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Science Symposium
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METCOMP

Metastable Solidification of Composites

WP 2: Solidification of nf/nf organic peritectics

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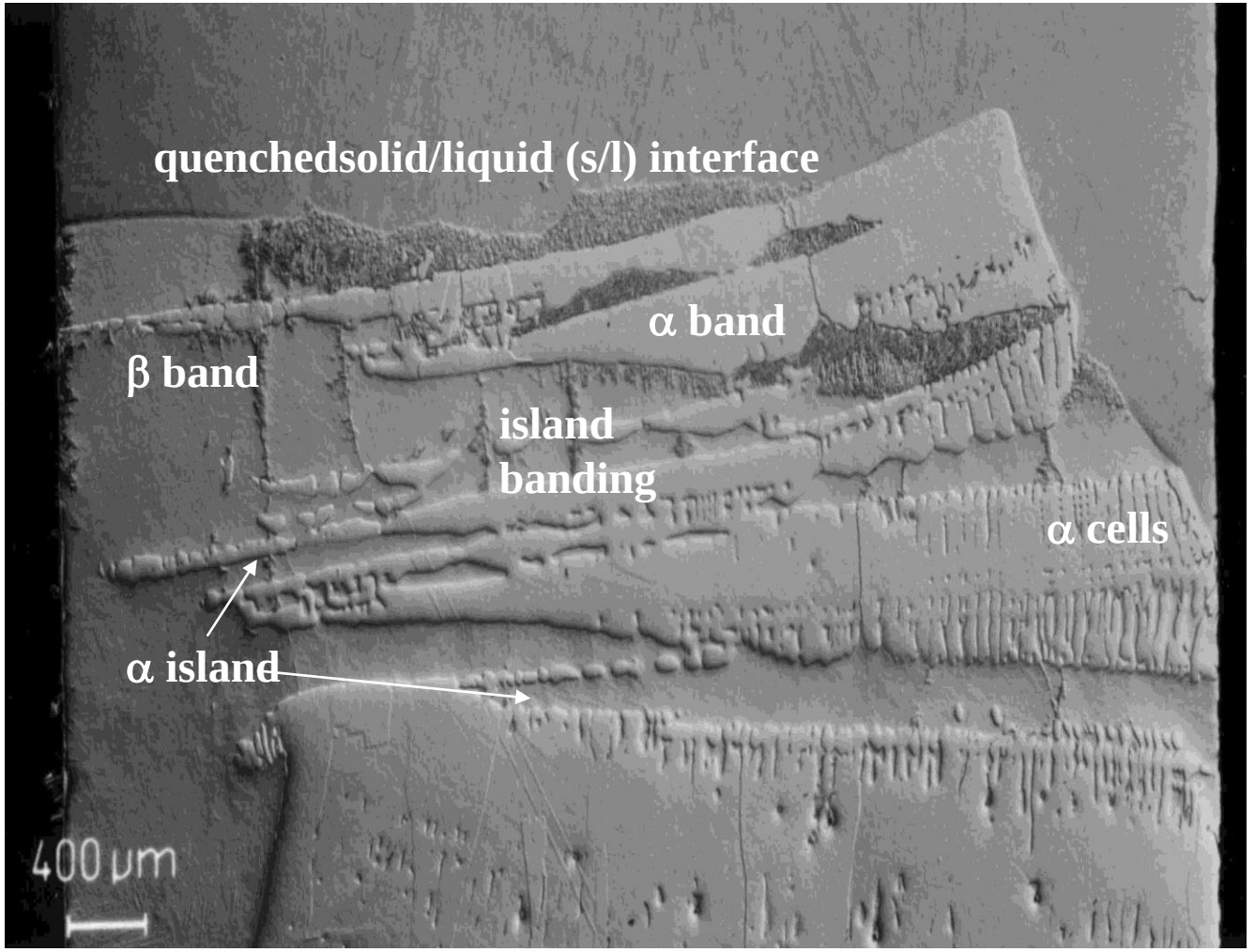
Outline

- **Science background and hypothesis**
- Investigation goals and objectives
- Measurement approach
- Importance and reason for ISS
- Expected results and how they will advance the field
- Earth benefits/spin-off applications

Peritectic solidification morphologies in binary metal alloys

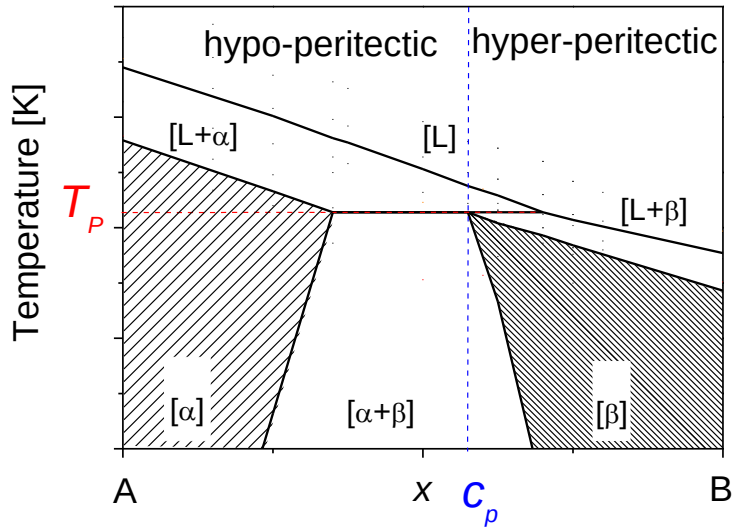
solidification front



pulling direction
(pulling velocity *Vp*)

taken from [Kurz, Dobler, EPFL, (2001)]

