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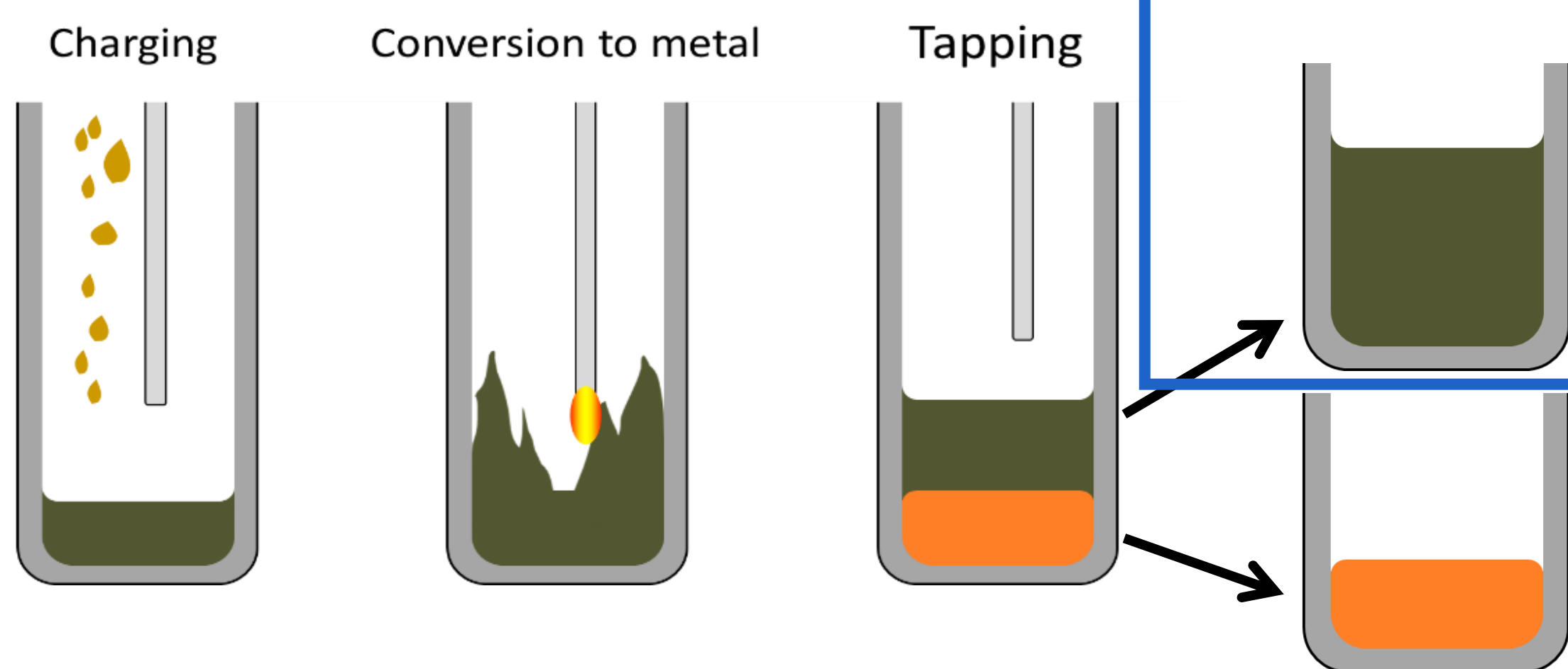
# METAL DROPLET ENTRAINMENT BY SOLID PARTICLES IN SLAGS: A PHASE FIELD - EXPERIMENTAL APPROACH

## Introduction

Pyrometallurgical processes:

End with **decantation**

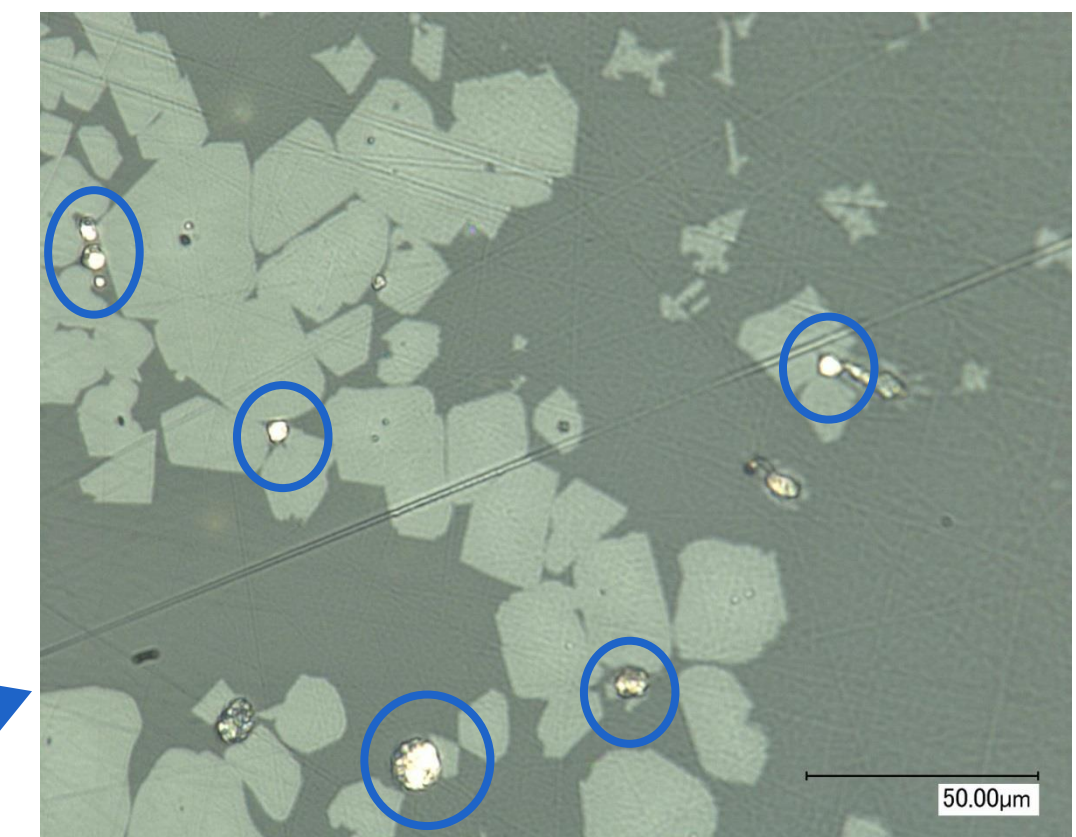
→ Separation between slag and metal/matte



Several causes:

- Charging or tapping
- Precipitation from slag
- Gas producing reactions disperse metal in slag

