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Title: Phase stability and thermophysical properties of Au-Zn-Al

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Phase stability and thermophysical properties of Au-Zn-Al

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Los Alamos National Laboratory

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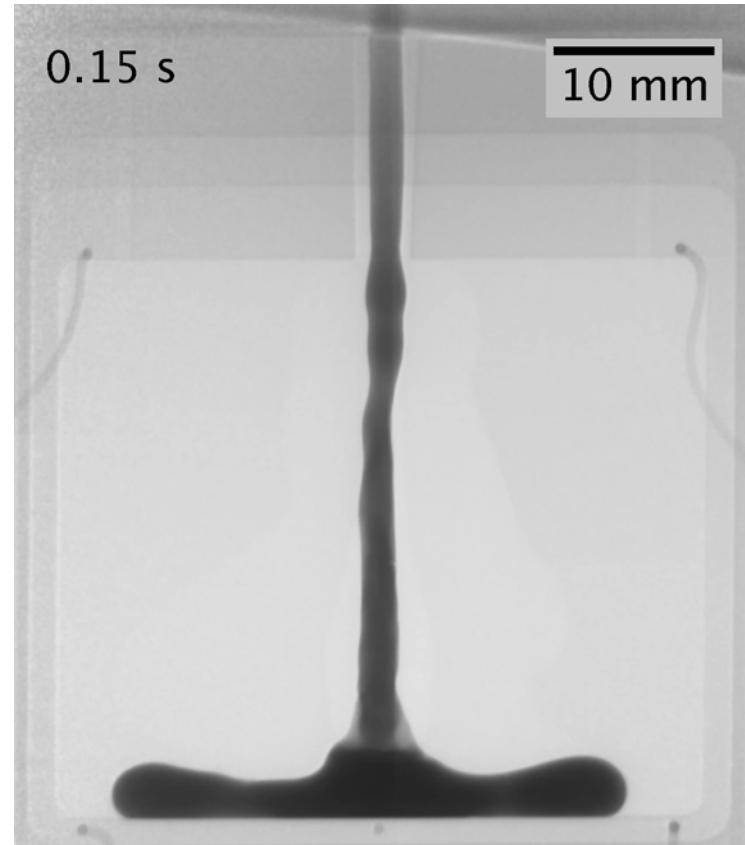
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Objectives

- What are the reasons for looking into Au-Zn-Al?
 - Main alloy of interest: $\text{Au}_{65}\text{Zn}_{30}\text{Al}_5$
- Existing thermodynamic models
- Selection between models
- Application to ternary system
- Vapor pressure assessment

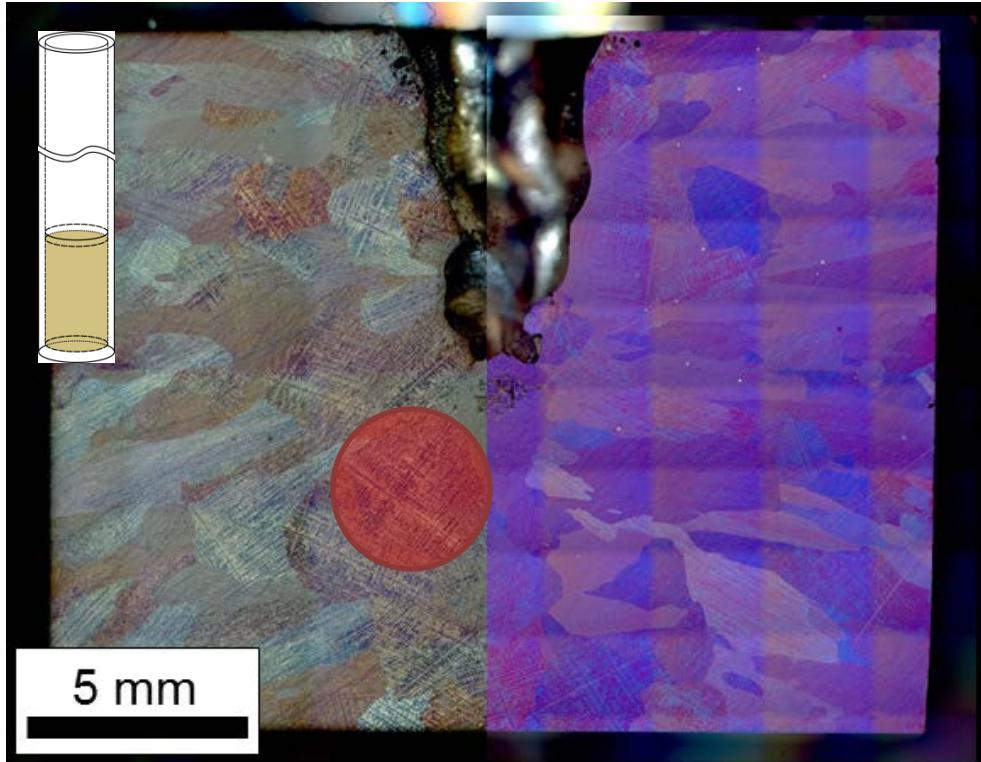
Motivation

- Casting and microstructural prediction
 - Accessible temperature ranges
 - Interesting microstructures
- Practical Concerns
 - Can the castings be reused easily?
Chemistry change due to Al oxidation and Zn volatilization
- Amenable to imaging



