Simulating mushy zone resolidification for multiphase and multicomponent alloys using ChemApp

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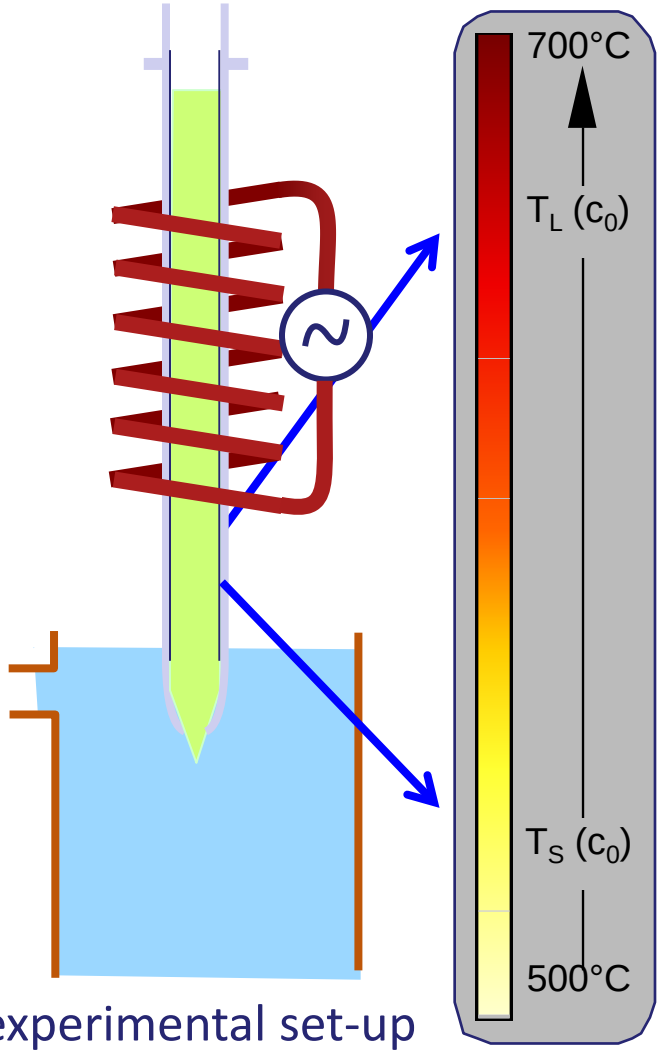
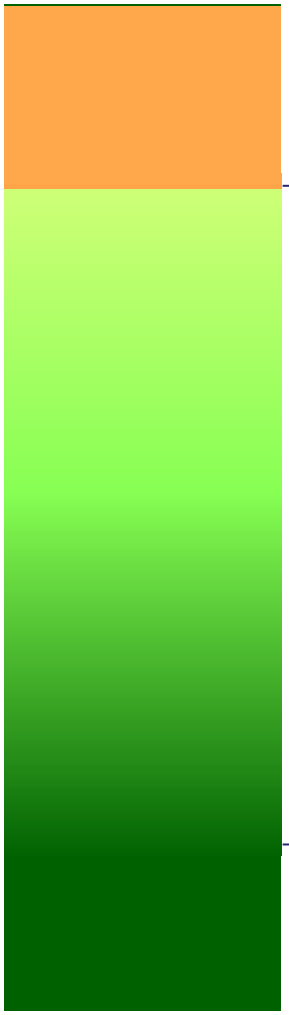
GTT User Meeting 2014

