

# The role of slags and other by-products within circular economy in the steel industry

- Investigating the high-temperature properties in oxidic slags through a combined molecular dynamics – experimental approach
- Inge Bellemans

5.-6.  
MARCH  
2025

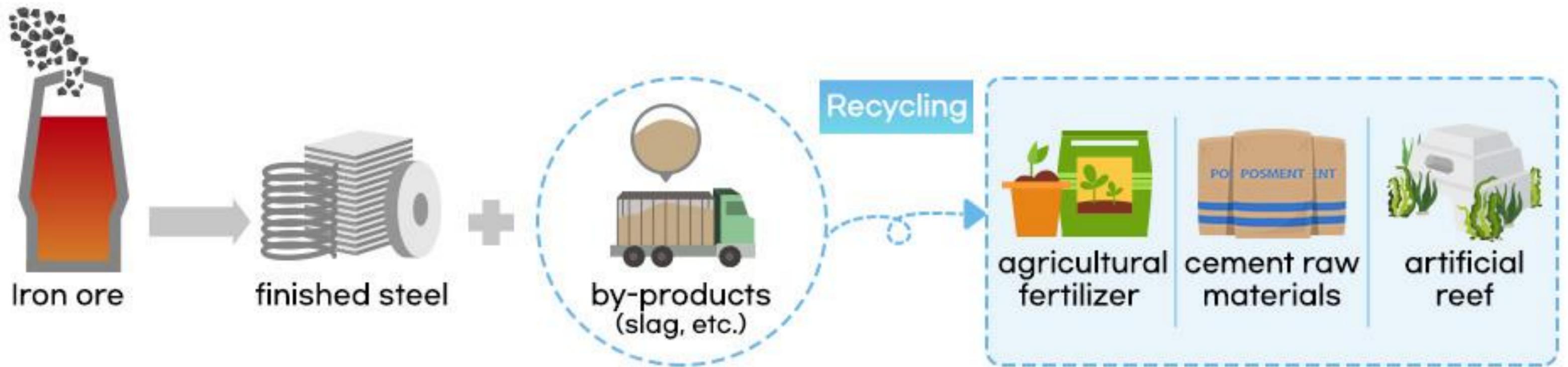
*ESTEP Focus  
Group Circular  
Economy &  
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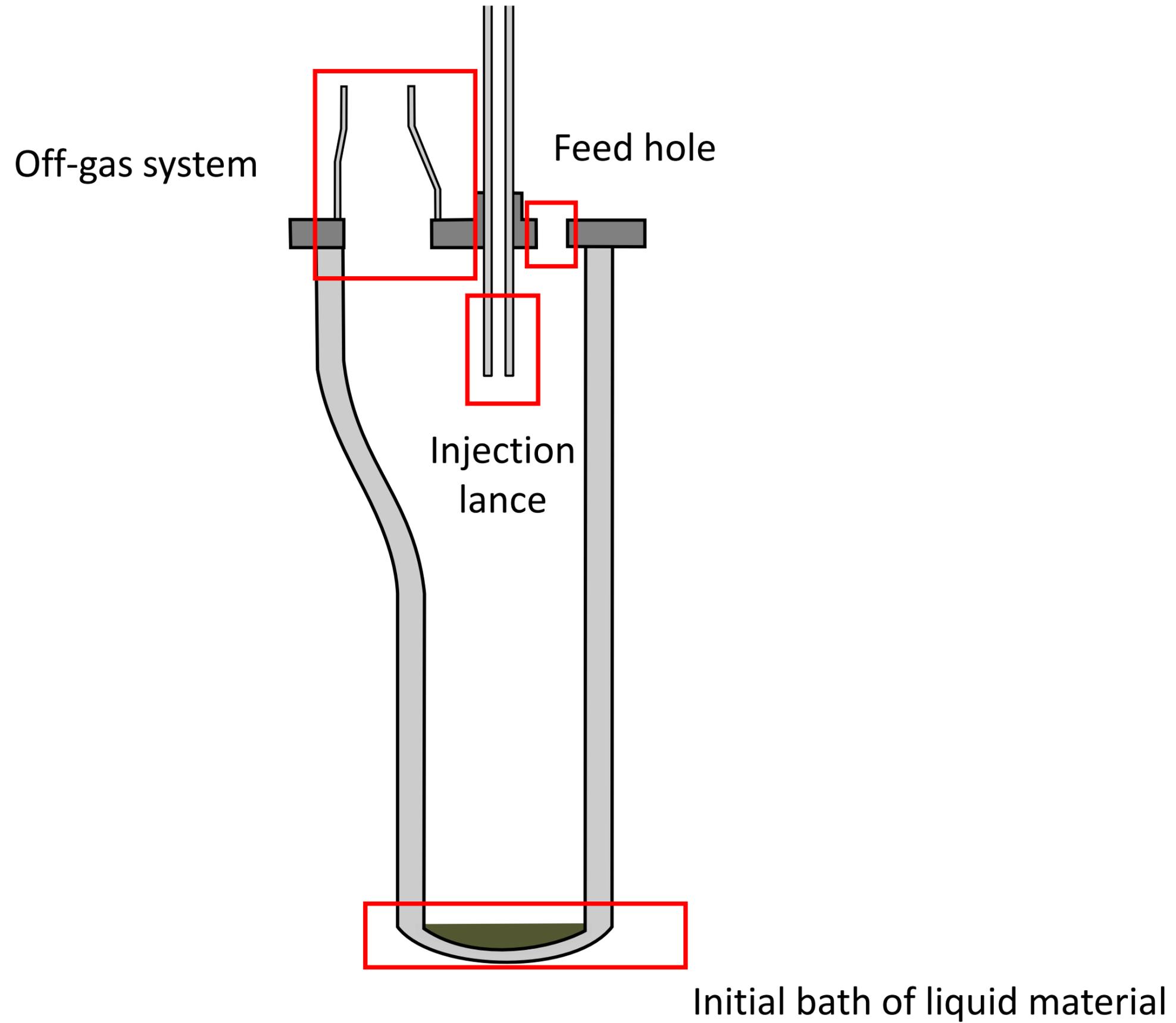
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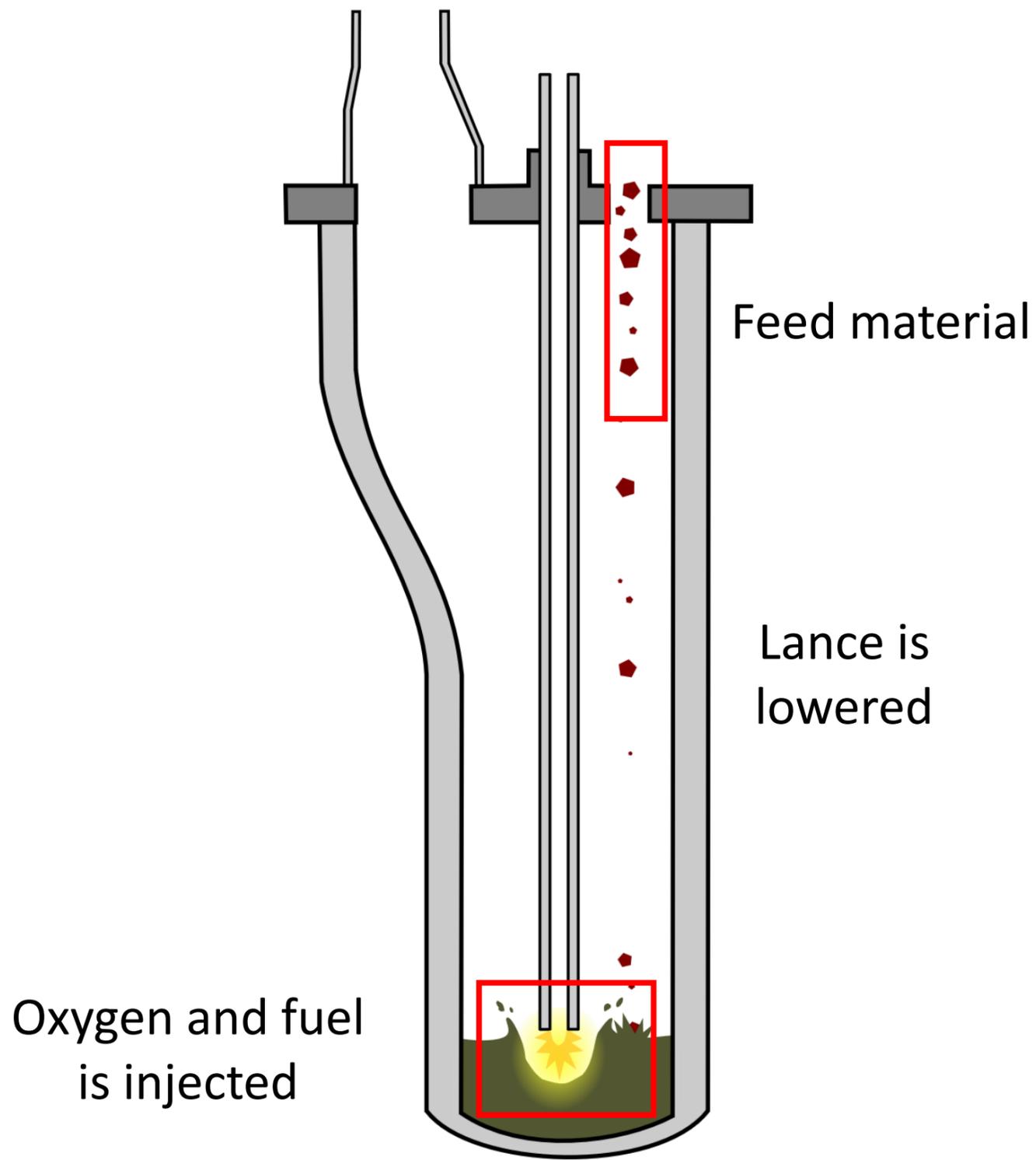
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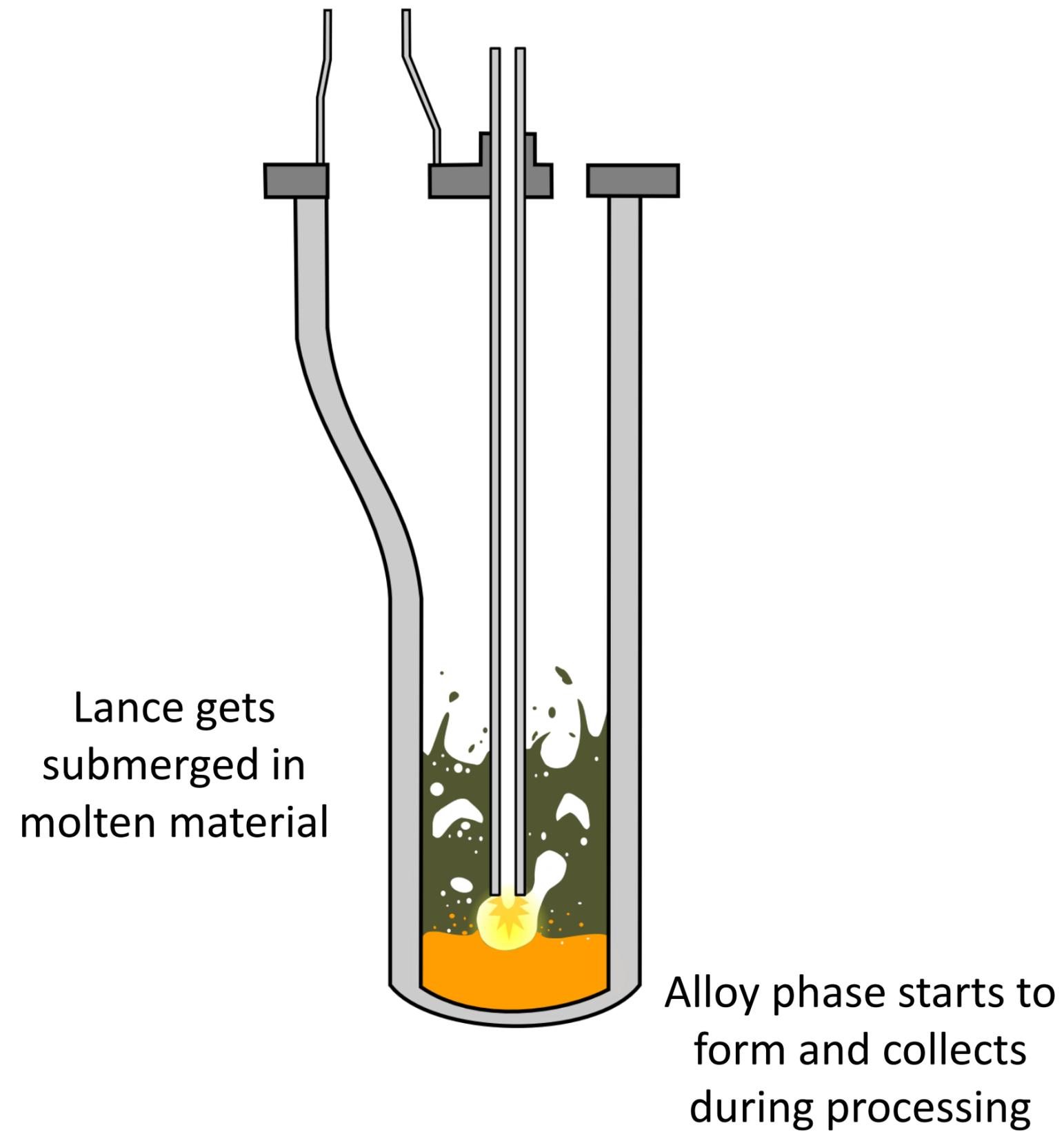
# The role of slags in a circular the steel industry



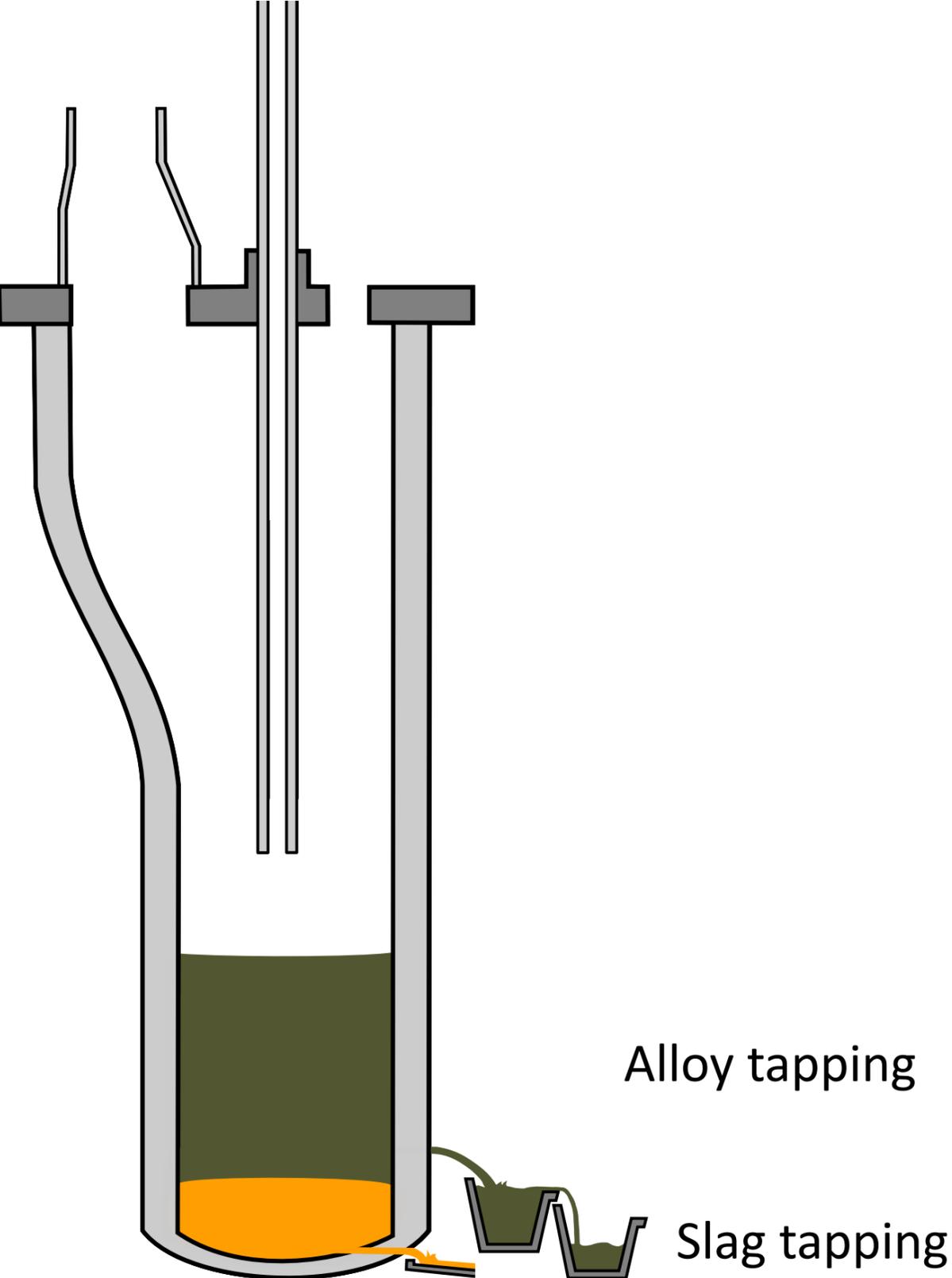
# But first: where does the slag come from?