Alloying

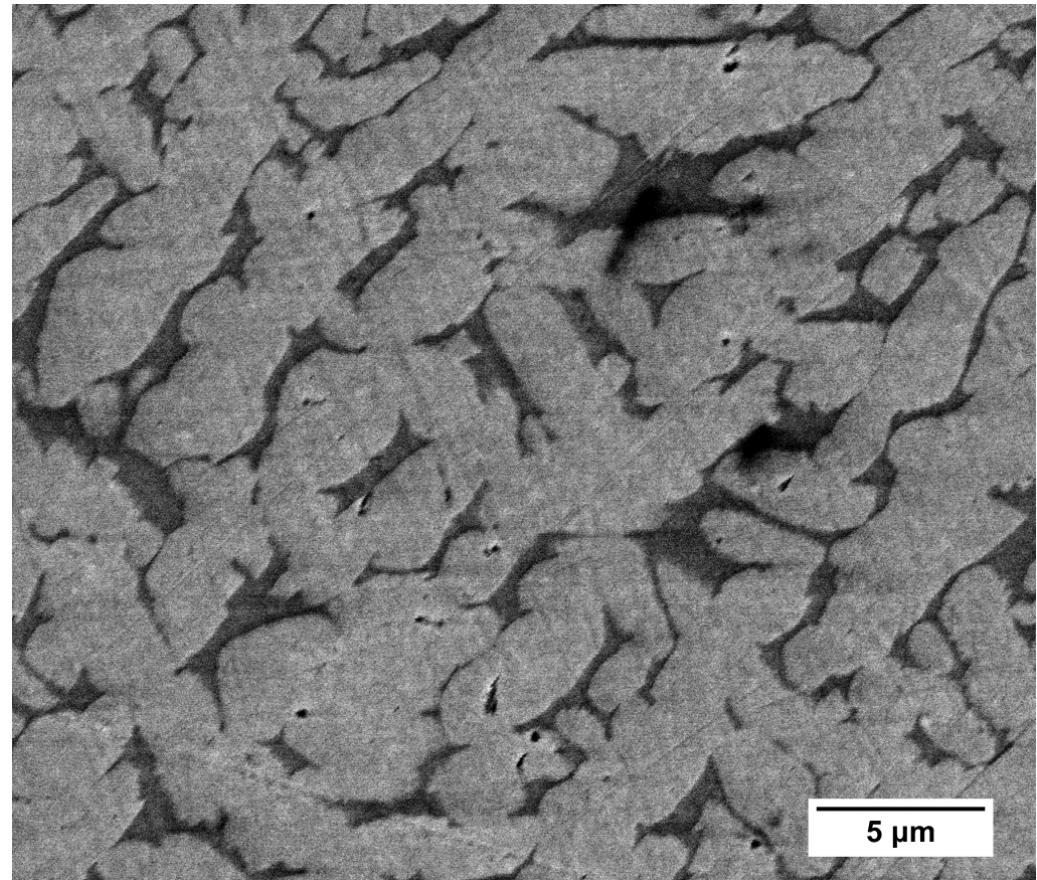
- Sample sizes from 5 – 1000 g
- Quartz encapsulation
 - <10 mTorr
 - 2 x Flushed with Ar
 - Ar backfilled
- 1050°C peak with vigorous shaking.
Cooled rapidly by water quench.
- Chemistry:
 - Bulk chemistries from DC Plasma Emission Spectroscopy (ASTM E 1097-12)
 - Locally with EDS



A cross sectional view of a 100g $\text{Au}_{65}\text{Zn}_{30}\text{Al}_5$ (at.%) sample after alloying and quenching. The left-hand side is standard light optical and the right-hand side was captured using polarized light.

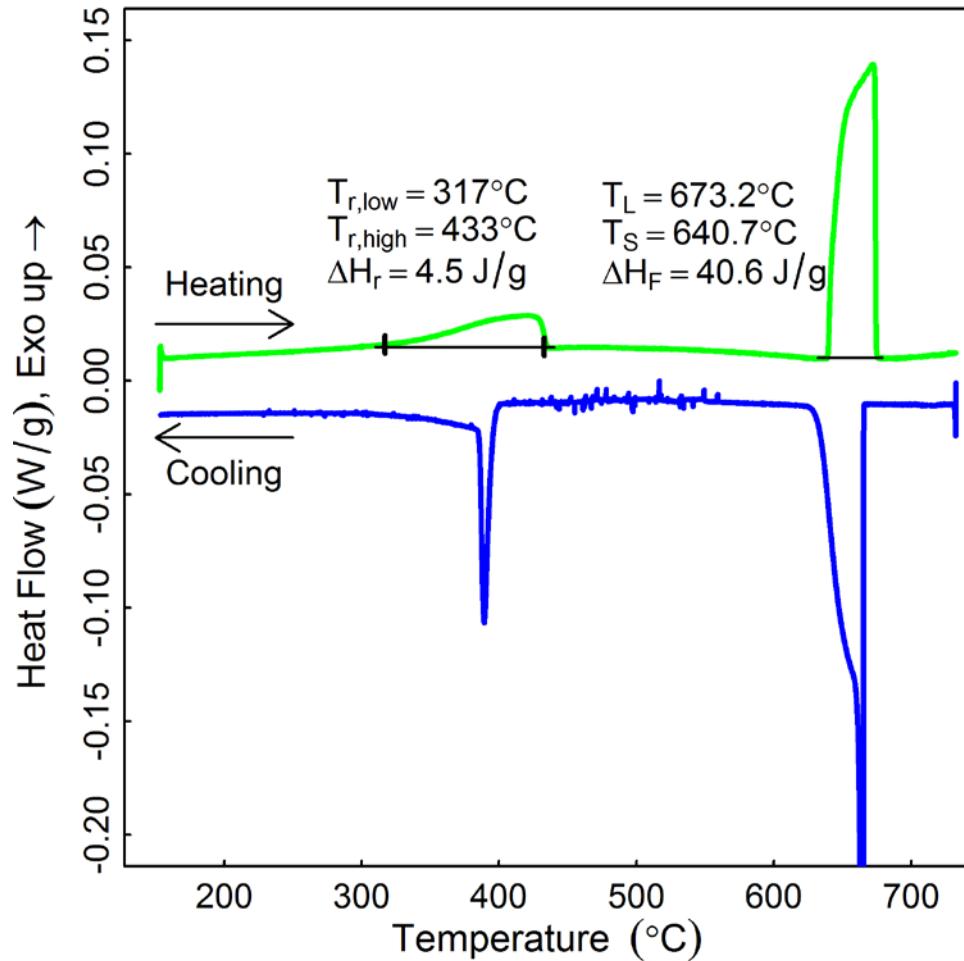
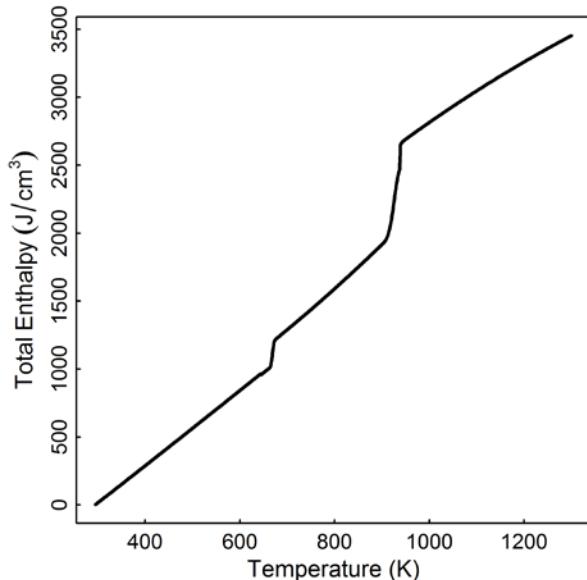
$\text{Au}_{65}\text{Zn}_{30}\text{Al}_5$

- Mixed microstructure α (light phase) and β (dark phase)
- Primary phase tie line composition at T_L :
 $\text{Au}_{70.8}\text{Zn}_{24.8}\text{Al}_{4.4}$