- Attachment to solid particles



Approach: Fundamental investigation

Experiments

Modelling

## Smelting experiment

Oxidation-reduction smelting experiment in induction furnace  
At 1400°C

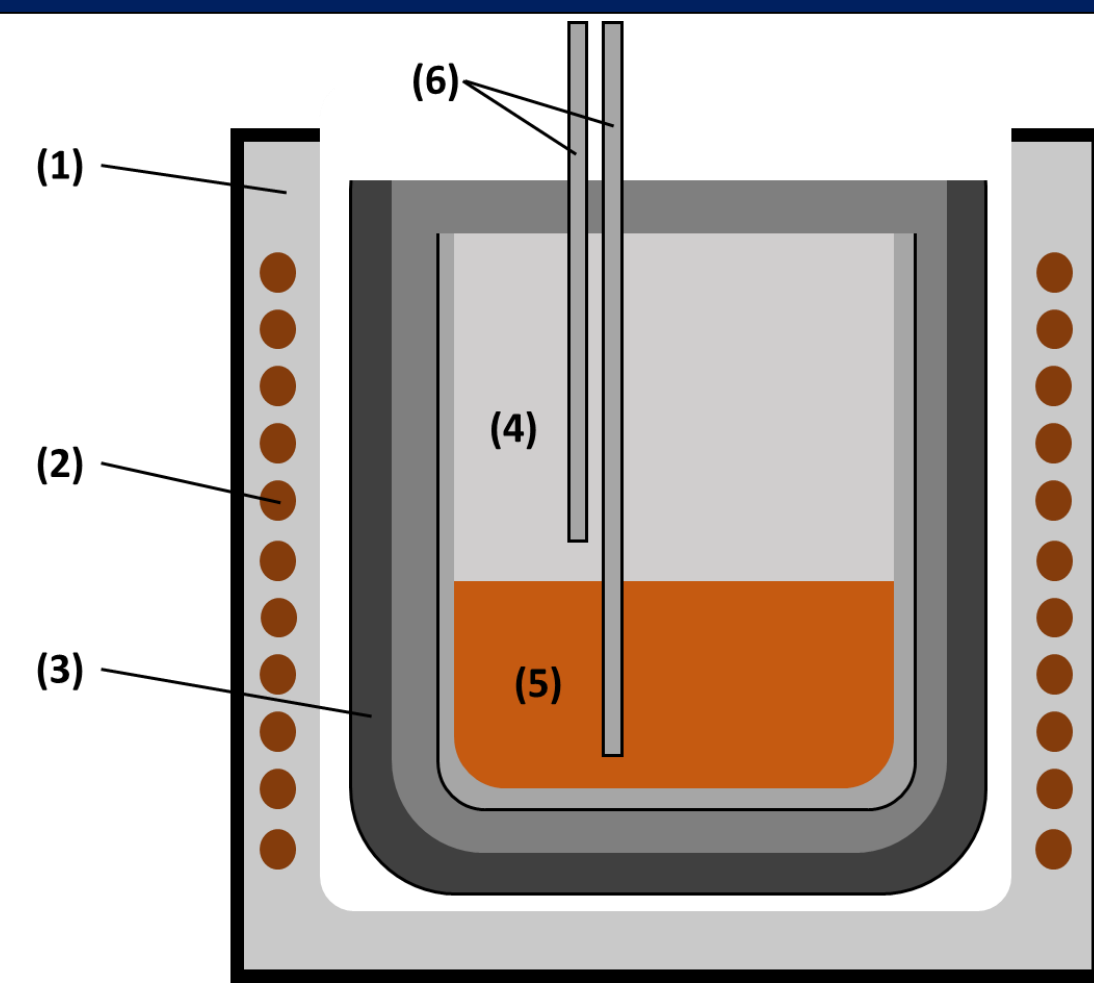
- 24.65 wt% Cu
- 1.38 wt% Ag (trace element)
- 18.63 wt% Al<sub>2</sub>O<sub>3</sub>
- 9.39 wt% Fe
- 26.85 wt% Fe<sub>2</sub>O<sub>3</sub>
- 19.09 wt% SiO<sub>2</sub>

