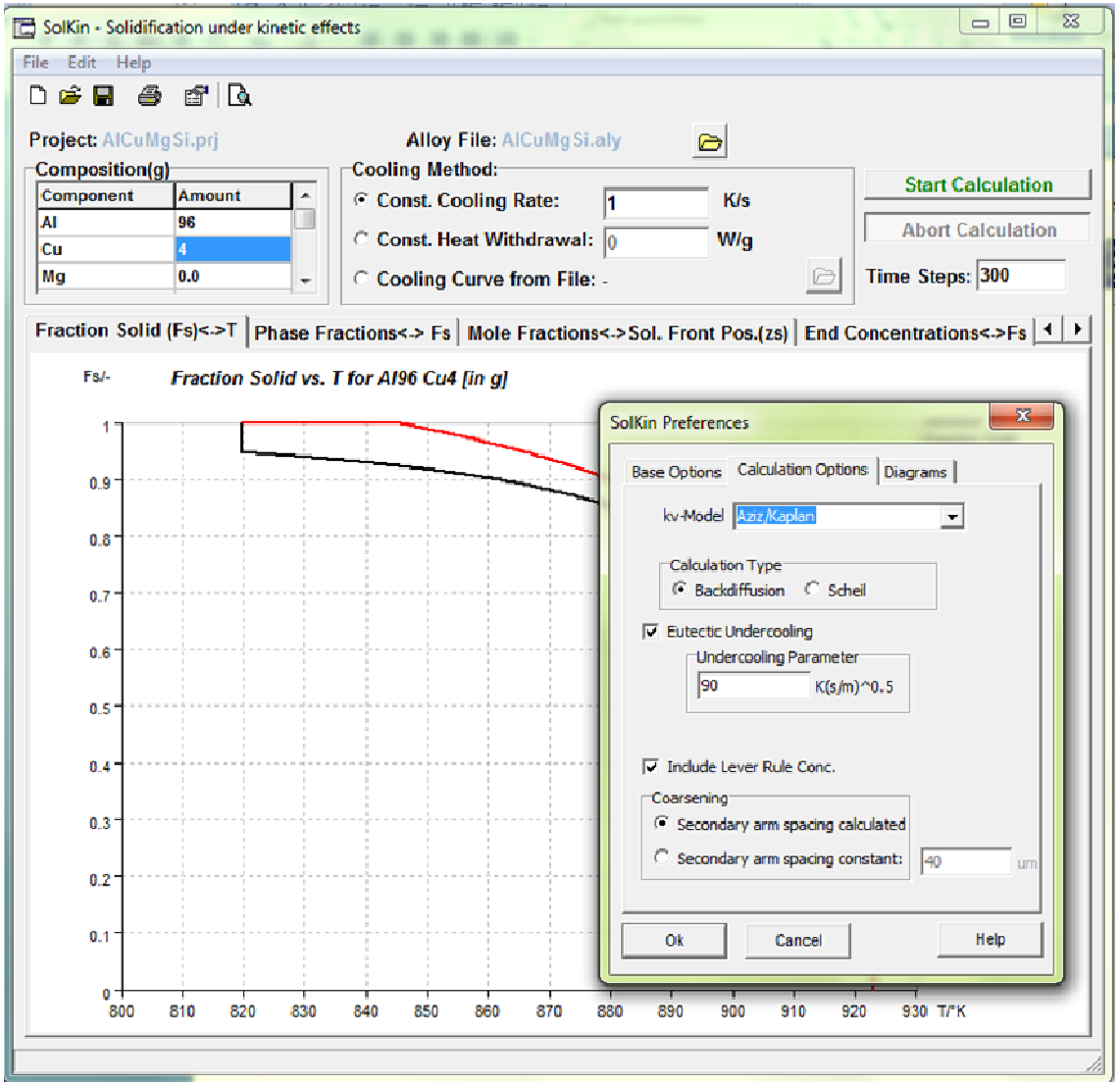
Plane front directional solidification experiments for thermochemical databases

A. Löffler, H. Engelhardt, M. Rettenmayr
Friedrich-Schiller-University Jena
Institute of Materials Science and Technology
Metallic Materials Department

GTT Workshop 2011

Metallische Werkstoffe

SolKin – Solidification considering kinetic effects



microsegregation modeling

input parameters

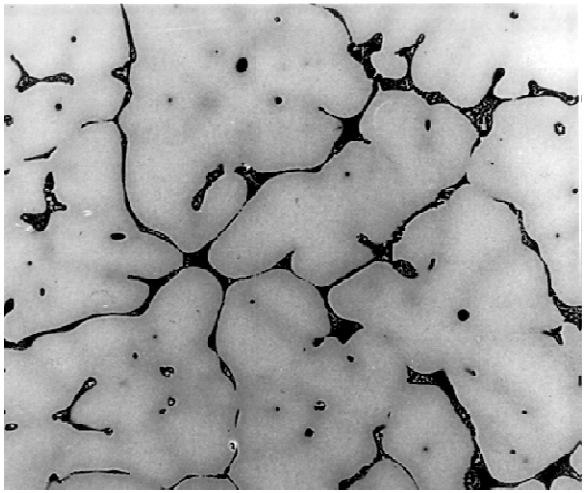
- composition
- cooling rate (or G_T and v_F)
- physical constants
- phase diagram
  (Calphad thermochemical database)

homogenizing effects

(with respect to Scheil conditions)

- back diffusion
- dendrite arm coarsening
- dendrite tip undercooling
- eutectic undercooling

?