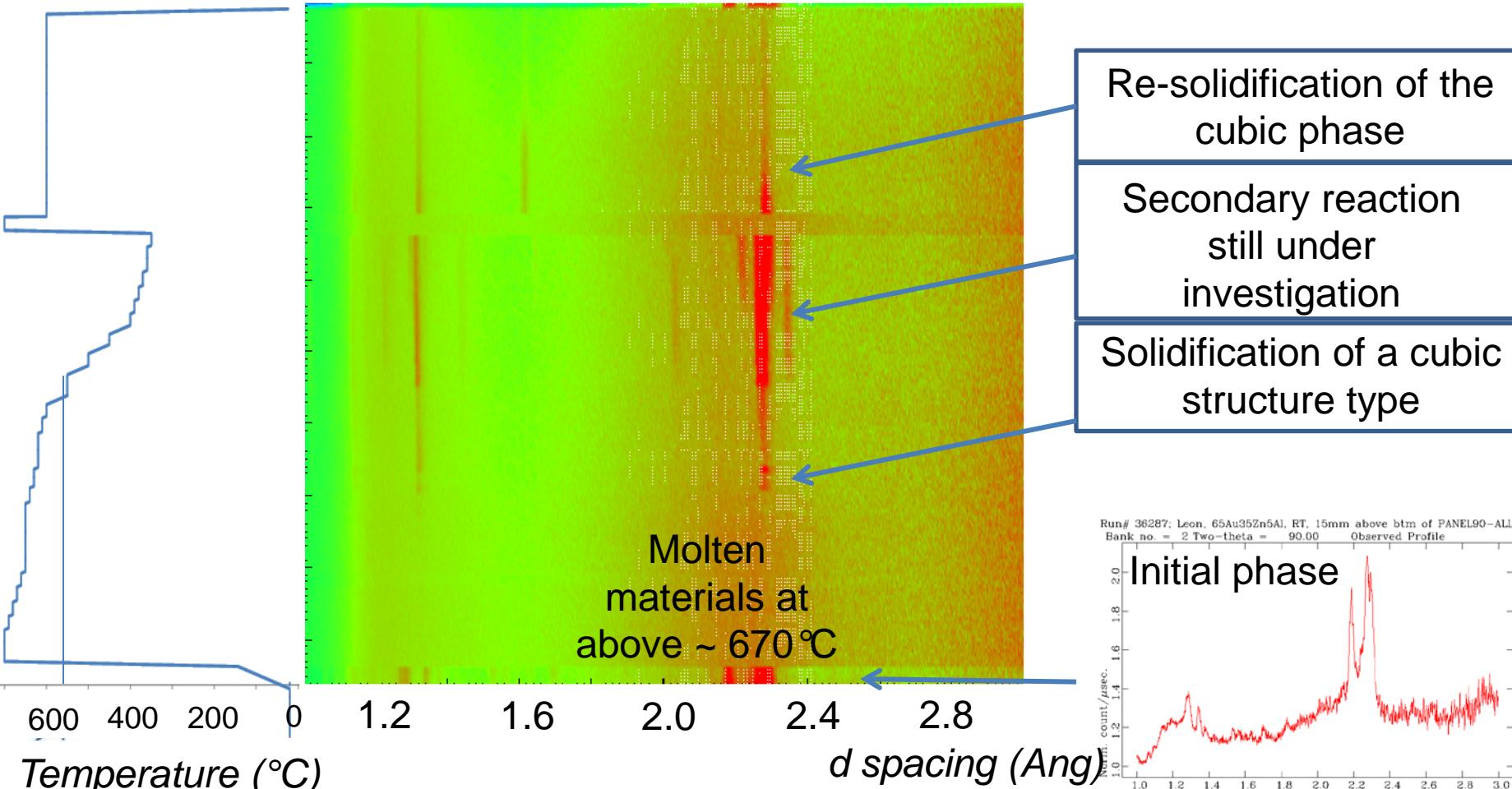


Au₆₅Zn₃₀Al₅ Details

- Au₆₅Zn₃₀Al₅
 - High density: 15.9 g/cm³
 - T_L=673°C ; T_S = 640°C
 - Solid state reaction, 380°C
 - $\alpha_L = 1.885 \times 10^{-5} \text{ K}^{-1}$



In-Situ Neutron Diffraction study of $\text{Au}_{65}\text{Zn}_{30}\text{Al}_5$



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Slide 7



Au-Zn

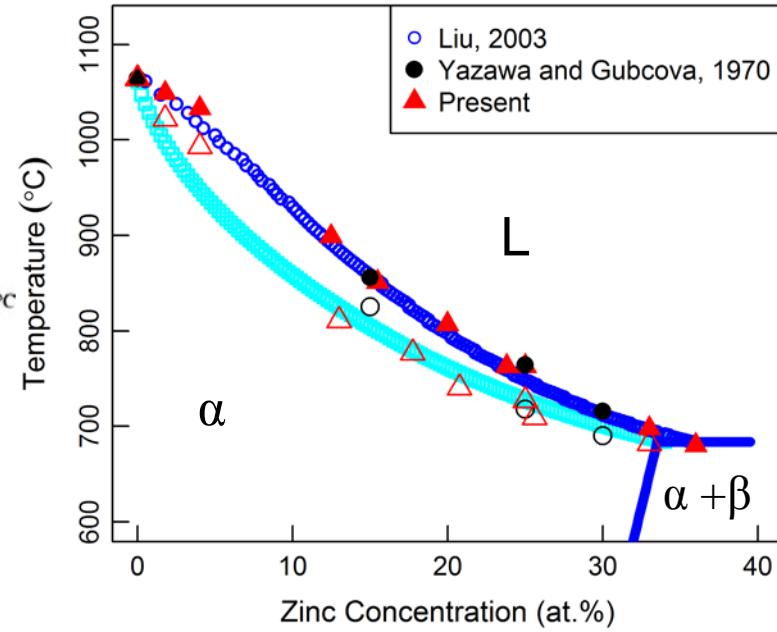
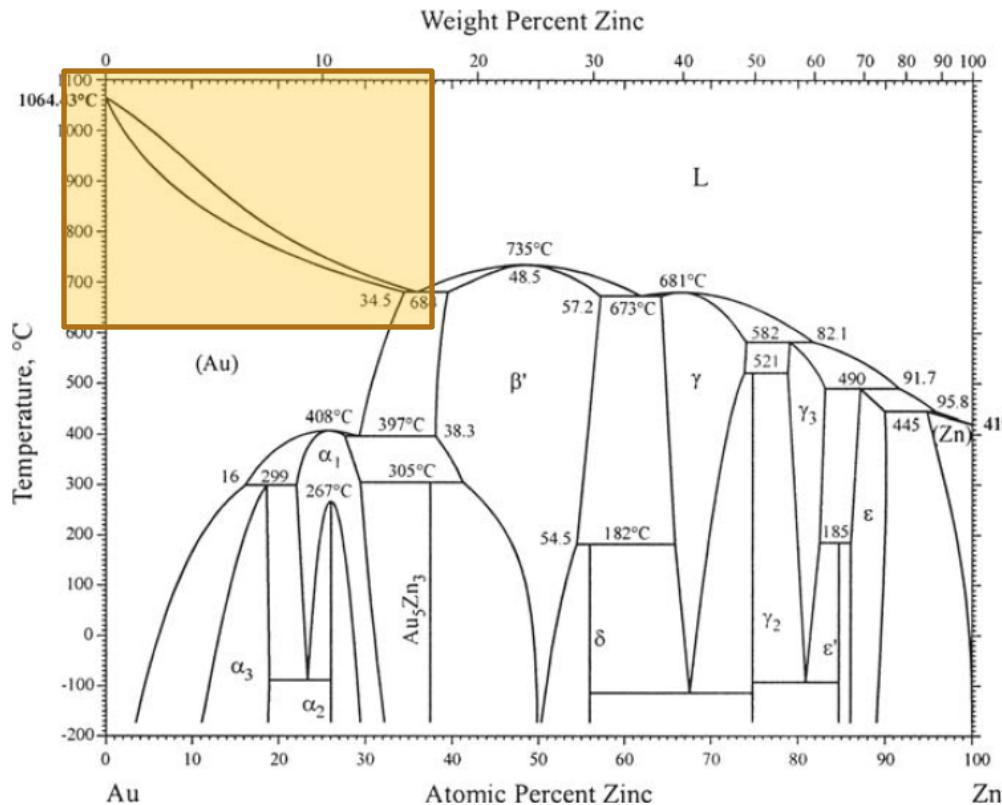