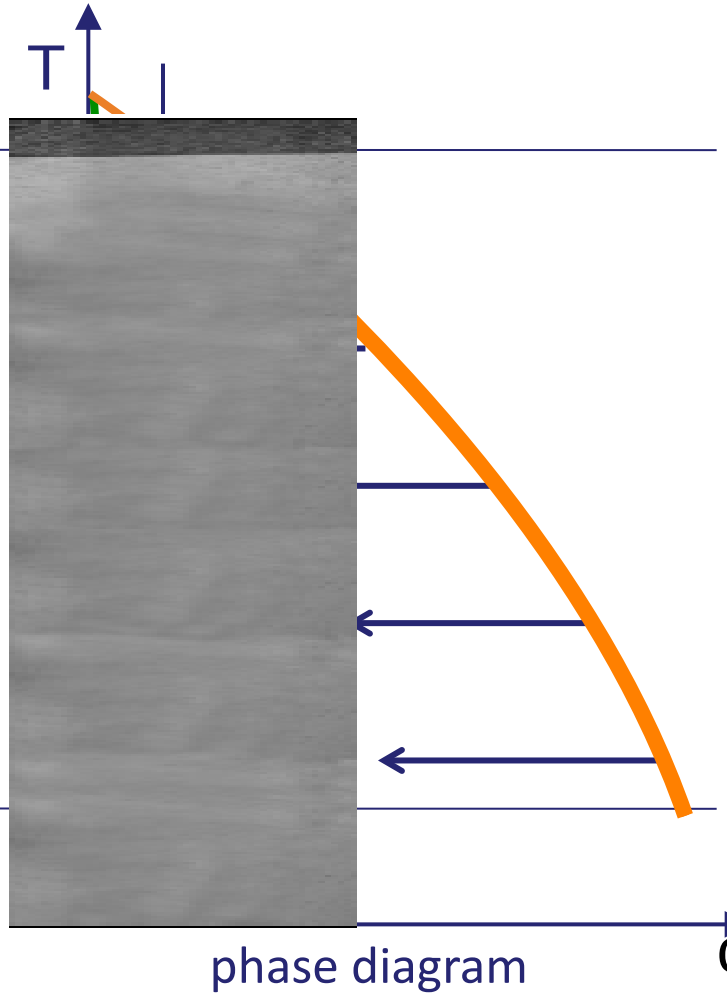
mushy zone resolidification

$dT/dx \longrightarrow df_s/dx$



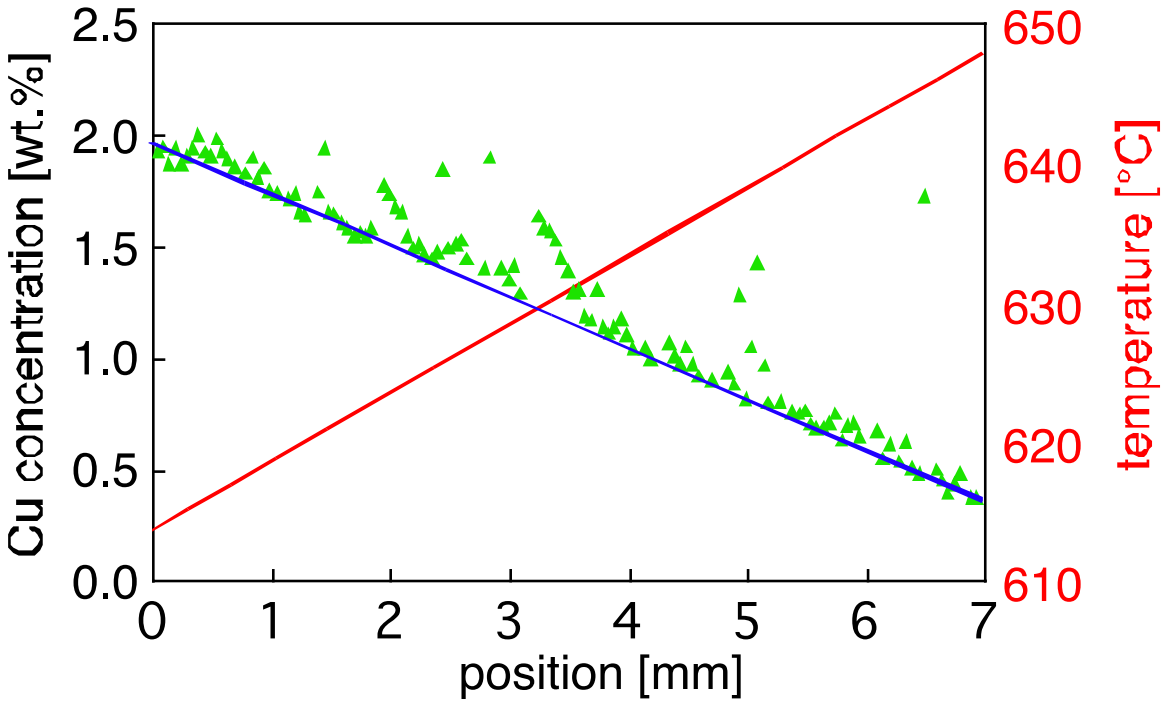
experimental set-up





phase diagram

binary systems



measured concentration

measured local temperature

corresponding solidus concentration

other effects documented in literature

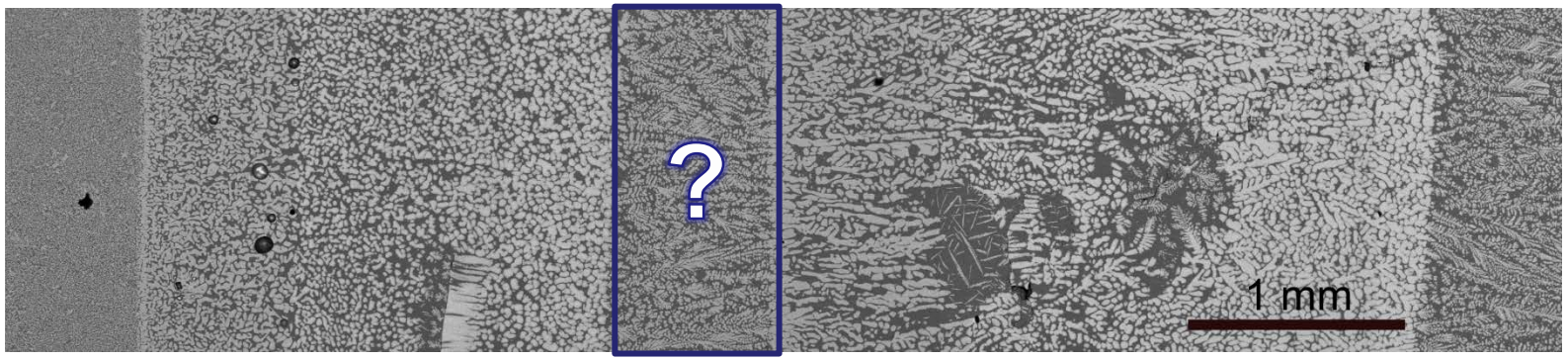
- TGZM
- LFM
- thermo migration
- coarsening
- …

analytical model by Combeau et al.

