

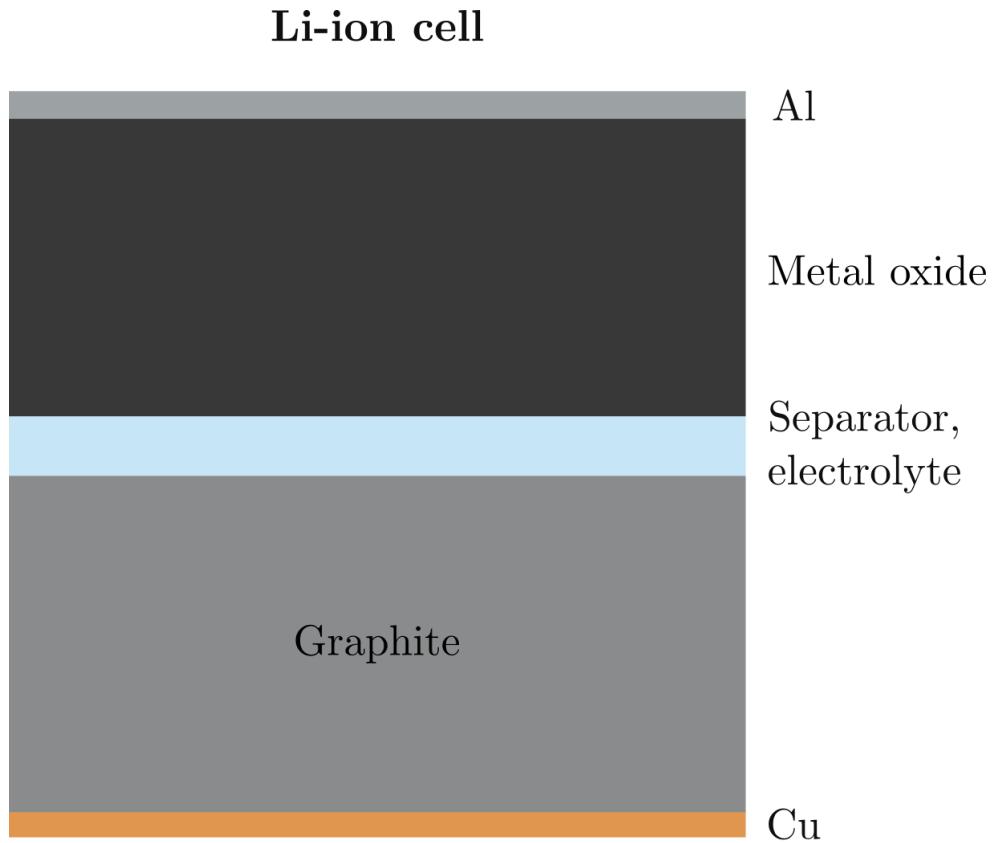
# Electrochemical Deposition of Lithium on Copper

Gottfrid Olsson

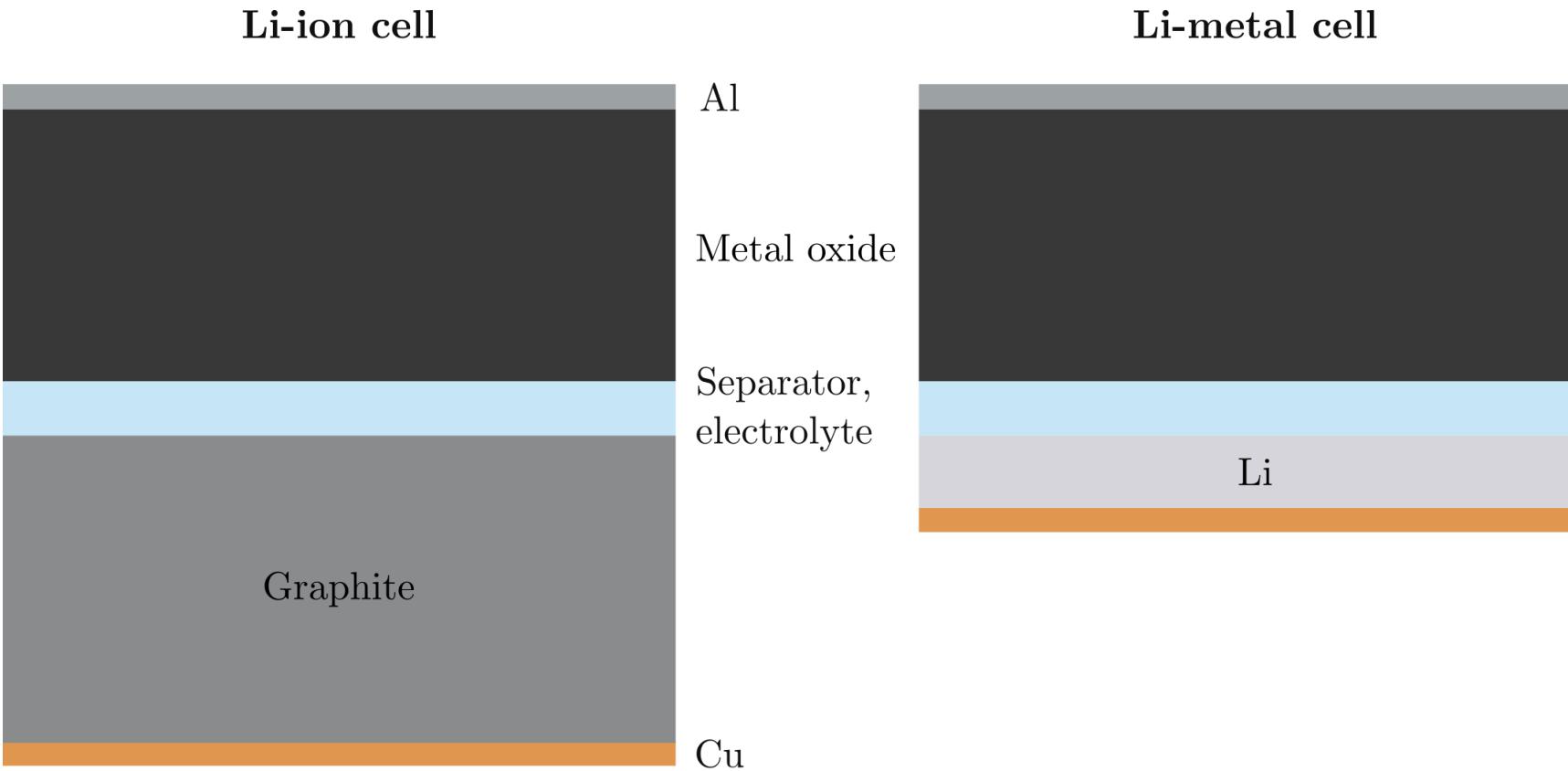
2024-05-29

# Batteries!

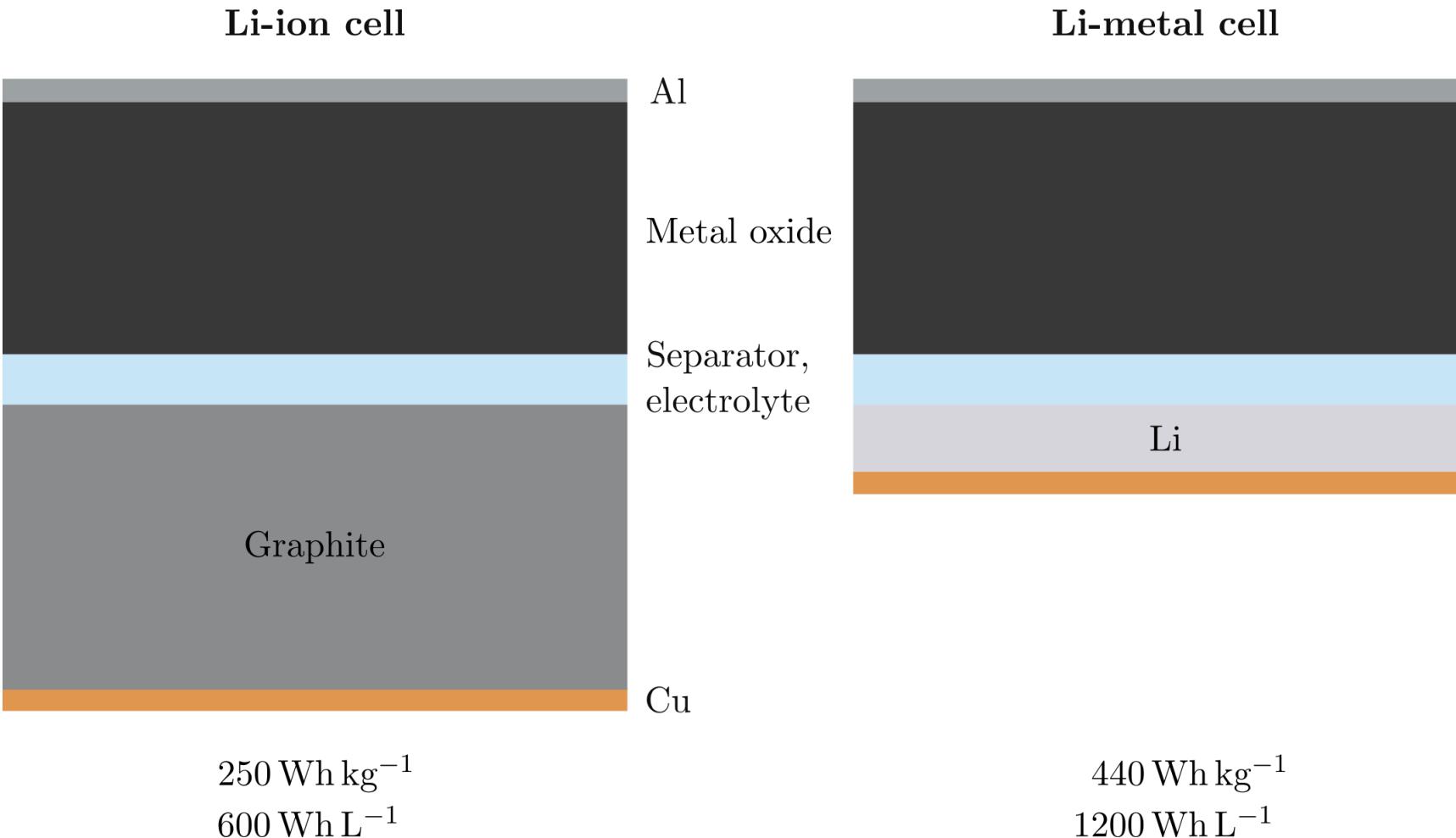
# Batteries!



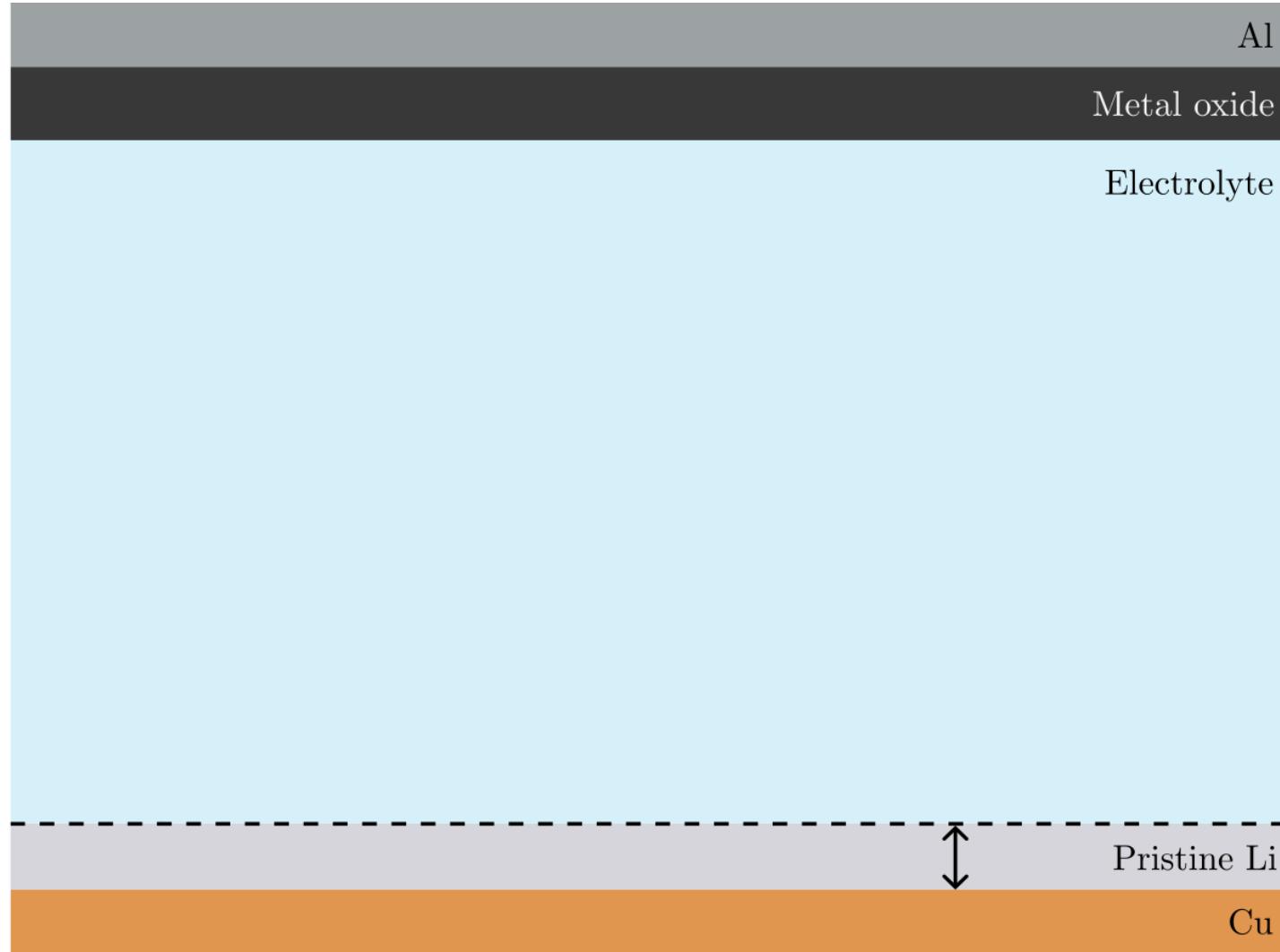
# Batteries!