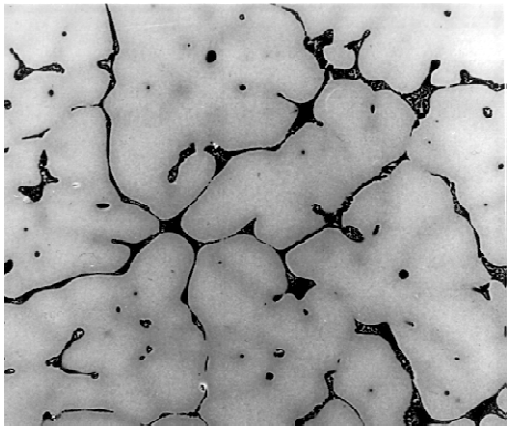


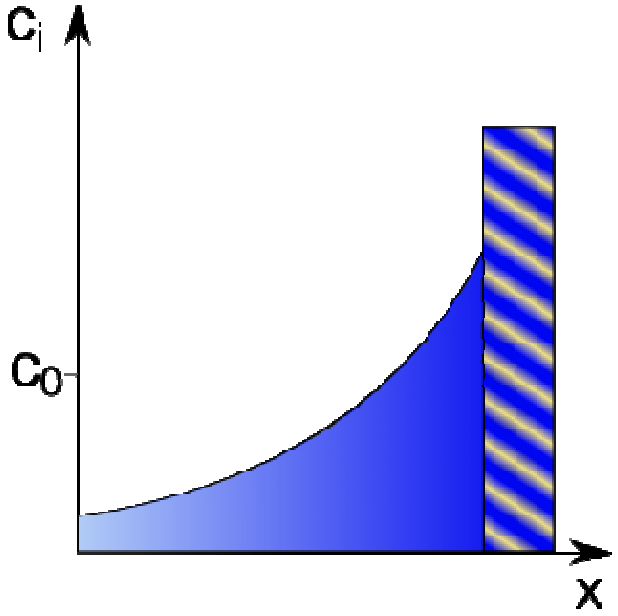
output parameters

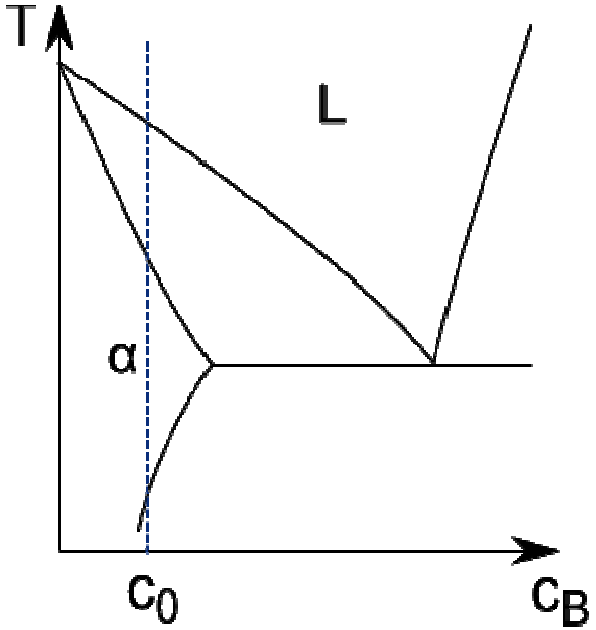
- concentration distribution
- phase fractions
- dendrite arm spacings
- …

Scheil conditions

- Complete mixing in the melt
  - induce strong convection
- No diffusion in the solid
  - increase diffusion distance