Figure on LHS and interaction parameters for RHS curves from [1].

Pure metal data from [2]

Additional Experimental data from [3]

Au-AI

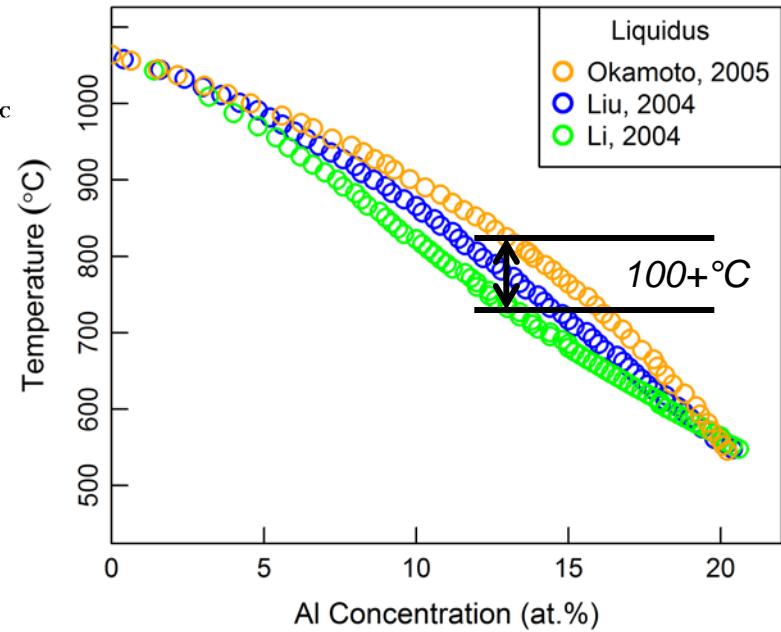