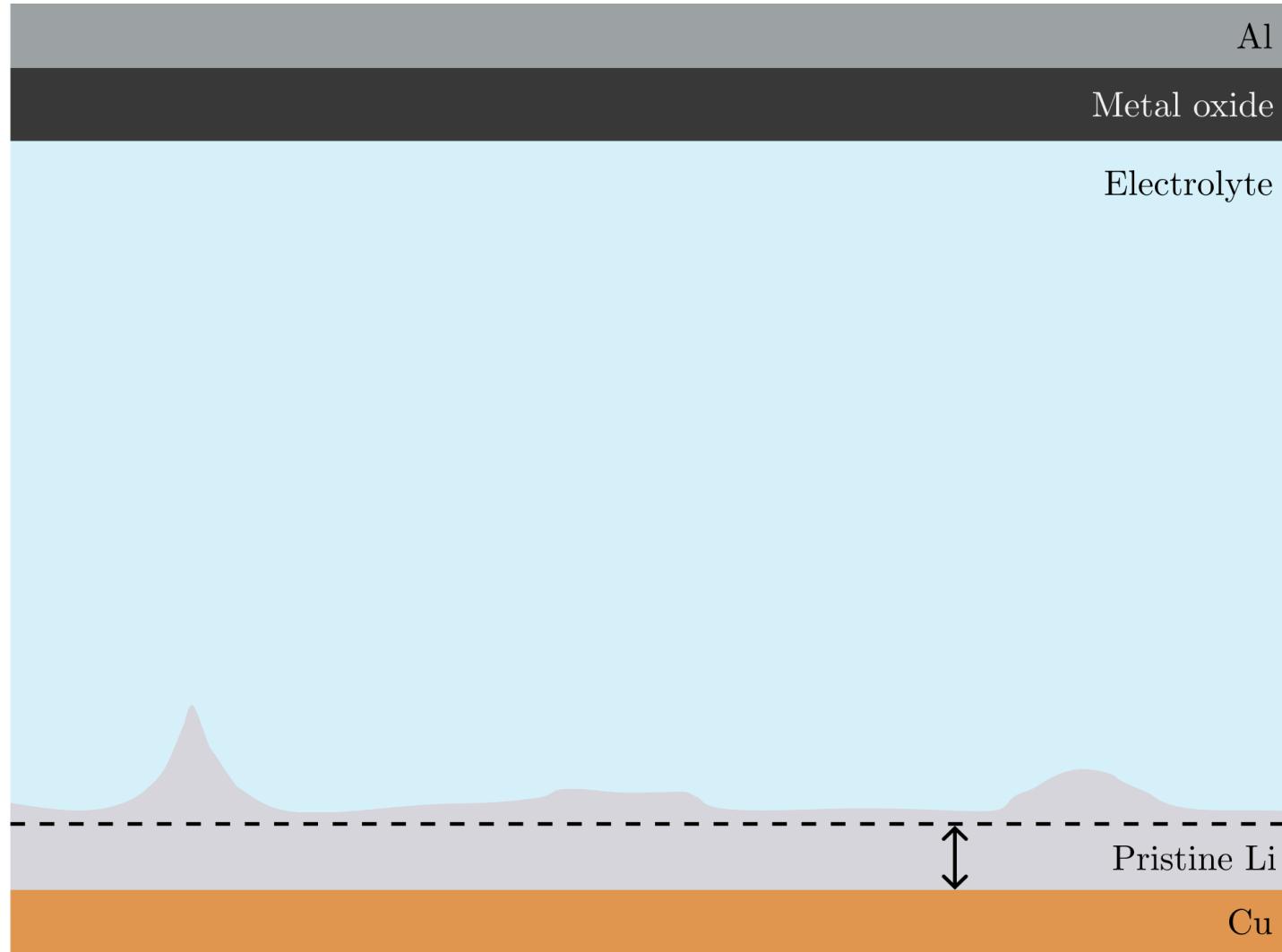
# Batteries!