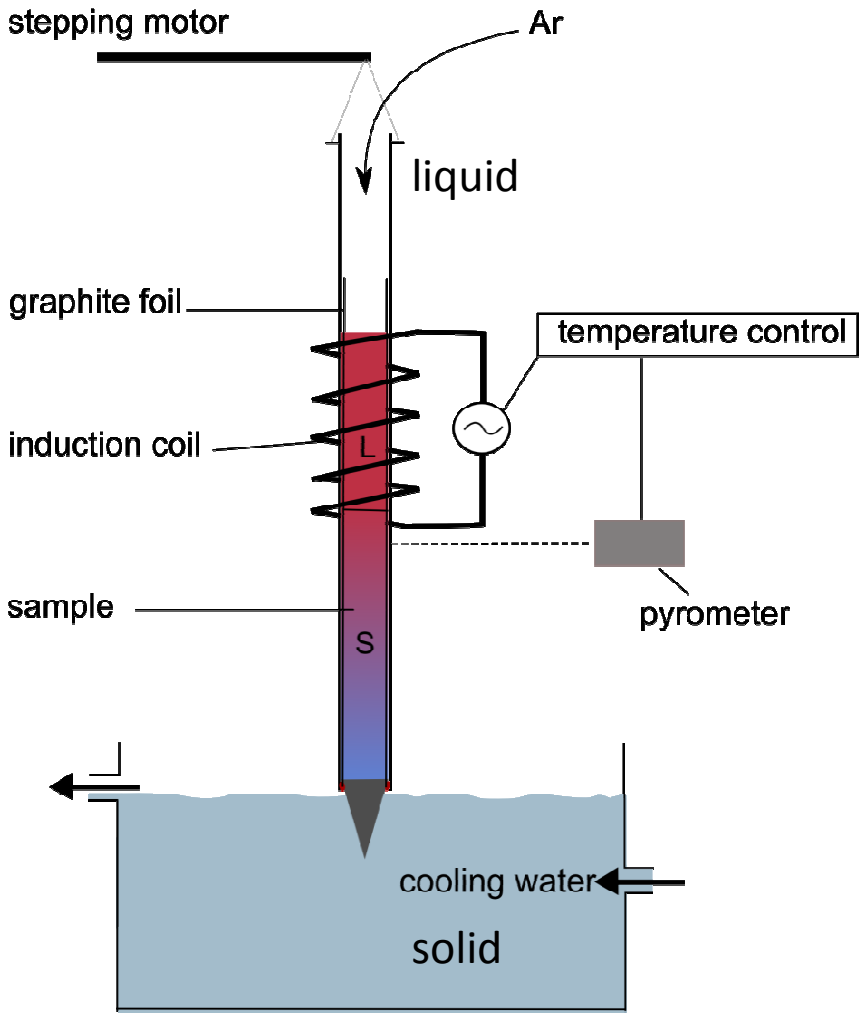
experimental set-up

- steep temperature gradient: *10…12 K mm^{-1}*
- slow solidification velocity: *0.2…1 µm s^{-1}*

→ **plane solidification front**

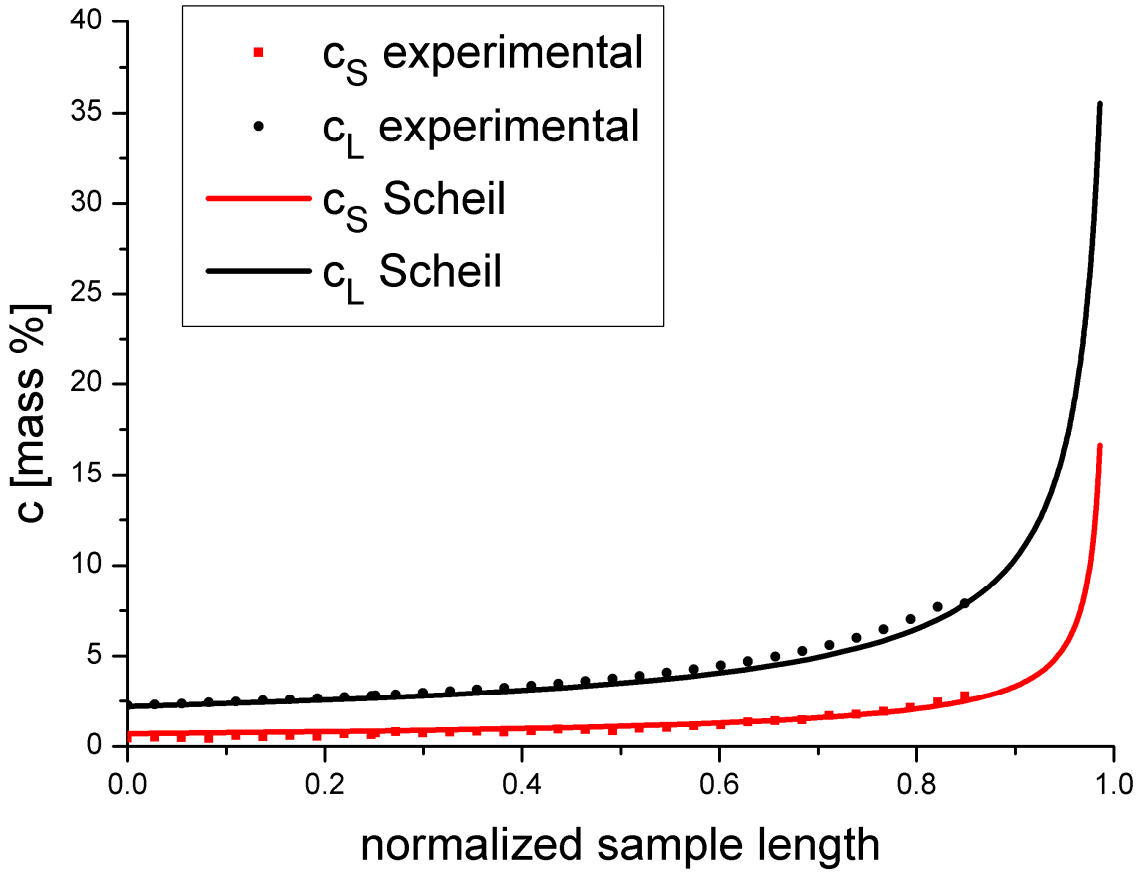
- high frequency induction furnace:

→ **strong melt convection**



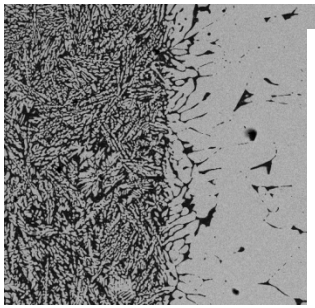
results: Al-Mg

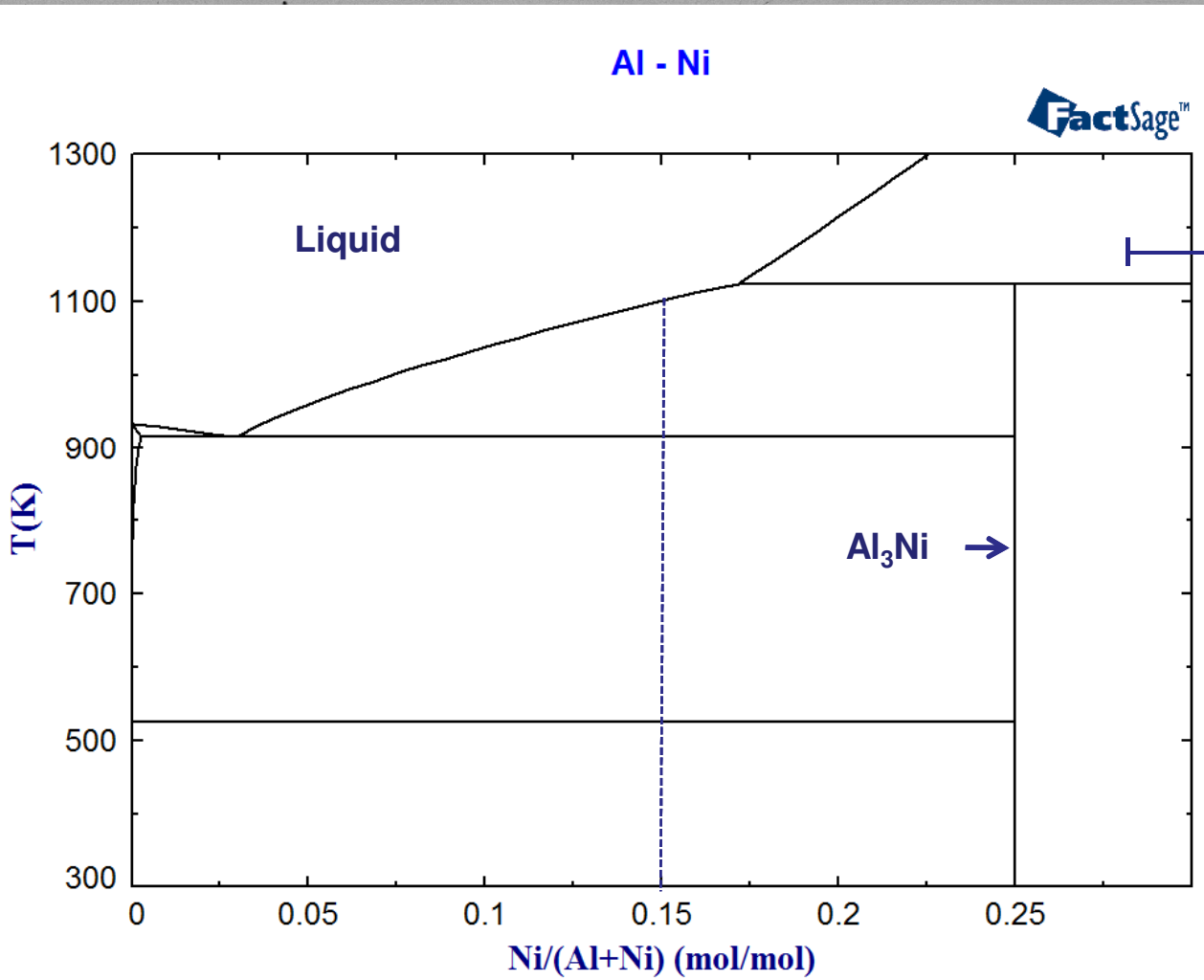
Plane front directional solidification

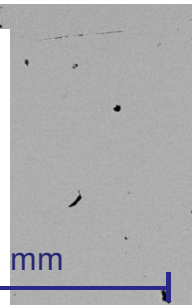


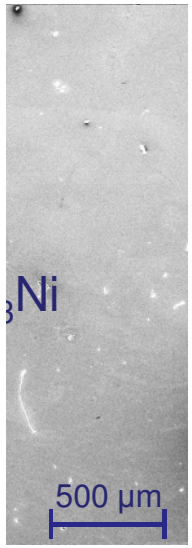
Al- 2.2 wt.% Mg

phase separation: Al-Ni