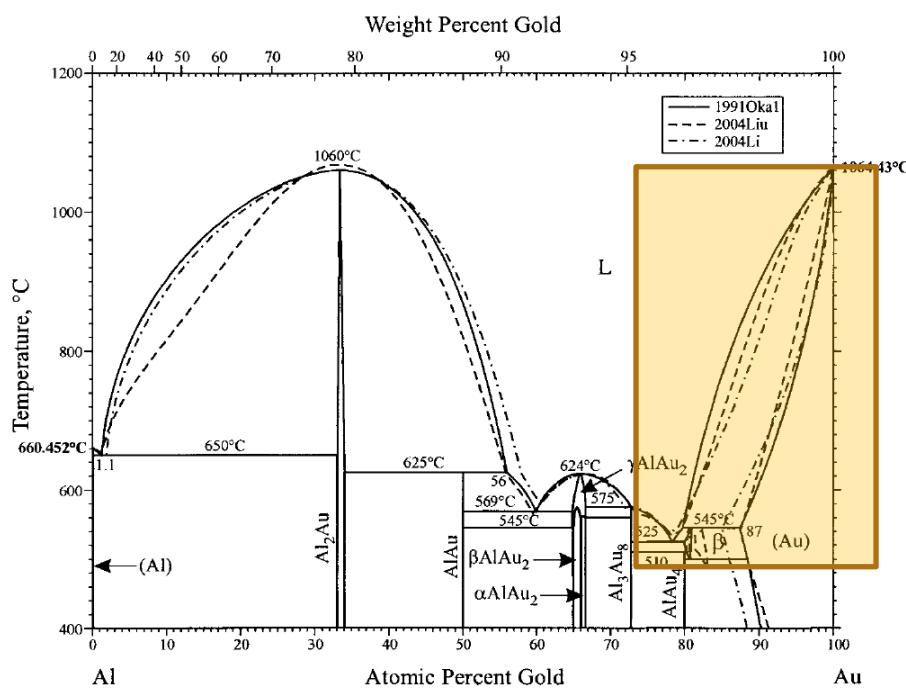
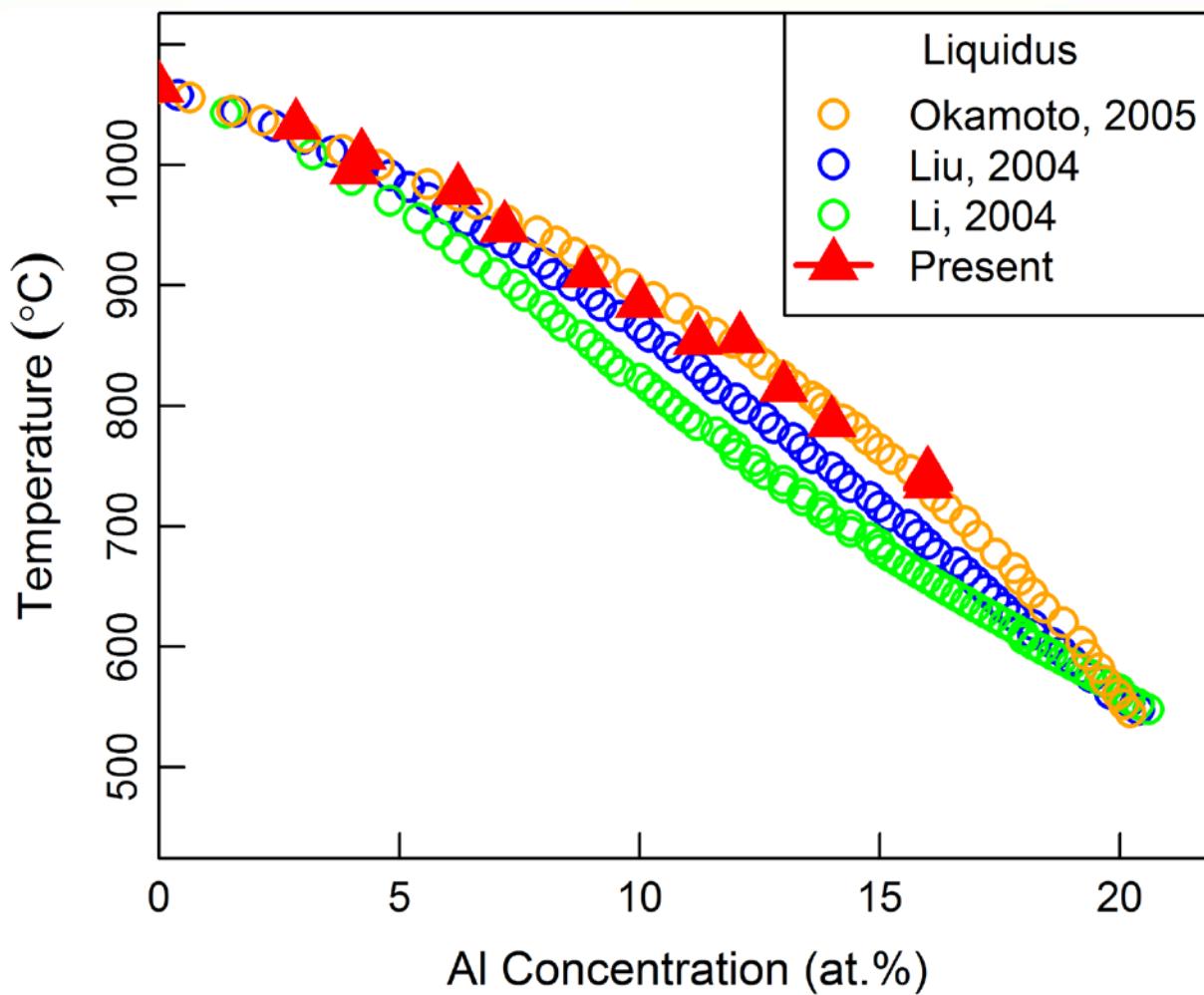
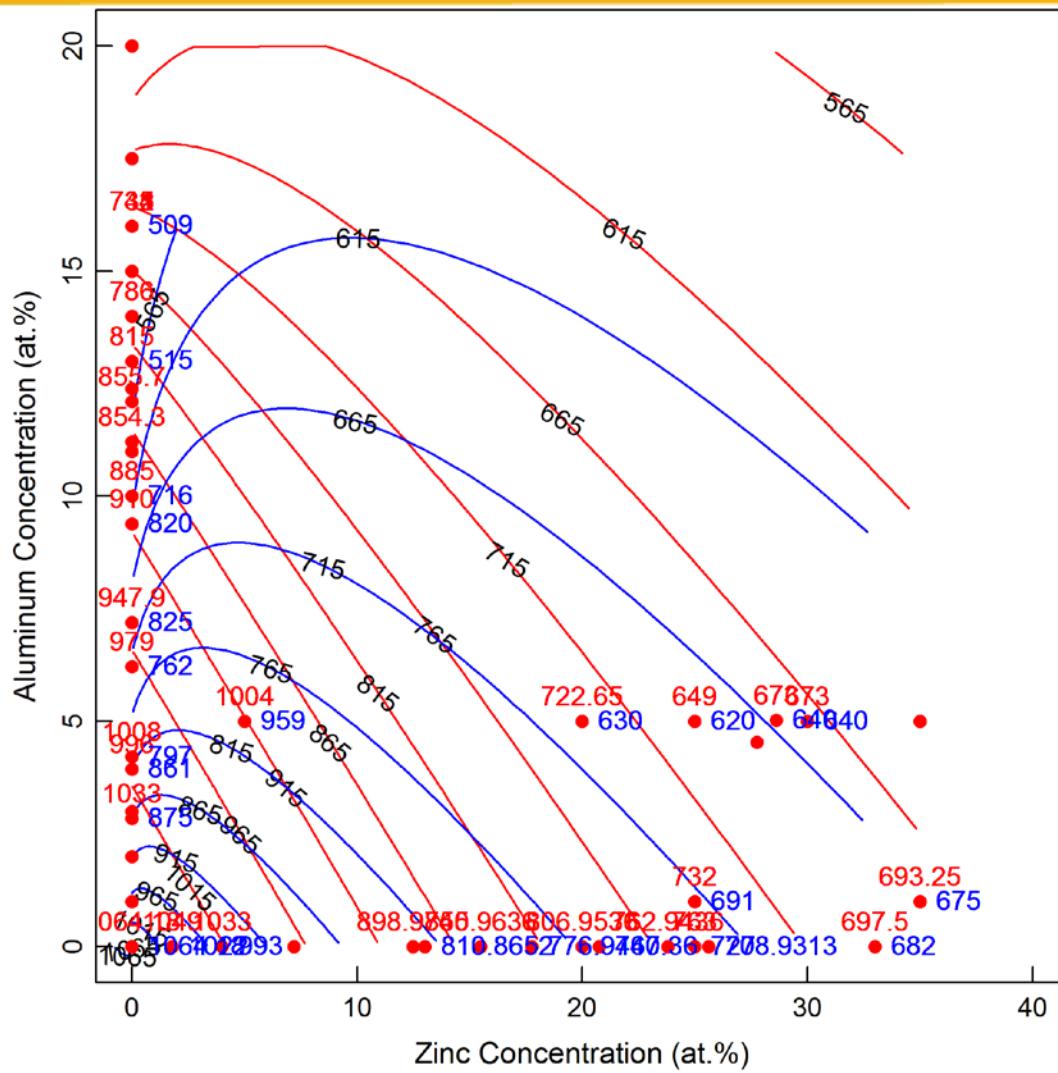


Figure from [4], models from [5], [6], [7].