Create supersaturated Cu solution  
+ enforce simultaneous precipitation

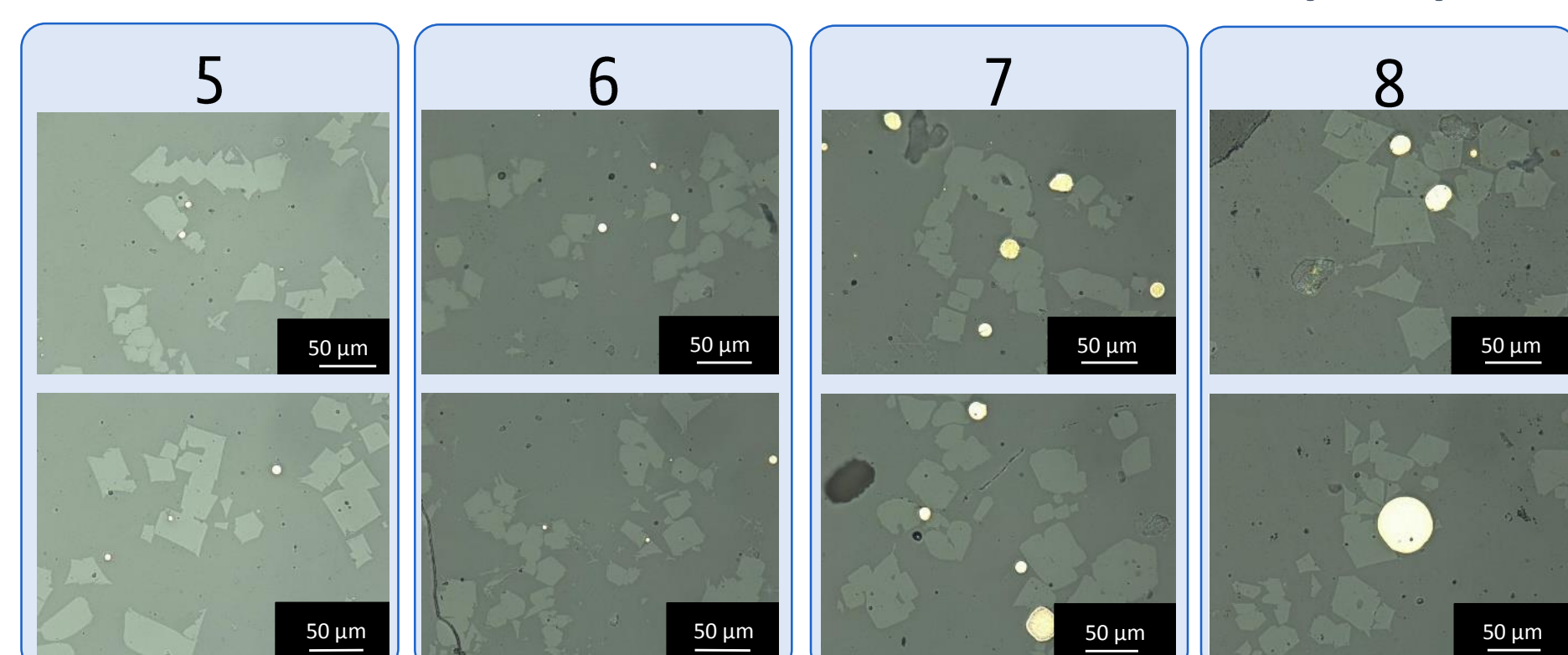