- resolidification in binary alloys with single solid phase forming in mushy zone

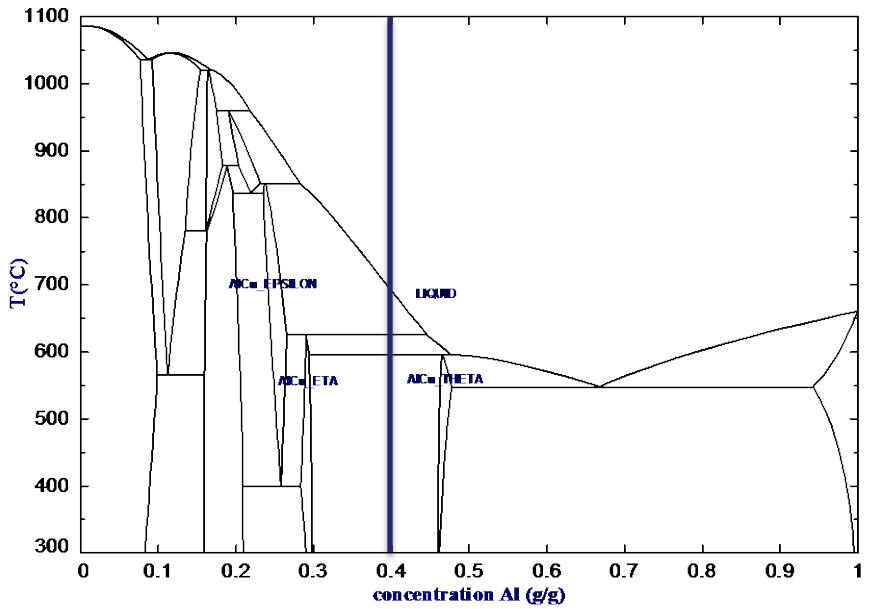
multiphase resolidification

T_S T_L



Al-60% Cu

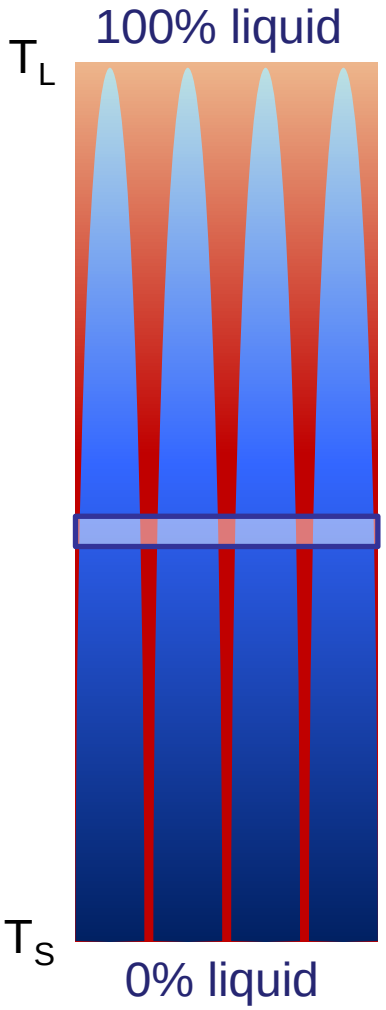
→ quenched after 2 min holding time



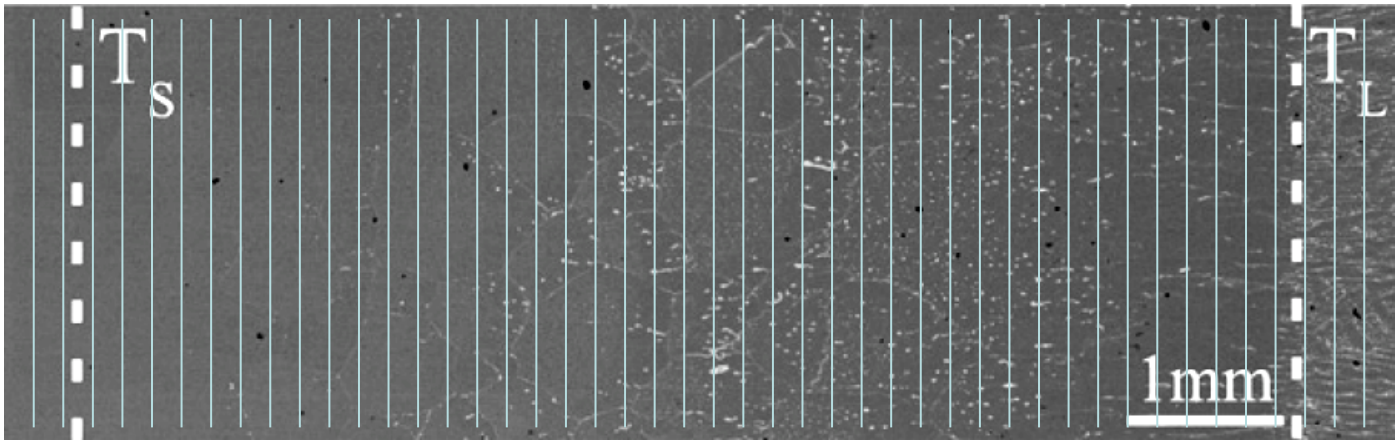
model

$$\frac{\partial c_{tot}}{\partial t} = \frac{\partial}{\partial x}\left(D_L f_L \frac{\partial c_L}{\partial x} \right)$$