Model selection



A lot to look at... it won't be long



A small example

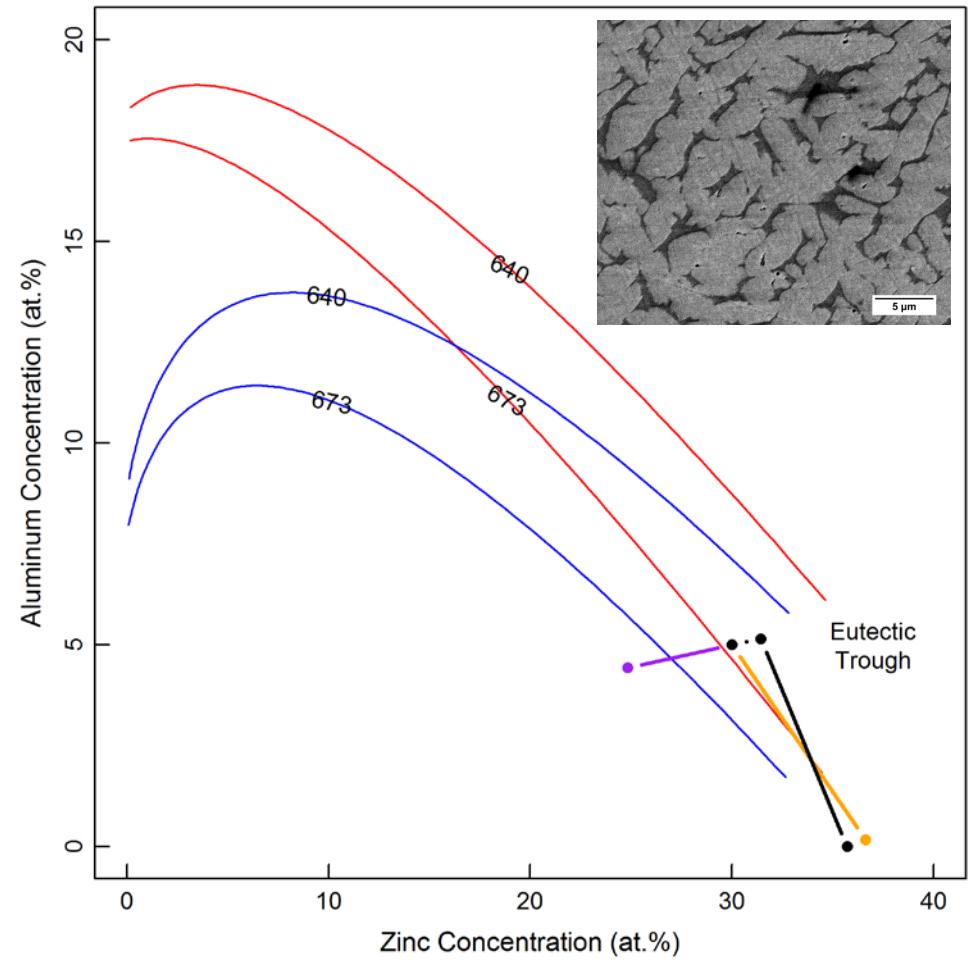
$$C_0 = \text{Au}_{65}\text{Zn}_{30}\text{Al}_5 \text{ (at. \%)}$$

$$V_f(\text{fcc}) \approx 78\%$$

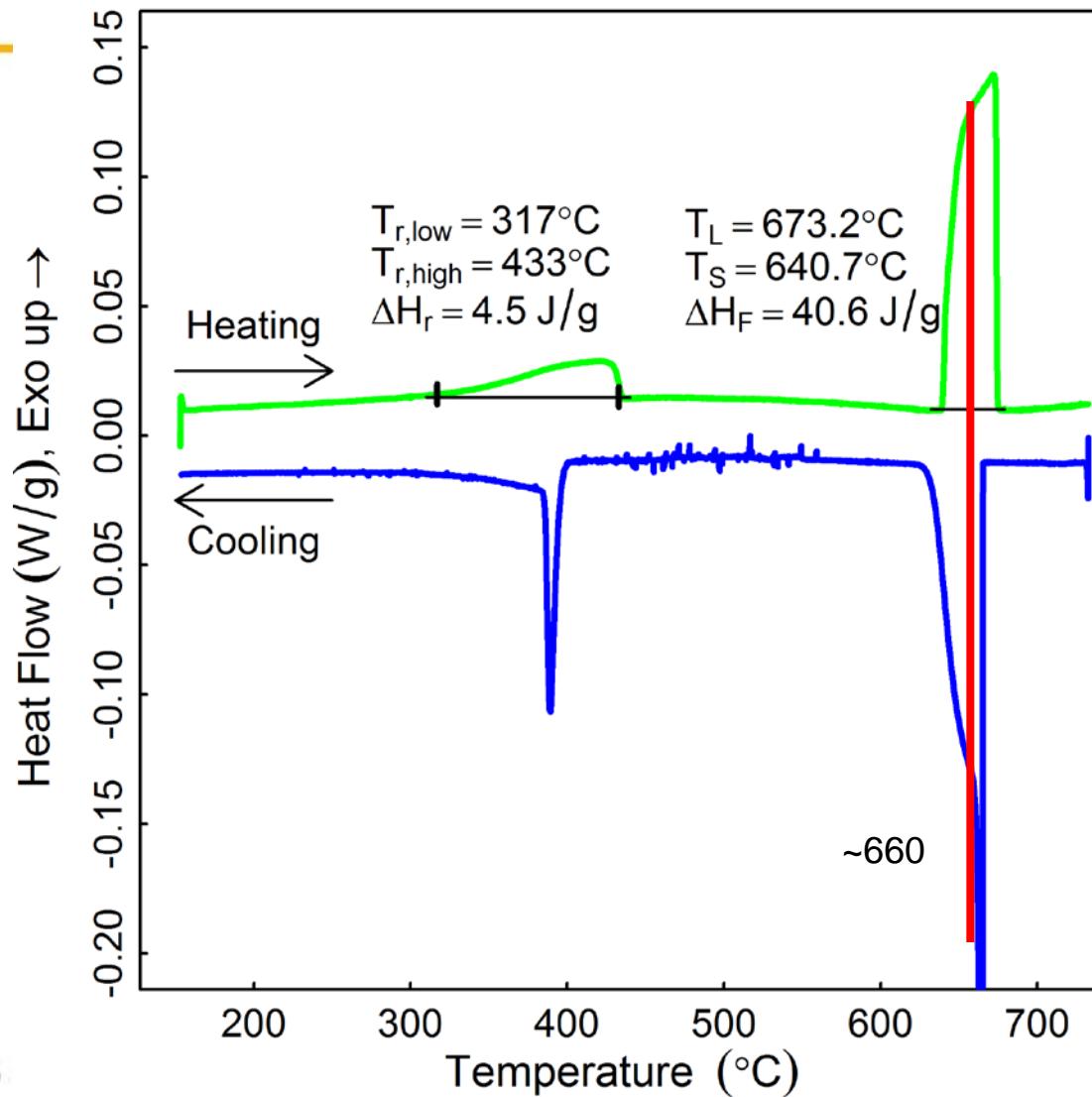
1. An approximate tie line composition can be obtained through EDS.