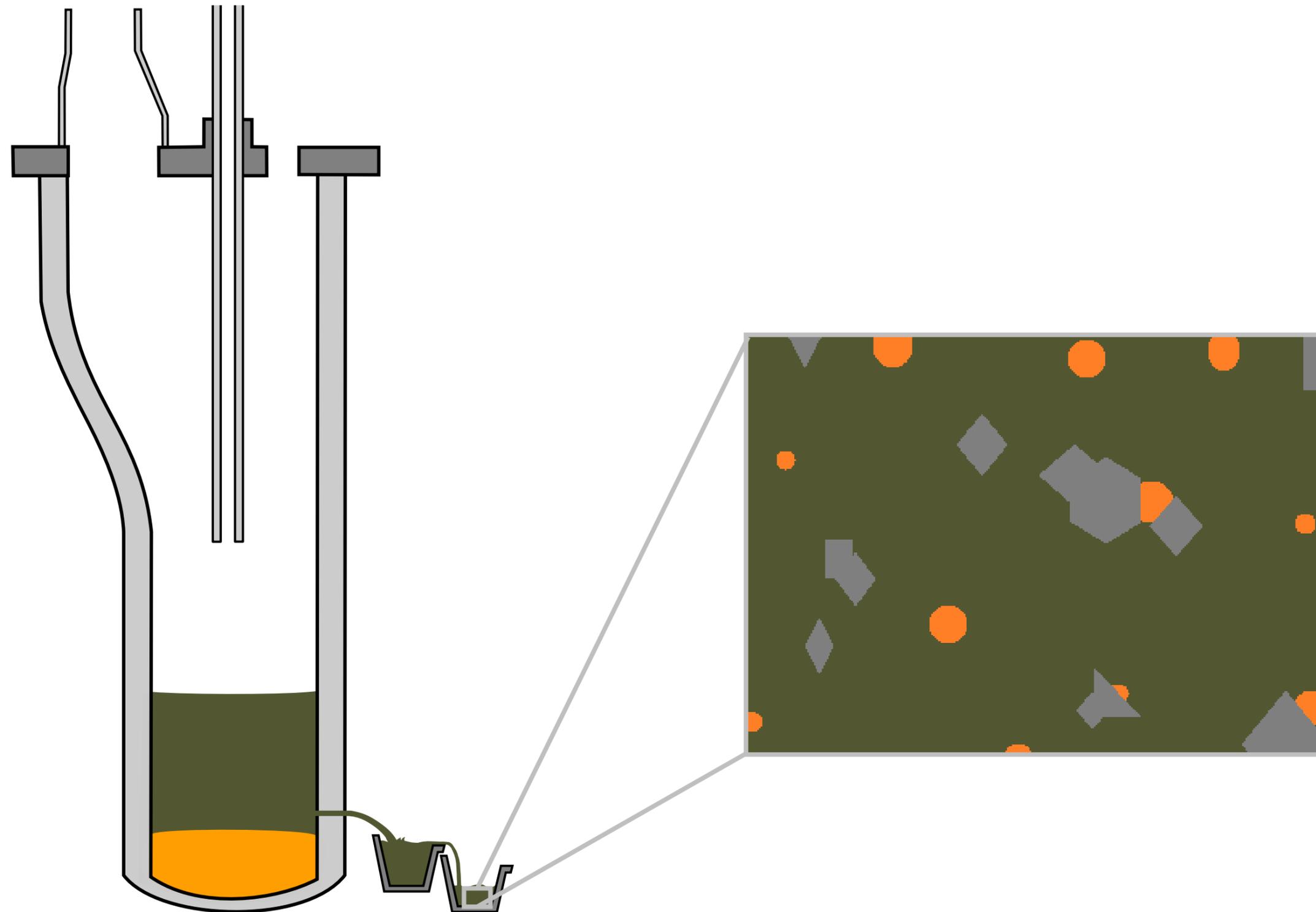




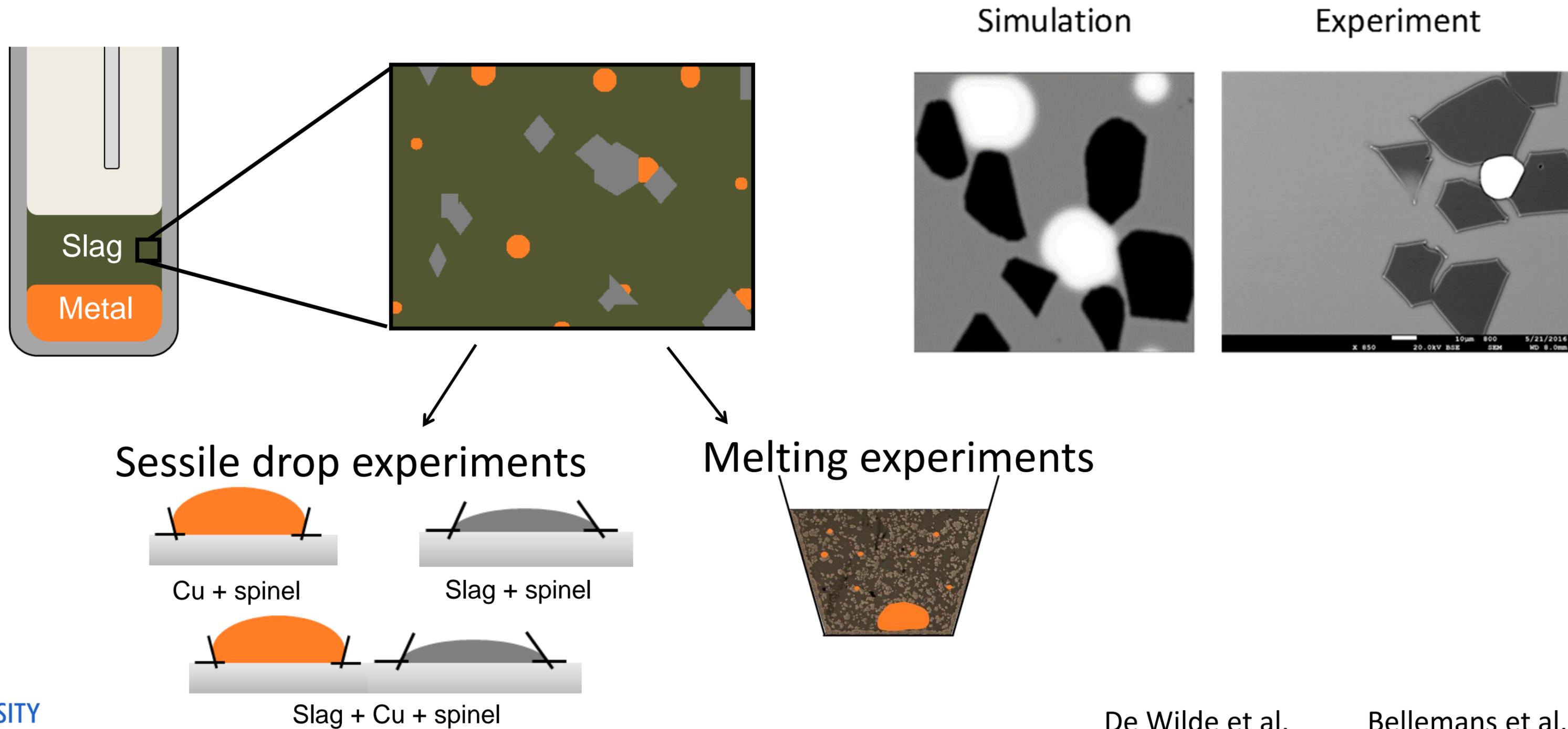
Decantation



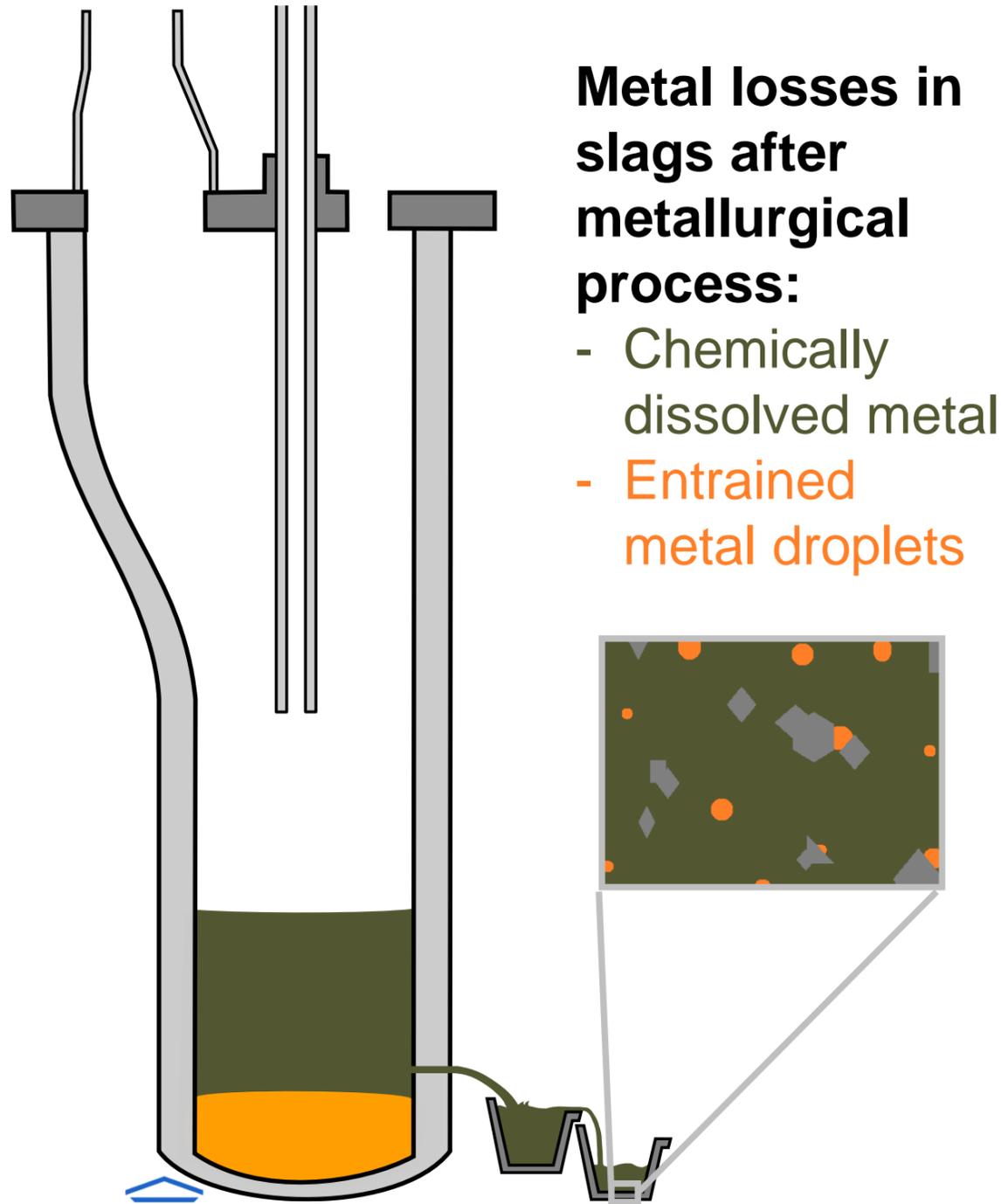
# Possible problem: metal losses in slags



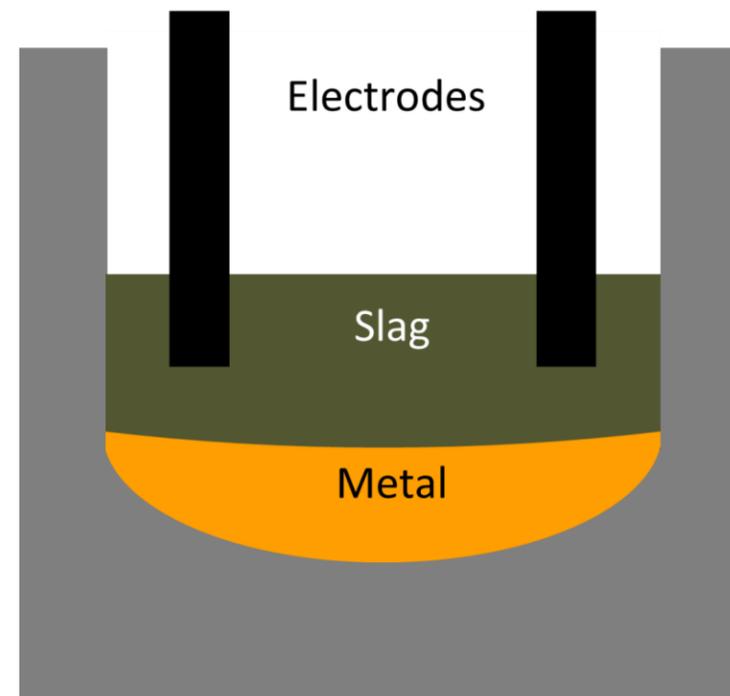
# Metal losses in liquid slags: Reactive origin