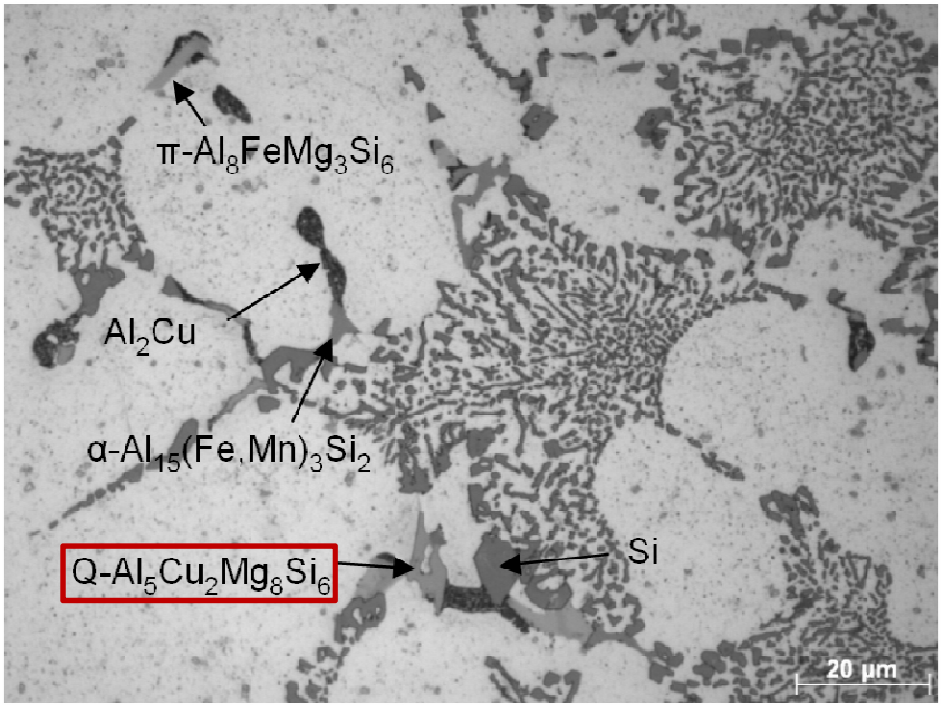


Al-Cu-Mg-Si

use spatial separation of solidifying phases to prepare intermetallic phases

quaternary phase ("Q-phase")

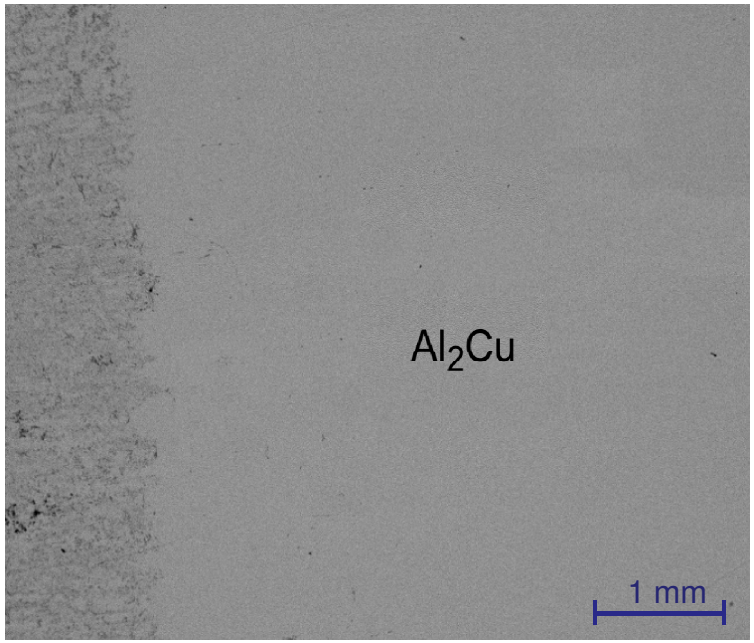
- has not been prepared in larger amounts
- composition, peritectic temperature, enthalpy of formation are uncertain