2. The liquid composition at the eutectic trough can be estimated

Temperature?

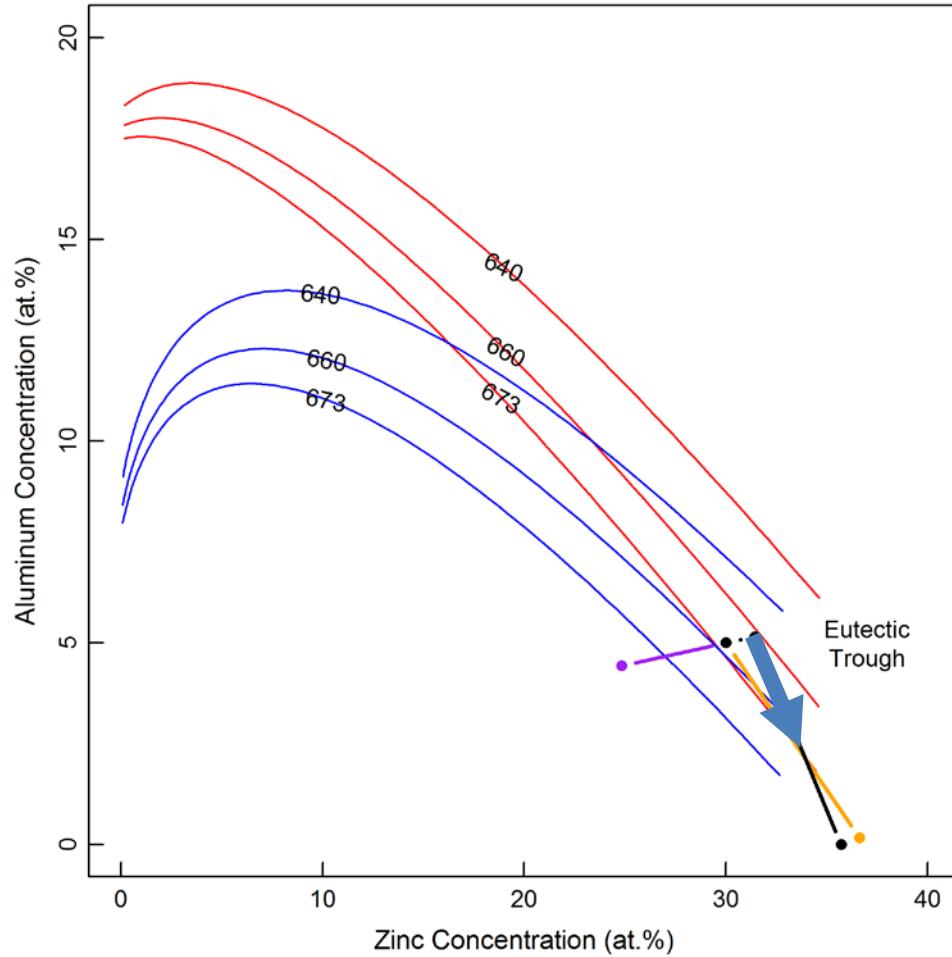


Ternary Details

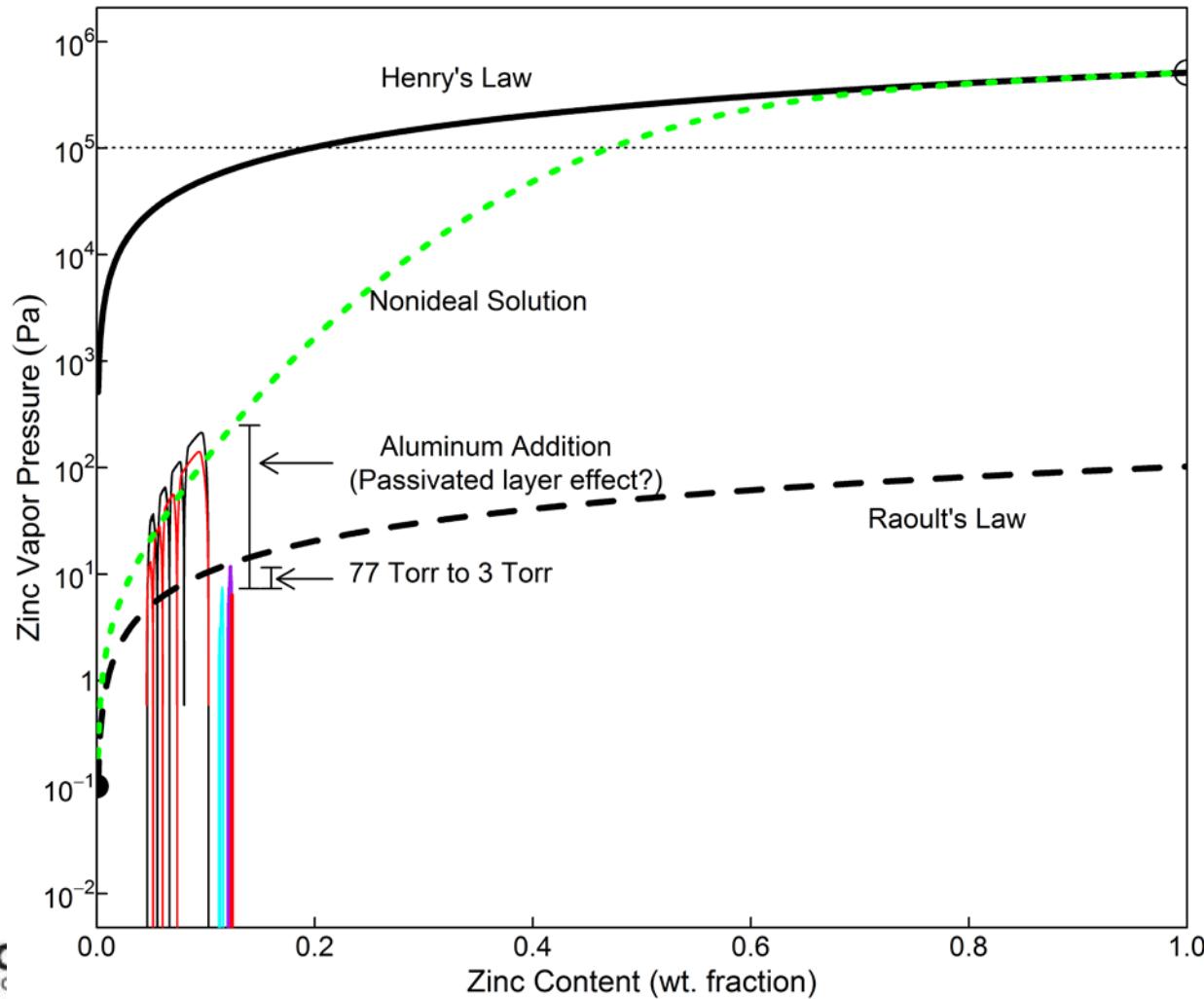


How'd we do?

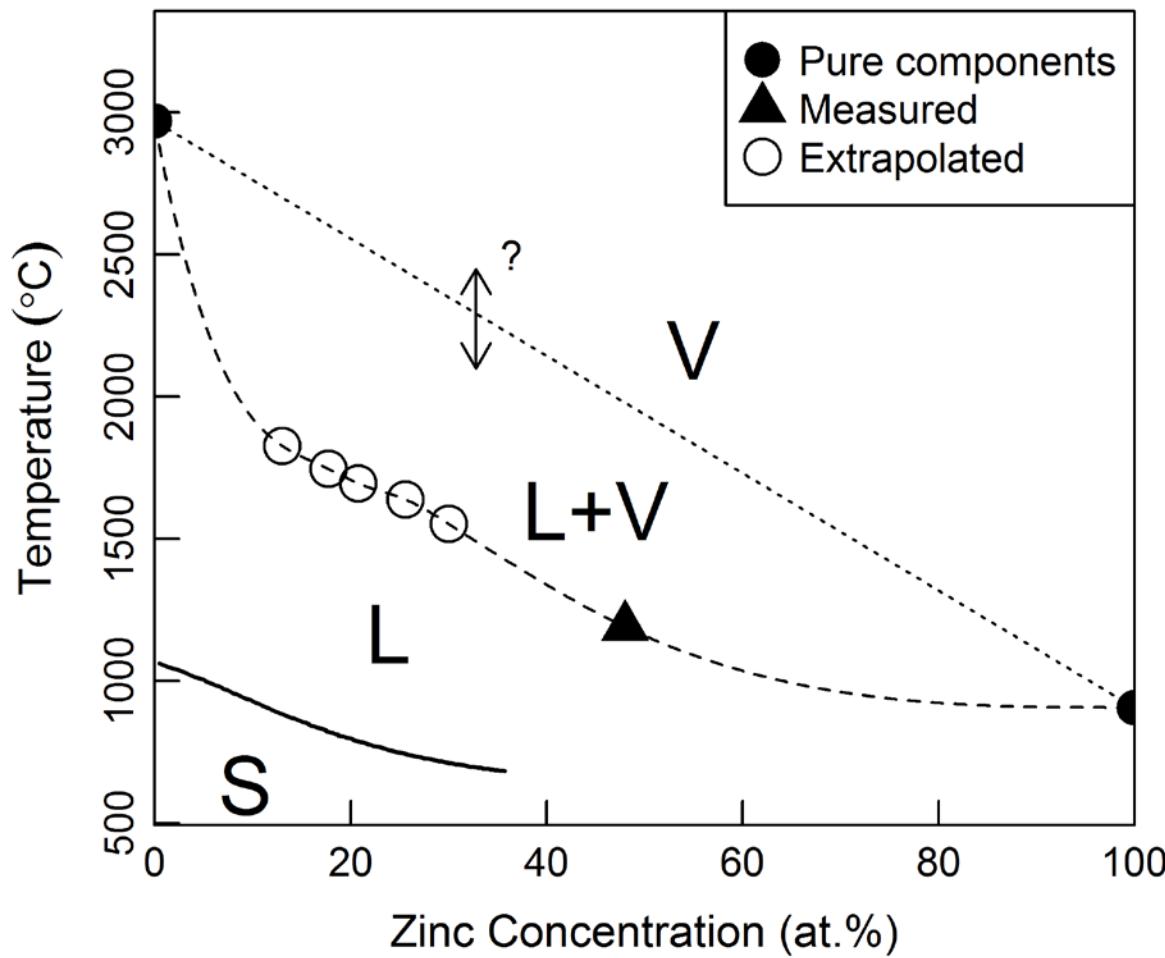
- The liquidus estimation (with dilute Al) is reasonable.
- Prediction of solidus temperatures will require a formal model.



Mass loss and vapor pressure



Some gas phase information



Conclusions and future work

- Binary models have been examined on the Au-rich side of the Au-Al and Au-Zn phase diagrams
 - Current Au-Zn model is appropriate
 - Interaction parameters from Murray et. al. and formal assessment of Okamoto fits the Au-Al data best
- Zinc vapor pressure has been assessed in order to determine the ability to reuse these alloys after casting.
- A preliminary ternary model gives reasonable agreement with the data, but further investigation is necessary