# Add slag cleaning step



Possible solution  
= slag cleaning in electric furnace



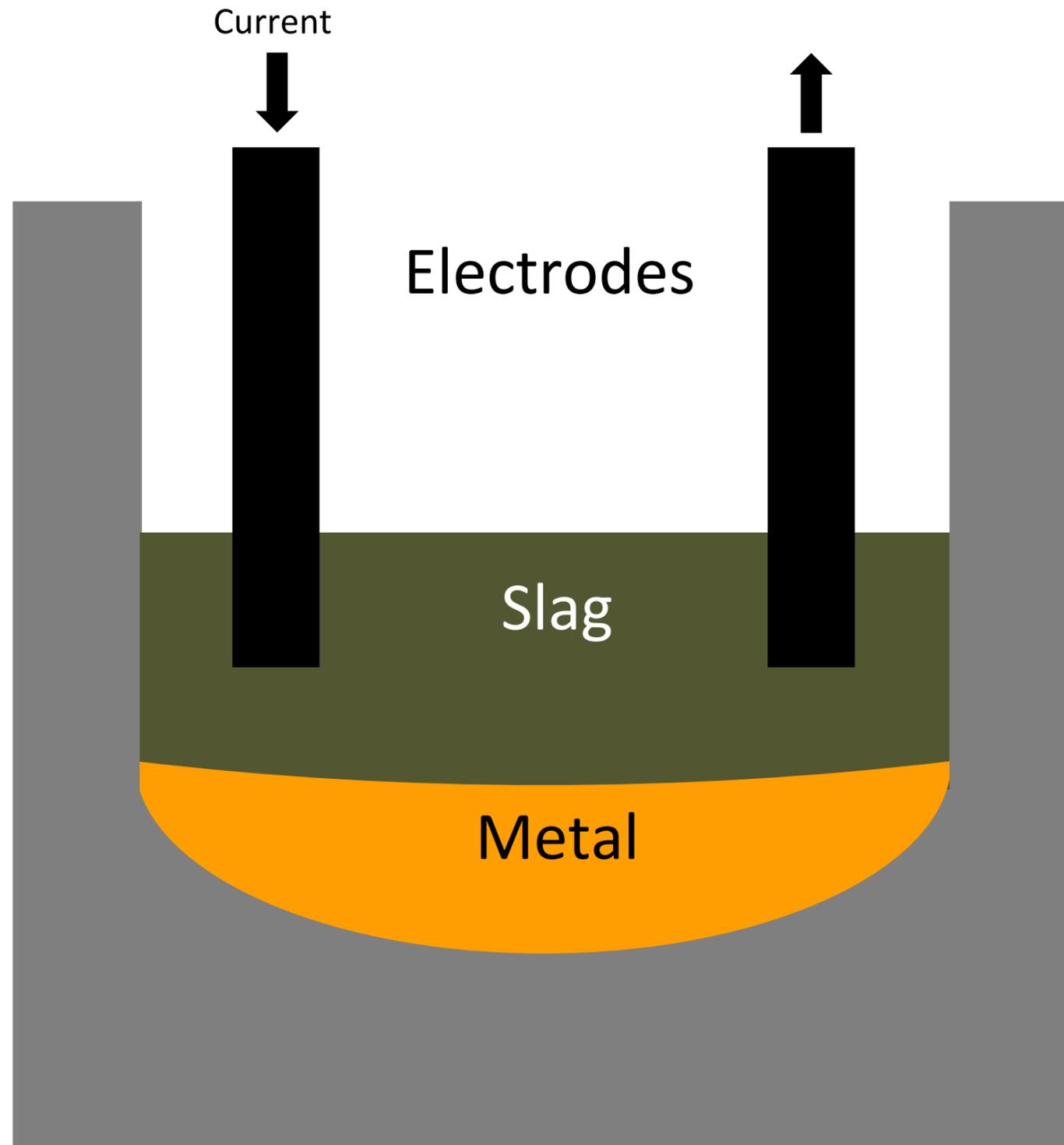
Recovery of

- Chemically dissolved metal

# Metal losses: electric furnace as solution

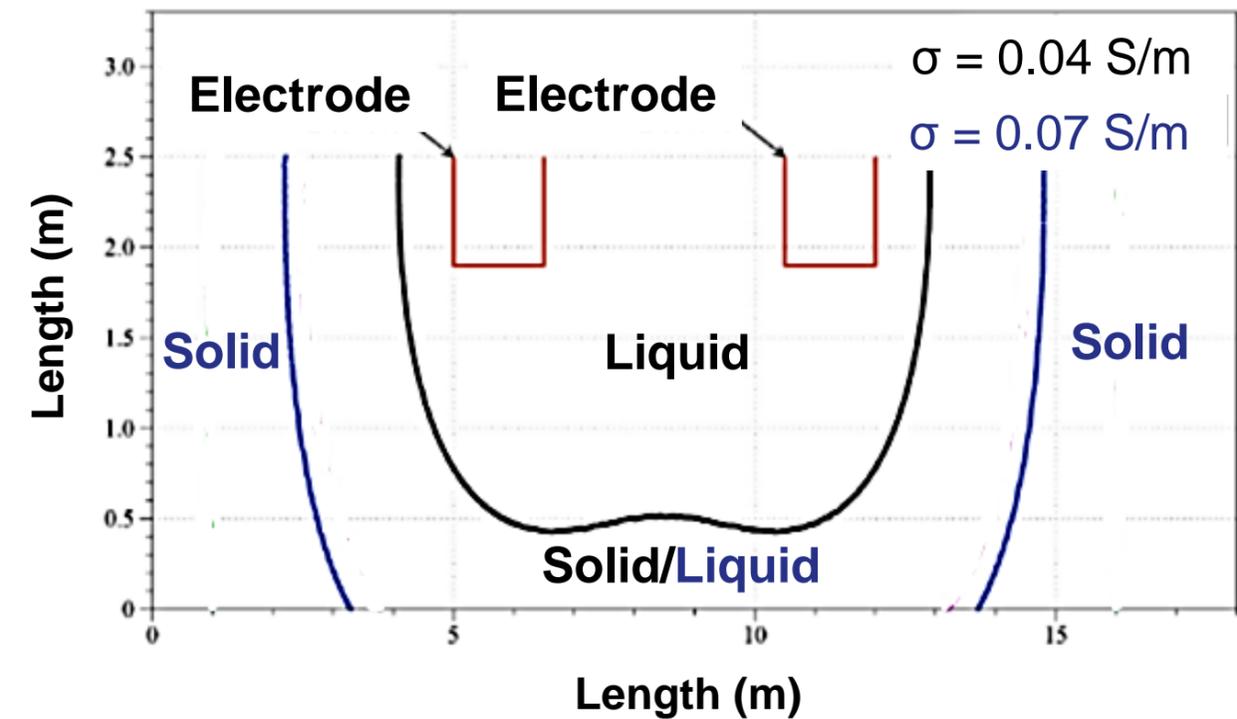
Submerged Electric Arc Furnace

Power generation via Joule heat



$$P = \frac{V^2}{R_{slag}}$$

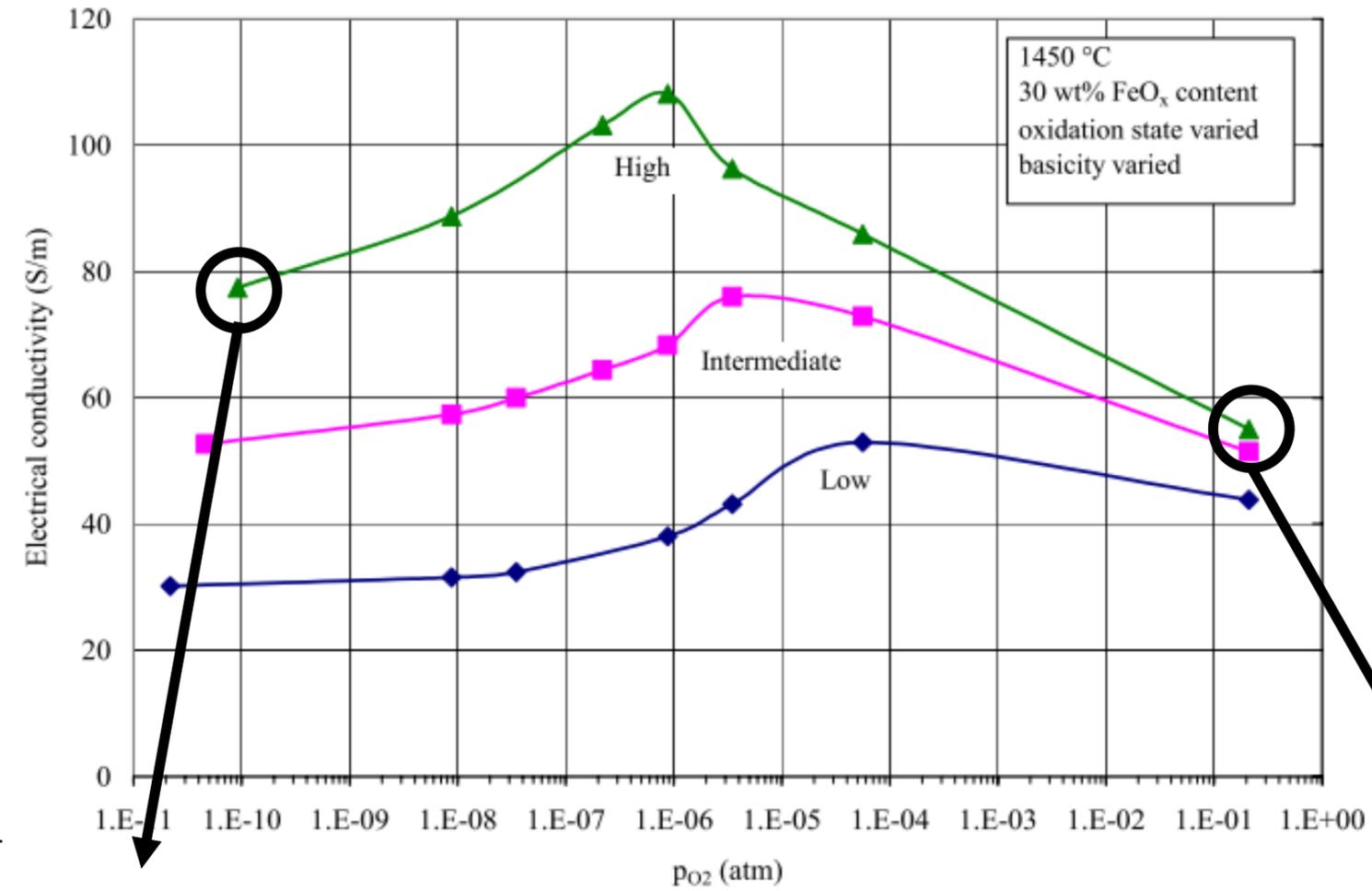
$$R_{slag} \sim \frac{1}{\sigma_{slag}}$$



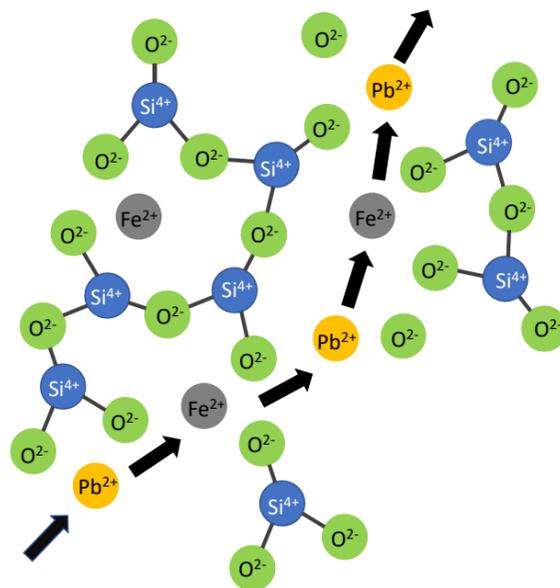
Karalis et al., Applied Mathematical Modelling  
Vol 40, Issues 21–22 (2016) P 9052-9066

# 2 contributions

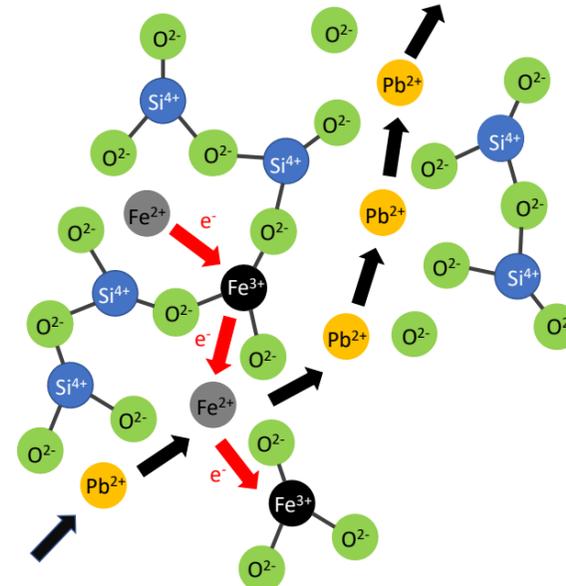
Hundermark et al., 2004, VII International Conference on Molten Slags Fluxes and Salts