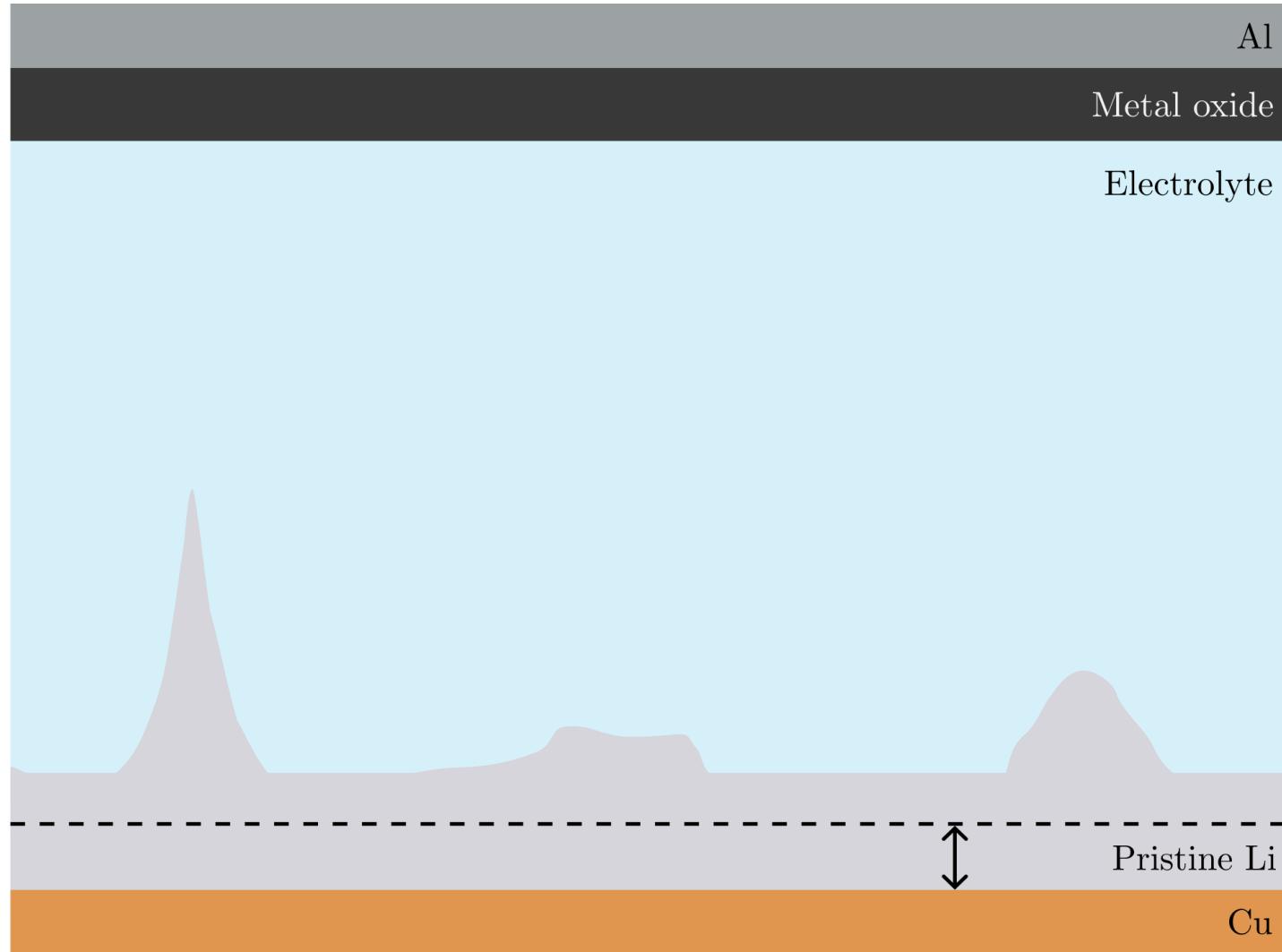
# Non-uniform deposition problems



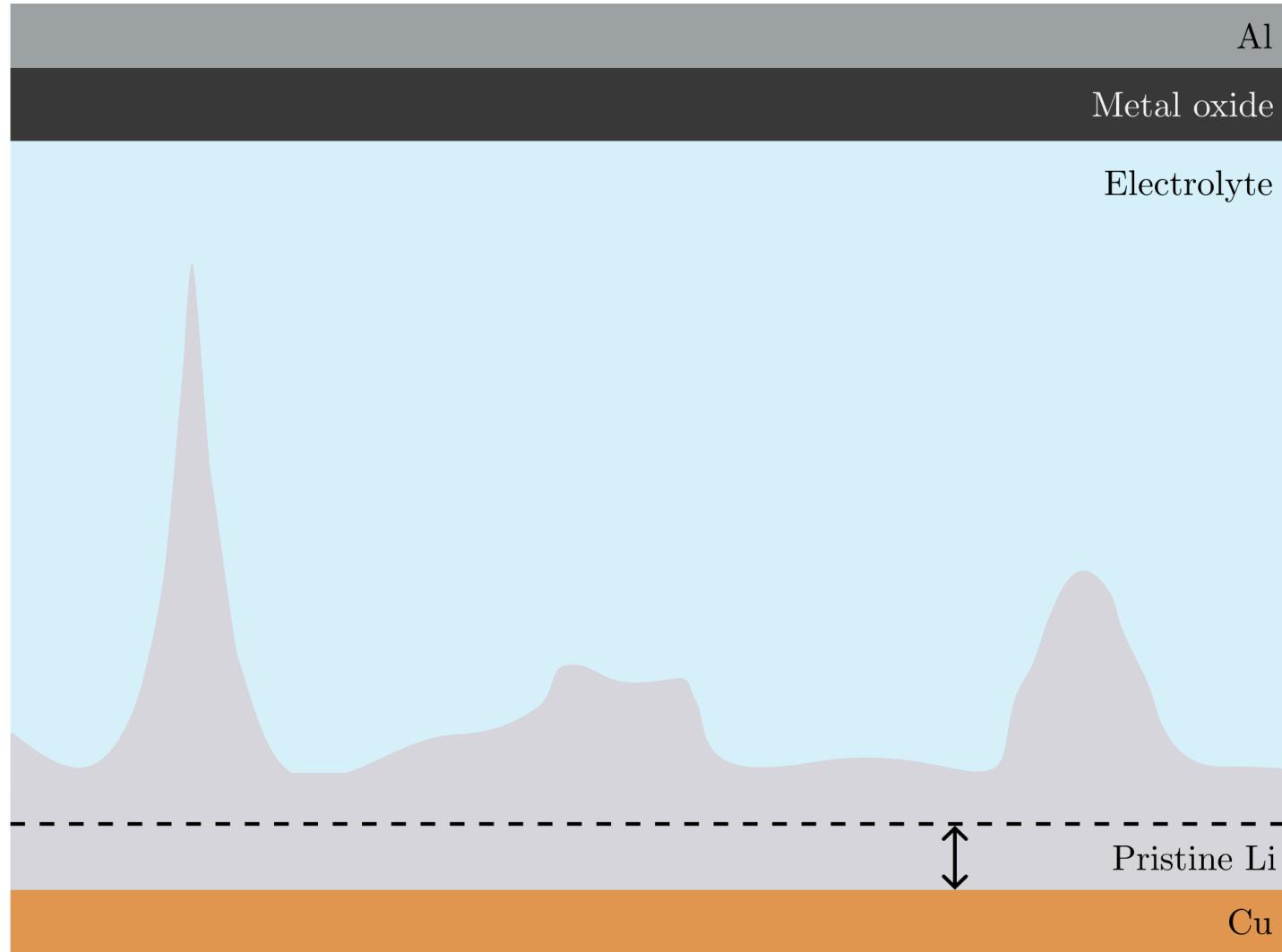
# Non-uniform deposition problems



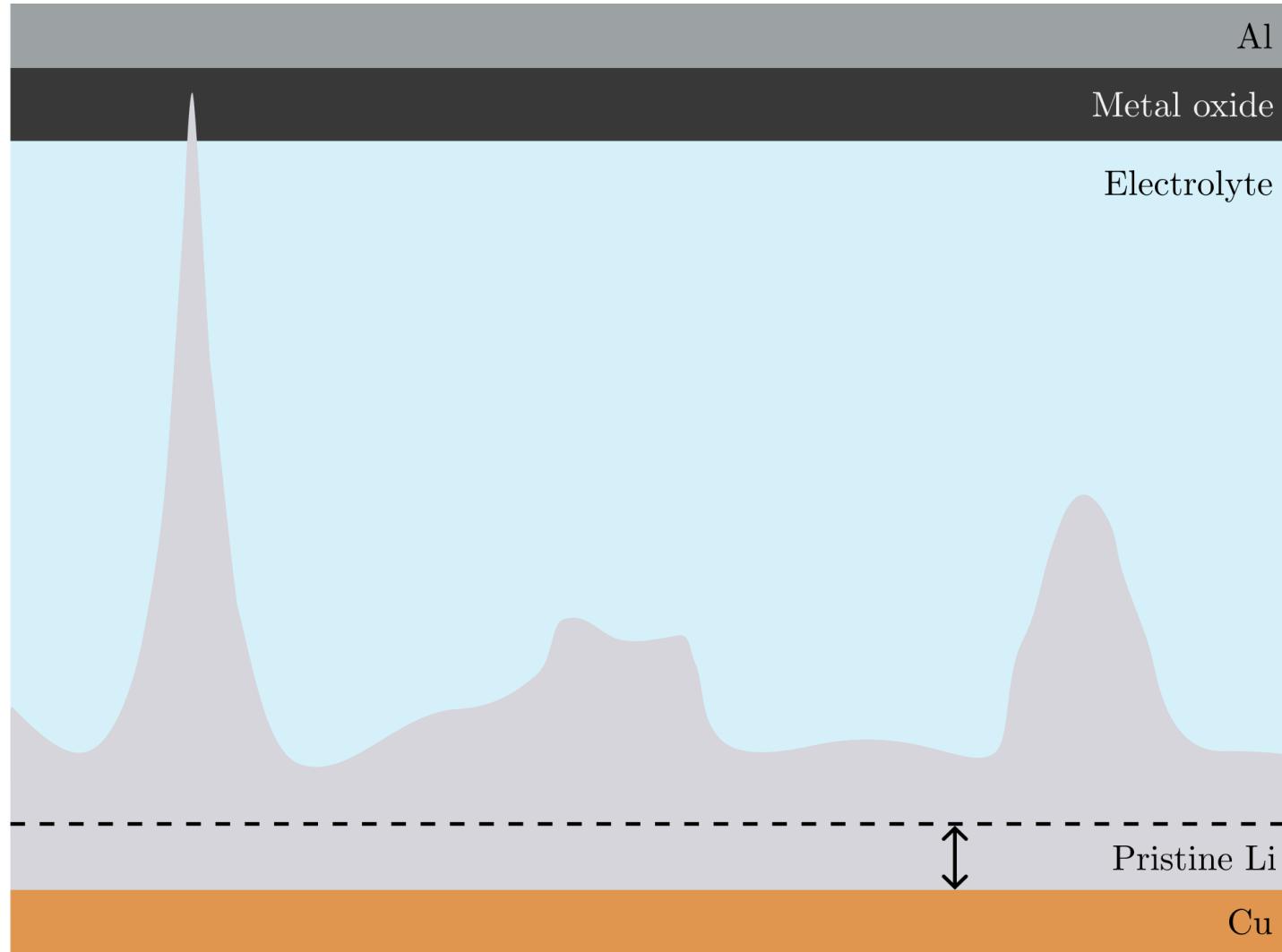
# Non-uniform deposition problems



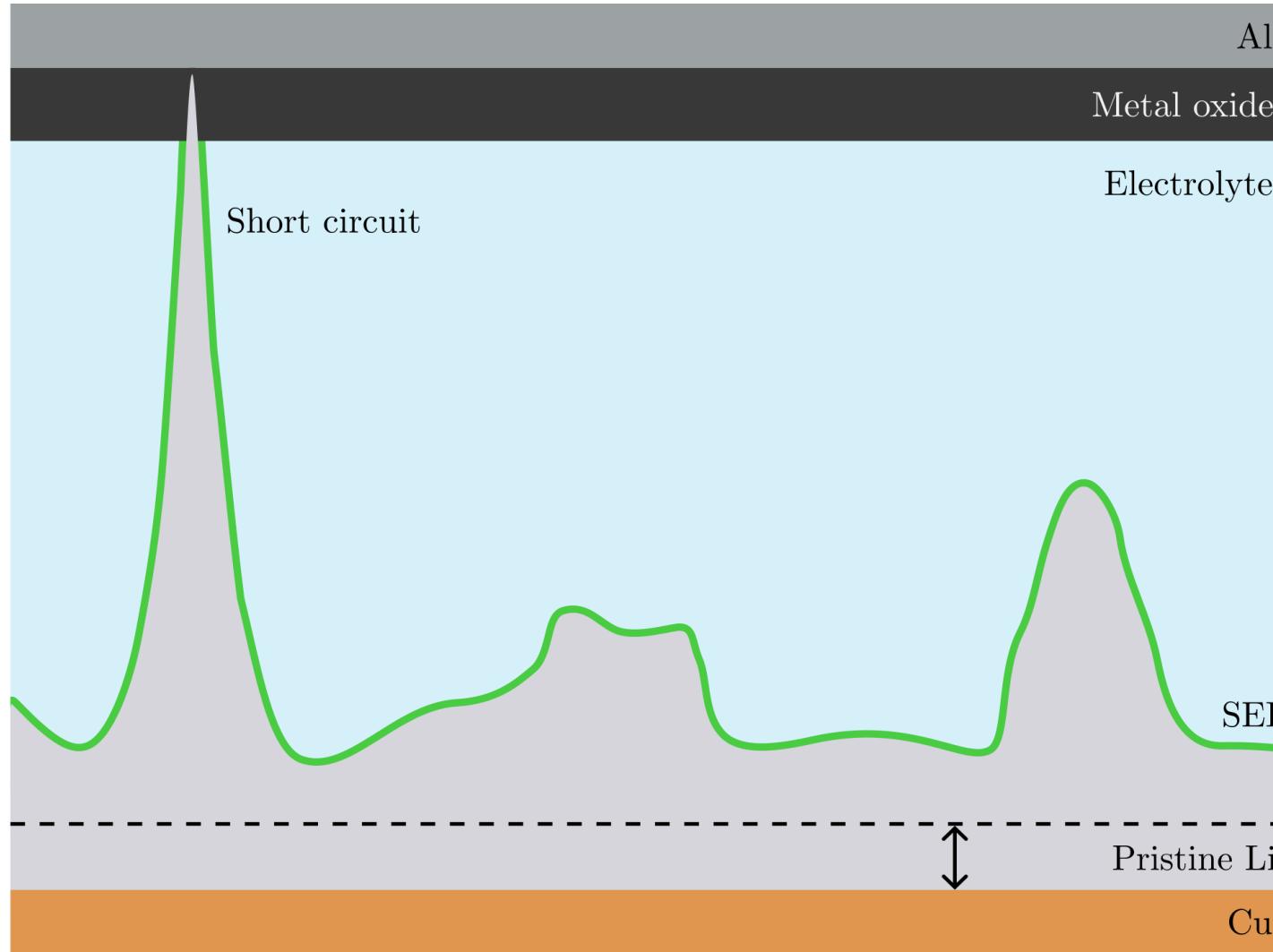
# Non-uniform deposition problems



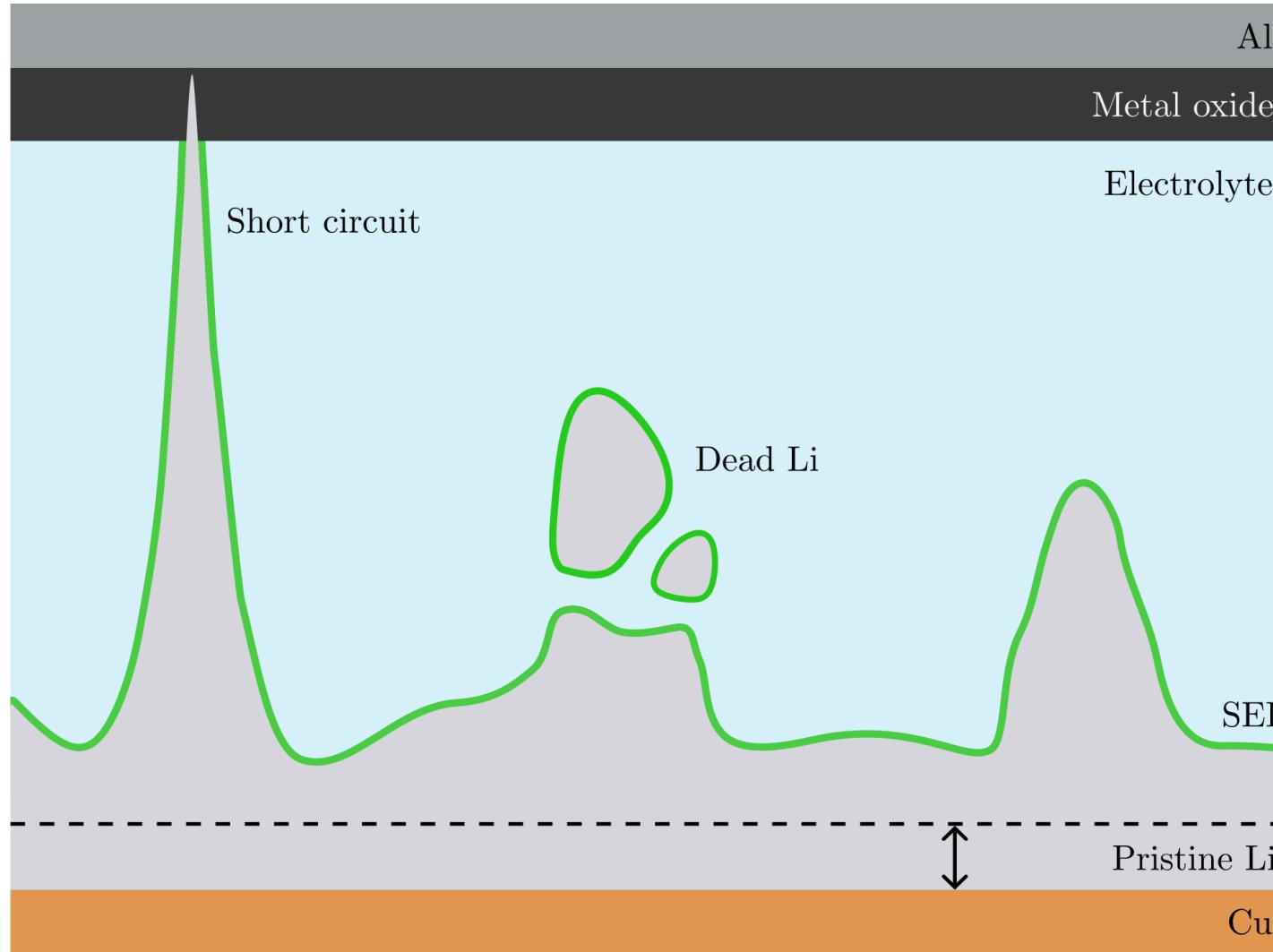
# Non-uniform deposition problems



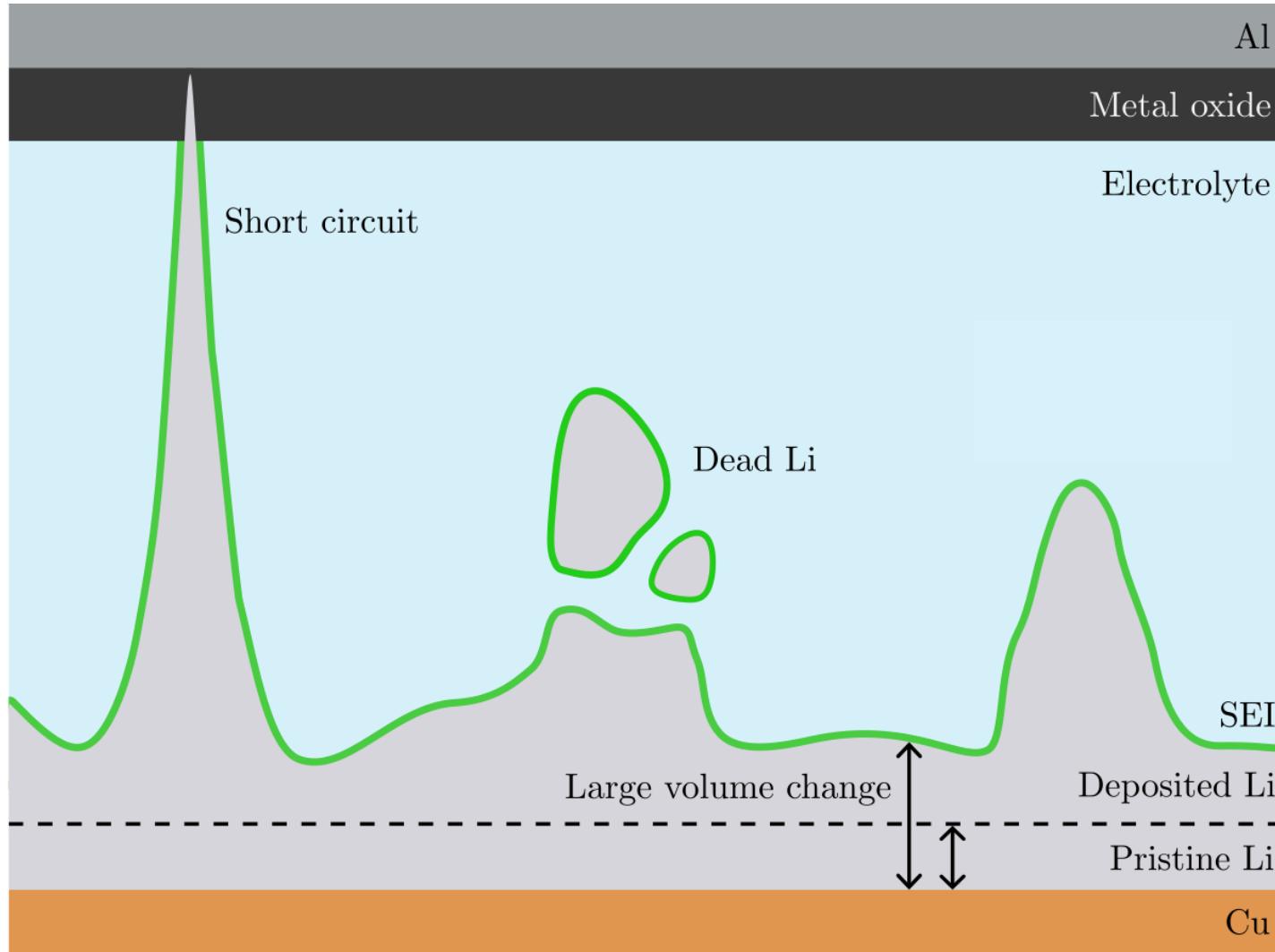
# Non-uniform deposition problems



# Non-uniform deposition problems



# Non-uniform