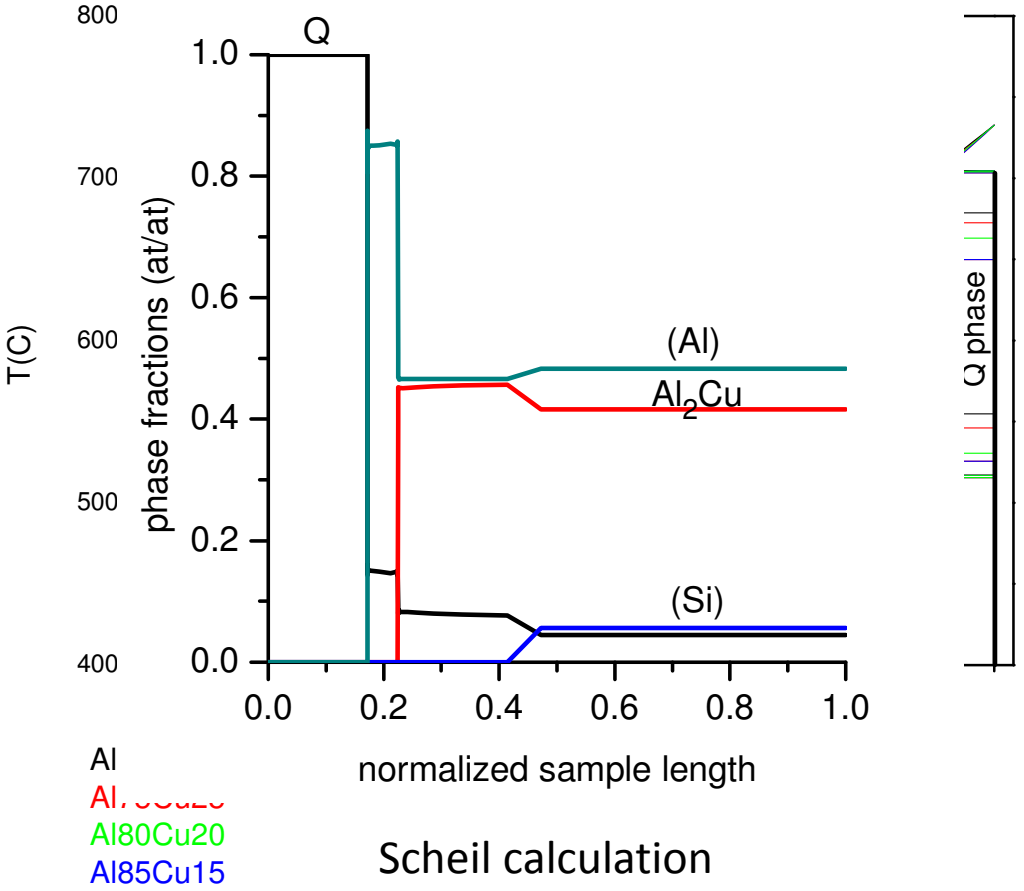
technical aluminum cast alloy with Q

preliminary investigation

prepare θ-Al_2Cu from quaternary melt

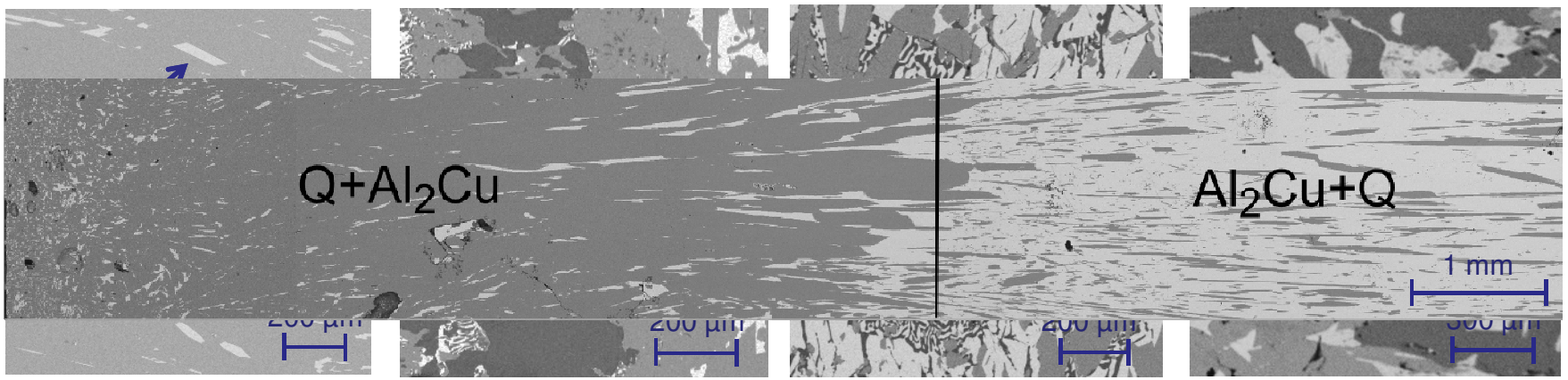


determine suitable initial concentrations



Scheil calculation

Q-phase

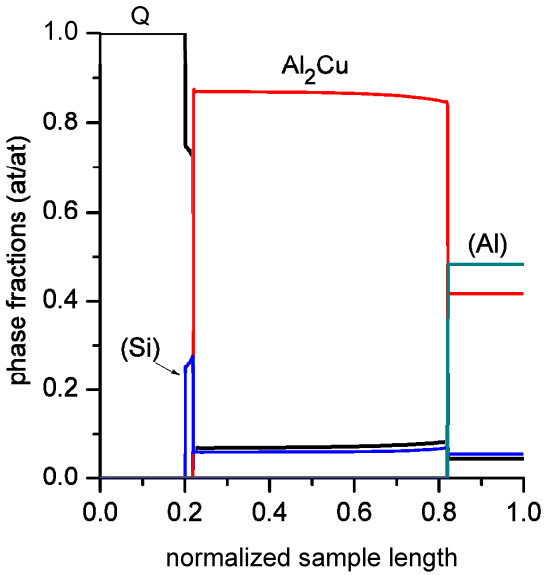


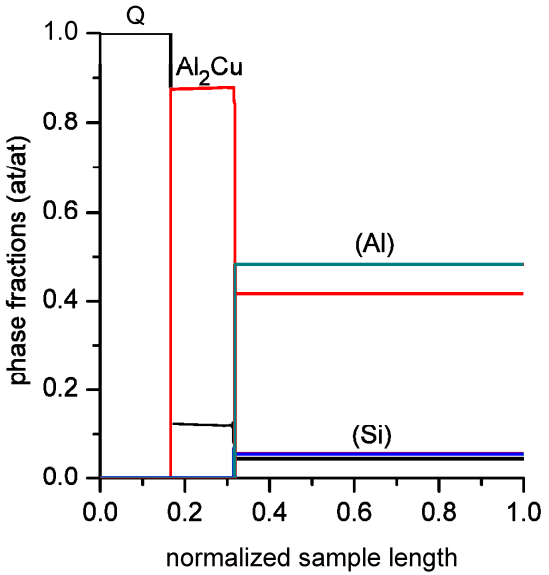