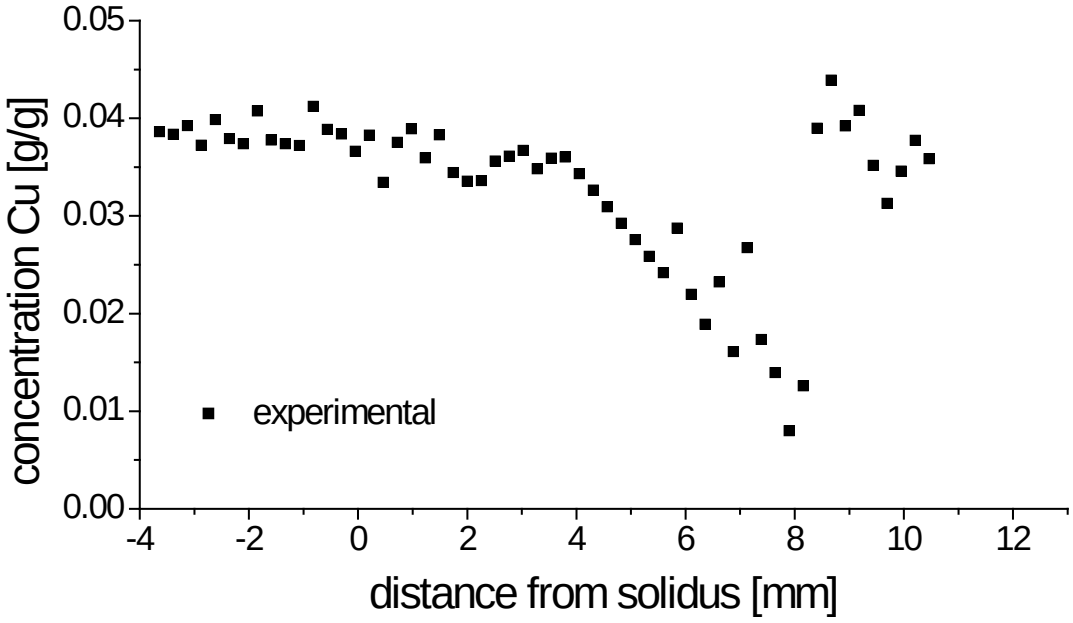
- constant temperature gradient assumed
- c_0, T, D_L known
- calculate liquidus concentration (c_L), liquid fraction (f_L), phase fractions and concentrations in solidified phases using **ChemApp**
- solve diffusion equation using Finite Differences Method to obtain new c_{tot}