Peritectic solidification morphologies for $V_p > V_C$



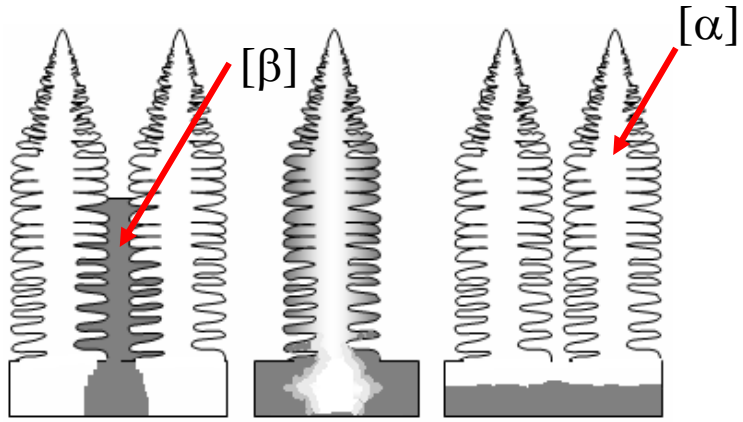
$V_p > V_C$ cells and/or dendrites

peritectic reaction: [L] + [α] → [β]

[L] → [β]
requires diffusion in the liquid (D_l)

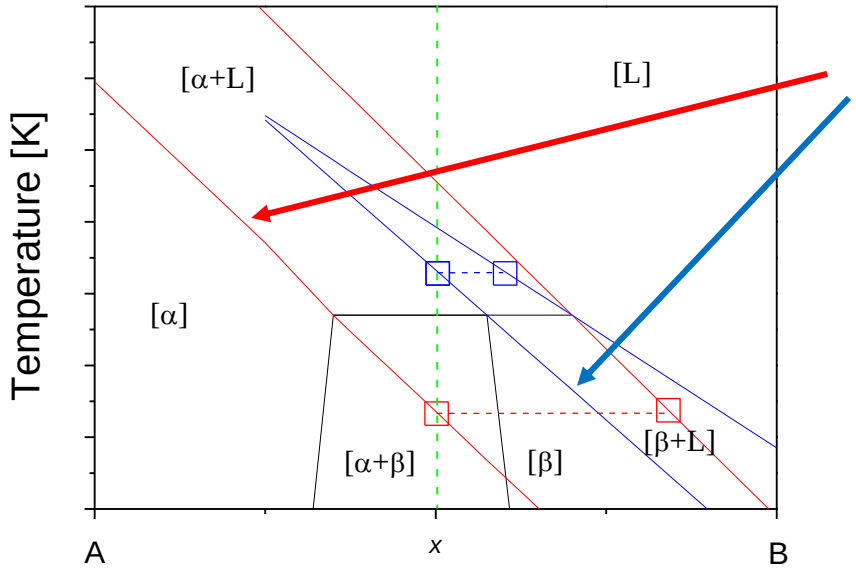
[α] → [β]
requires diffusion in the solid (D_s), whereby (D_l) >> (D_s)

- Direct solidification from liquid
- Peritectic reaction
- Peritectic transformation



F. Kohler, Thèse EPFL, no 4037 (2008)

Expected solidification morphologies for $V_p \leq V_C$



$V_p \leq V_C$ planar solidification front

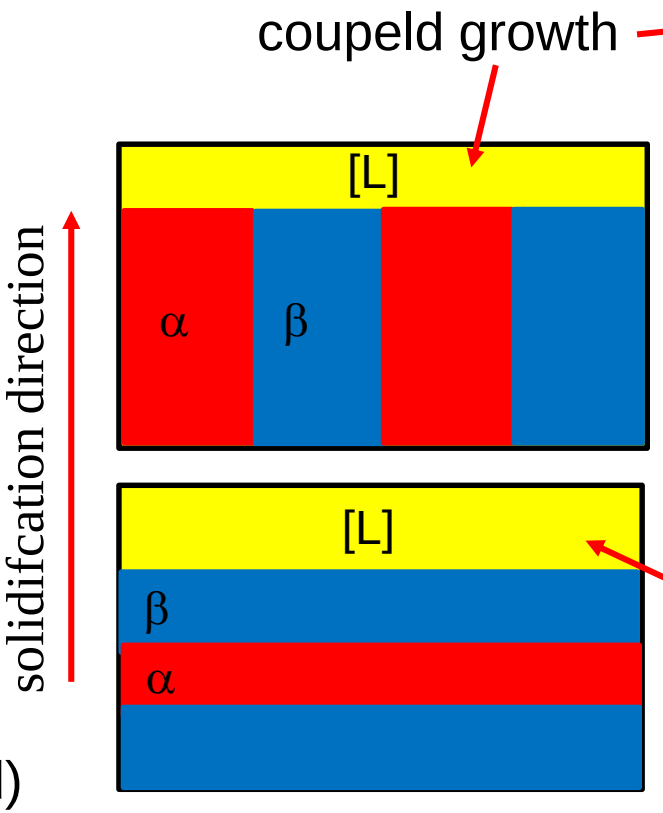
- α and β: coupled growth

  (Ni-Al/Ti-Al/Fe-Ni/Sn-Cd)

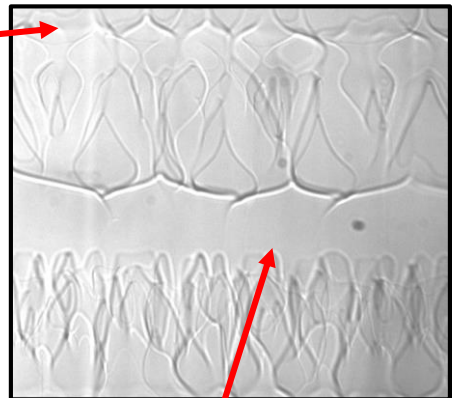
- α or β: banded growth

  (Sn-Sb/Zn-Cu/Ag-Zn/Fe-Ni/Sn-Cd)

The s/l interface wants to grow at the α or β solidus temperature.



experimental result (@ 1g)



Ludwig A, Mogeritsch J, Pfeifer. (2017) In-situ observation of coupled peritectic growth in a binary organic model alloy. Acta Mat. 126, 329-335.