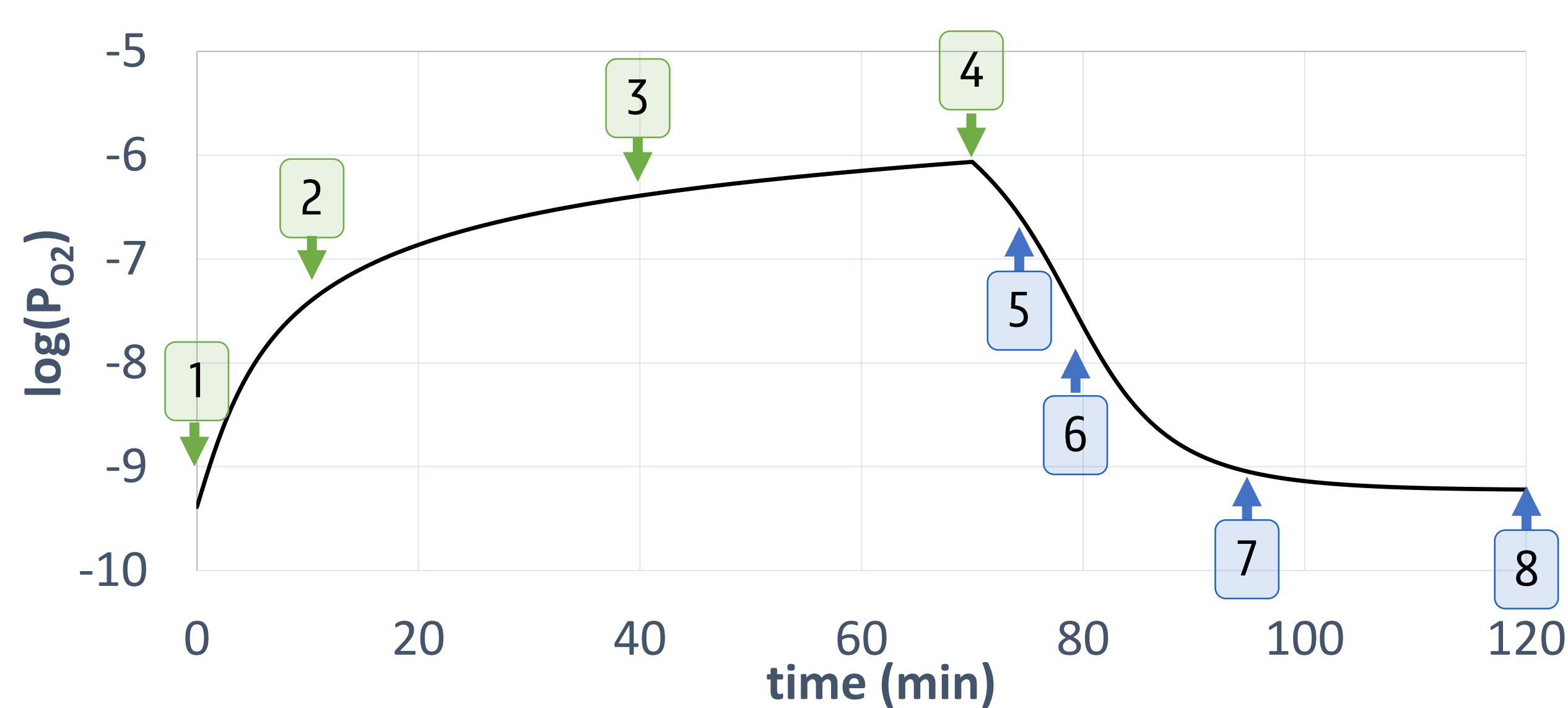
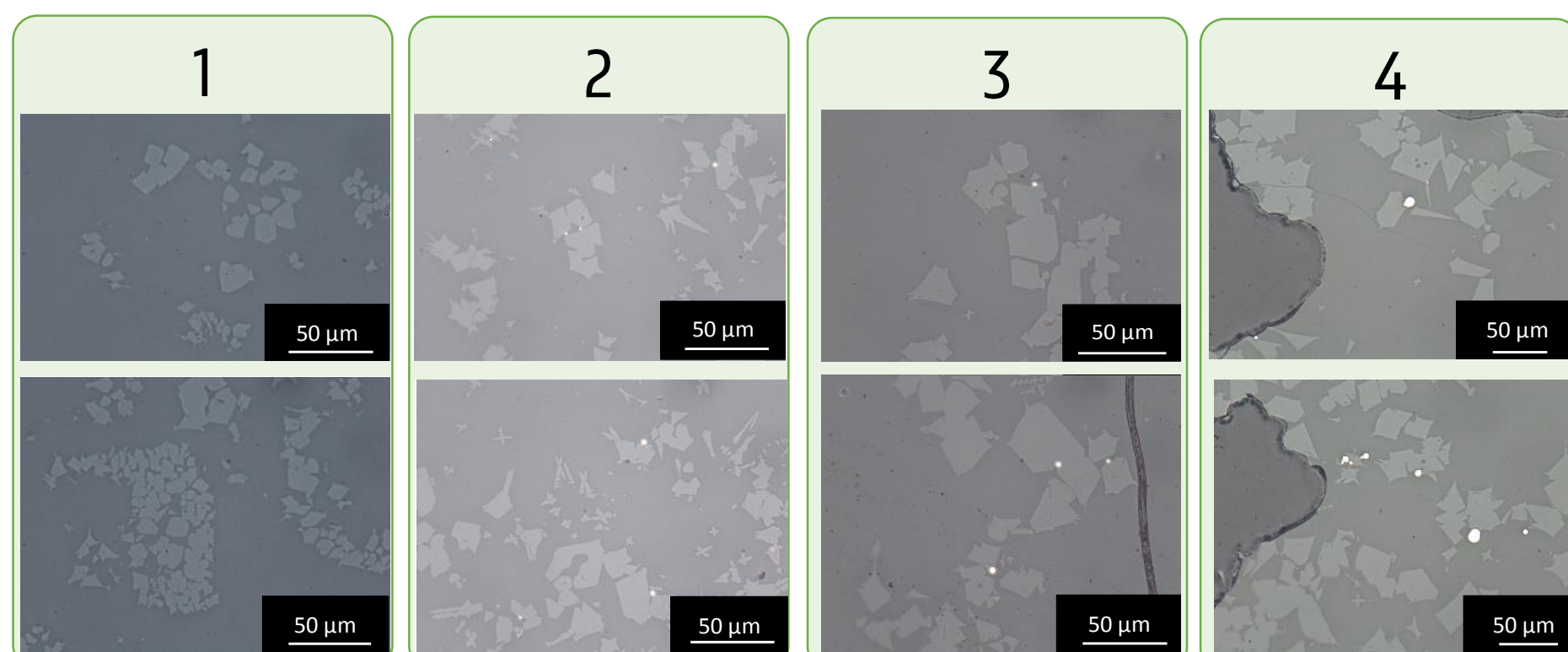
→ Oxidation: 60l/h CO<sub>2</sub>