Q-phase composition (at%):

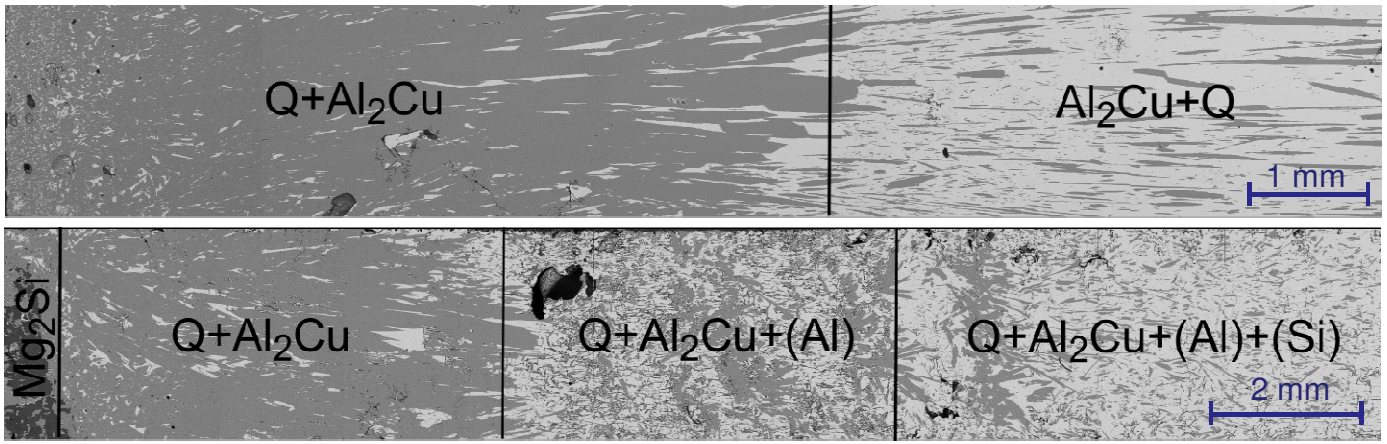
	Al	Cu	Mg	Si
EDX	**16.8±0.5**	**9.1±0.3**	**44.3±0.6**	**29.8±0.3**
$Al_3Cu_2Mg_9Si_7$	14.3	9.5	42.9	33.3
$Al_5Cu_2Mg_8Si_6$	23.8	9.5	38.1	28.6
$Al_4Cu_2Mg_8Si_7$	19.0	9.5	38.1	33.3
$Al_4CuMg_5Si_4$	28.6	7.1	35.7	28.6

peritectic temperature was determined by DSC measurement (703°C)