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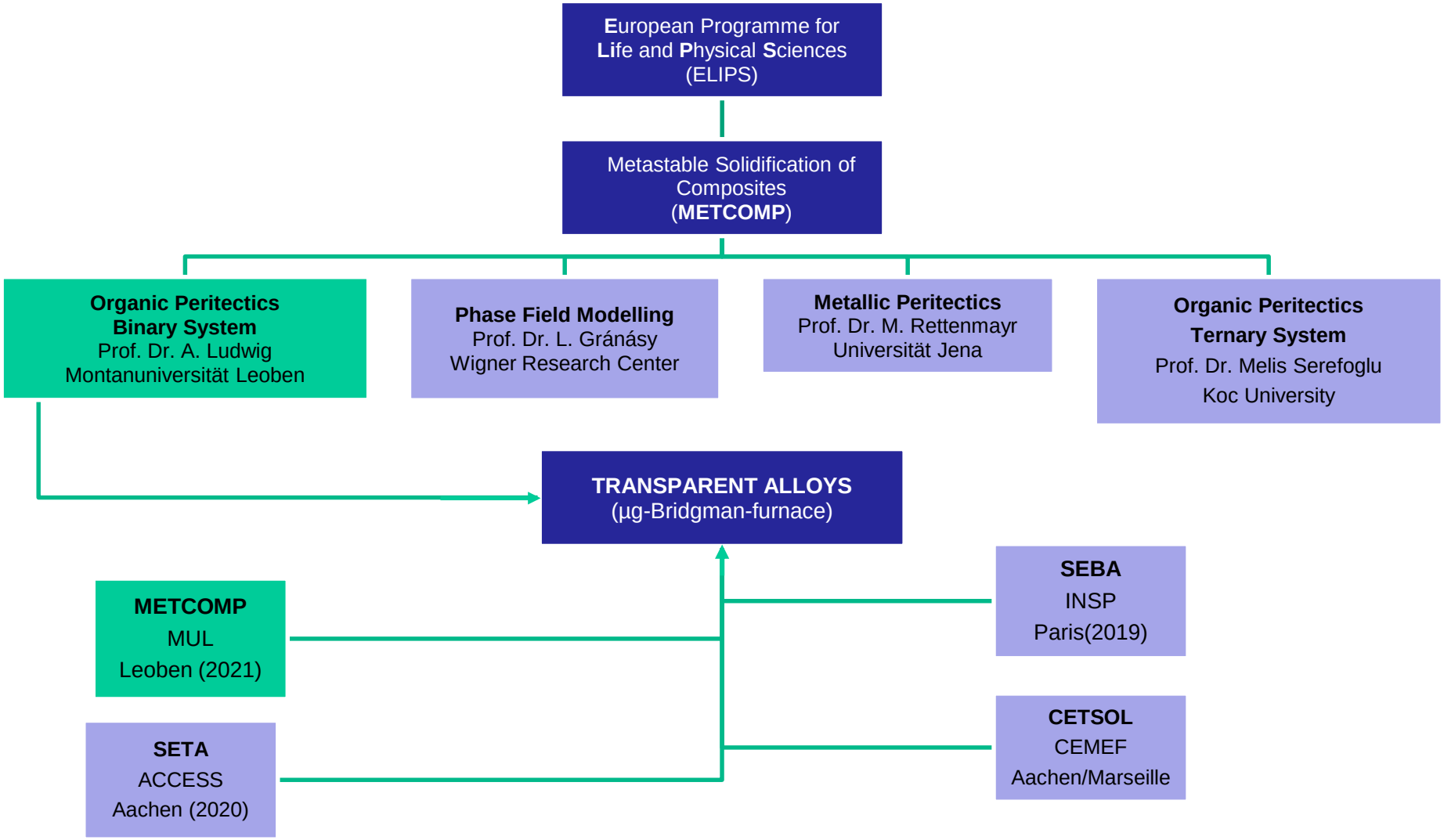
Goals and objectives at MUL

- New metastable microstructures were detected in solidification of peritectics, which make them suitable for the preparation of in situ composite materials.

- Nevertheless, the solidification behaviour is not well understood in particular, because especially the formation of in situ composite microstructure from liquid sensitively depends on convection that is always present under 1g-conditions.

Project organization and partners (2020)



Goals and objectives at MUL

- Goals
  - Deepening of our understanding of the context between the convection in the melt and the competitive growth of the primary and peritectic phase during the formation of coupled peritectic growth.

- Objectives
  - Direct optical observation of predicted discrete band formation by diffusive growth of a transparent model with a peritectic reaction.
  - Comparing of results with convection (on earth) and without convection (in space).