deposition problems



# Purpose of this thesis

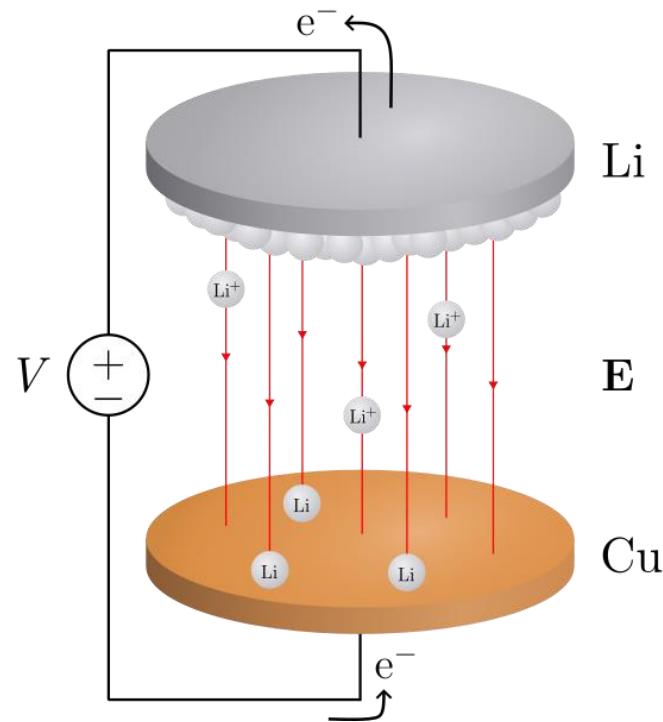
# Purpose of this thesis

- Investigate the nucleation – the first step in deposition.

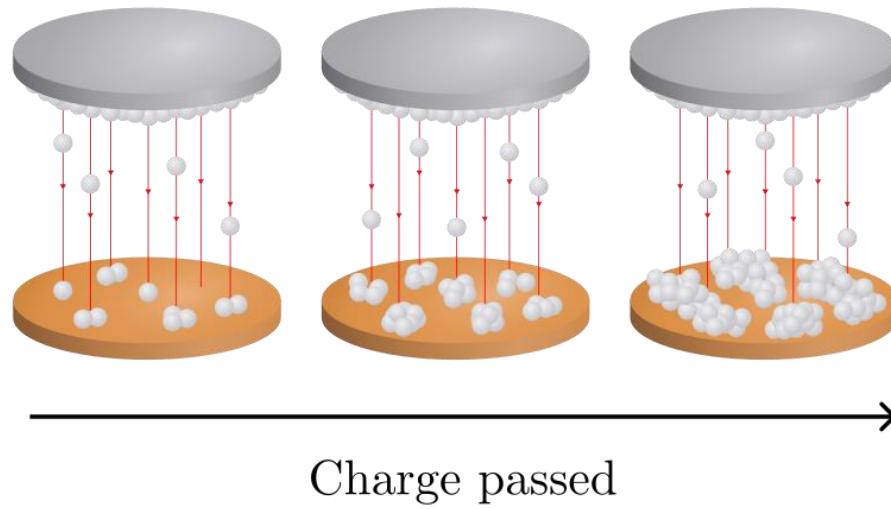
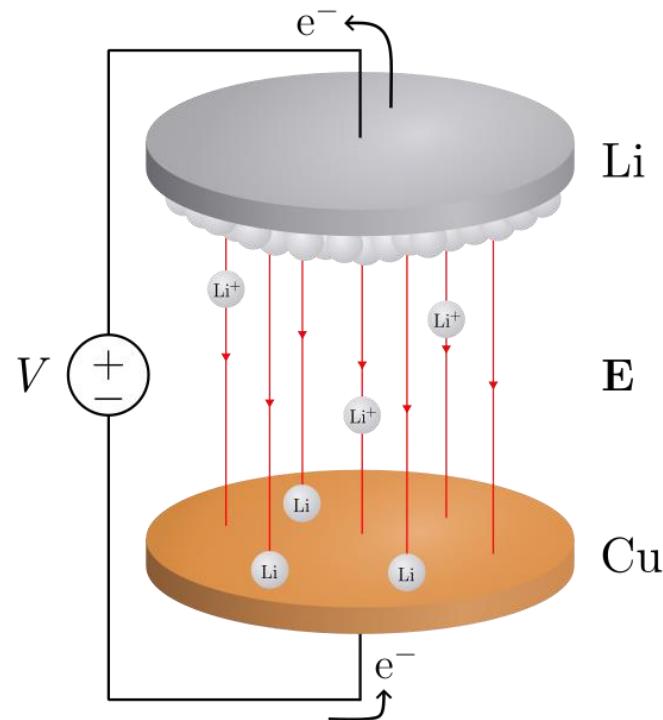
# Purpose of this thesis

- Investigate the nucleation – the first step in deposition.
- Electrochemical measurements and scanning electron microscope.

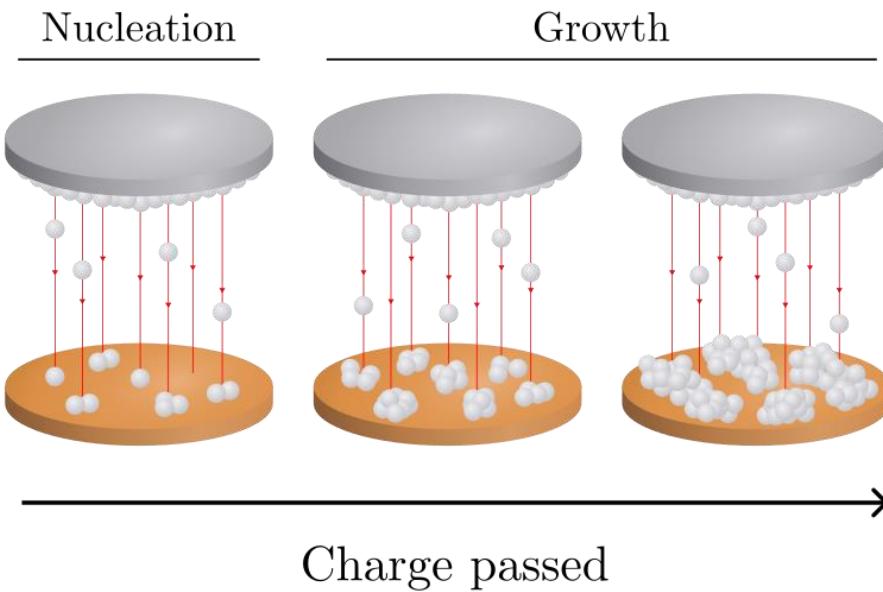
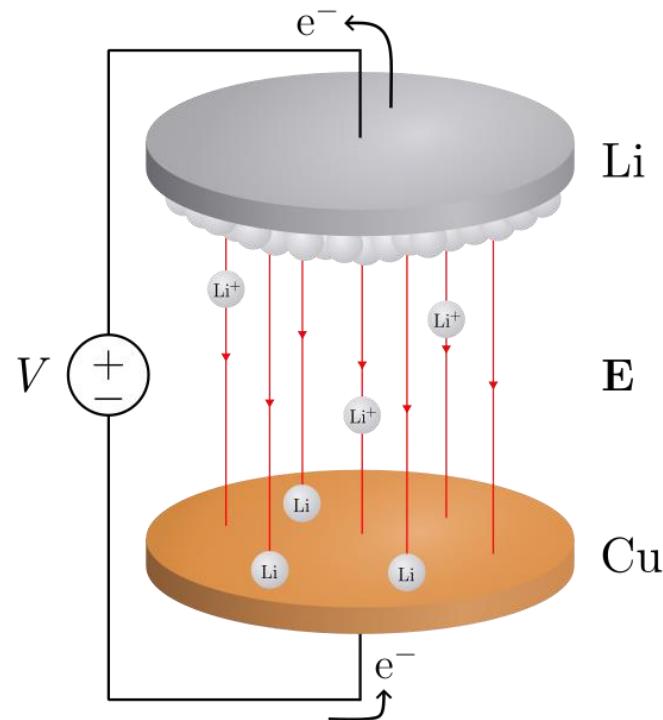
# Deposition in a Li/Cu cell