comparison with Scheil calculations







conclusions

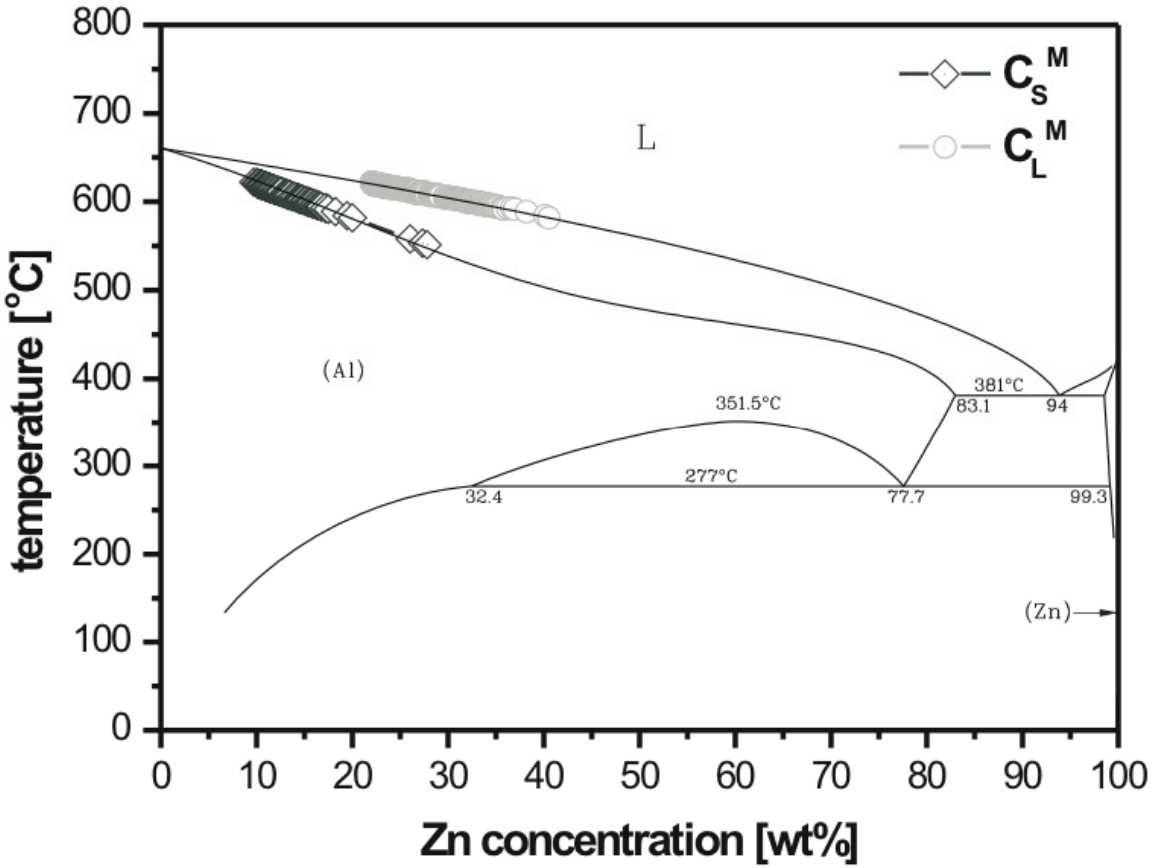
plane front directional solidification with forced convection:

determination of solidification path and tie-lines along the solidification path

selective preparation of intermetallic phases for further investigation

evaluate and improve thermochemical databases

results: Al-Zn

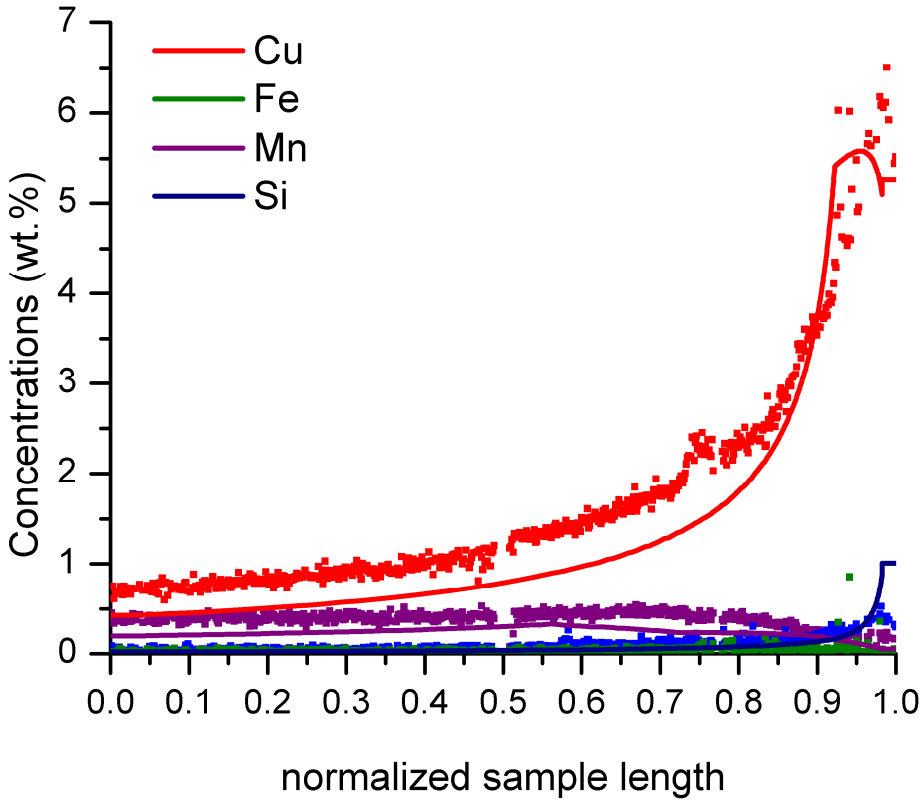


Al- Zn

(from: G. Zhao, M. Rettenmayr, *J. Crystal Growth*, 2005, **279**, 540).

results: Al-Cu-Mn-Fe-Si

Plane front directional solidification



Al- 4 wt.% Cu- 0.3 wt.% Fe-0.4 wt.% Mn- 0.2 wt.% Si

(exp. values from: G. Zhao, M. Rettenmayr, *J. Crystal Growth*, 2005, **279**, 540).