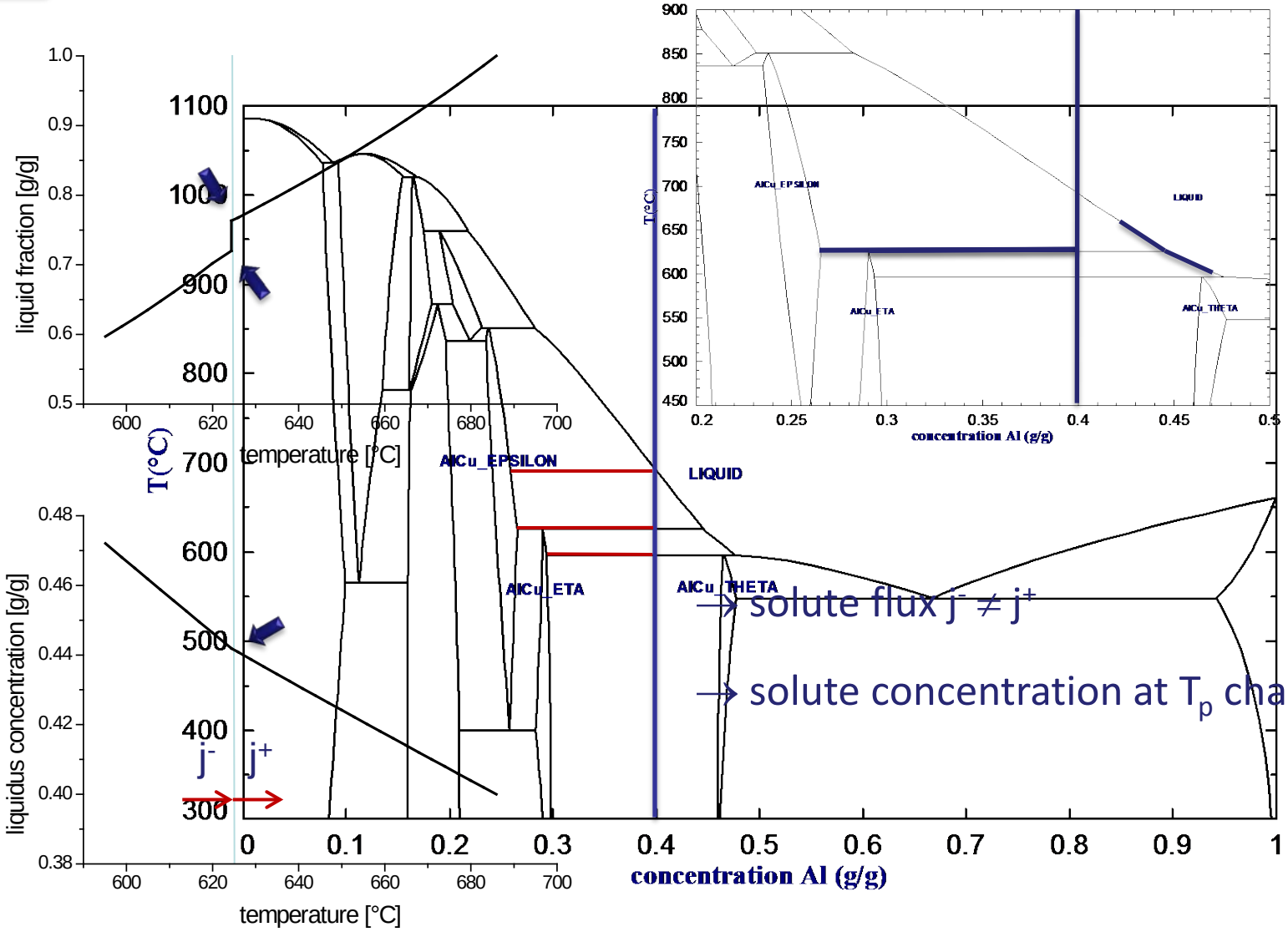
results: Al-3.8 % Cu



holding time:10 min
temperature gradient: 10 K/mm



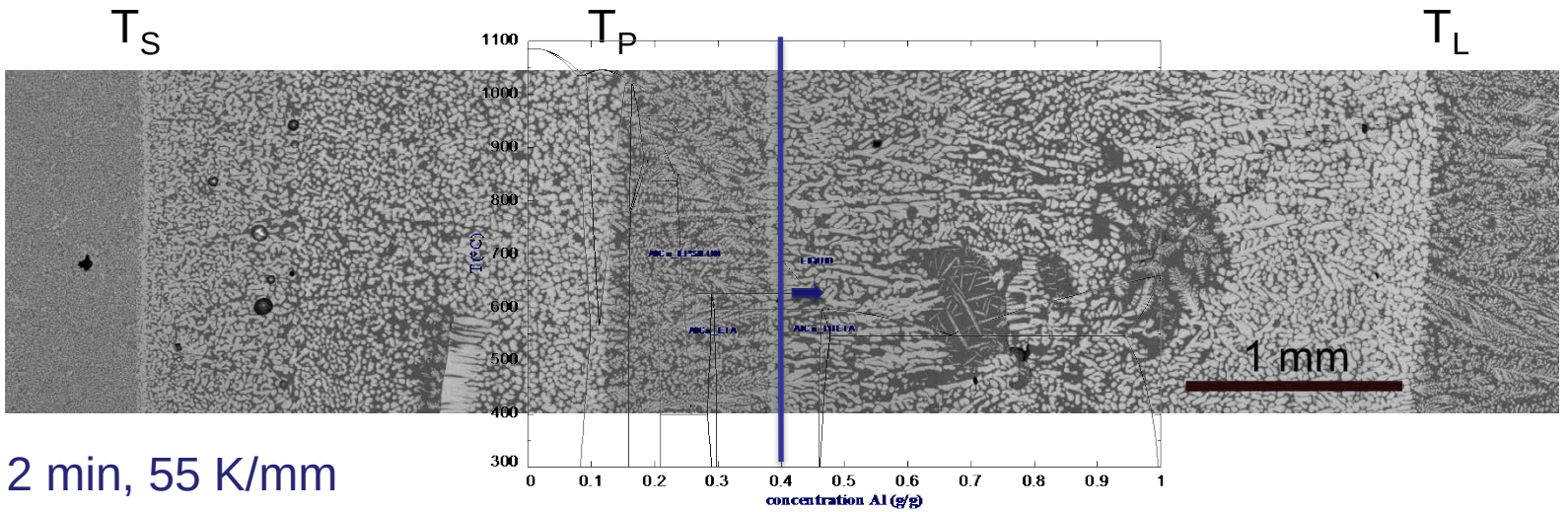
multiphase case: Al-60 wt.% Cu



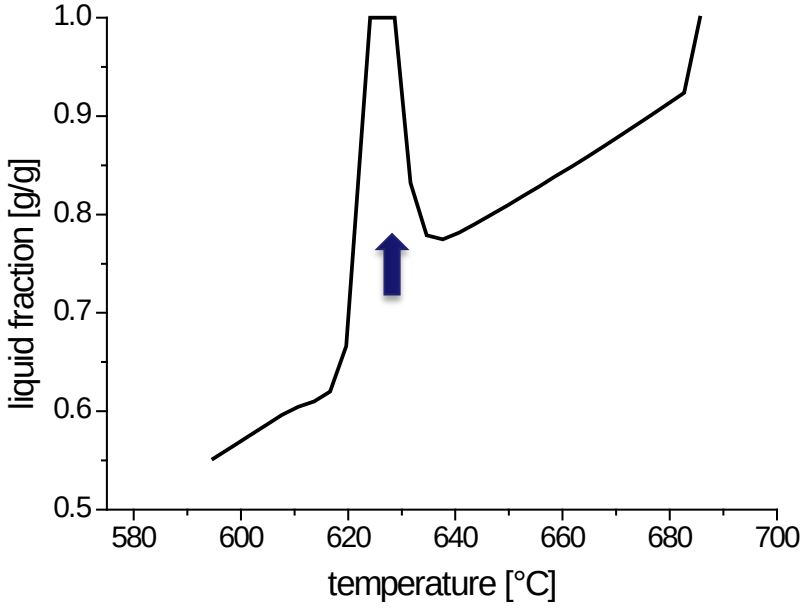
→ solute flux $j^- \neq j^+$

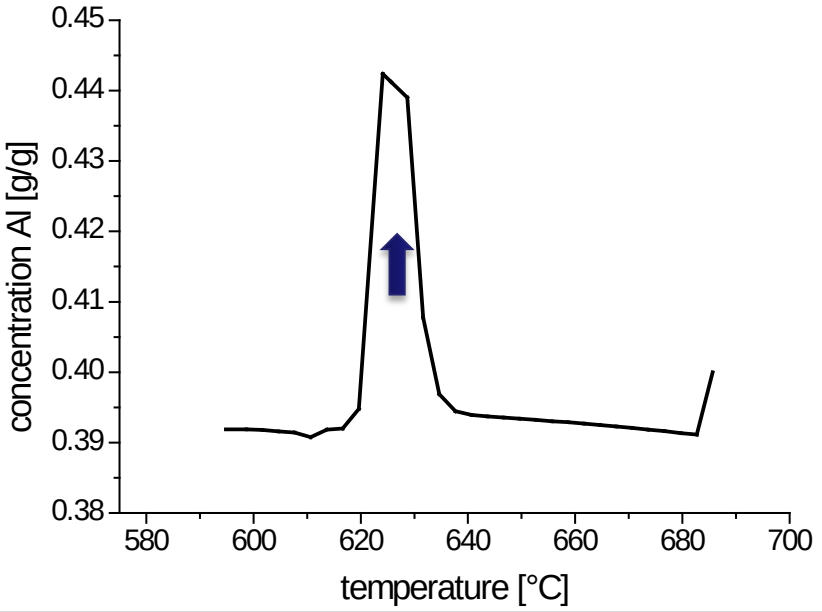