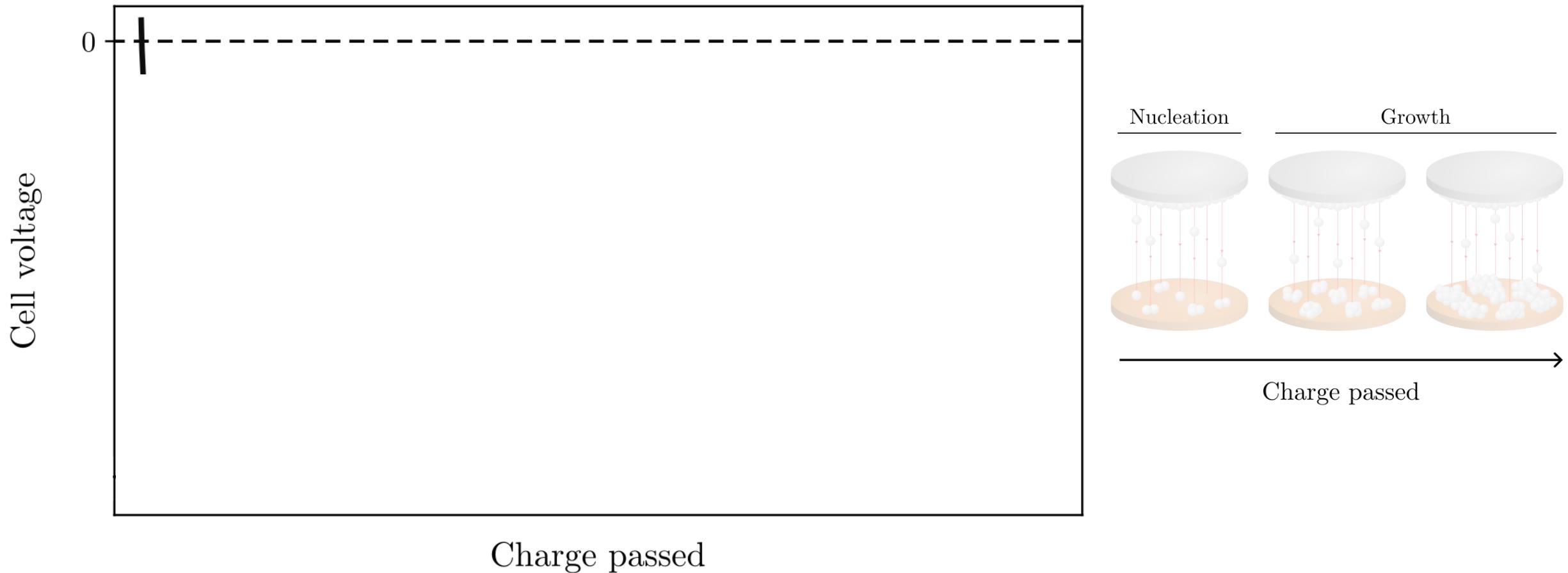
# Deposition in a Li/Cu cell



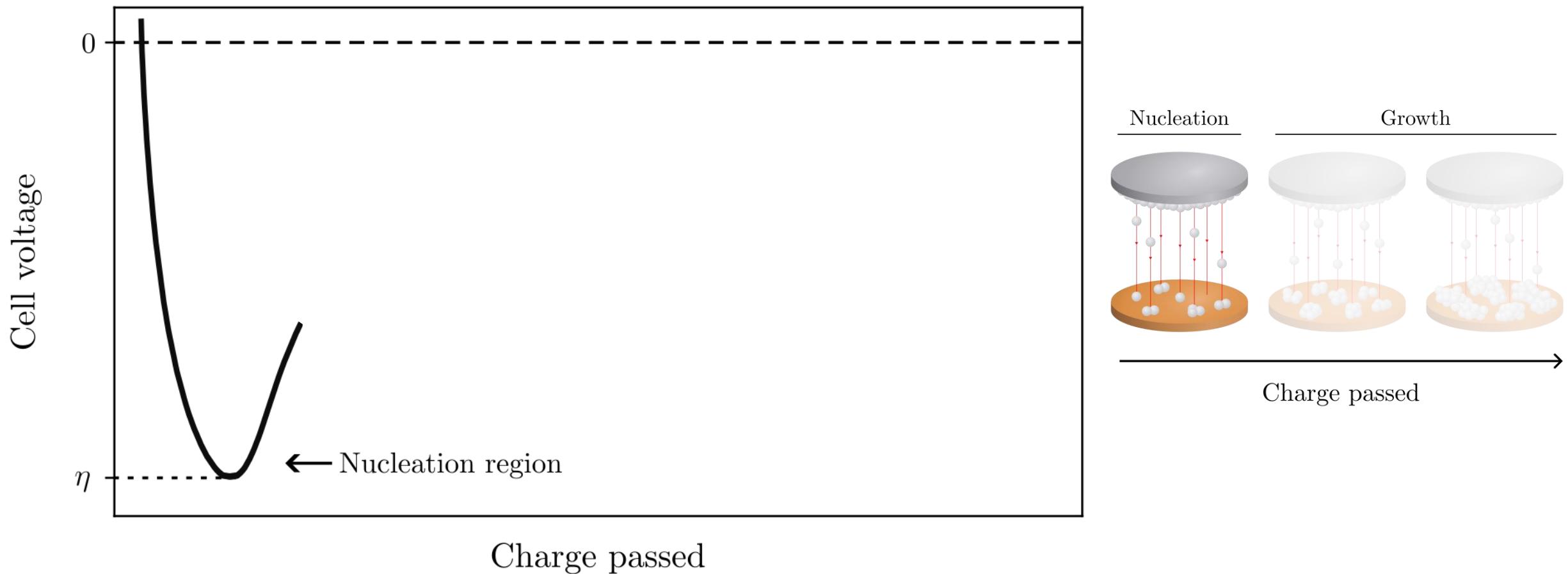
# Deposition in a Li/Cu cell



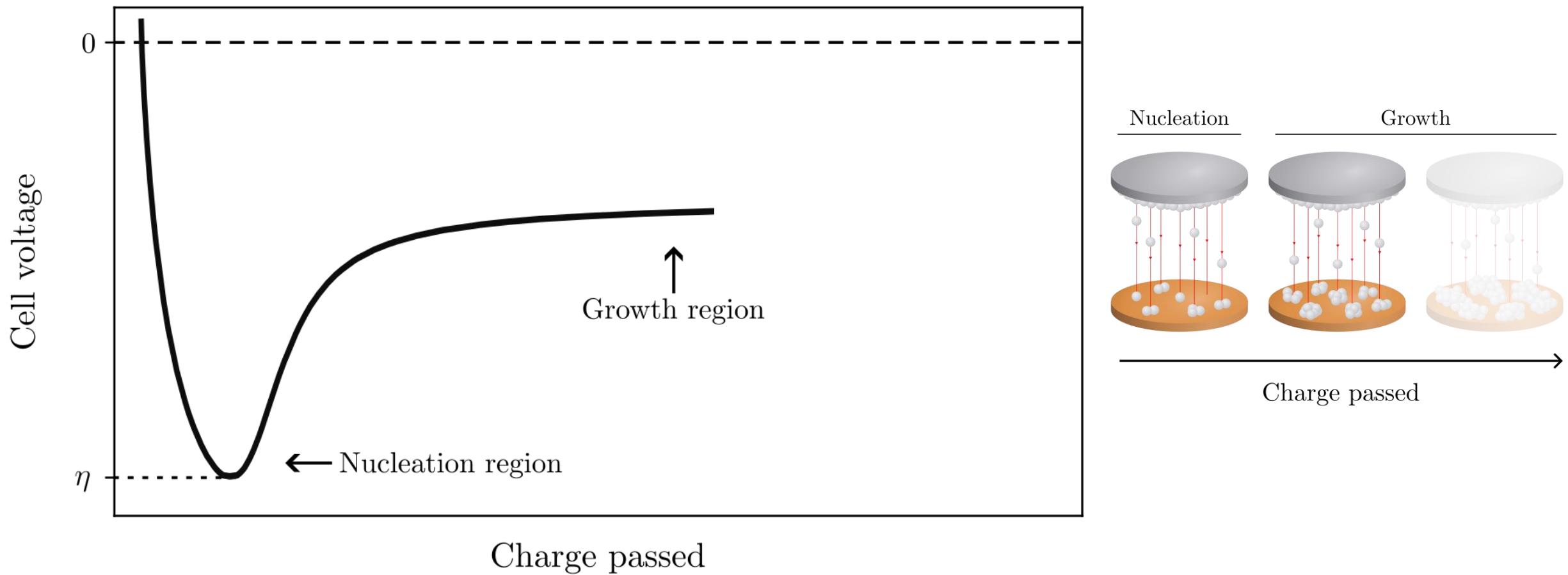
# Deposition in a Li/Cu cell



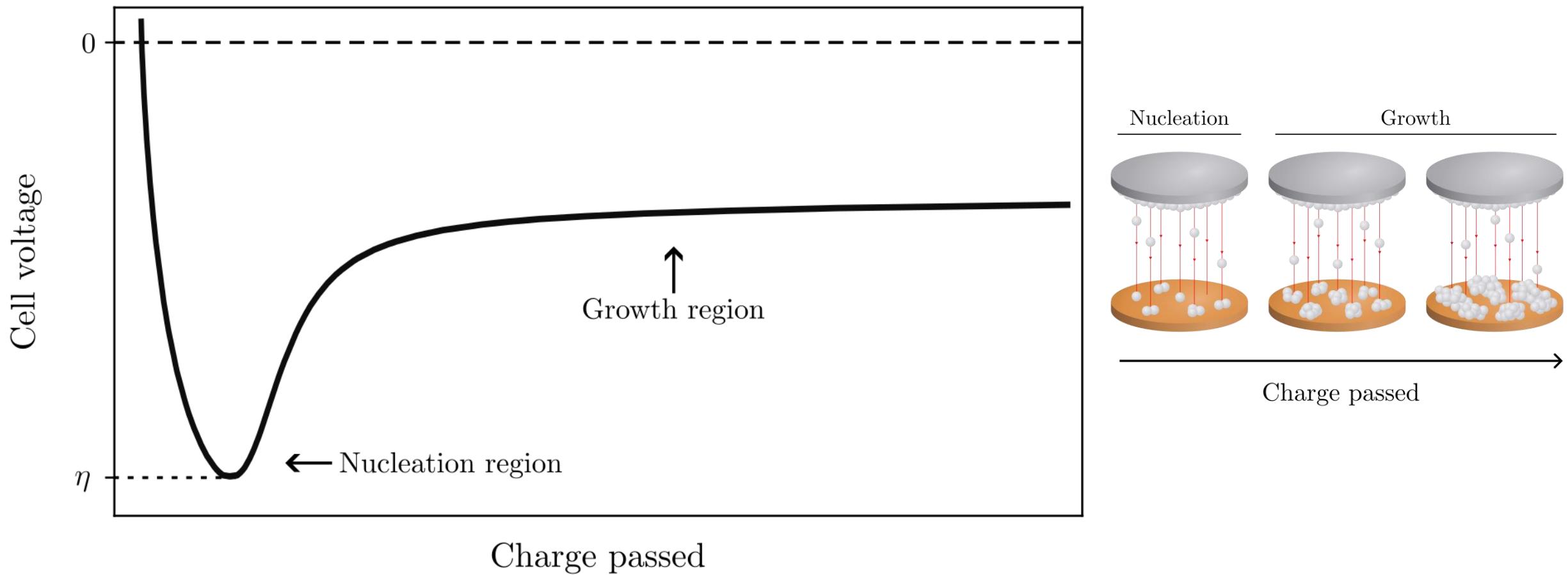
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# Deposition in a Li/Cu cell

