Lead-Free Solder Binary Alloys: X-Ray Studies of BiSn

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Abstract

- Lead-Free Solders:
  - ✓ Of great practical importance
  - ✓ Understanding surface thermo-dynamics of two-component liquid alloys
- Experimental measurements:
  - ✓ Surface is strongly layered
  - ✓ Deviation from standard model
  - ✓ Consistent with high surface density
  - ✓ Structure is different from similar feature found in pure Sn

MOTIVATION

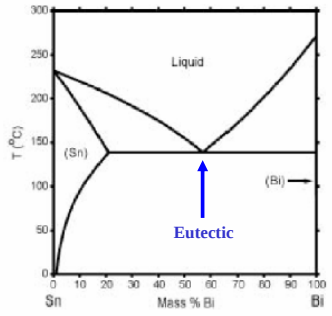
Practical:

- Use of Pb-based solders in electronics is a major health risk
- Need to replace PbSn solders by Pb-free alternatives
- Appealing candidate – BiSn:
  - ✓ Low melting temperature
  - ✓ No health hazards
  - ✓ Inexpensive

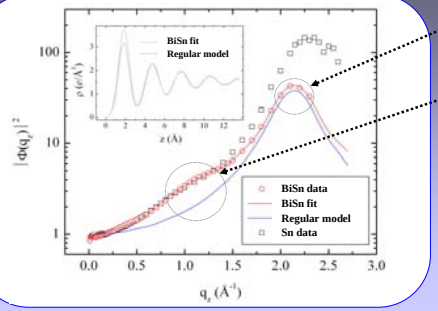
Fundamental:

- Lack of understanding of surface thermodynamics of binary alloys: studied so far - BiIn, GaIn, GaBi, AuSi, AuGe, HgAu - behave differently!
- How do the properties of the two components define the surface of the binary alloy?

BiSn Phase Diagram:



Reflectivity: Surface Structure Factor



- Surface is strongly layered (main peak at q_z=2.2Å^{-1})
- Structure deviates from standard model (peak at 1.1Å^{-1})
- Interpretation: higher density of top atomic layer, however:
  - ➢ Bi monolayer at the surface? or
  - ➢ Structural property of Sn?

BiSn vs. pure Sn

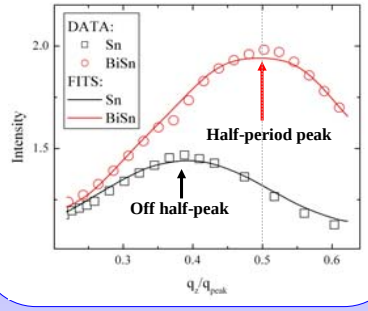
- Pure Sn has a similar feature, shown to be intrinsic property of Sn

Q: Does this Sn effect prevail in BiSn?

A: No! Sn feature (off half-period) can only be explained by a reduction atomic spacing at the surface

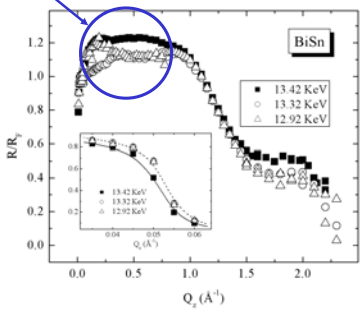
BiSn (half period) effect requires increased monolayer density

Structure factor normalized to DC model:



Resonant X-Ray Reflectivity

Energy-dependent Changes



Additional Data: (preliminary results)

Method – Resonant X-Ray Reflectivity:

Change of effective electron density (and therefore contrast) while scanning through resonant edge.

Changes in reflectivity?

✓ Yes ⟹ Bi surface enhancement

✖ No ⟹ Surface is the same as bulk

Summary

- Studies of Pb-free solders such as BiSn are of great importance for both industry and fundamental science
- BiSn surface shows a well-defined layering
- In addition we find a high surface density feature
- A similar feature was found for pure Sn, however BiSn effect is fundamentally different
- Full story can be learned with resonant reflectivity

Acknowledgements

This work was performed at ChemMAT-CARS sector of Advanced Photon Source, Argonne National Laboratory. It is supported by DOE grants DE-FG02-88-ER45379 and DE-AC02-98CH10886. Use of the APS was supported by the DOE under contract W-31-109-ENG-38

Presented by Oleg Shpyrko at the APS Users Meeting, Argonne National Laboratory, May 2004