Surface Structure Study of Liquid Eutectic Alloys: AuSi and AuGe

Alexei Grigoriev[1], Oleg Shpyrko[1], Christoph Steimer[1], Peter Pershan[1], Ben Ocko[2], Moshe Deutsch[3],
Binhua Lin[4], Jeff Gebhardt[4], Timothy Graber[4], Mati Meron[4]

[1]Department of Physics, Harvard University, Cambridge, MA; [2]Brookhaven National Lab, Upton, NY; [3]Bar-Ilan University, Israel;
[4]The University of Chicago and Argon National Lab, Chicago, IL

Introduction

Motivation:

Knowledge of surface properties is crucial for rapidly developing nanotechnology especially when speaking of such technologically important materials as Si, Ge and Au.

Eutectic alloys AuSi and AuGe are technological solders with melting temperature about 360C. These eutectics are important for high quality soldering of semiconductor devices.

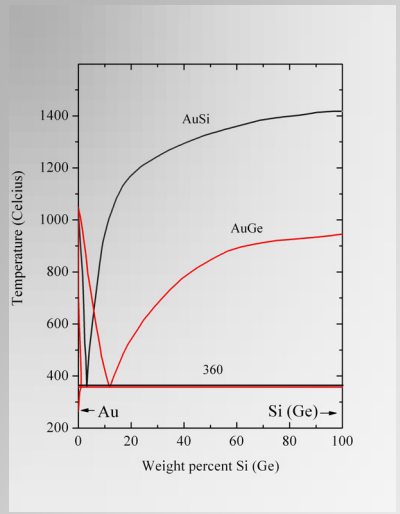
Idea:

Study the surface structure of liquid eutectic alloys AuSi and AuGe with surface x-ray scattering techniques such as specular x-ray scattering and off-specular diffuse scattering.

Tools:

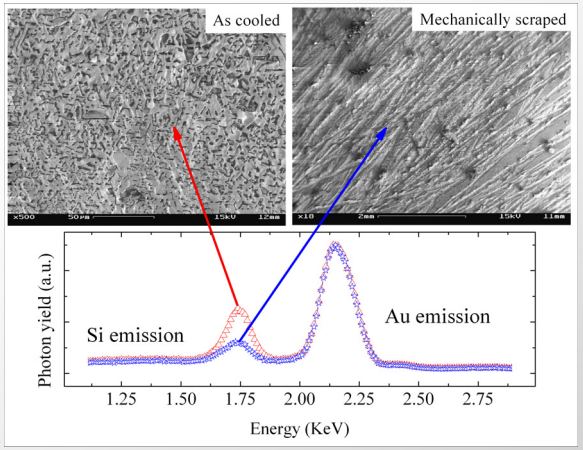
AuSi and AuGe liquid samples are prepared and their surfaces have been cleaned and studied *in situ* in UHV chamber. Liquid diffractometers: 15-ID ChemMatCARS beamline at APS and X22B at NSLS

Phase Diagrams



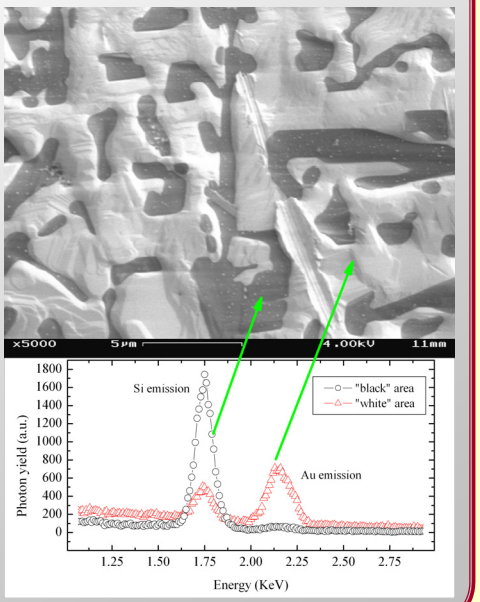
Melting point of AuSi and AuGe eutectic is about 360C; this temperature is significantly lower than melting point of Au (1064C), Si (1410C) or Ge (937C)