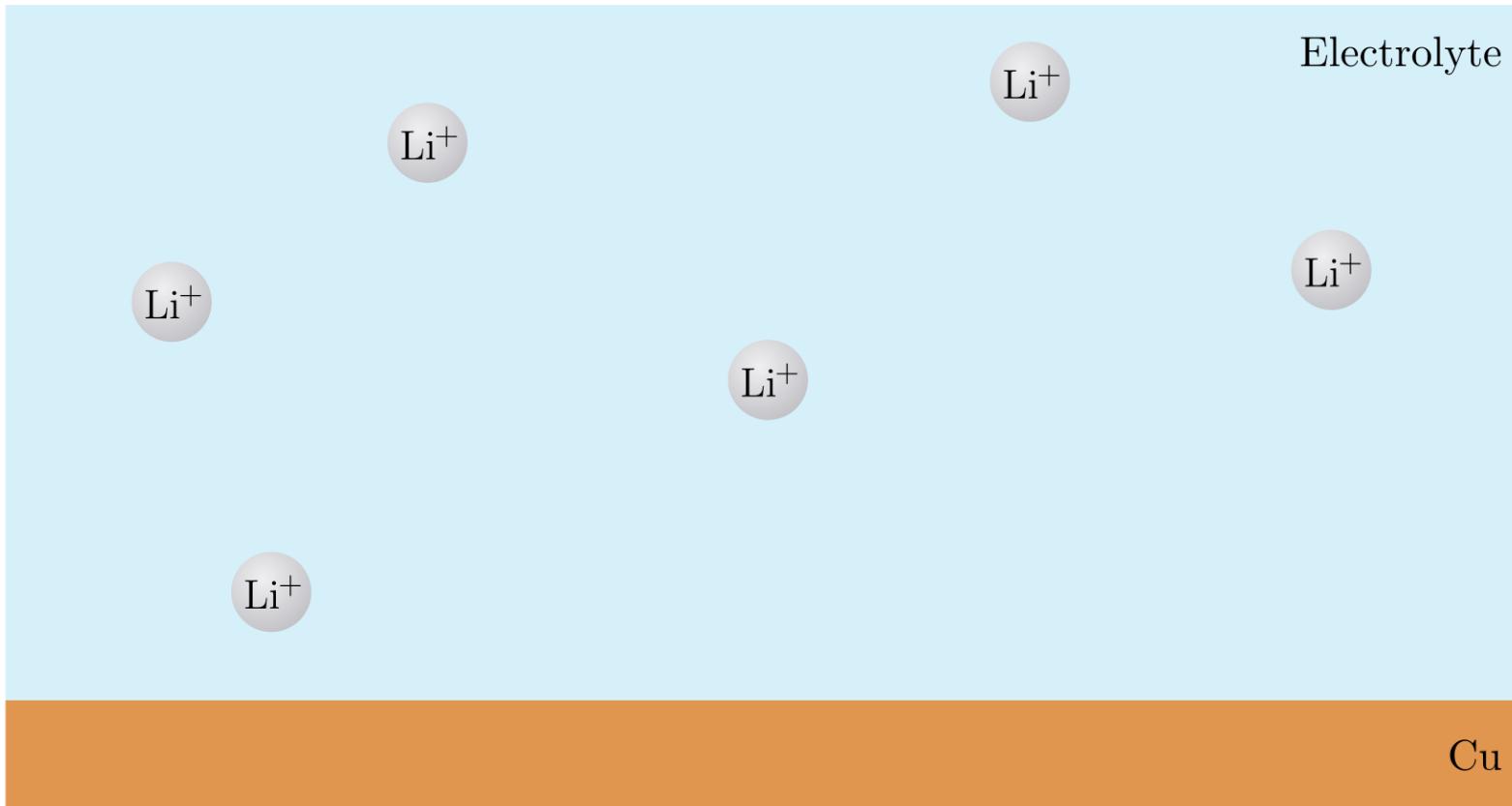


# Deposition in a Li/Cu cell

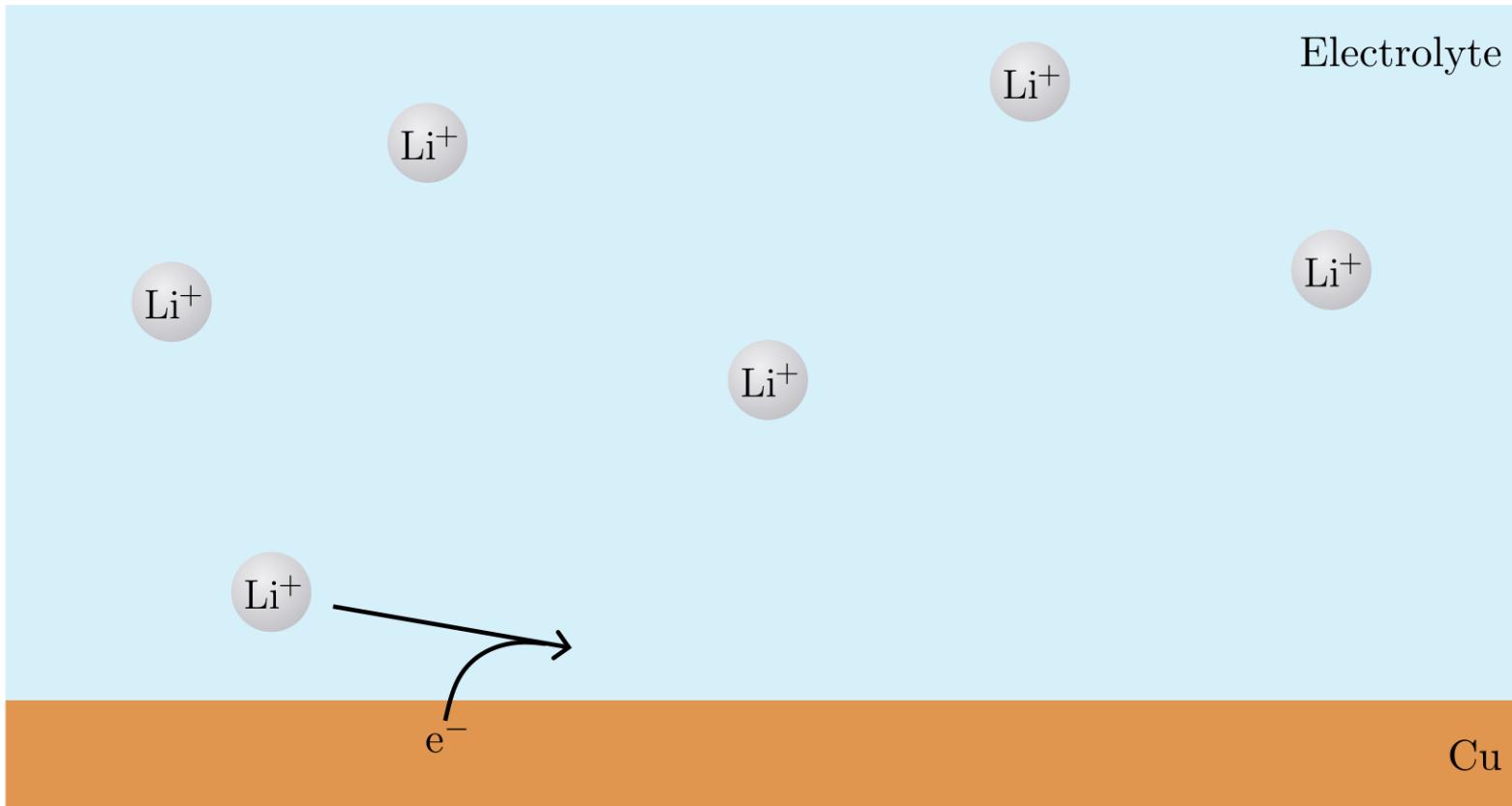


# Nucleation

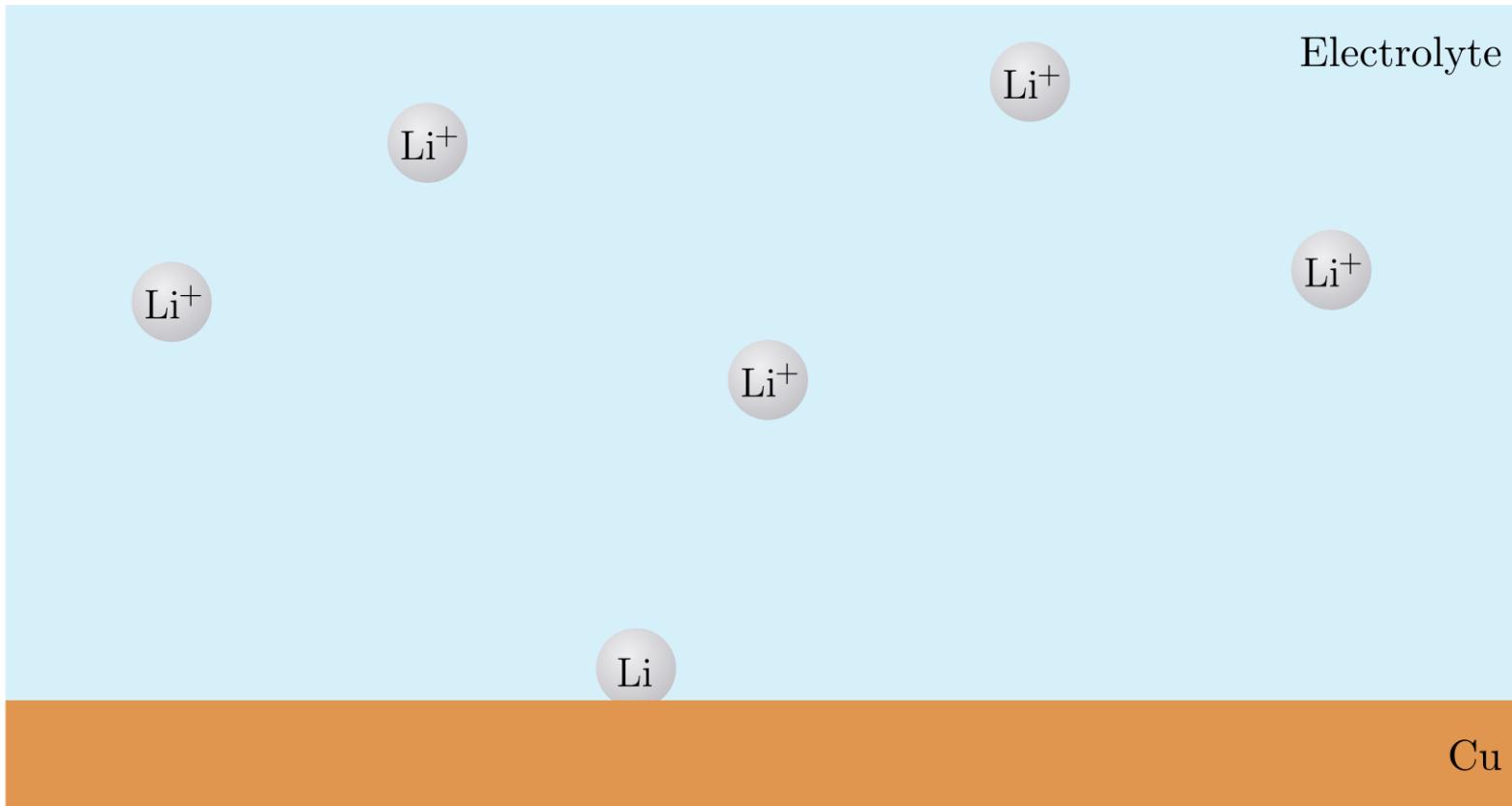
# Nucleation



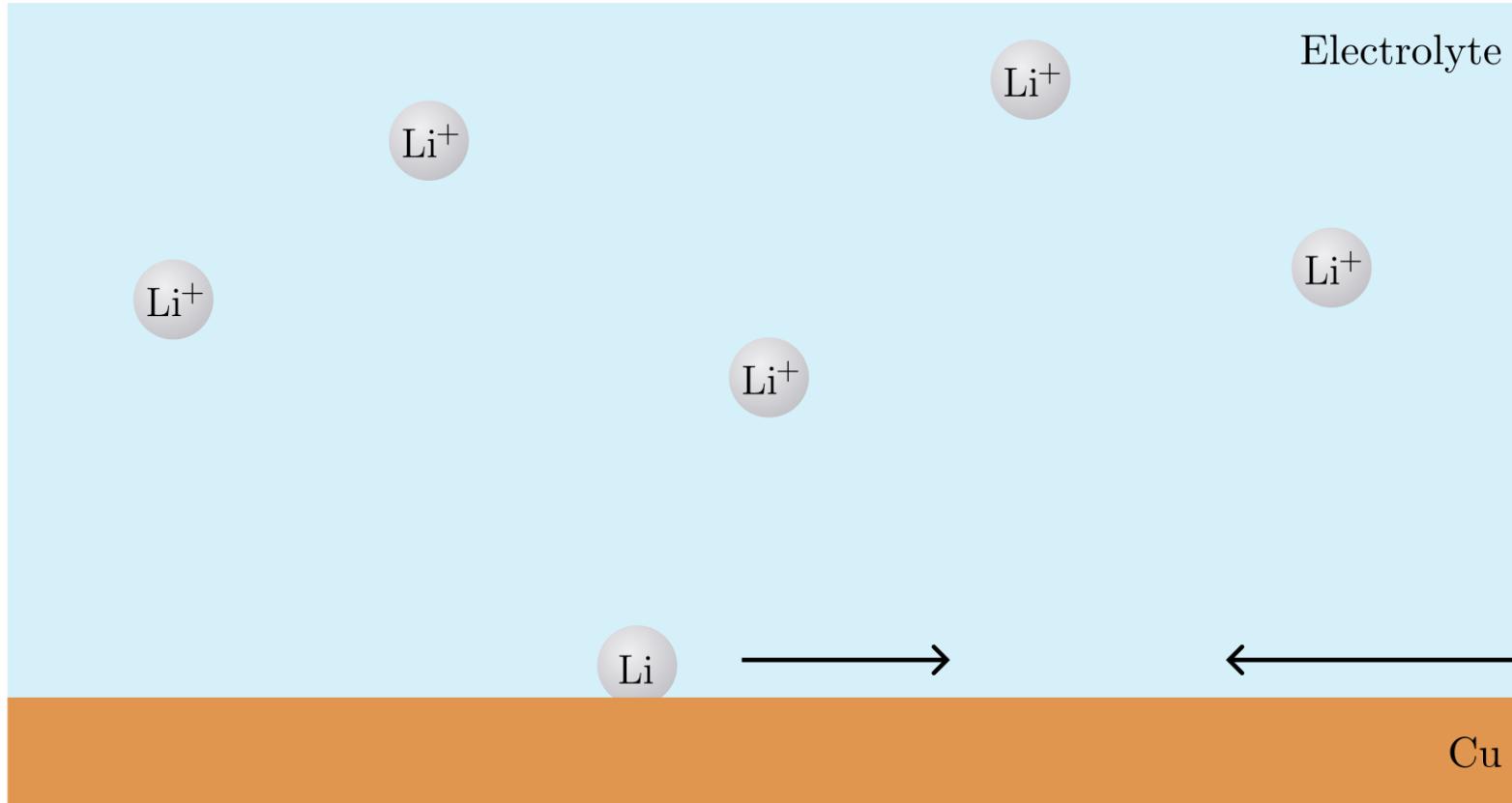