- In-situ diffraction studies are as of yet inconclusive in the ternary region, but work is ongoing.
- Microstructure predictions

References

- [1] H.S. Liu, K. Ishida, Z.P. Jin, Y. Du, "Thermodynamic assessment of the Au-Zn binary system", *Intermetallics* 11 (2003), 987-994.
- [2] A.T. Dinsdale, "SGTE Data for Pure Elements" *CALPHAD* 15 317-425.
- [3] A. Yazawa and A. Gubcova, "Thermodynamic studies of liquid Au-Zn" *Transactions of the Japan Institute of Metals* 11 (1970) 419-423.
- [4] H. Okamoto, "Au-Zn (Gold-Zinc)", *Journal of Phase Equilibria and Diffusion* 27 (2006) 427.
- [5] J.L. Murray, H. Okamoto, T.B. Massalski, "The Al-Au (Aluminum-Gold) System" *Bulletin of Alloy Phase Diagrams* 8 (1987) 20-30.
- [6] H.S. Liu, J. Wang, Y. Du, Z.P. Jin, "Thermodynamic description of the Au-Al system" *Zeitschrift fur Metallkunde* 95 (2004) 45-49.
- [7] M. Li, C. Li, F. Wang, D. Luo, W. Zhang, "Thermodynamic assessment of the Al-Au system" *Journal of Alloys and Compounds* 385 (2004) 199-206.