# Wetting Transitions in Liquid and Solid Alloys

**Paul Wynblatt, Carnegie Mellon University, DMR Award #9820169**

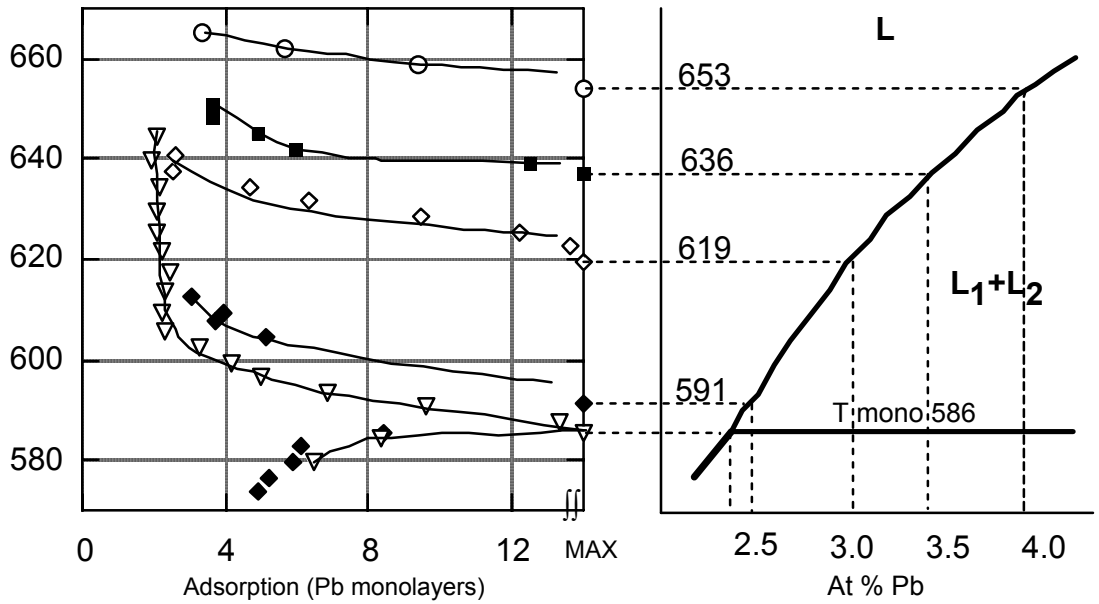


Fig. 1 Left panel: Rapidly increasing Pb adsorption for various Ga-Pb alloys as two-phase coexistence is approached from higher temperatures. Right panel: Segment of Ga-Pb phase diagram showing two-phase liquid domain

- **Wetting transitions have been well documented in organic systems but not in metallic alloys**
- **In metallic systems, wetting plays an important role in many technological processes, including joining, e.g. soldering**
- **Our studies have confirmed the presence of wetting transitions in several Ga-based liquid alloys**
- **The rapidly increasing adsorption of the wetting component (Pb in Ga-Pb alloys), as two-phase coexistence is approached, is a key characteristic of a wetting transition (Fig. 1 above)**

Wetting phenomena are ubiquitous in both nature and technology. A duck's feathers or a waterproof tent repel water because the solid surfaces of the feathers or tent material are poorly wetted by water. In contrast, water will be sucked into a sponge because water wets the sponge surface. Similar phenomena are at work in such diverse technologies as recovery of fossil fuels from oil reservoirs, or the soldered connections in integrated circuits.

The degree of wetting of a surface by a liquid is measured by the contact (or dihedral) angle made by a the liquid on the surface of interest. Wetting transitions are transitions from partial wetting (finite contact angle) to complete wetting (zero contact angle). Whereas such transitions had been studied previously in organic systems, little information was available on this type of transition in metallic systems prior to our work in this area.

Like other surface-related phenomena, wetting behavior is very sensitive to low levels of surface contamination, and this type of contamination cannot readily be controlled or eliminated in the previously studied organic systems. In contrast, wetting in metallic systems can be studied under ultrahigh vacuum conditions, where surface cleanliness can be both monitored and controlled. One of the first tasks we undertook was to develop the techniques for studying wetting transitions in liquid metallic systems by observing the changing composition of a liquid alloy surface by a surface analytic technique (Auger electron spectroscopy). Surface composition measurements are important, because the adsorption of one component of an alloy is expected to increase very rapidly with decreasing temperature, as two-phase coexistence is approached, if a wetting transition is present in the system at some lower temperature.

The results displayed in the left panel of Fig. 1 show changes in adsorption with temperature for several Ga-Pb alloys. In each case, the adsorption increases rapidly with decreasing temperature, as the two-phase liquid coexistence domain (shown on the phase diagram in the right panel) is approached. This behavior persists all the way down to the monotectic temperature, where the Pb begins to freeze, thereby preventing observations at lower temperatures. Nevertheless, these results clearly demonstrate that a wetting transition is present in liquid Ga-Pb alloys. In other work, we have demonstrated that the wetting transition in this system is virtual, and only occurs at much lower temperatures, where the two liquid phases are metastable.

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## Training

- Two graduate students have thus far participated in the research (Hyunjong Shim and Yang Song)
- Both students have received extensive training in the tools of surface science. These tools are used in a wide variety of scientific and technological activities, ranging from quality control of integrated circuits to the development of improved catalysts, and will serve them well in their future careers
- One of the students (Shim) was exposed to the importance of international scientific collaboration by spending two weeks performing experiments with the PI's collaborators in Marseille (France)
- The results of research on wetting transitions were incorporated into graduate level courses taught by the PI