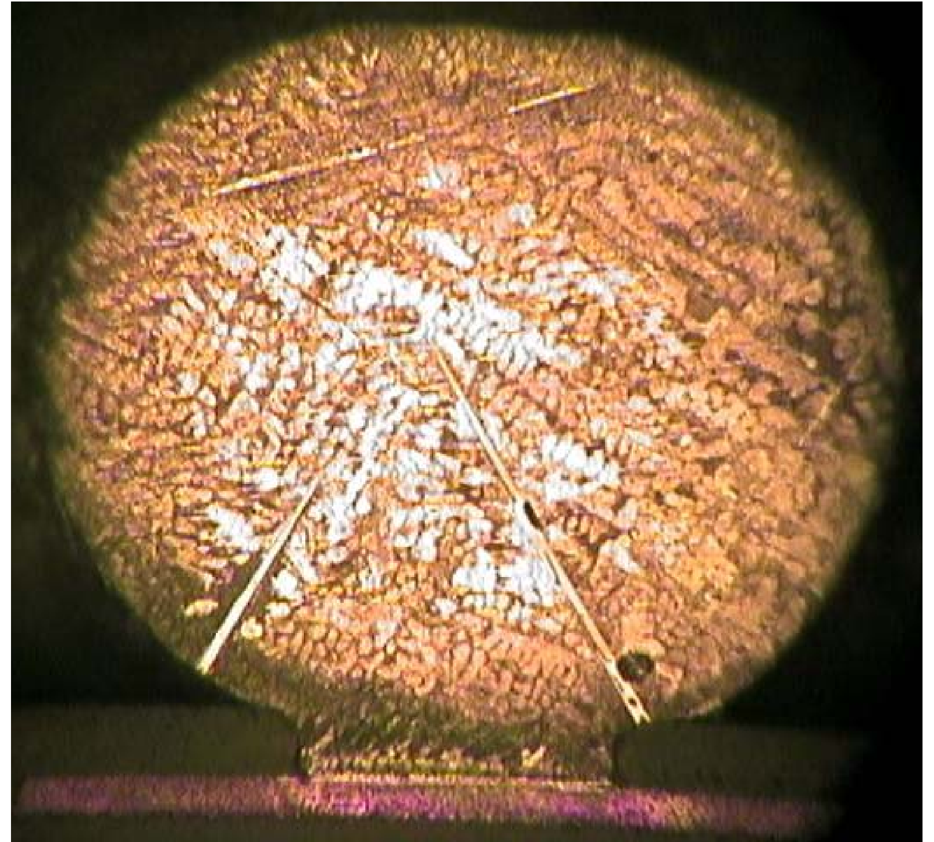
Sn95.5/Ag3.0/Cu0.5



Sn96.5/Ag4.0/Cu0.5

Ag_3Sn Needles ("Platelets")



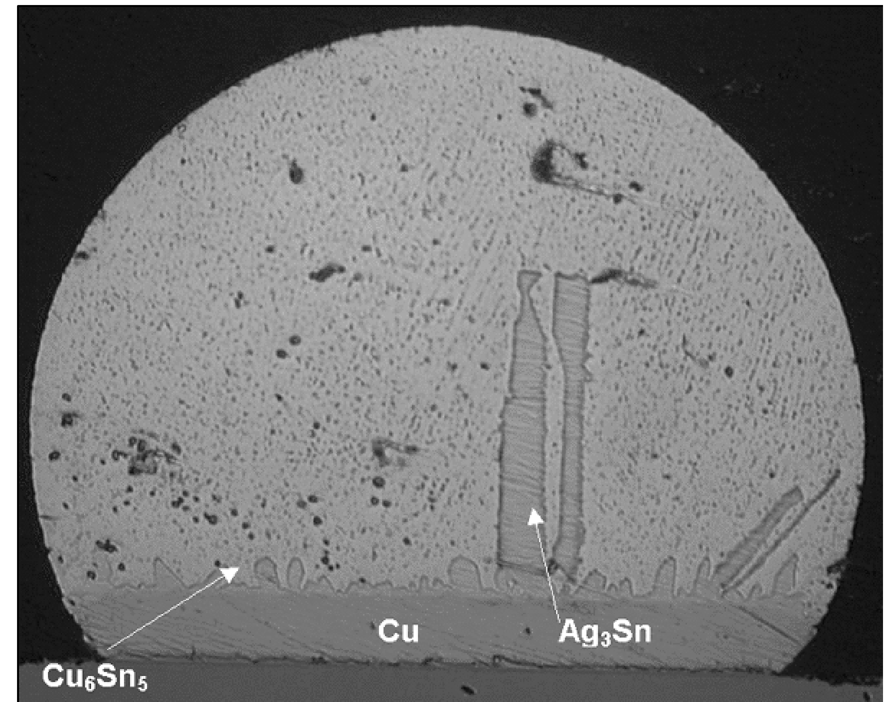


Microstructure Comparison

- The image to the right is of the Ag_3Sn forming as large plates attached to the interfacial intermetallics. This results in plastic strain localization at the boundary between the Ag_3Sn plates and the bounding b-Sn phase.