Copper gets oxidized  
= is transferred to the slag

Some metal drops due to mixing



Insulating outside (1), water-cooled copper electromagnetic coil (2), silicon carbide crucible (3), alumina crucibles (4), slag and alloy (5) and extra equipment (6)



→ Reduction:  
40l/h CO + 20l/h CO<sub>2</sub>  
Slags gets supersaturated  
with copper oxide

Metal droplets attached to solids  
Formation + growth

## Model

Phase field model for solid-liquid binary system (O-M) with spinodal decomposition in the liquid

$$\gamma_{S,L} = \frac{1}{3\sqrt{2}} \sqrt{W\kappa} + \gamma_{S,L}^{\nabla x_M} \text{ With } \gamma_{S,L}^{\nabla x_M} \approx \frac{1}{6} \sqrt{\kappa_{x_M} 0.5(A_{sp} + A_s)} (|x_{eq,k} - x_S|)^3$$

$x_S$  can be used as a parameter to vary the solid-liquid interfacial energies

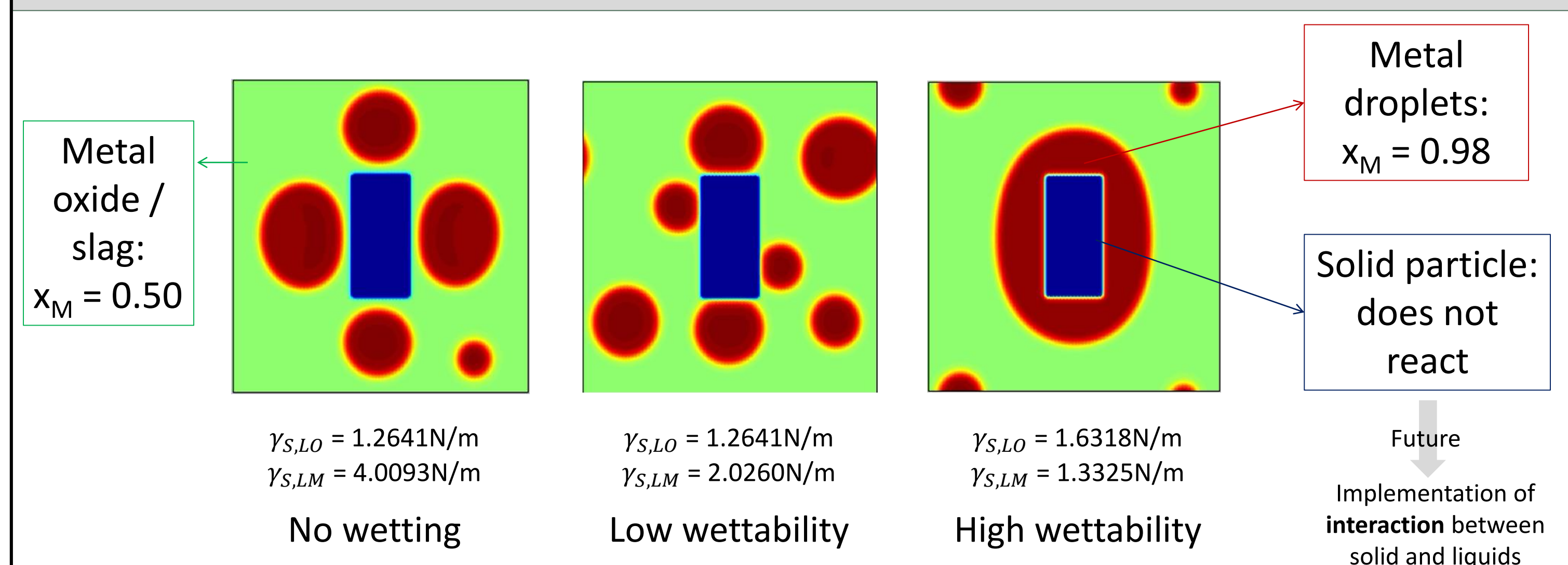
Evolution equations

$$\frac{\partial x_M}{\partial t} = \nabla [M \nabla [(1 - h(\phi)) f'_{Liquid}(x_M) + h(\phi) f'_{Solid}(x_M) - \kappa_{x_M} \nabla^2 x_M]]$$