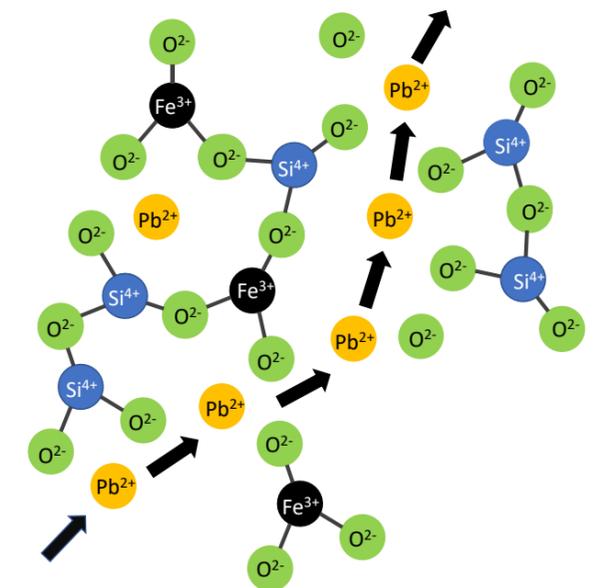
Reducing: Fe<sup>2+</sup>



Intermediate: Fe<sup>2+</sup> & Fe<sup>3+</sup>

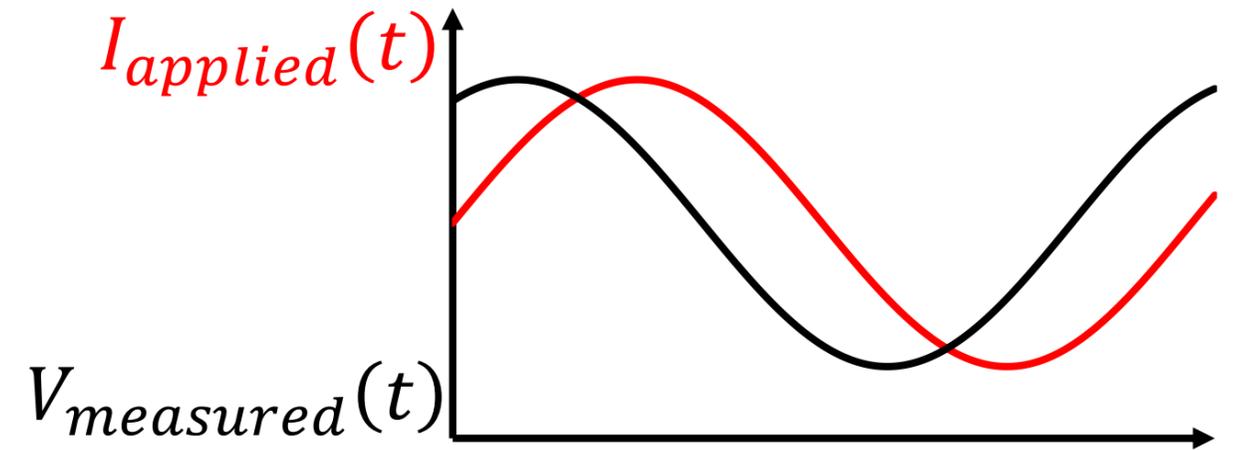


Oxidizing: Fe<sup>3+</sup>



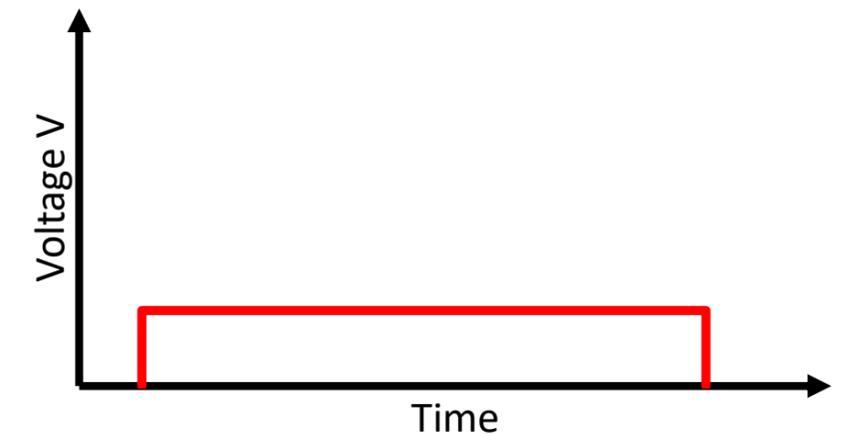
# Electrical conductivity measurements

AC Impedance measurements

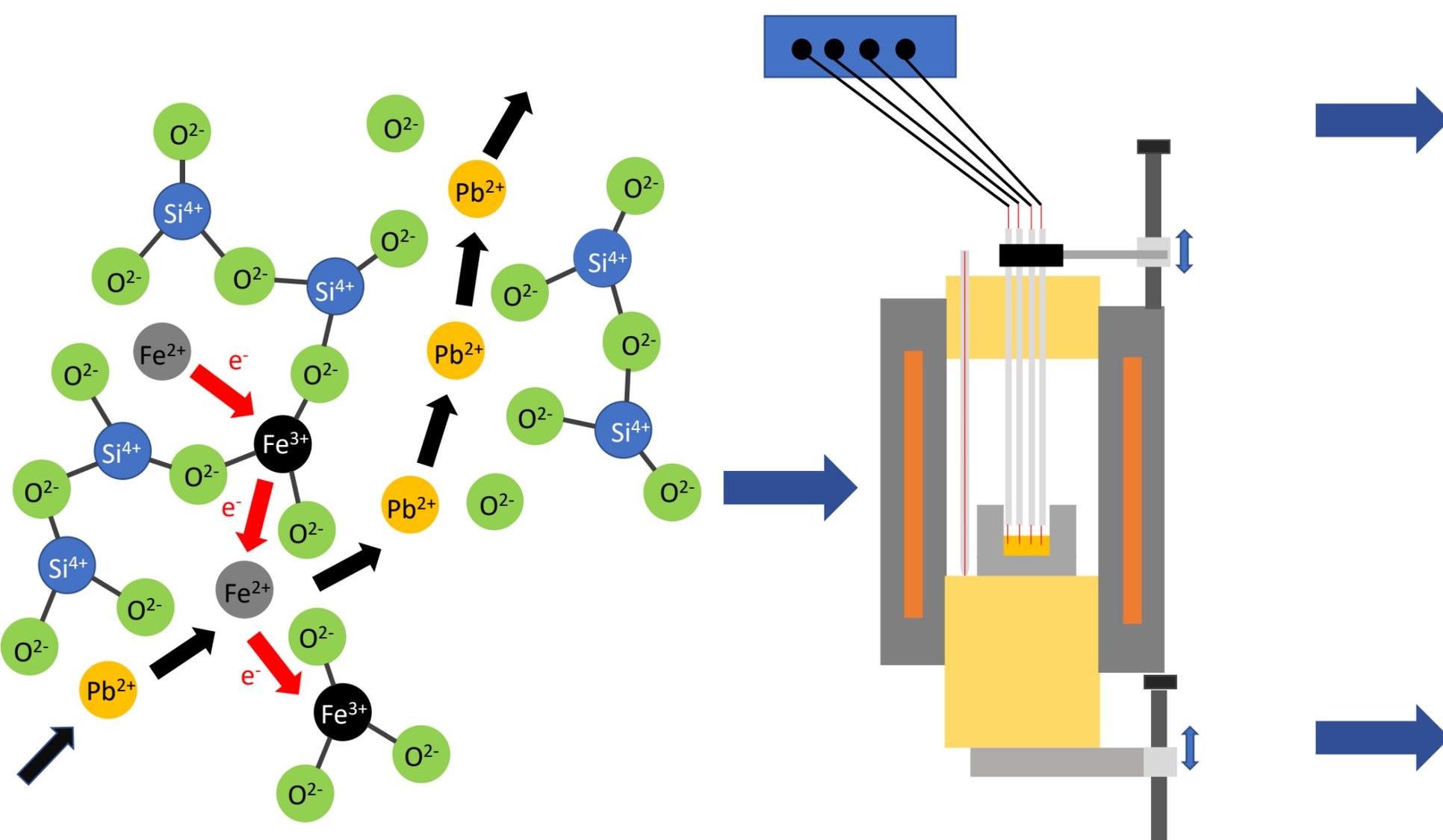


 Ionic current  
 Electronic current

DC Chronoamperometry

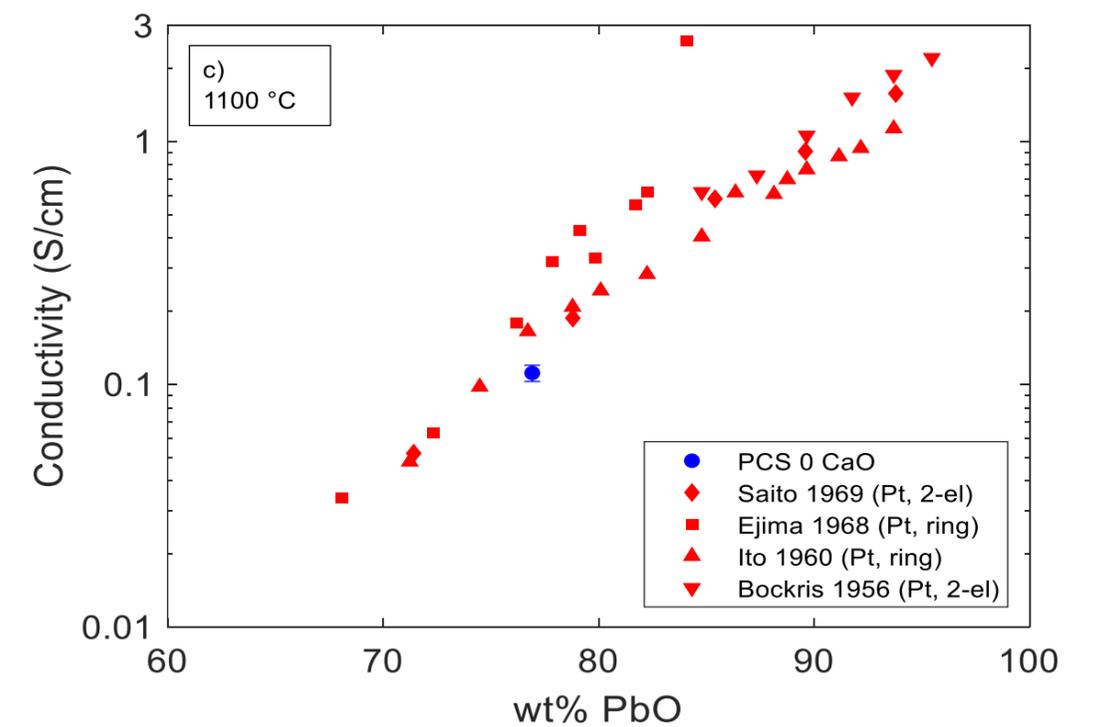
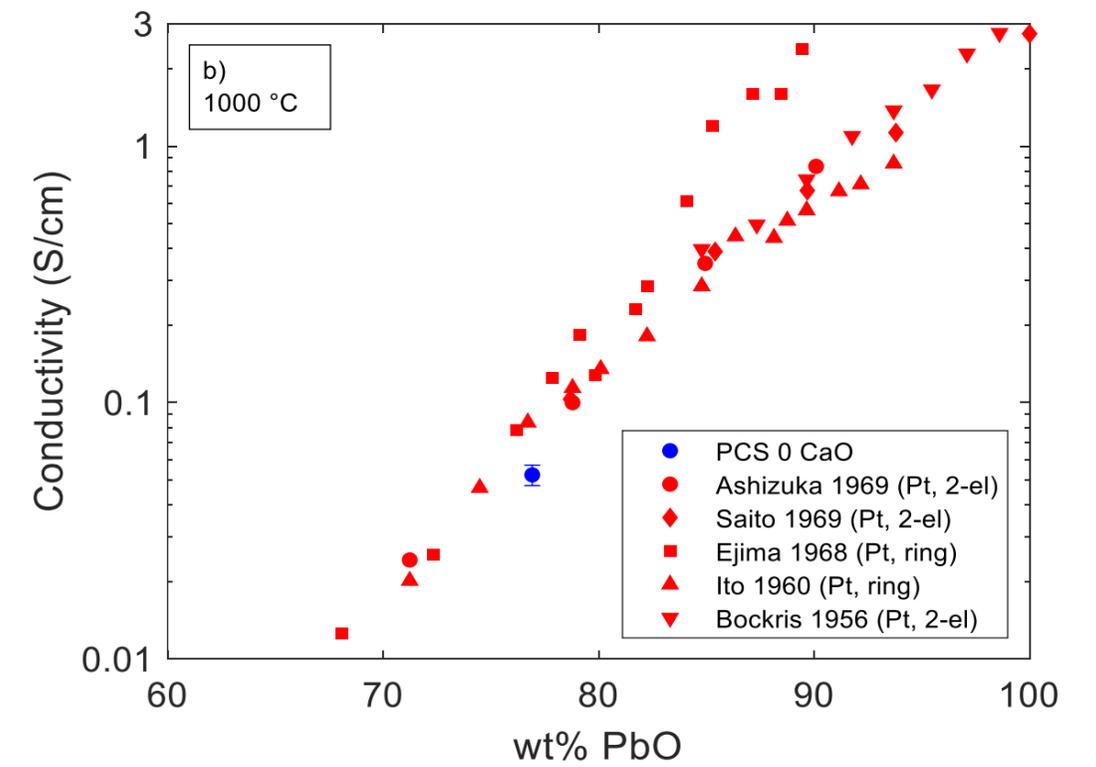
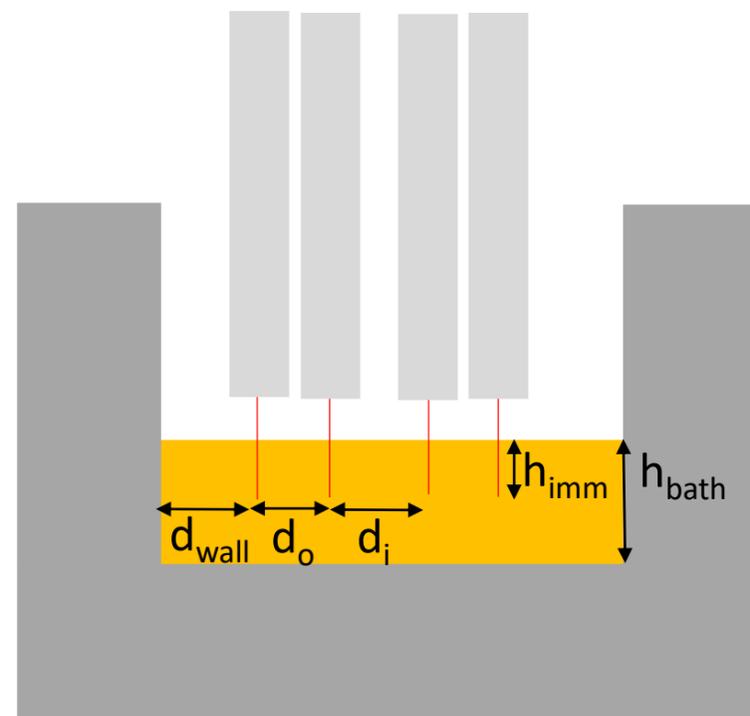
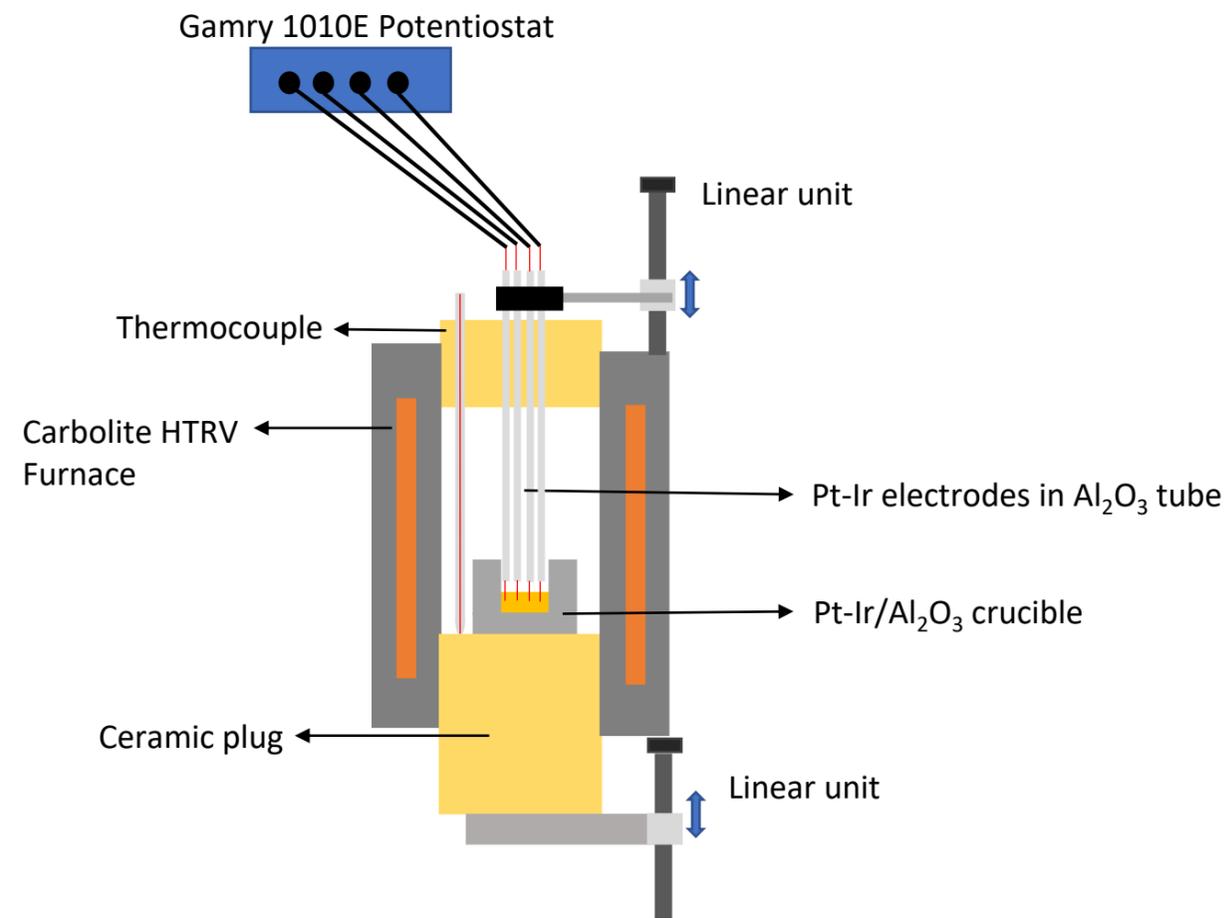