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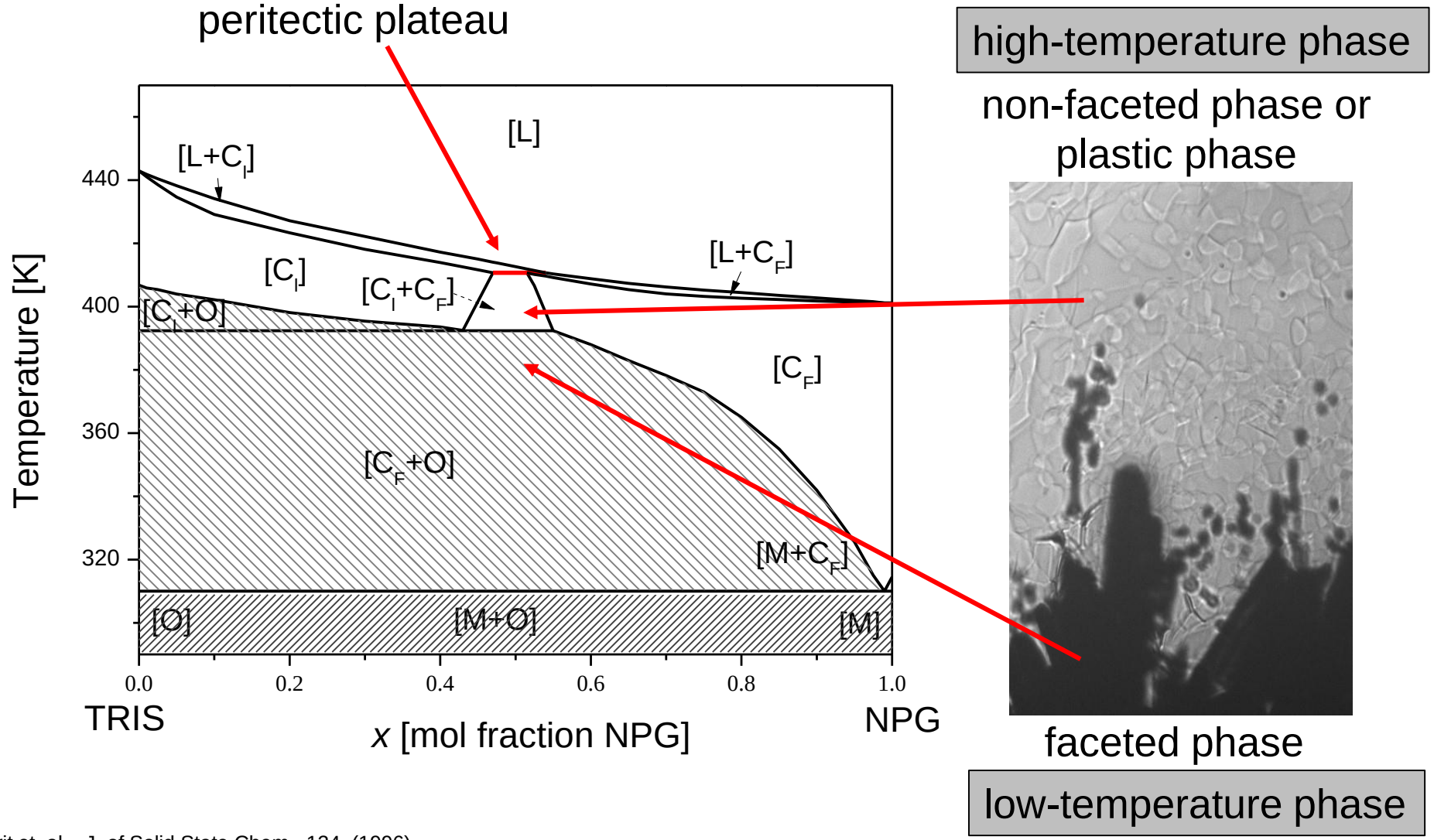
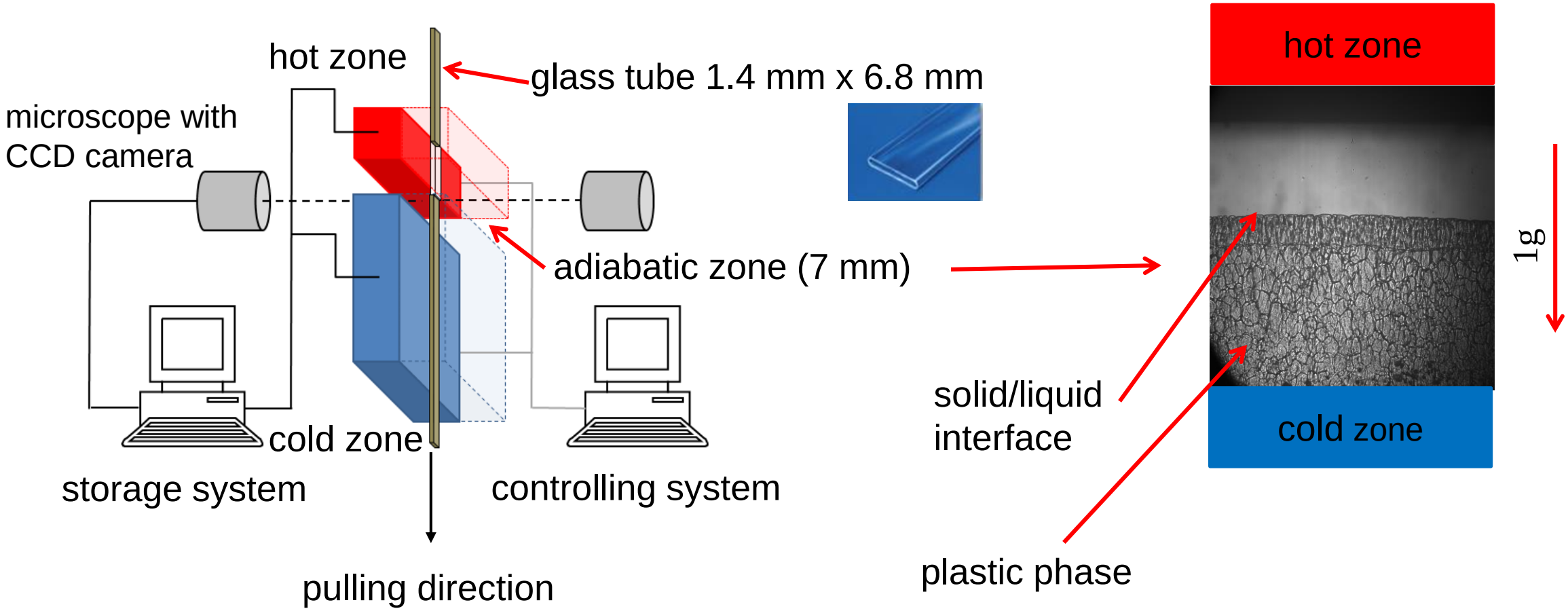
Transparent organic modell system TRIS-NPG



Tamarit et. al., J. of Solid State Chem., 124, (1996)