→ solute concentration at T_p changes

results: Al-60 wt.% Cu

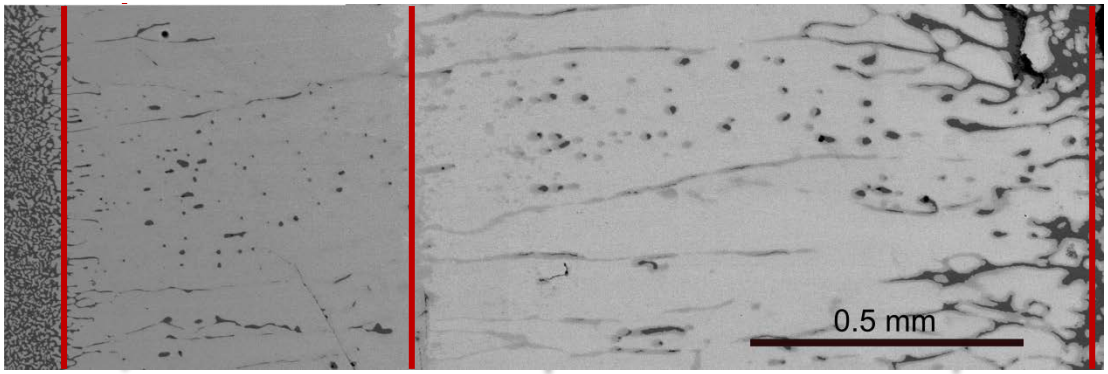


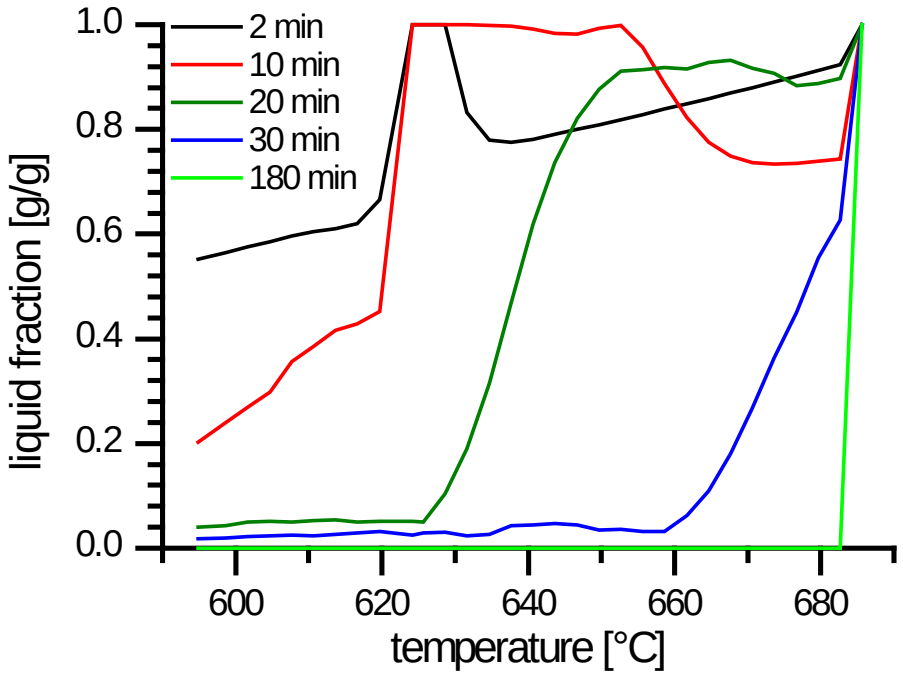
2 min, 55 K/mm





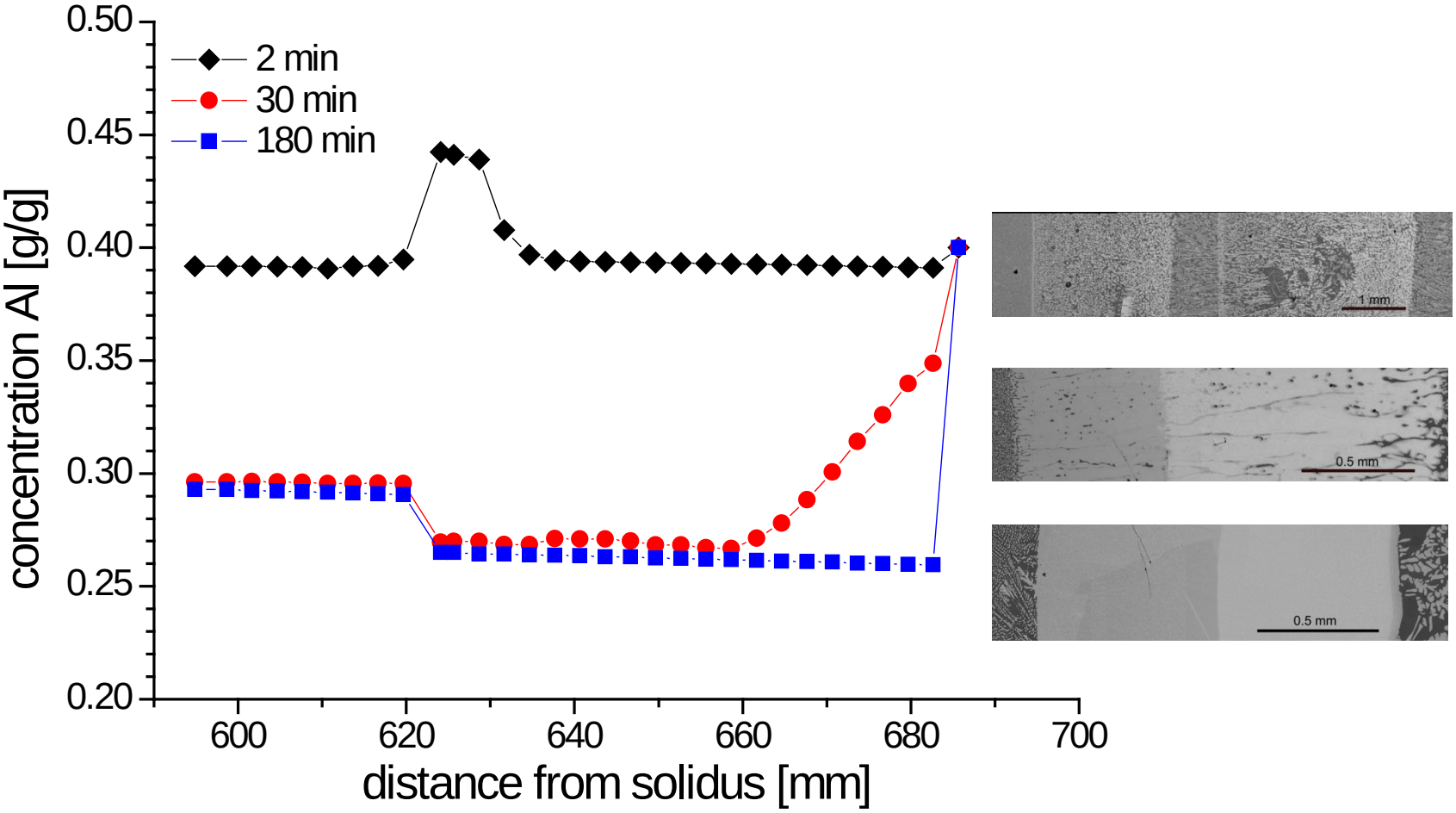
Al-60 wt.% Cu – liquid fraction



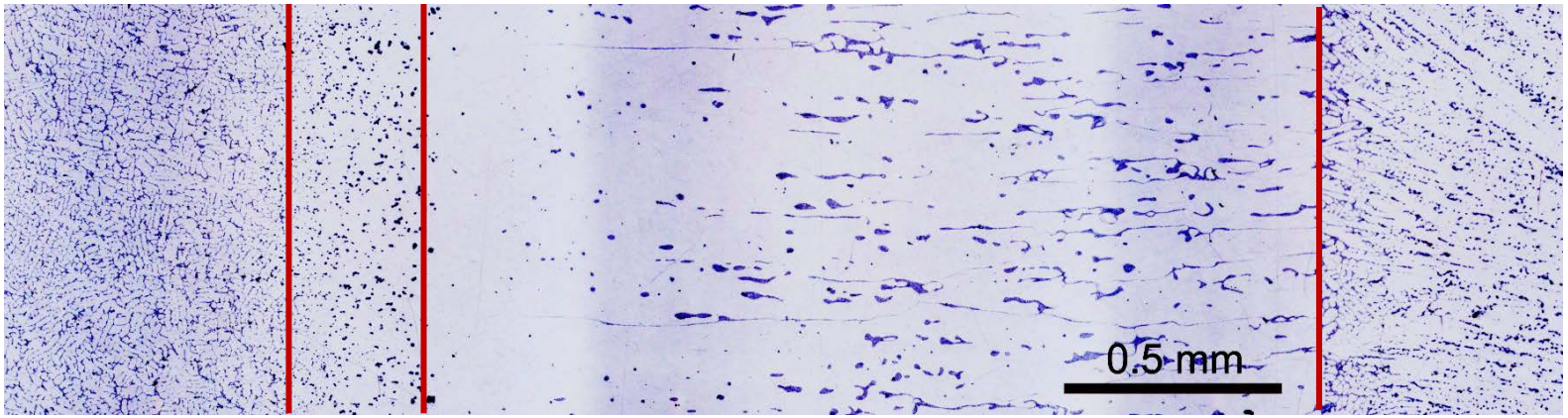