 Electronic current

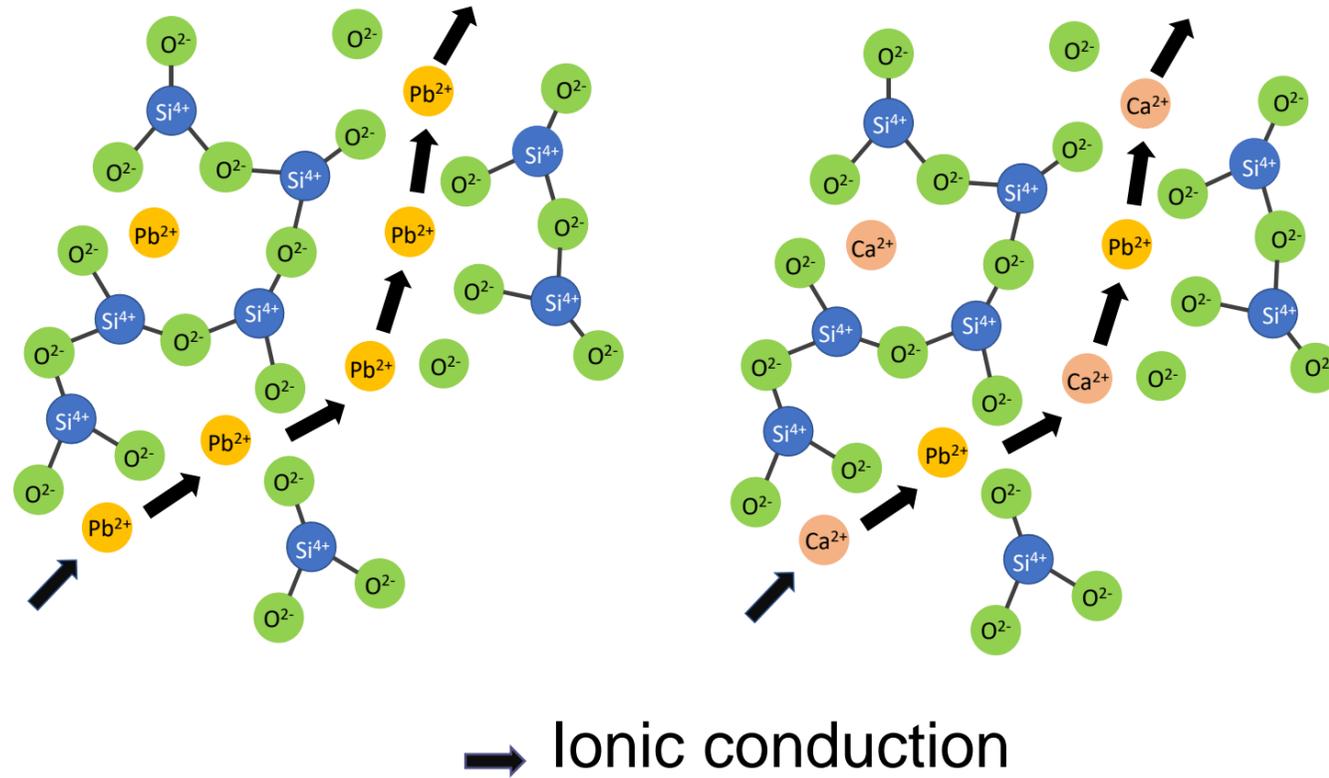


Four-electrode conductivity setup

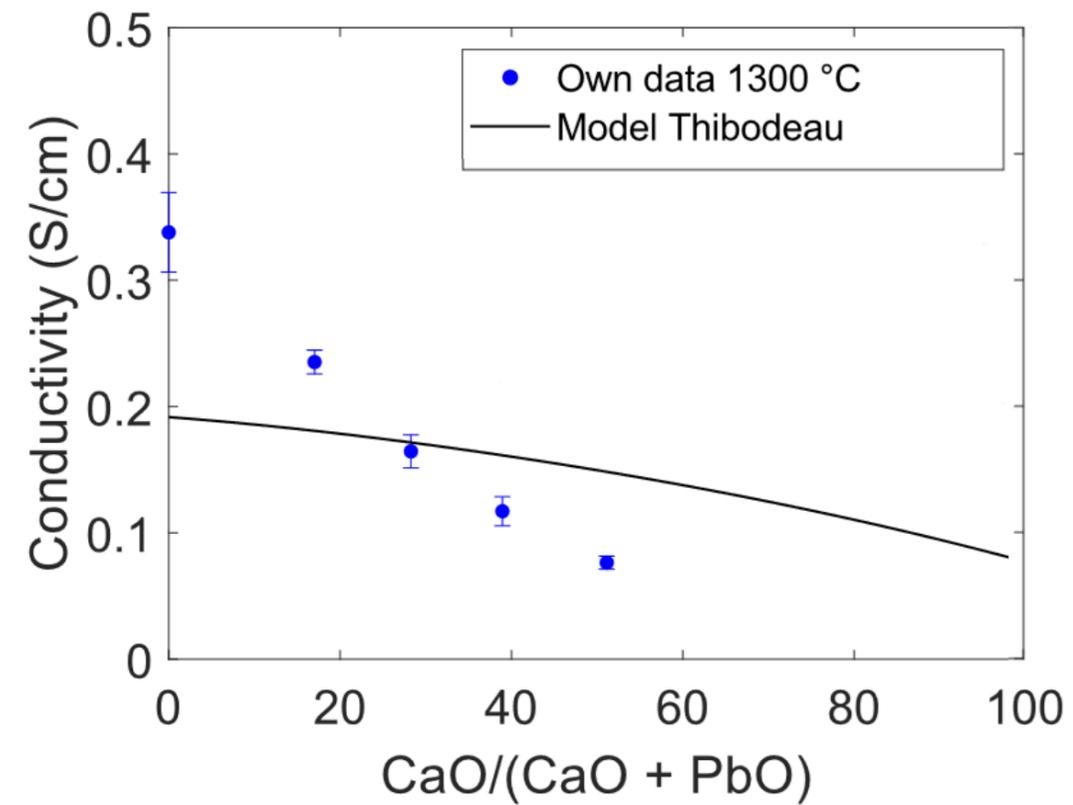
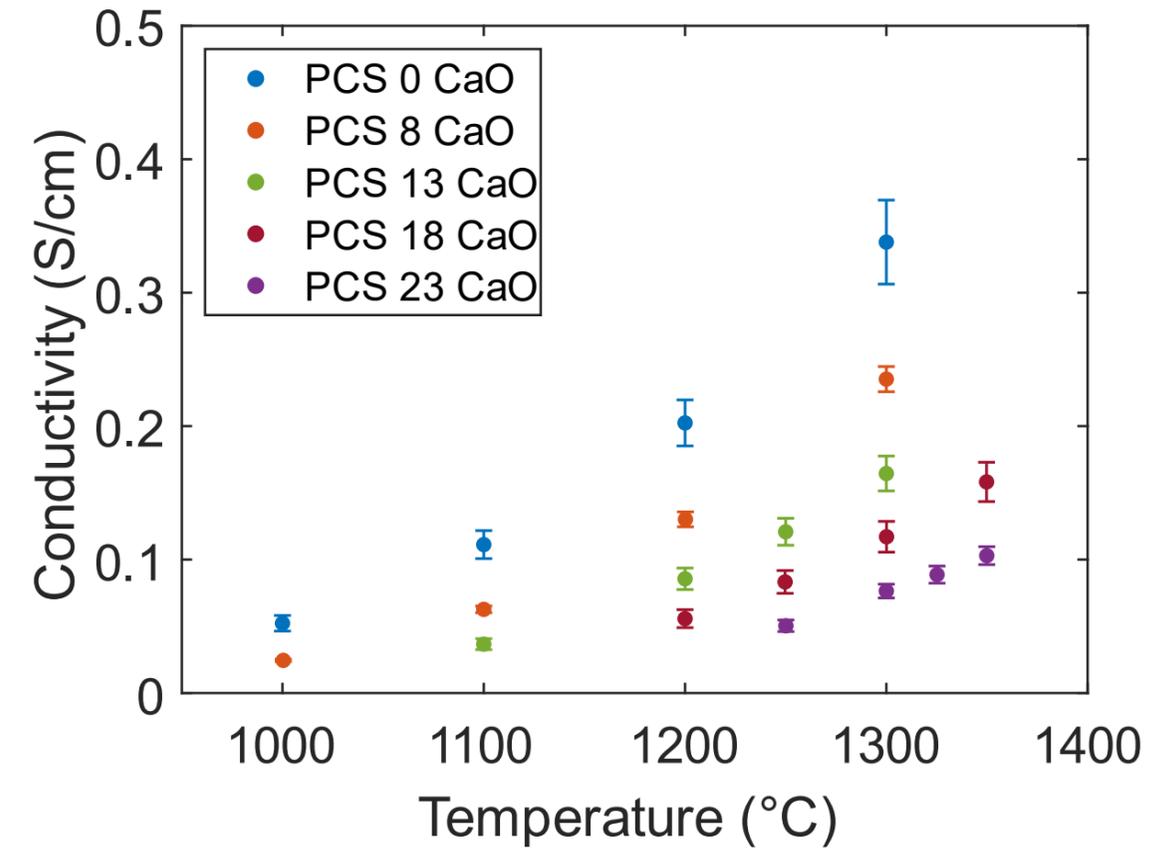
# Electrical conductivity – Ionic contribution



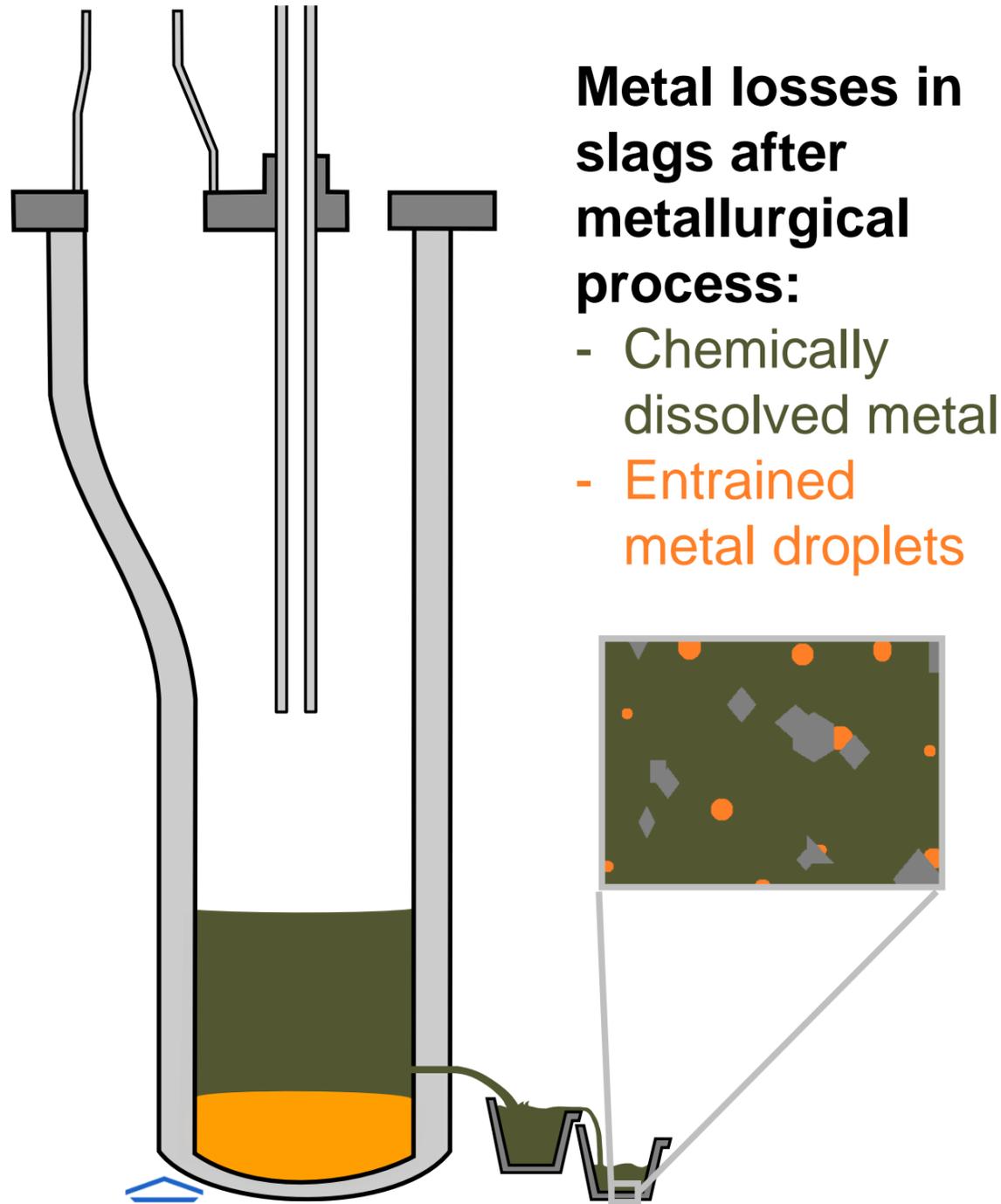
# Results: Effect substitution of PbO by CaO



Sample composition:  $\text{SiO}_2 = 52 \text{ mol}\%$   
 Varying amounts of CaO (and PbO)