Experimental set-up: Micro Bridgman-furnace



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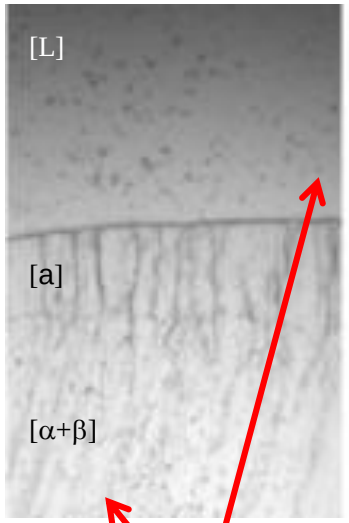
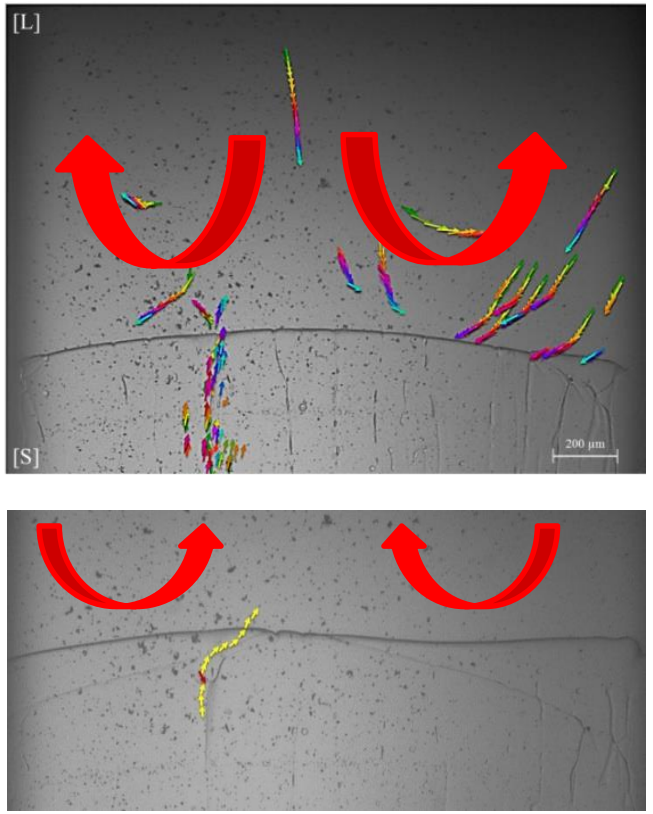
Why we need experiments aboard the ISS?

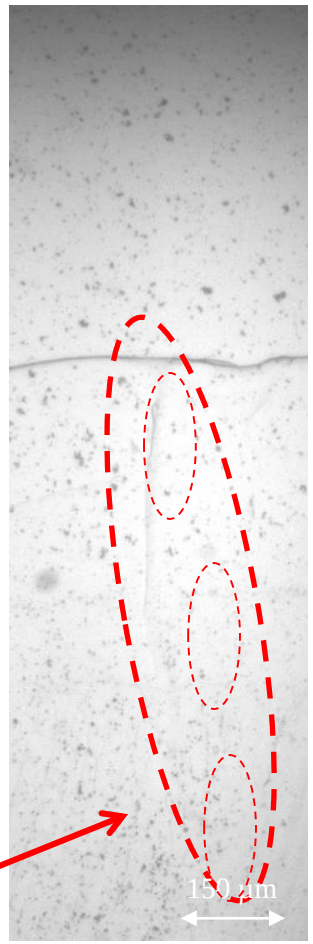
convection due to liquid channels



seeding particles

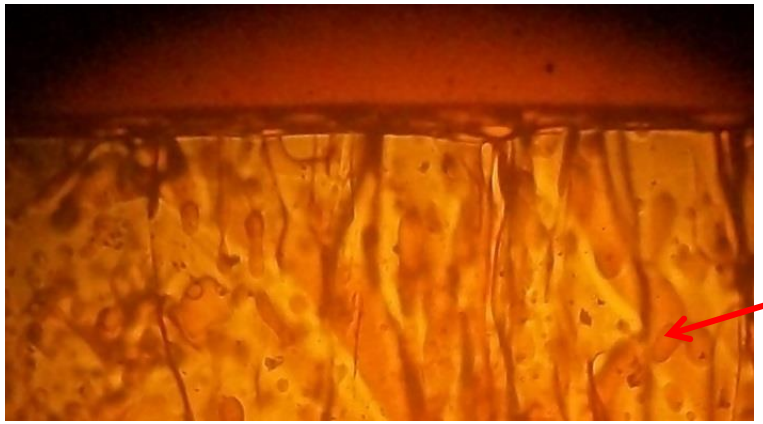


caused by liquid channel
(length ~ 1500 µm)

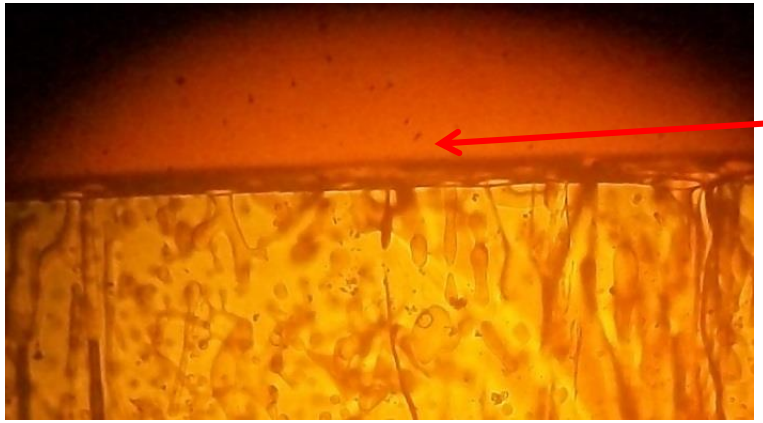


Mogeritsch J.P., Pfeifer T., Ludwig A., Formation of micro-plumes at a planar solid liquid interface in a temperature gradient , Series: Mater. Sci. & Eng., 529 (2019) 012025

Change in concentration by droplets migration within the solid



NPG enriched droplets
migrates toward the liquid bulk



The liquid bulk ahead the
solid/liquid interface
becomes NPG enriched.

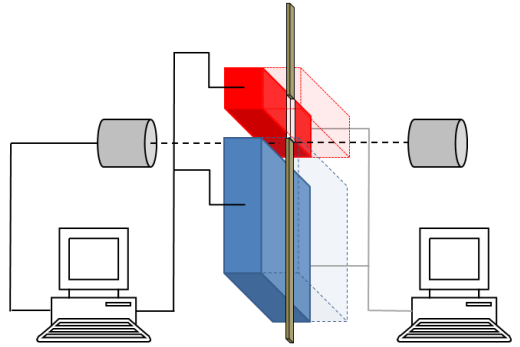
Alloy colored with Sudan red (pH indicator).