# Nucleation



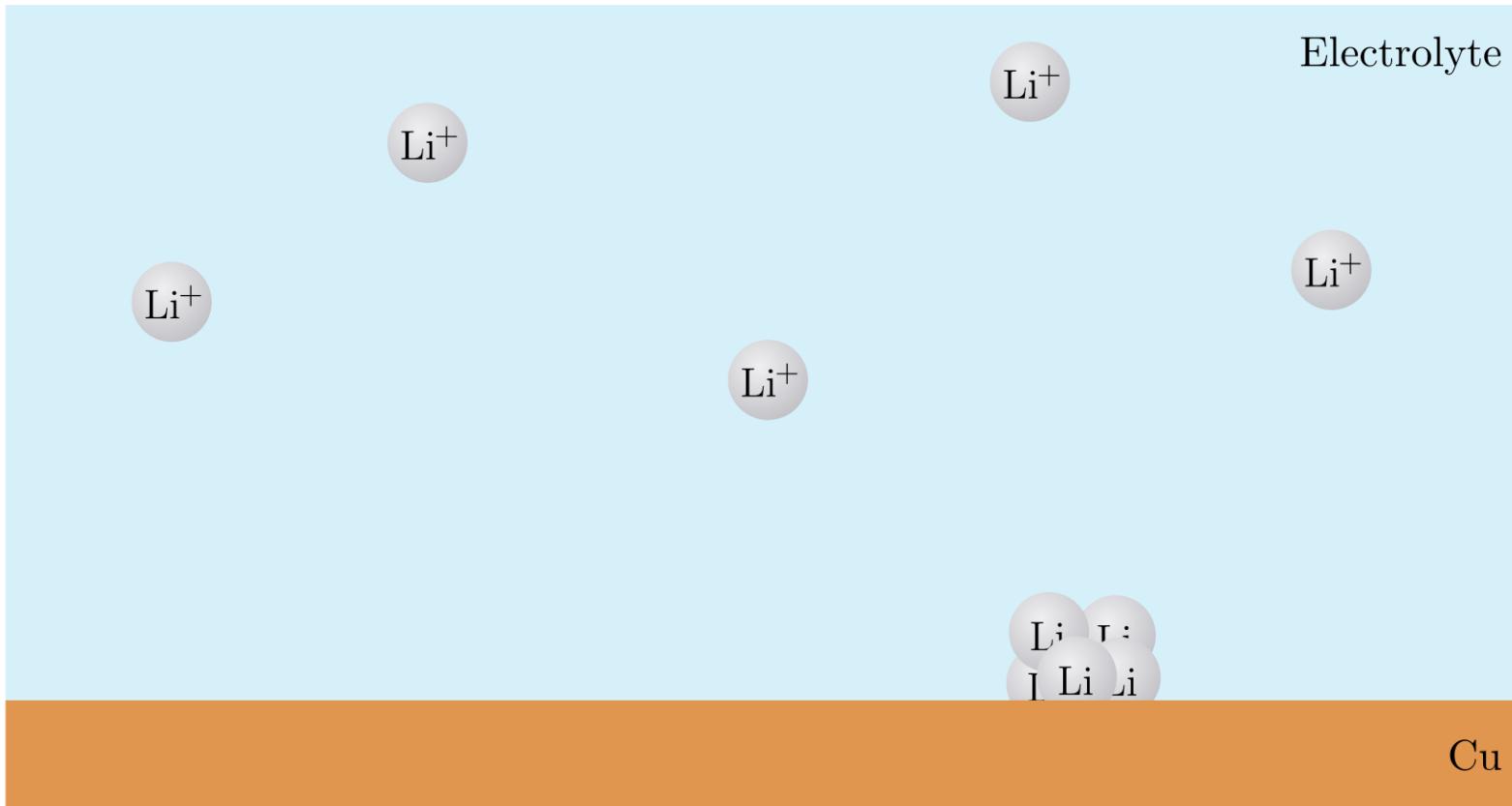
# Nucleation



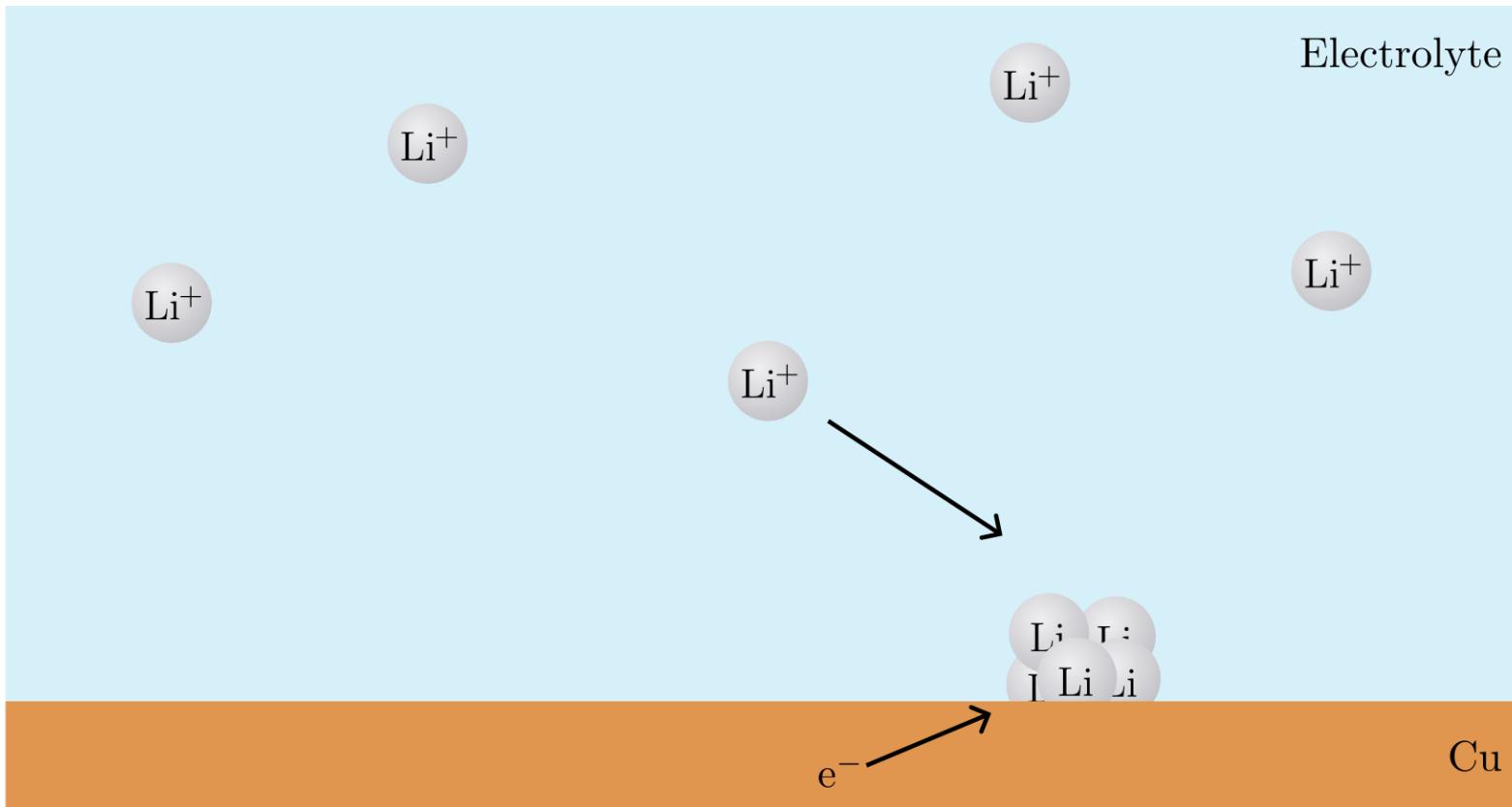
# Nucleation



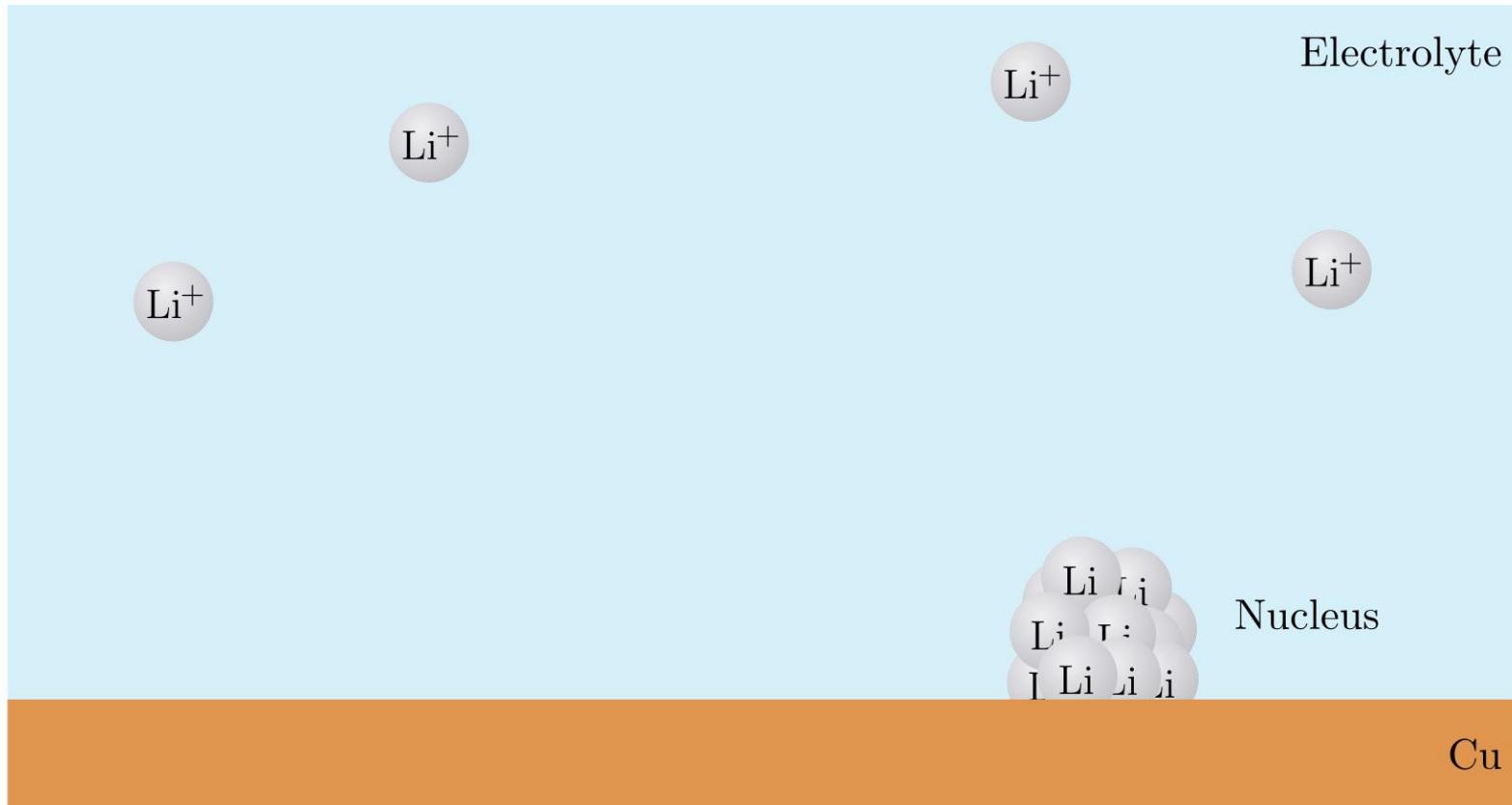
# Nucleation