- Adverse effects on the plastic deformation properties of the solidified solder have been reported when large Ag_3Sn plates are present.

- It also has been suggested that silver segregates to the interface and weakens it by “poisoning”. The brittle fracture is exacerbated by gold contamination.



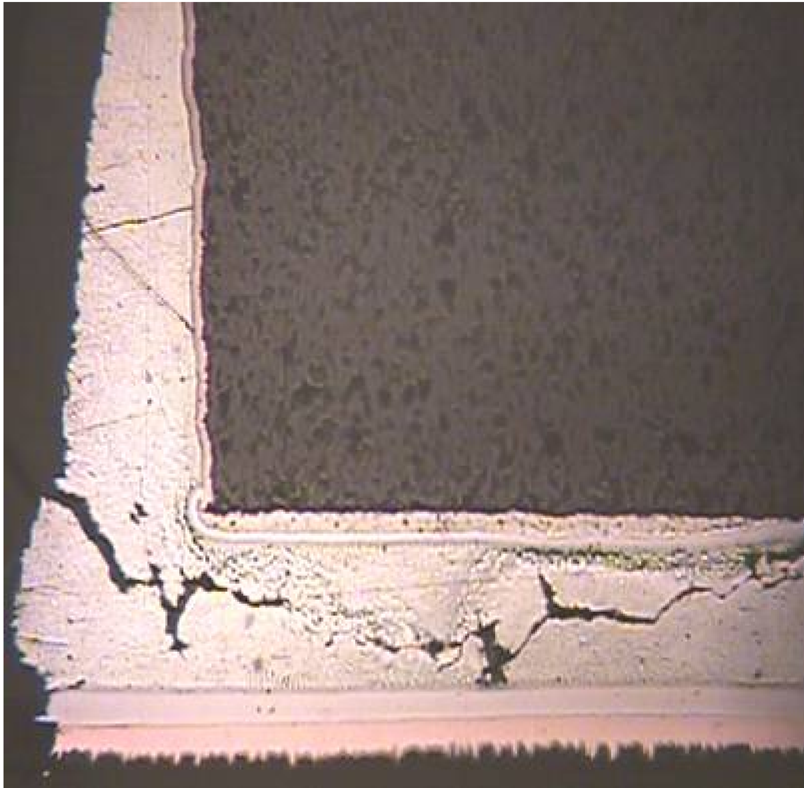
Reliability Study

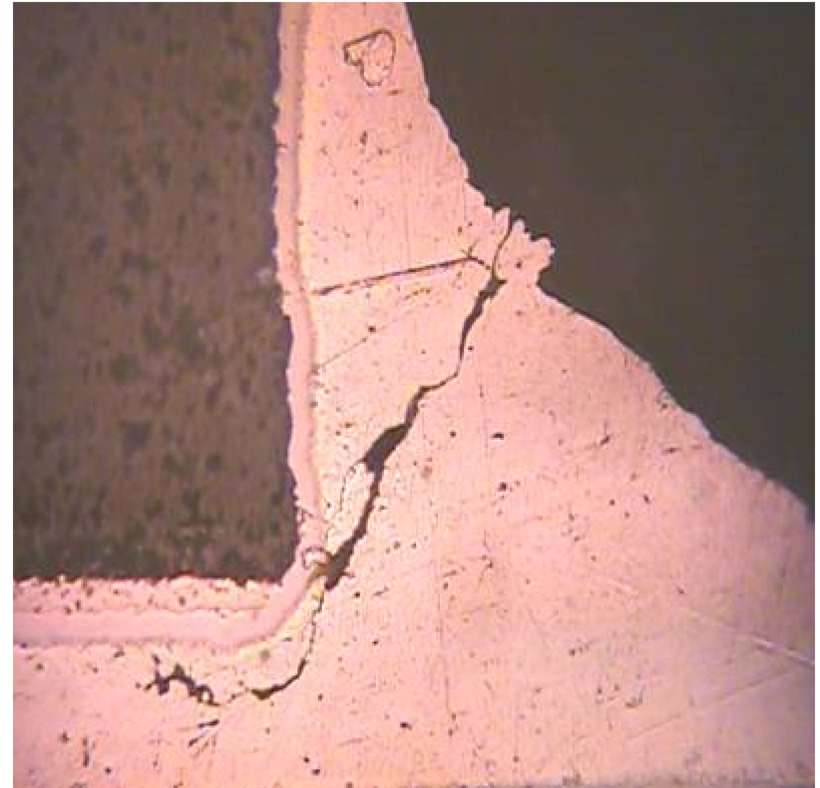
- Test boards were built with 1206 thin film resistors. The boards were then thermal shocked from -40° to +125°C for 300, 400 and 500 15 minute cycles. Solder joints were then cross-sectioned and inspected for cracks.