Solid Surface (AuSi sample) studied by SEM and Photoluminescence

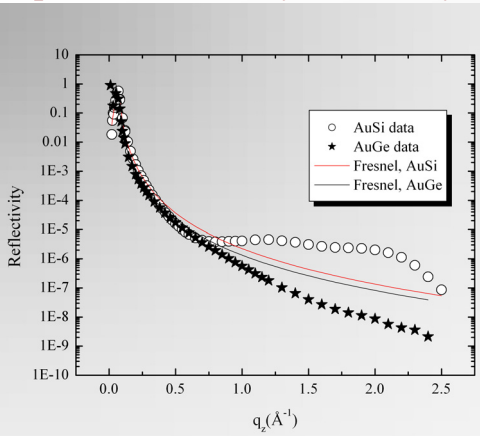


Solid AuSi eutectic surface is enriched in Si; mechanically scraped surface reveals alloy close to eutectic composition (above)

The solid surface consists of patches of Si rich alloy and almost pure Si (right)

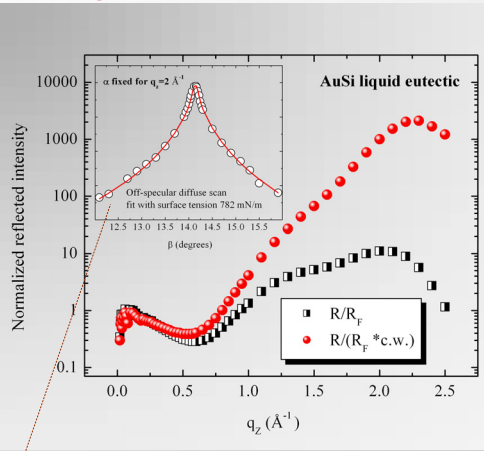


Liquid Surface Study with X-ray Scattering



Specular x-ray reflectivity shows that AuSi surface reflects noticeably stronger signal than the AuGe surface.

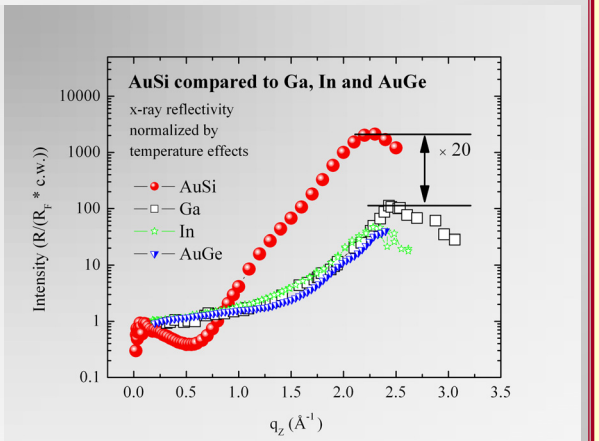
AuSi reflectivity stays well above the Fresnel line for entire range of q_z=1.0-2.5Å^{-1}.



Off-specular diffuse scattering (the inset) proves liquid character of the surface.

When thermal effects are removed the reflectivity is ~2000 times more intense than the Fresnel prediction.

This maximum can only be explained by well organized layering at the eutectic surface



Maximum amplitude of normalized surface form factor squared is ~20 times larger than measured for any other pure metal or alloy.

In addition to the strong layering peak there is a pronounced minimum in the reflectivity from the AuSi alloy that is similar to one observed for liquid Hg. No other liquid metals or alloys exhibit such a feature.

Summary

- AuSi and AuGe are unique low melting temperature eutectic alloys (compare to melting points of components)
- low vapor pressure allows UHV studies
- In spite of similarity between two alloys their surfaces have significantly different structure
- Surface form factor of the AuSi eutectic alloy is 20 times higher than for any other studied metallic systems including the AuGe eutectic
- Surface structure of AuSi system can not be explained with models previously developed for pure metals and alloys
- Further studies are needed to understand the AuSi surface structure.

Acknowledgements

This work is supported by DOE grants: DE-FG02-88-ER45379 and DE-AC02-98CH10886. Special thanks to Ilan Shalish for assistance in solid AuSi eutectic SEM and photoluminescence measurements

Presented by Alexei Grigoriev at the APS Users Meeting, Argonne National Laboratory, May 2004