C_0 = 50 [mol%]
$G/V = 6.1 \cdot 10^{10}$ [s·K/m^2]

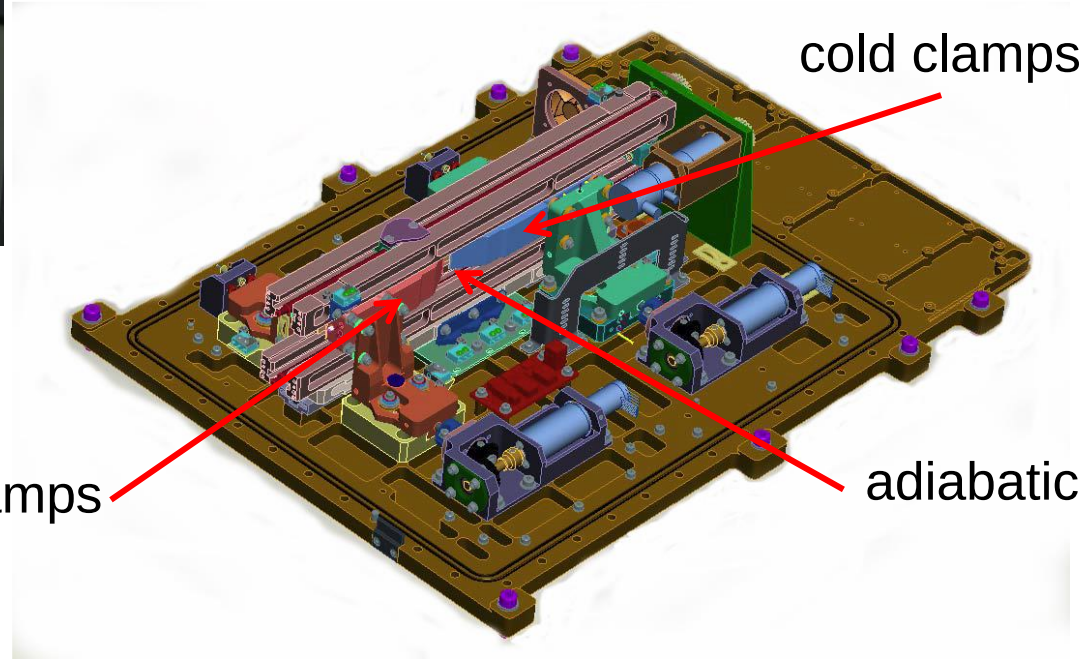
Experimental set-up aboard the ISS

MSG (Material Science Glovebox)

Bridgman assembly at MUL



Bridgman assembly



Construction details of the TRANSPARENT ALLOYS devices taken from the ESA TRANSPARENT ALLOY Design Report (page 26).

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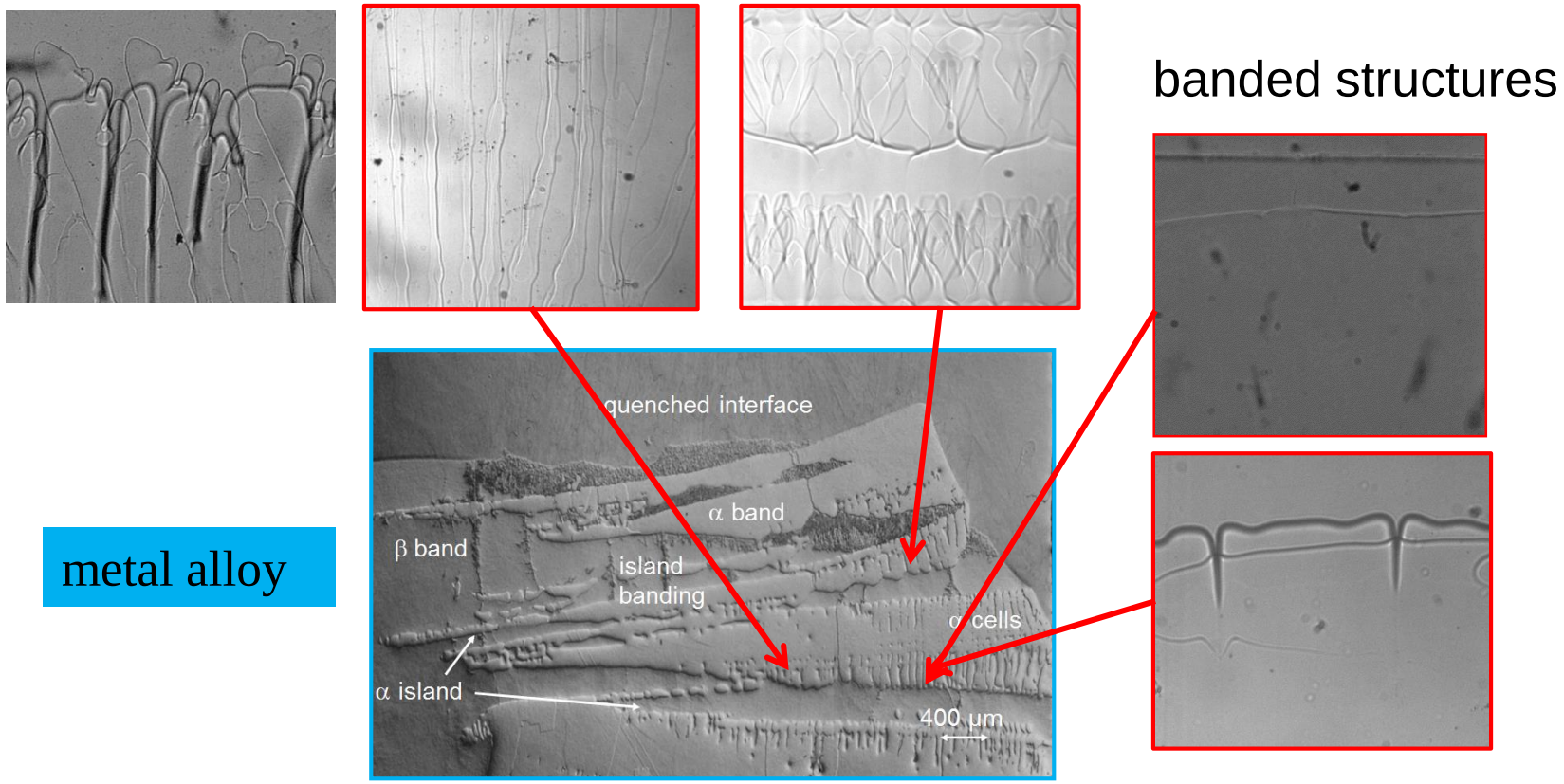
Coupled growth at MUL (1g)