- These same assemblies were then subjected to mechanical fatigue testing.

Tin-Copper Thermal Cycling Test Results

- Post-test inspection shows that the Sn/Cu alloy exhibited some cracked solder joints on the third set of boards cycled to 500 repetitions.



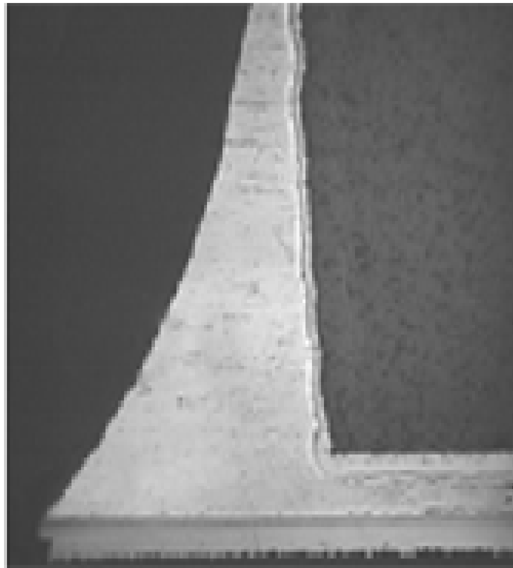


Tin-Copper Mechanical Strength- Flex Testing

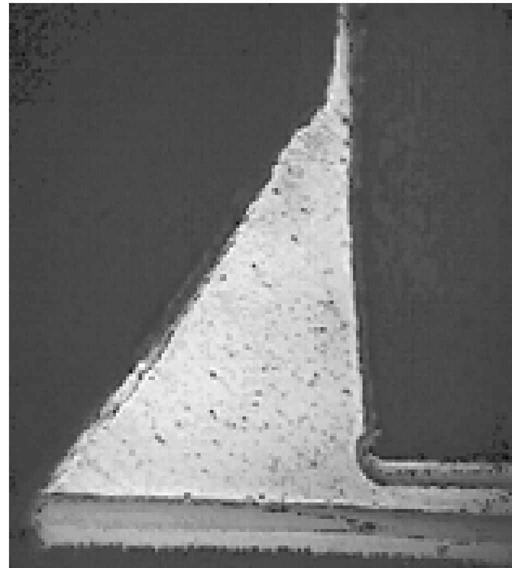
- Test boards were subjected to flex testing.
  - Solder joints produced from Sn/Cu0.7 cracked during flex testing.

Tin-Silver-Copper Thermal Cycling Test Results

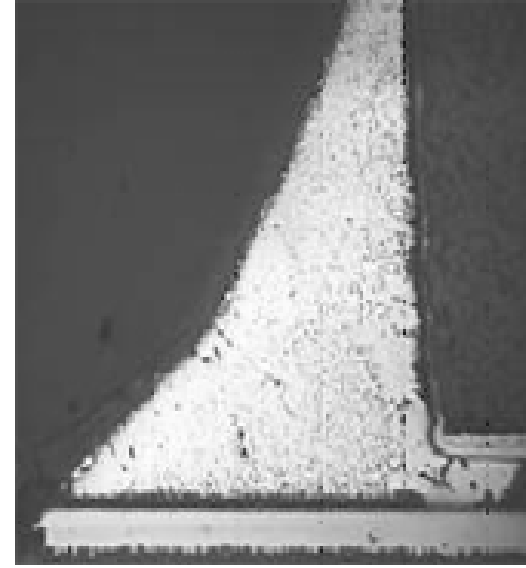
- As shown below, none of the alloys tested showed any cracks during testing up to 500 repetitions. However, it should be noted that the Sn95.5/Ag3.8/Cu0.7 and Sn95.5/Ag4.0/Cu0.5 alloys did exhibit some change in grain structure throughout the joint after the thermal shock testing.



Sn96.5/Ag3.0/Cu0.5



Sn95.5/Ag3.8/Cu0.7



Sn95.5/Ag4.0/Cu0.5