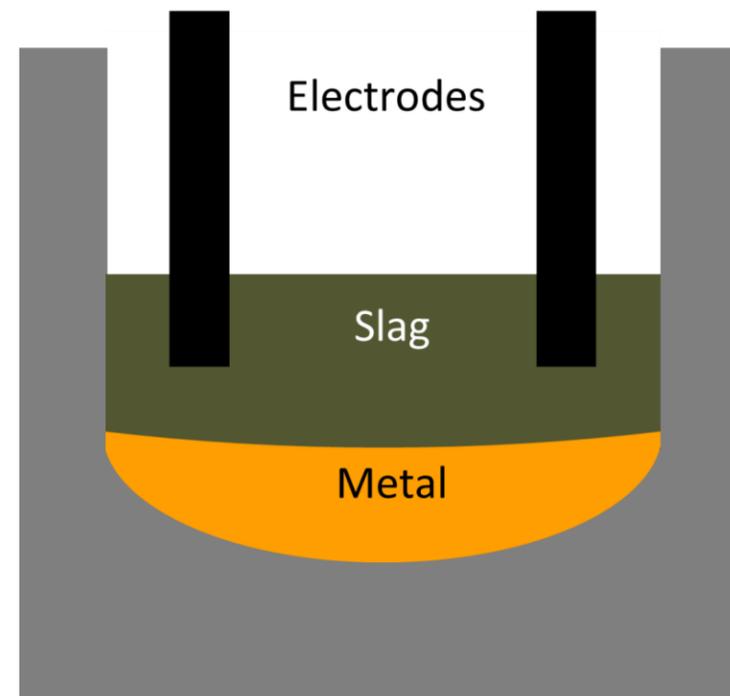
# Add slag cleaning step



**Metal losses in slags after metallurgical process:**

- Chemically dissolved metal
- **Entrained metal droplets**

**Possible solution = slag cleaning in electric furnace**



Recovery of

- Chemically dissolved metal

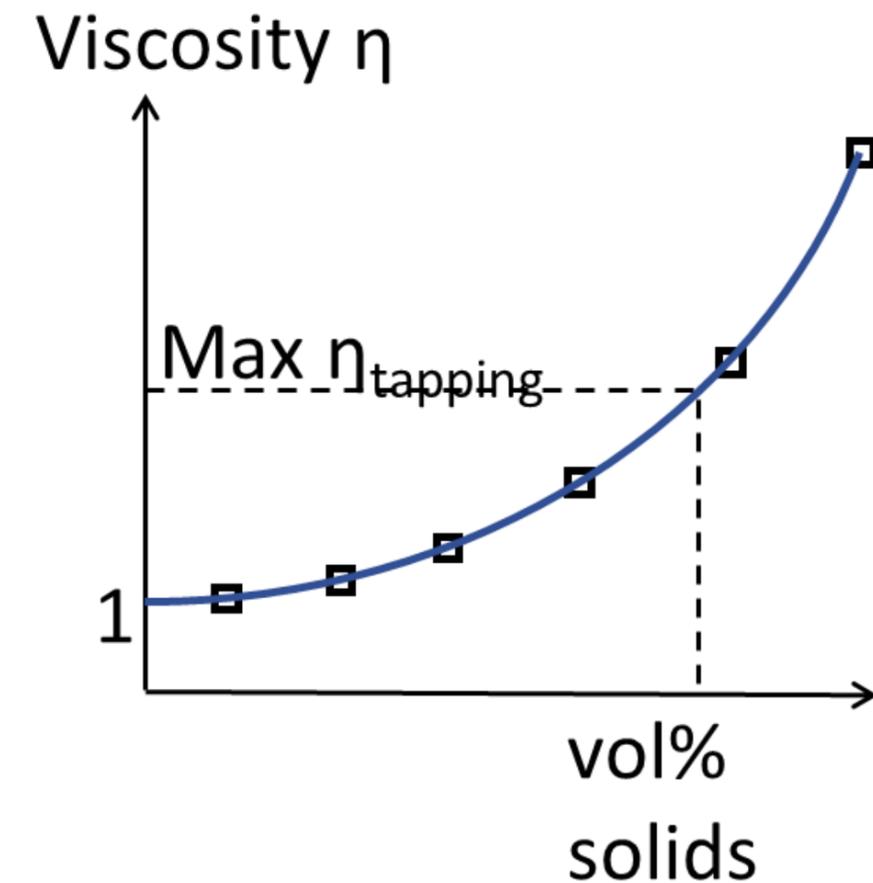
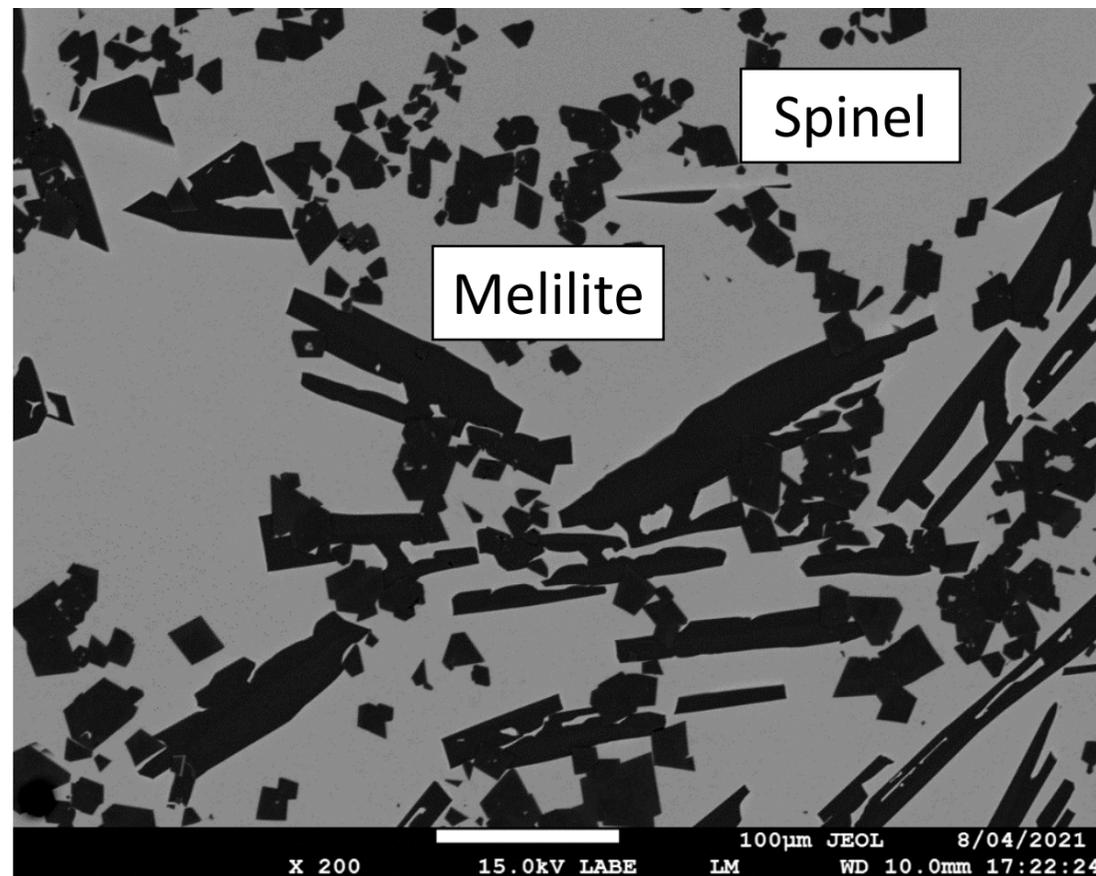
- **Entrained metal droplets**

# Settling: slag viscosity

**Slag viscosity = resistance against flow**

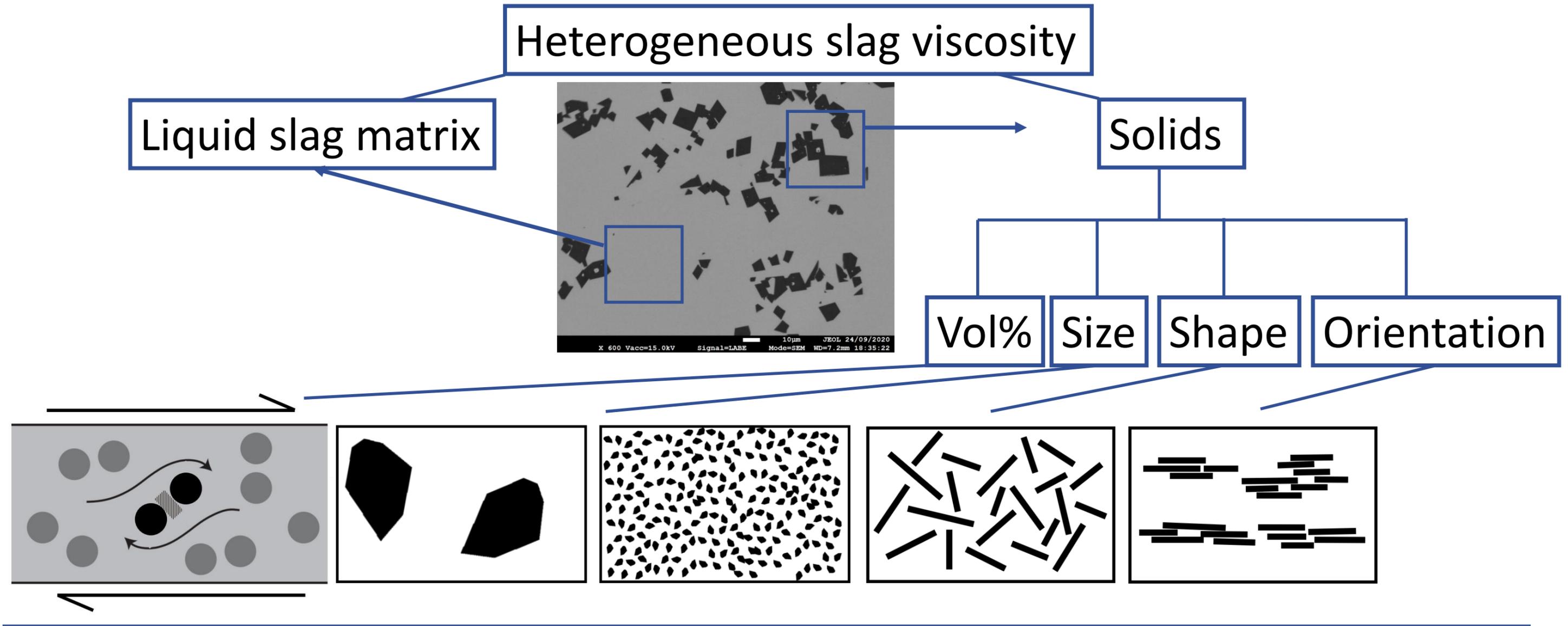
Depends on:

- slag structure
- temperature
- **presence of solids**



“Reproducibility slag suspension viscosity measurements is low”

# Heterogeneous (liquid + solid) slag viscosity



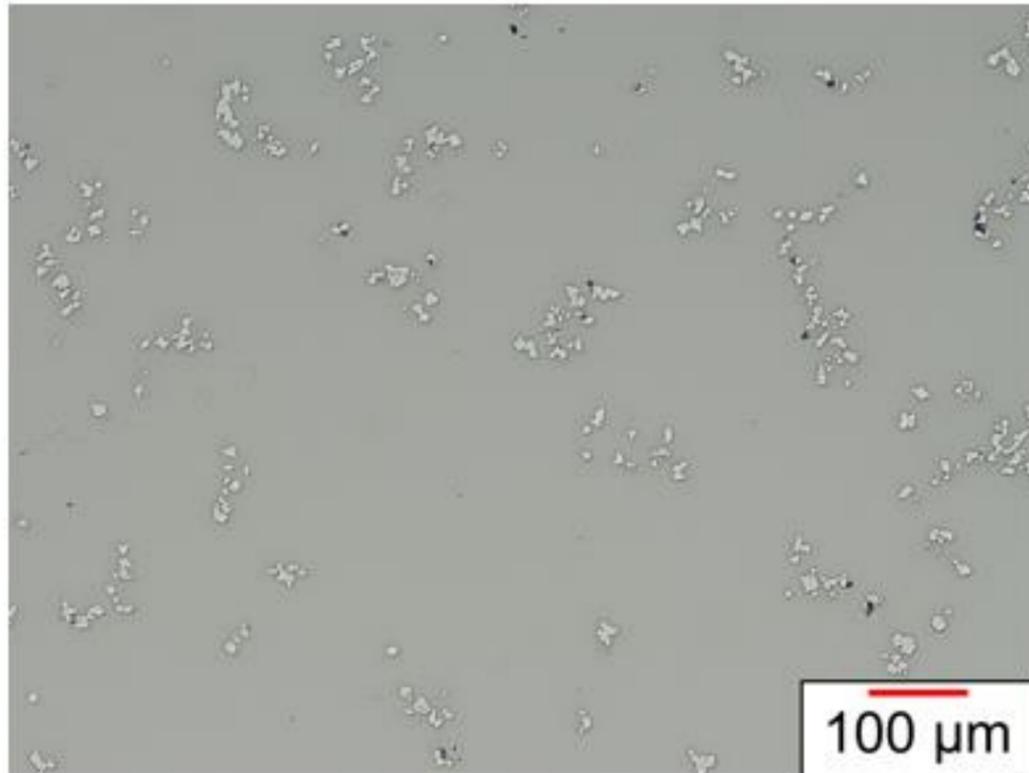
$$\eta = \eta_{\text{liquid}} \times f_{\text{solids}} (\Phi_{\text{solids}}, \text{morphology, orientation})$$