coupled growth

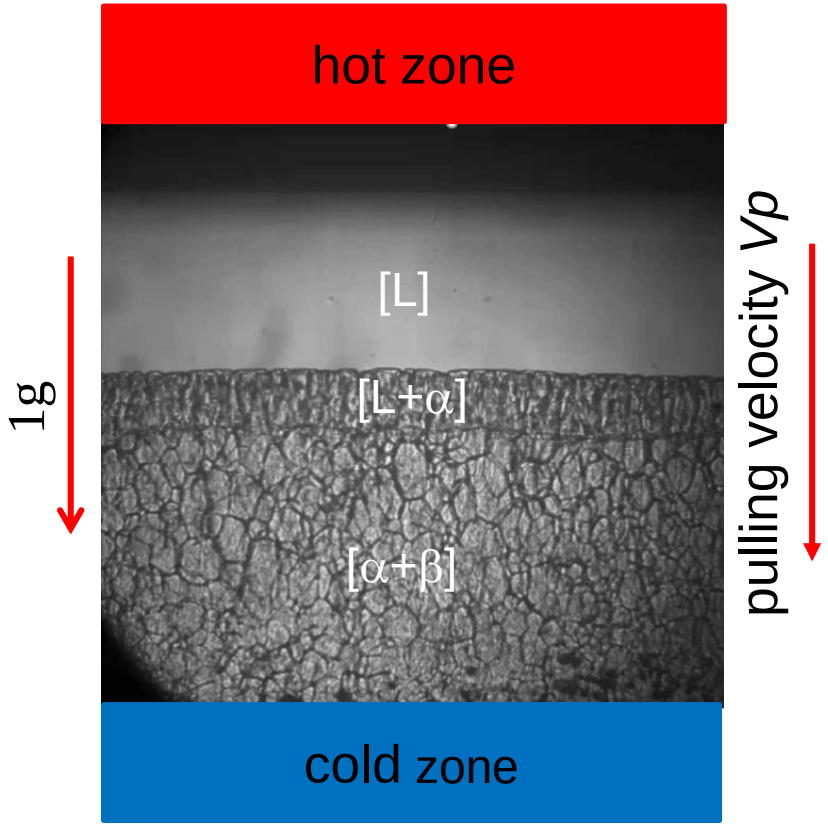
banded structures

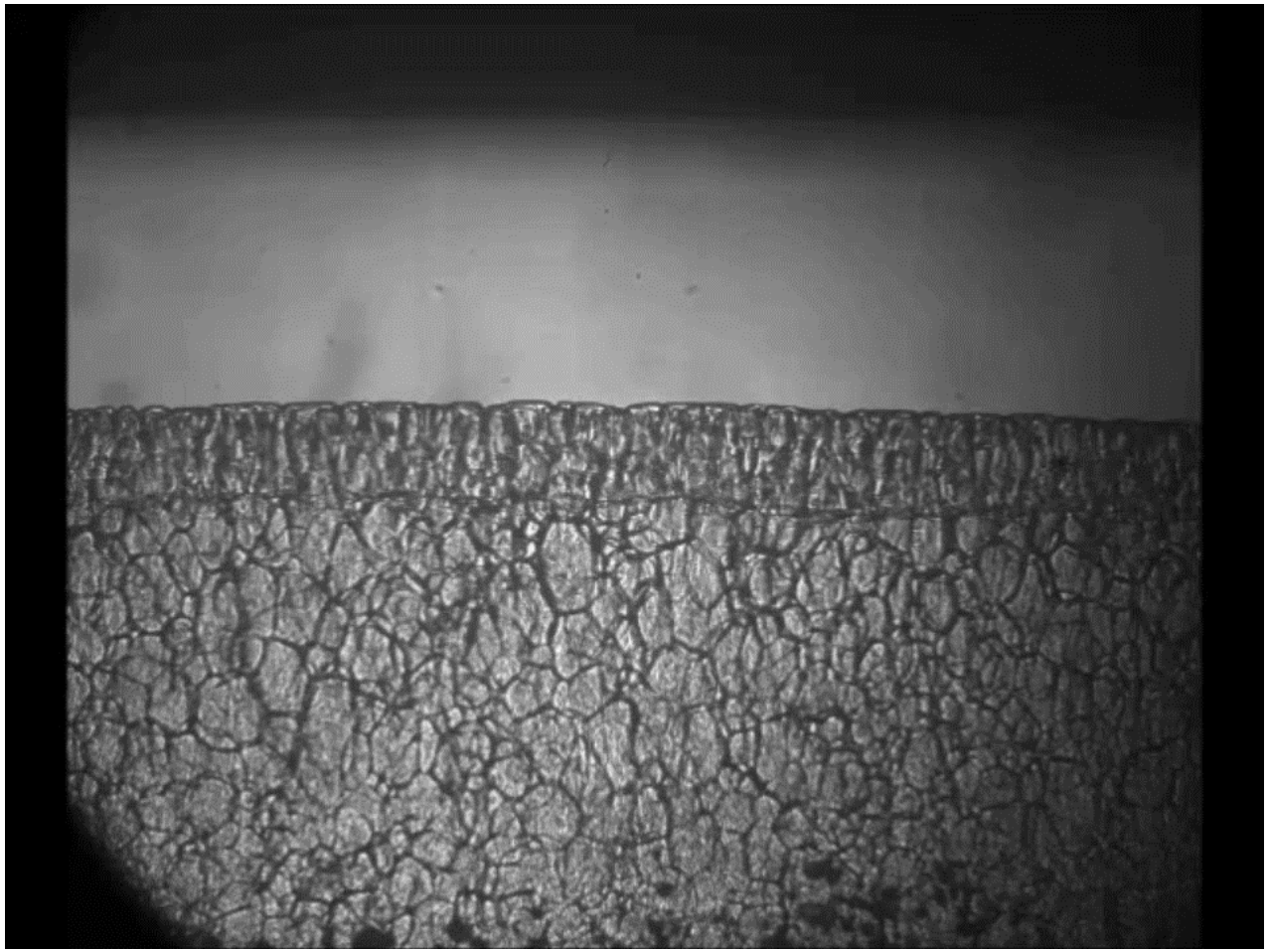


metal alloy

organic components

Banded structures and peritectic coupled Growth (1g)