results: Al-60 wt.% Cu - concentrations

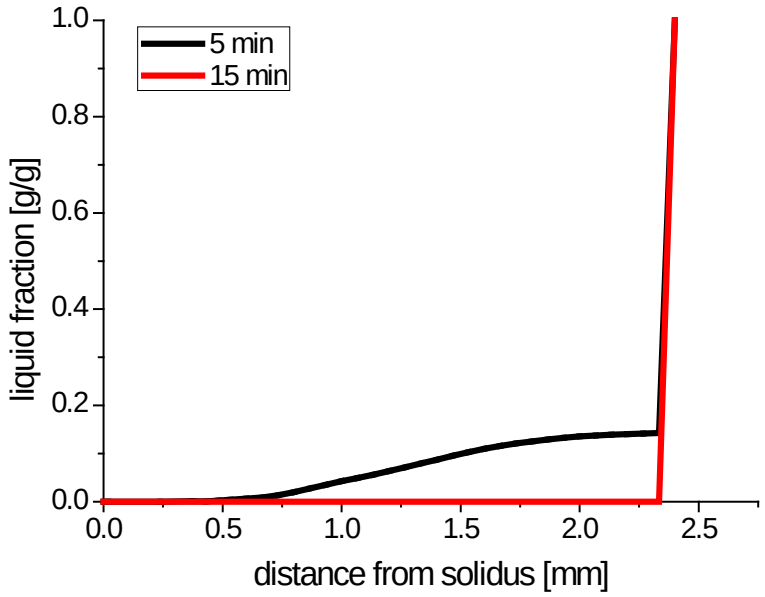
Temperature gradient: 55 K/mm

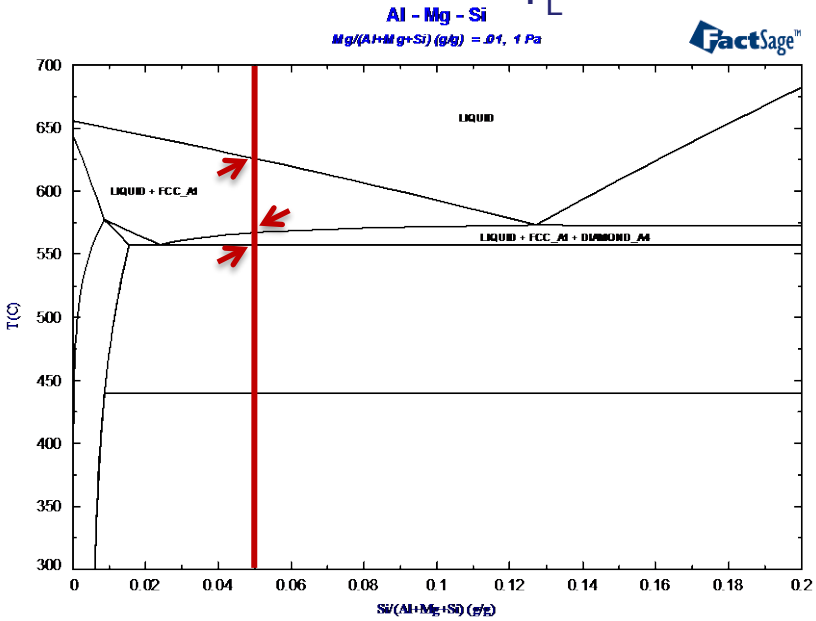


results: Al-5 wt.% Si- 1 wt.% Mg, 30 K/mm



T_S T_L





conclusions

- a model for mushy zone resolidification was presented:
  - temperature dependent local equilibria calculated using thermodynamic software package ChemApp
  - diffusion equation solved numerically
- multiphase and multicomponent alloys
- verification via temperature gradient annealing experiments in Al-Cu and Al-Mg-Si alloys