Various parameters, many neglected

# Methodology – slag system

Three datasets studied

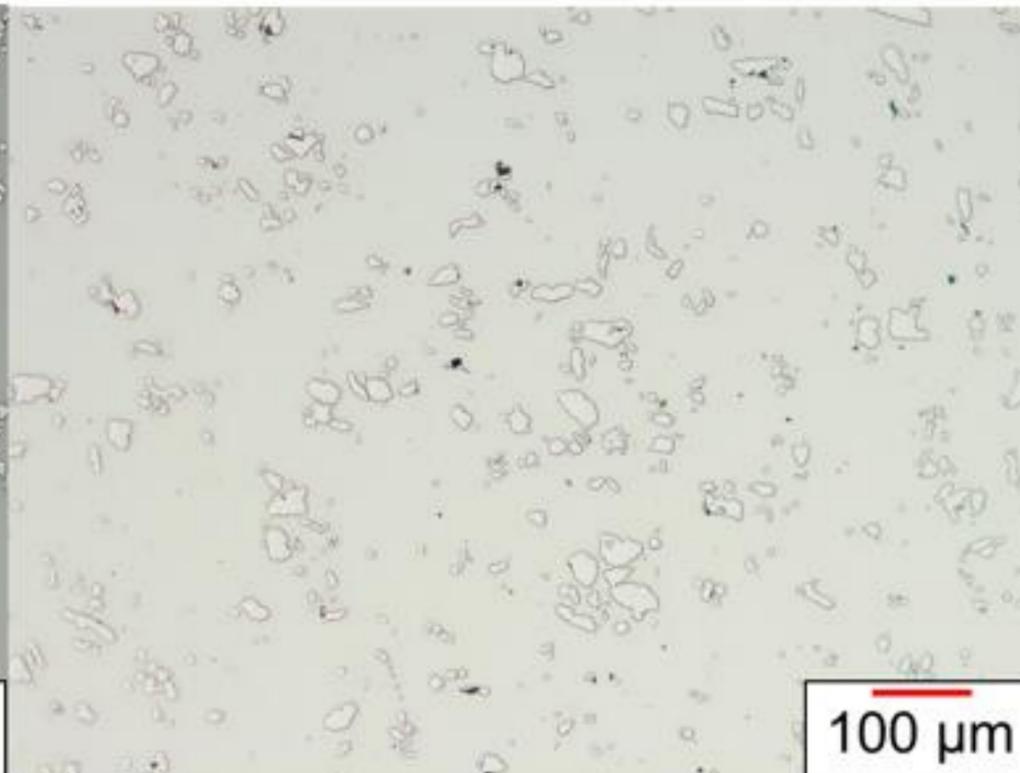
Spinel small



13 µm

0 – 7 vol%

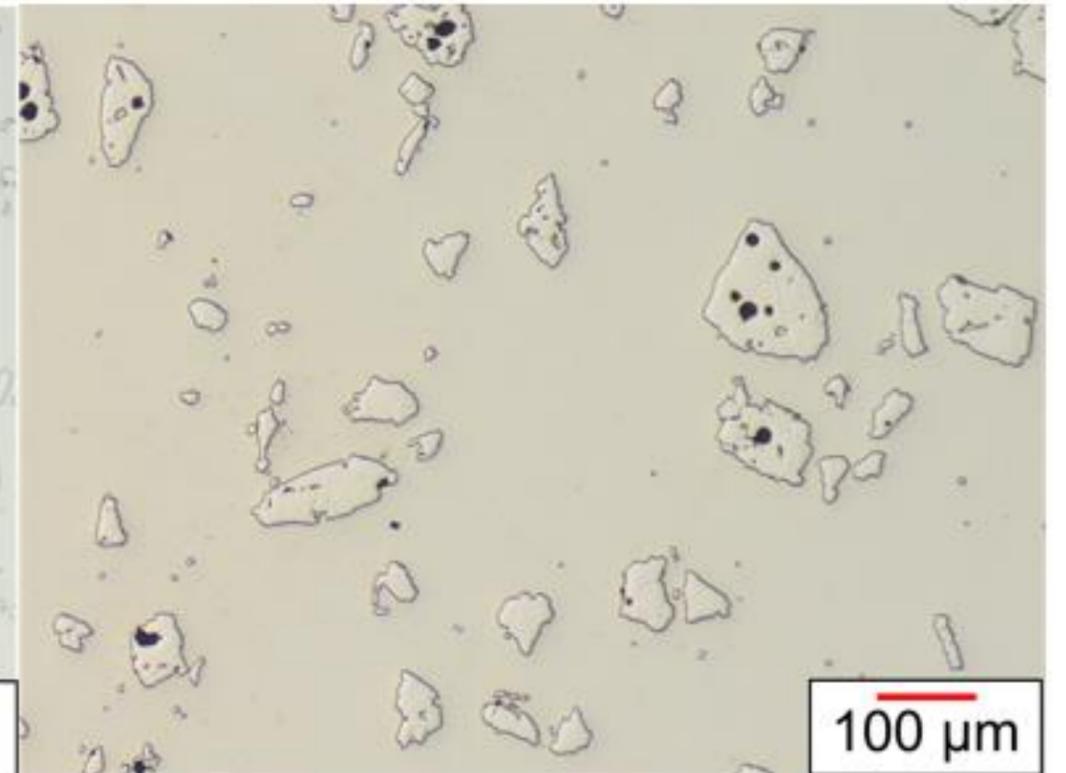
Spinel medium



34 µm

0 – 12 vol%

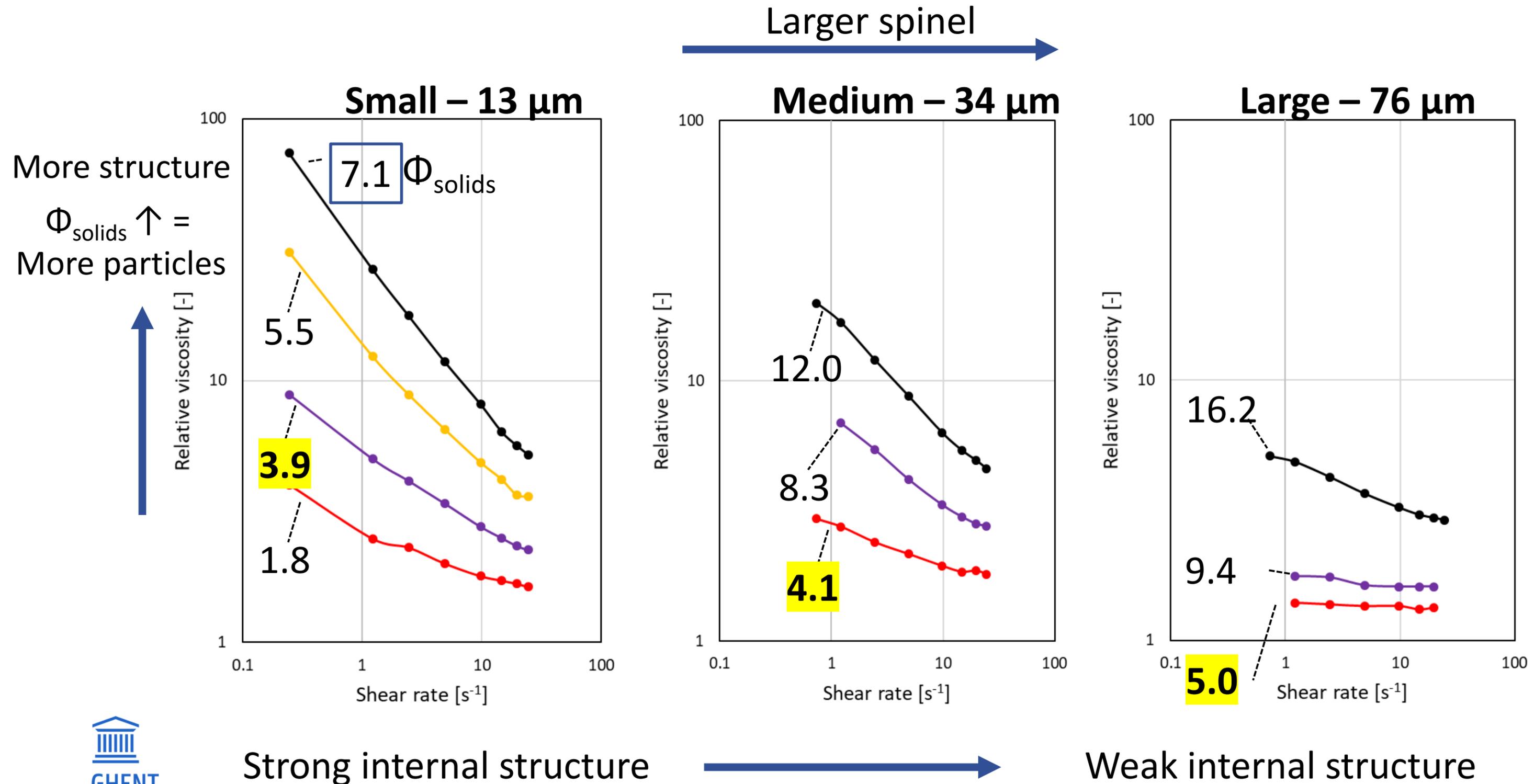
Spinel large



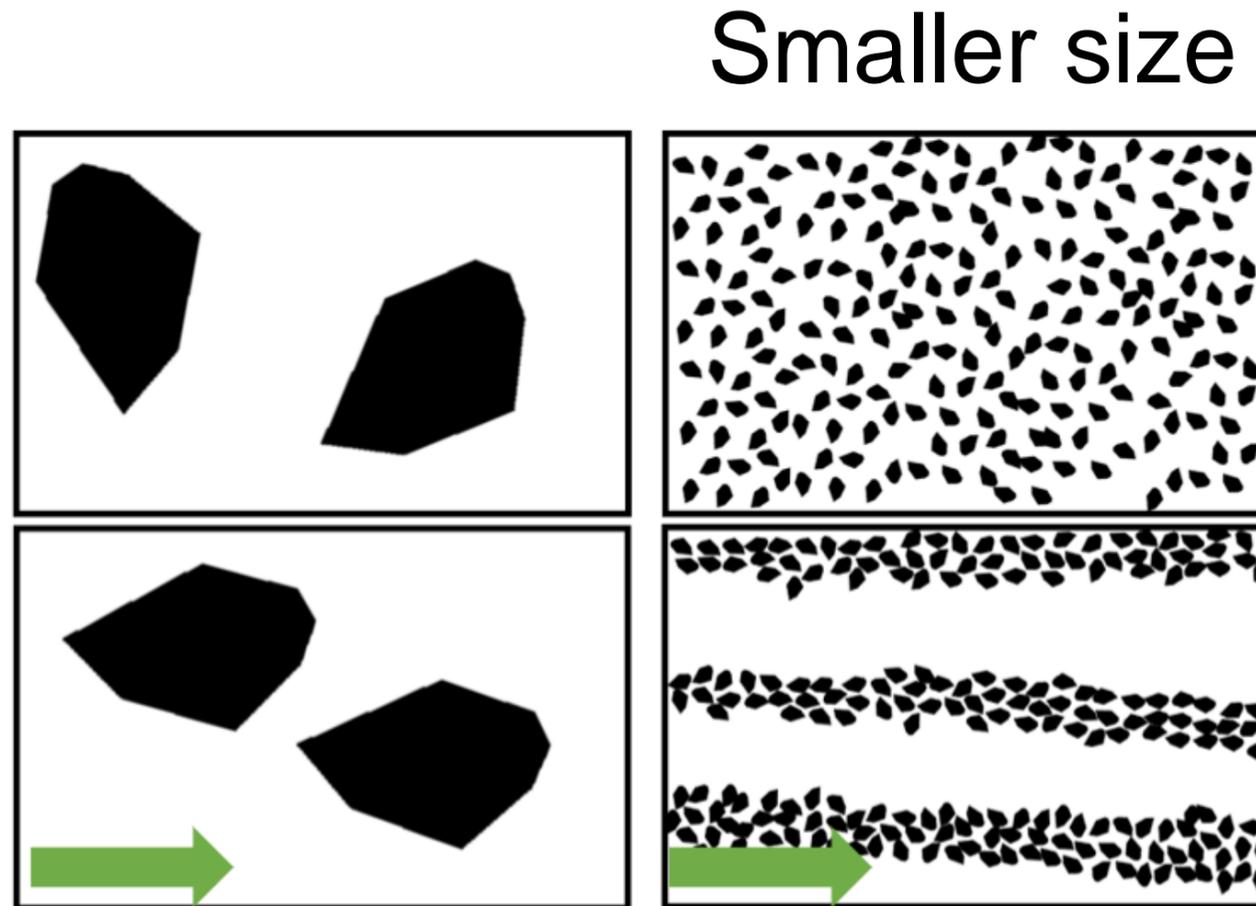
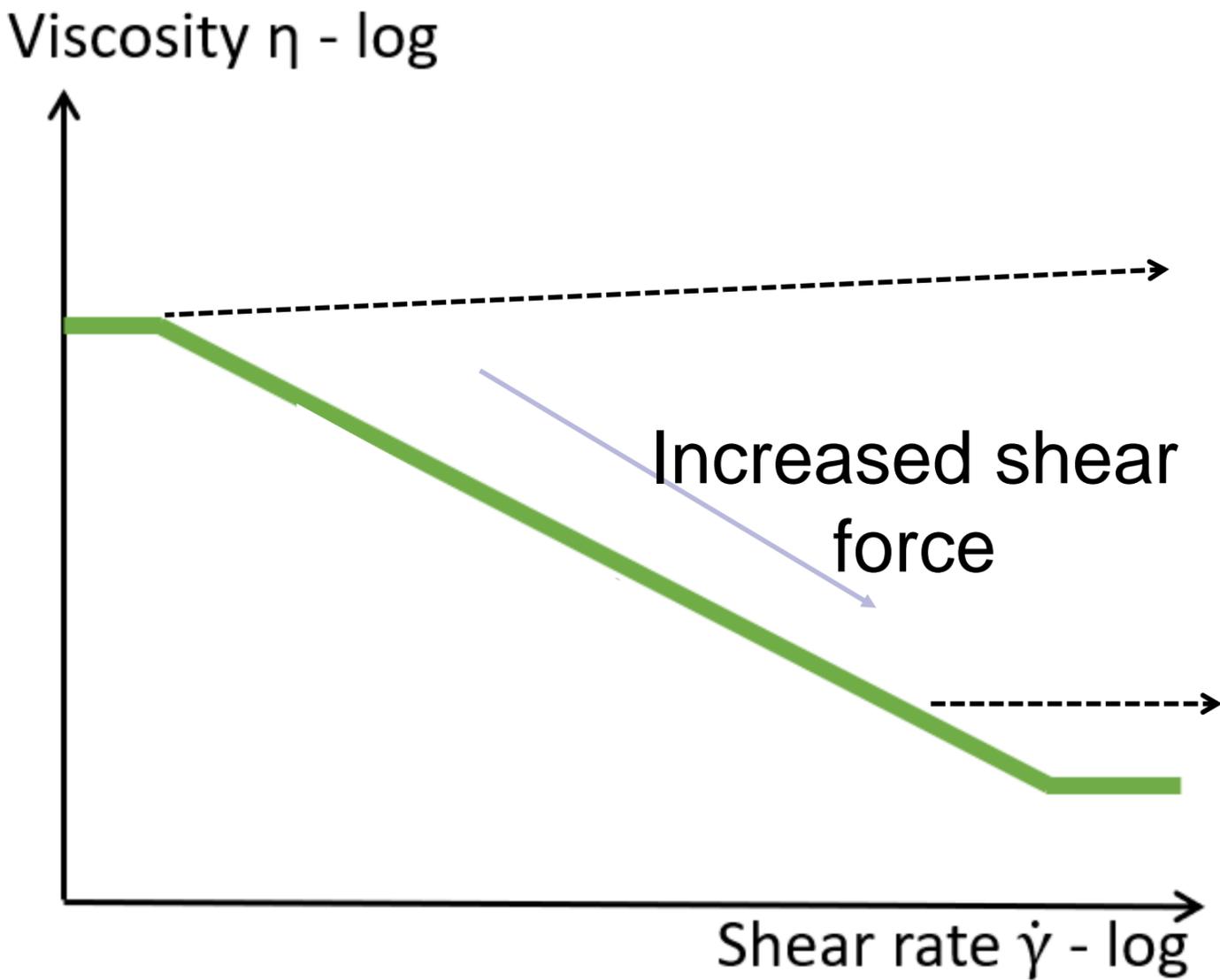
76 µm