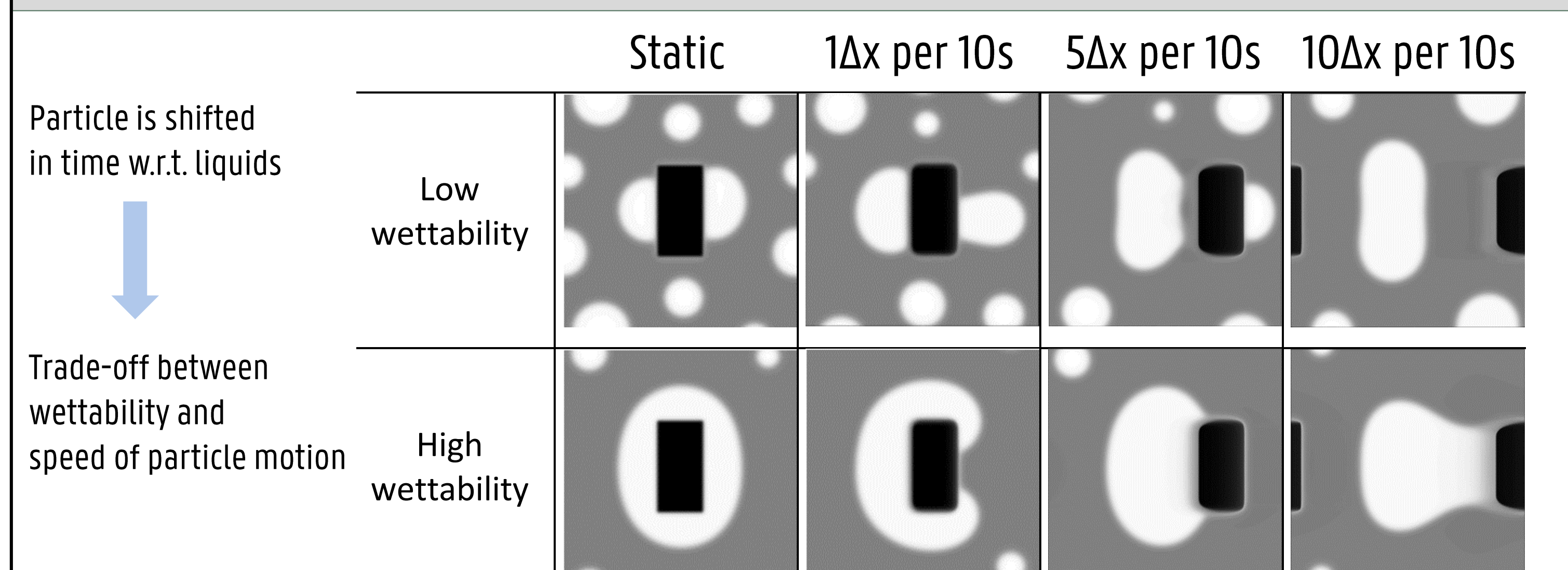
$$\frac{\partial \phi}{\partial t} = -L[W g'(\phi) + h'(\phi)(f_{Solid} - f_{Liquid}) - \kappa \nabla^2 \phi]$$

## Results (after evolution of 100s = 10<sup>6</sup> steps)

### Influence of interfacial energies



### Influence of particle motion



## Conclusions

- Mechanical entrainment of metallic droplets by solid particles occurs in several industries. To understand the nature of the interaction, a fundamental investigation has started recently, consisting of both an experimental and a modelling part.
- Oxidation-reduction smelting experiment shows possible heterogeneous formation: during mixing metal droplets dispersed in slag + act as nucleation site for reduction reaction of copper oxide, while spinel forms and grows aside from it.
- A recently developed phase field model can help understanding the attachment. Future investigations will ultimately result in the modelling of redox reactions in more realistic systems.
- The simulations can help to classify and interpret experimental observations and measurements of the attachment.