C_0 = 52 [mol%]
G/V = 5.2·10^{10} [s·K/m^2]

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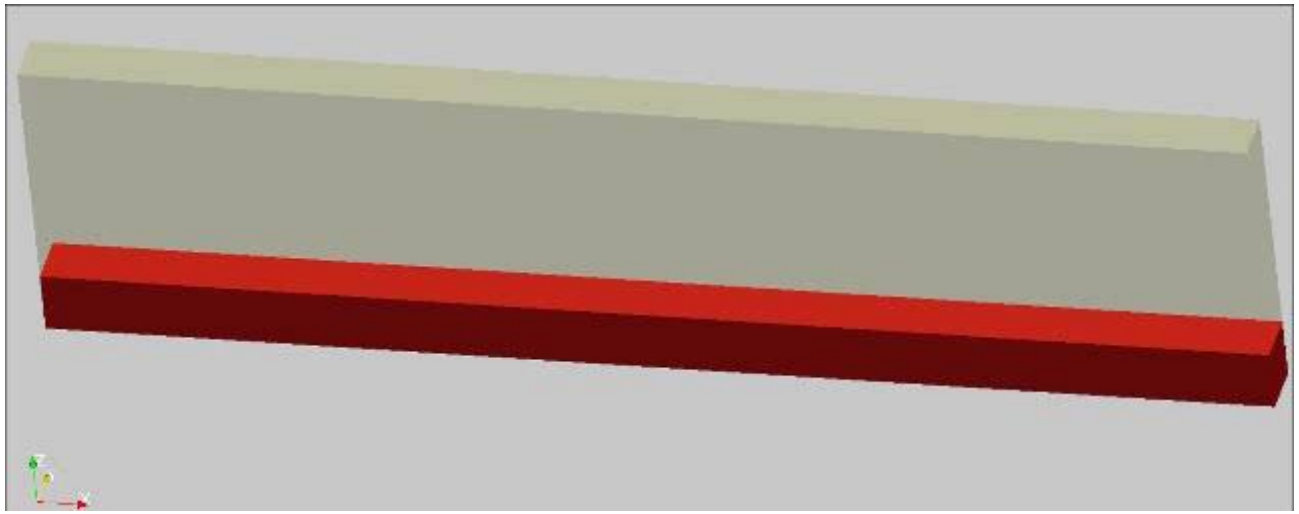
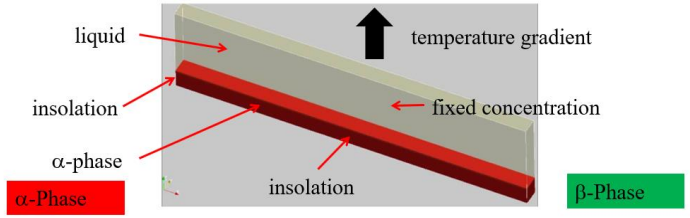
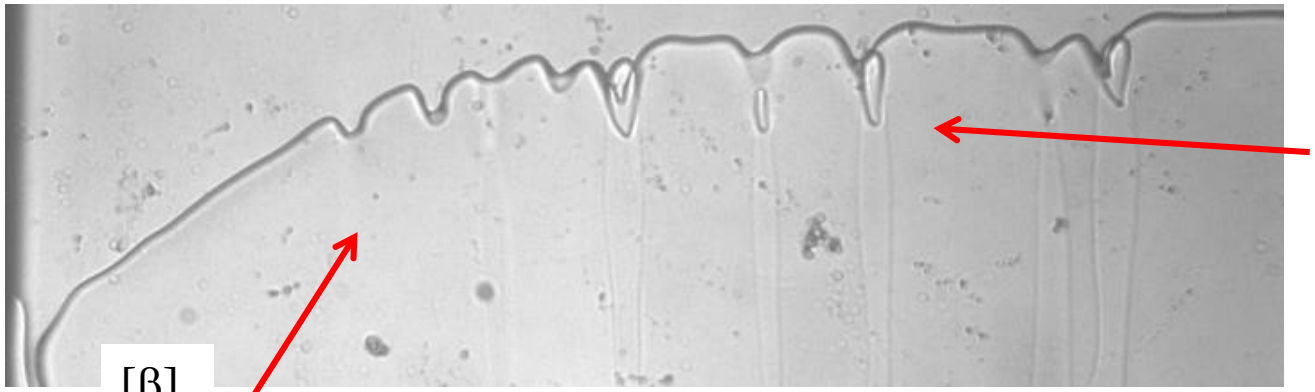
Accompanying numerical investigations at MUL



α-Phase

β-Phase





The actual numerical investigations with the phase field method are carried out by our project partner, Prof. Dr. L. Gránásy & PhD Tamás Pusztai, Wigner Research Center, Hu.

Summery and outlook

- 1g-experiments were carried out by using the Bridgman-technic and the transparent organic model system TRIS-NPG at MUL.
- The evaluation of the observed peritectic layered structures were supported by numerical analysis.
- The ground experiments were carried out at E-USOC (Madrid) in summer 2020.
- Execution of the µg-experiments aboard the ISS is scheduled for spring 2021.

Thank you for your attention!

FFG

http://www.smmp.unileoben.ac.at