0 – 16 %

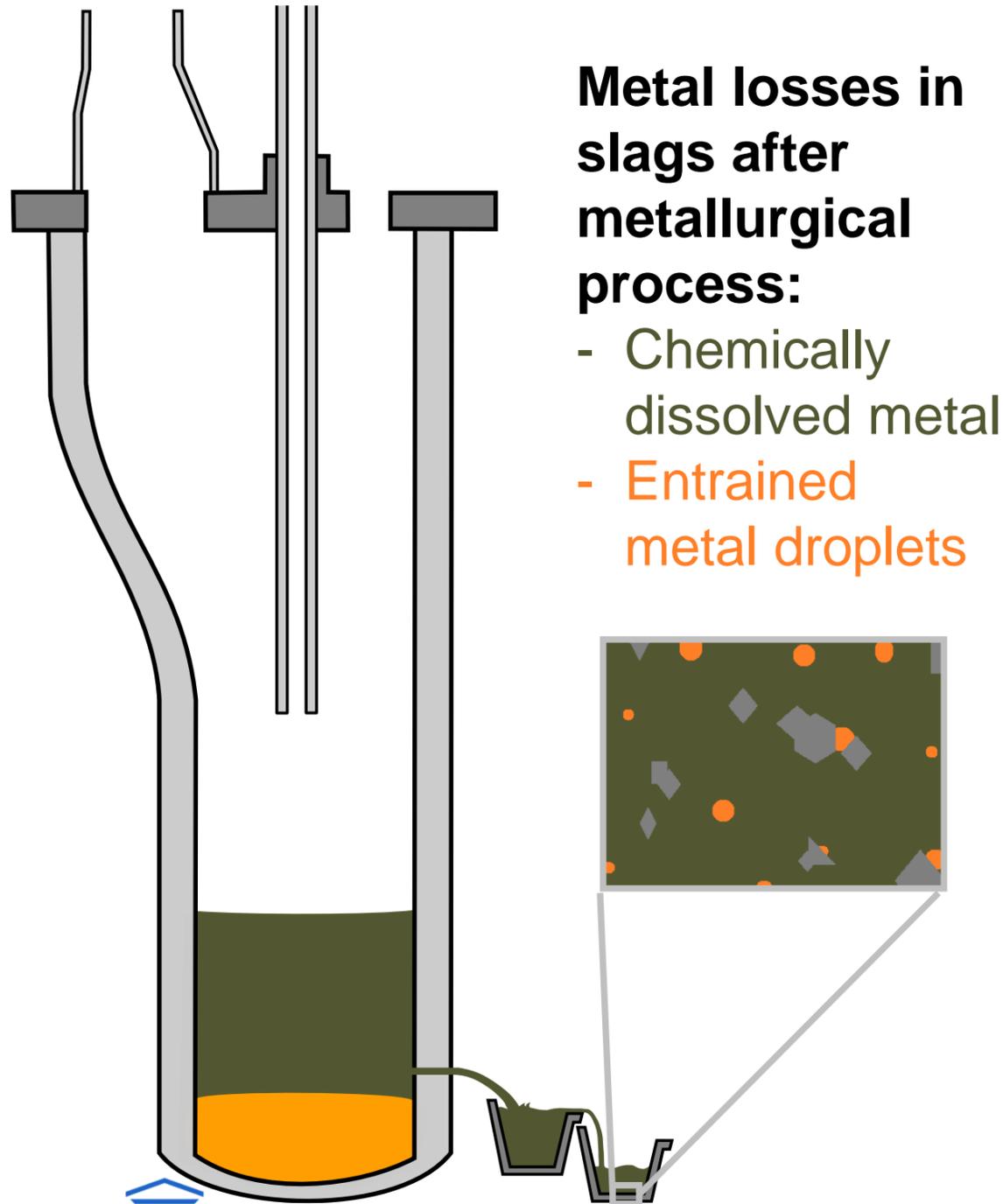
# Results: spinel – effect of size



# Interpretation: shear thinning - internal structure



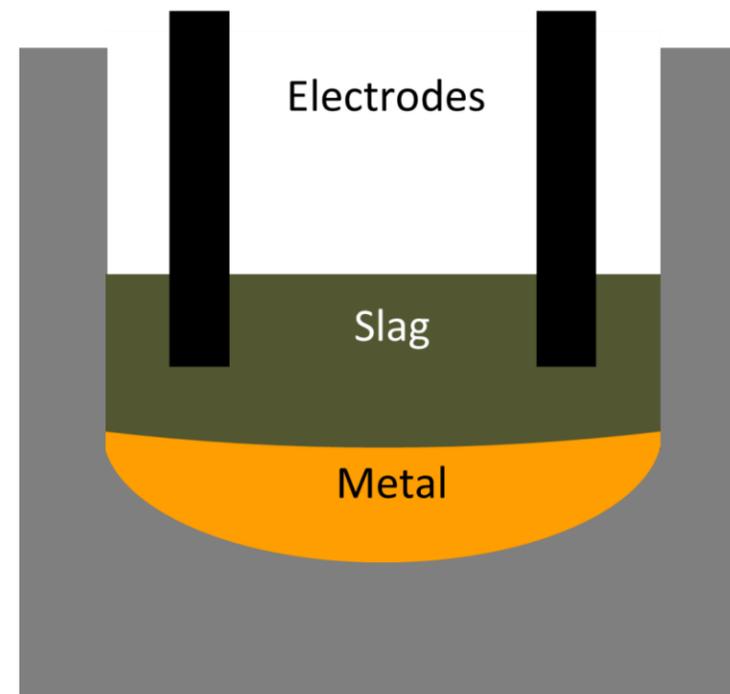
# What to do after slag was cleaned?



## Metal losses in slags after metallurgical process:

- Chemically dissolved metal
- **Entrained metal droplets**

## Possible solution = slag cleaning in electric furnace



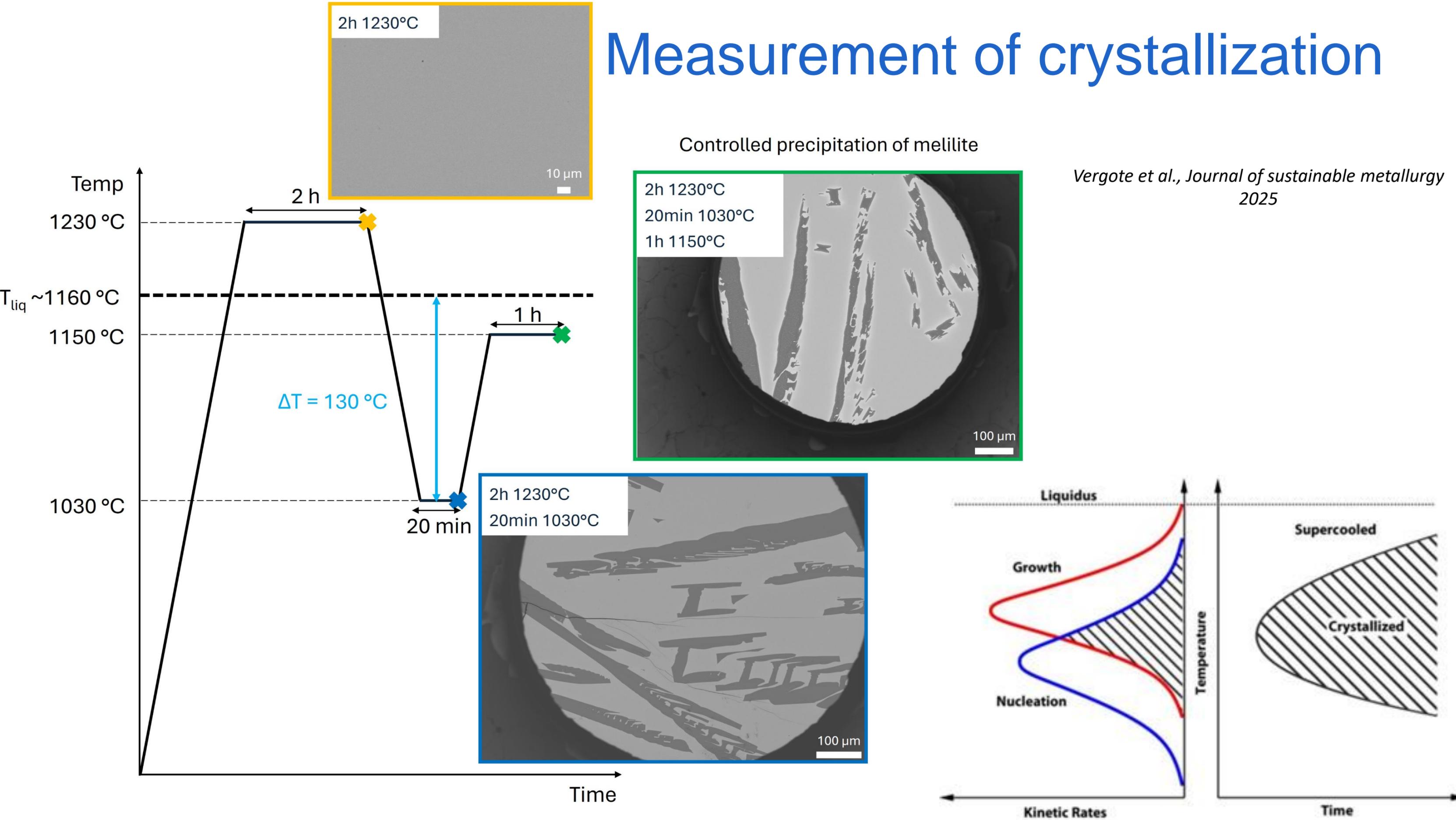
## Recovery of both types of losses

- Chemically dissolved metal

- **Entrained metal droplets**

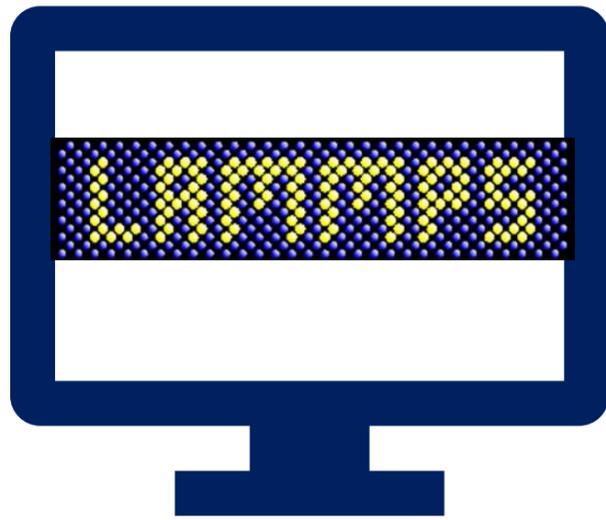
+ investigate crystallization for use of cleaned slag as supplementary cementitious material

# Measurement of crystallization

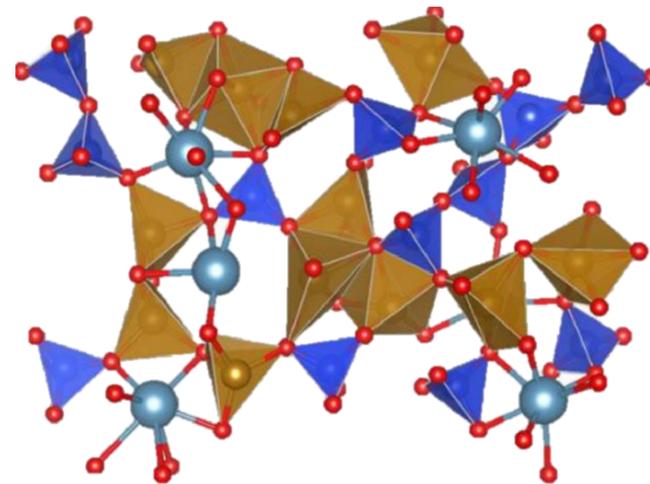


# Opportunity: combination with modelling

MD of slags

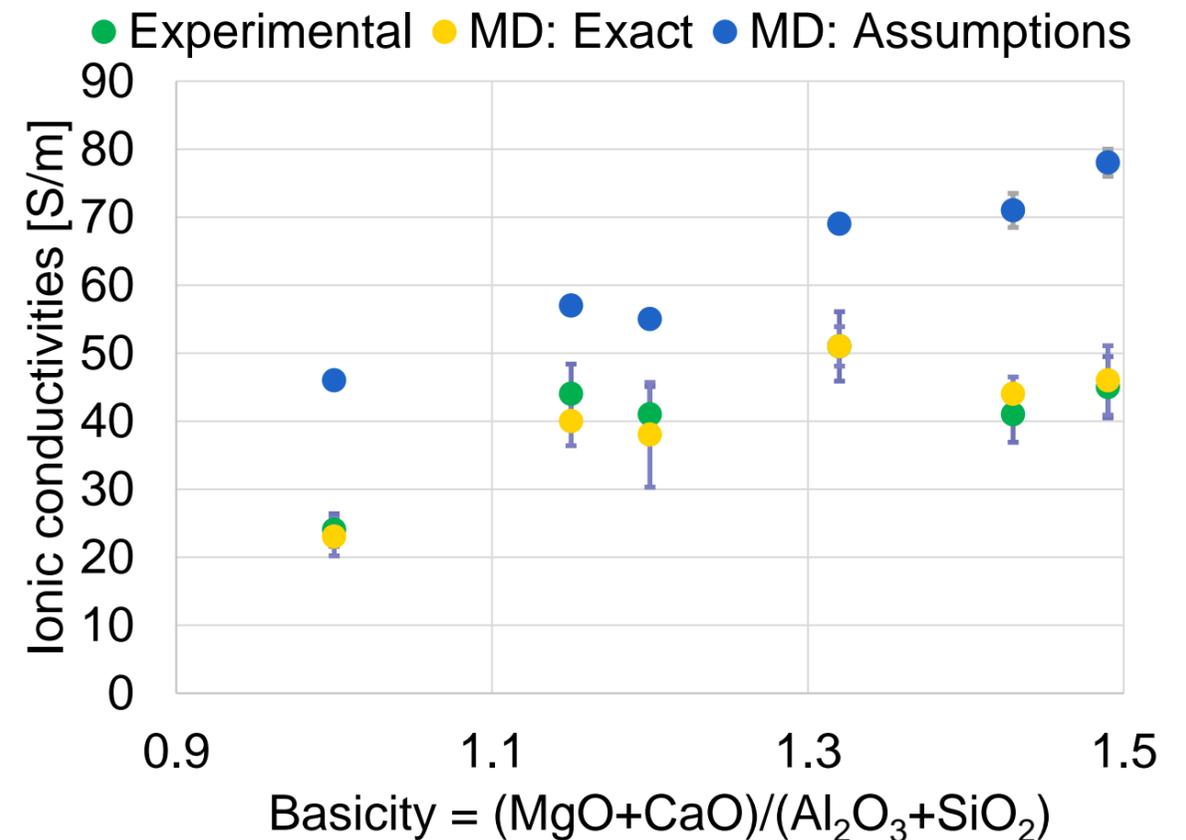
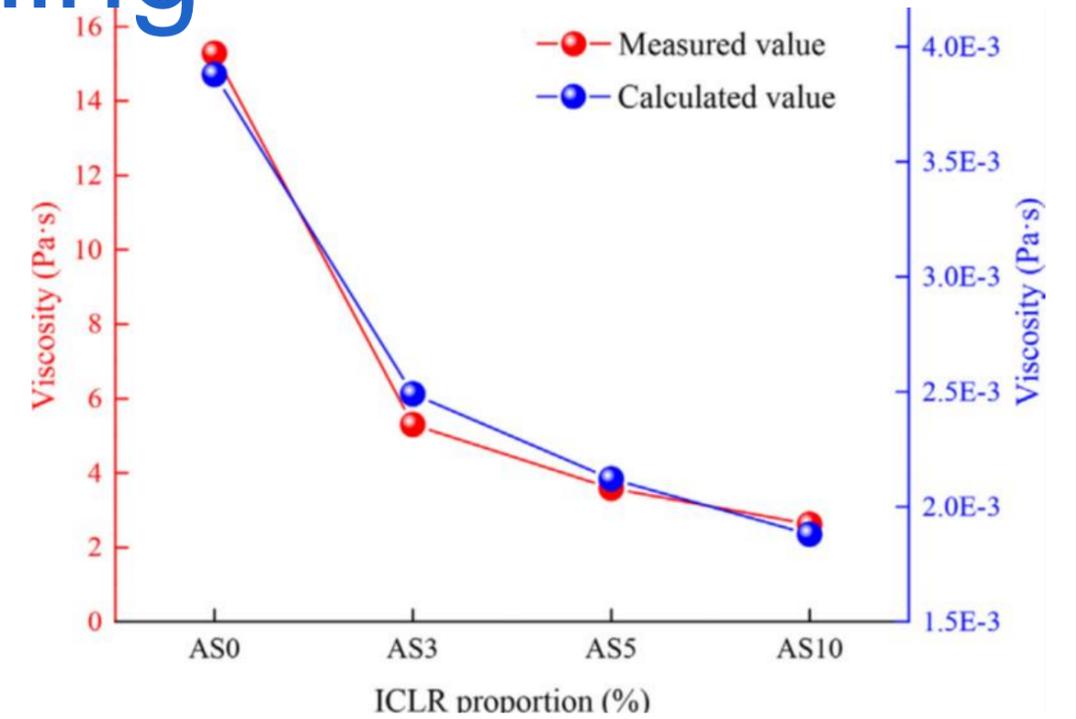


Simulation Output  
Slag structure



Thorough analysis gives  
physical slag properties:

- ✓ Diffusivity
- ✓ Viscosity
- ✓ Electrical Conductivity
- ✓ Surface tension



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