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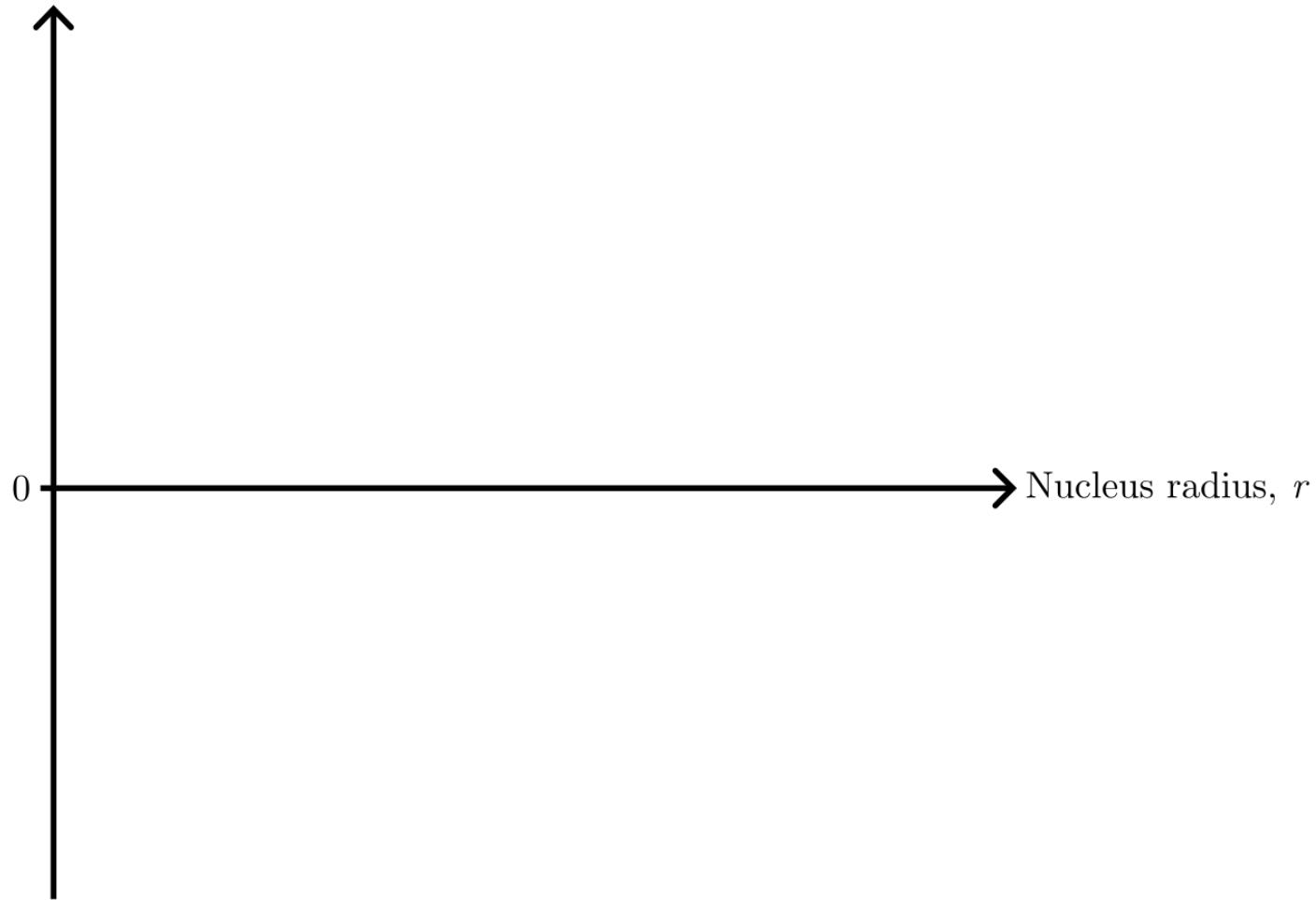


# Nucleation

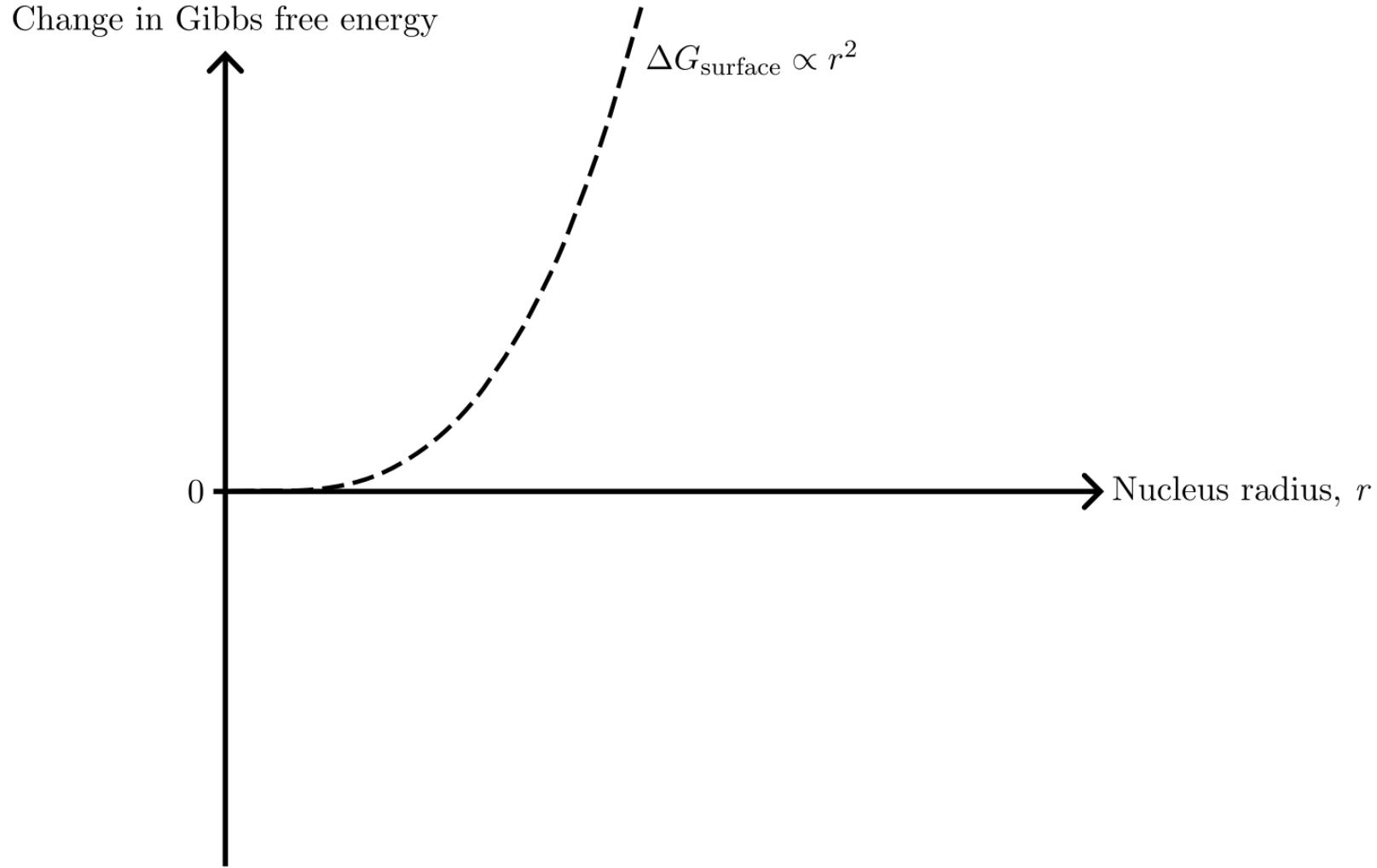


# Nucleation theory

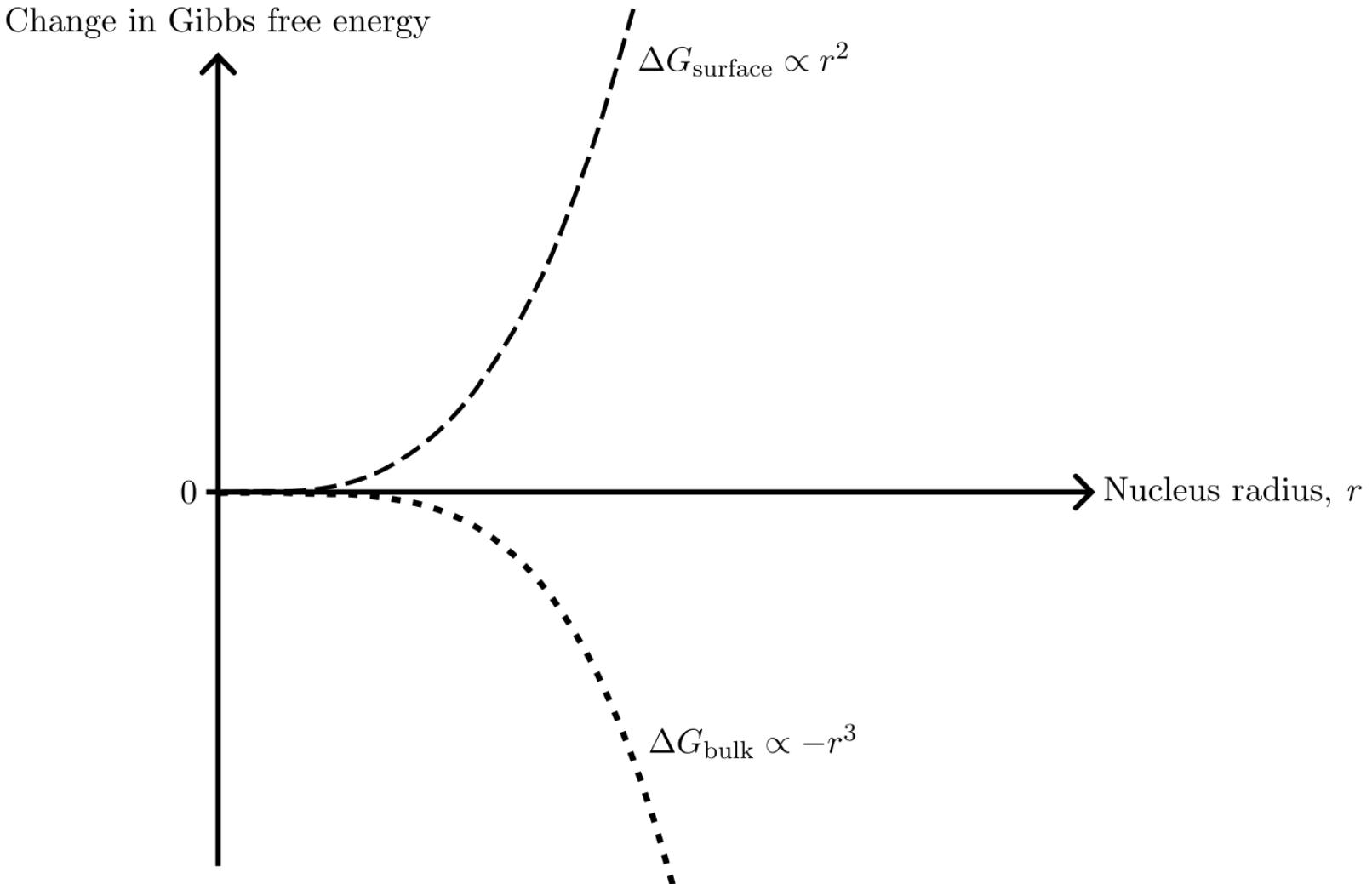
Change in Gibbs free energy



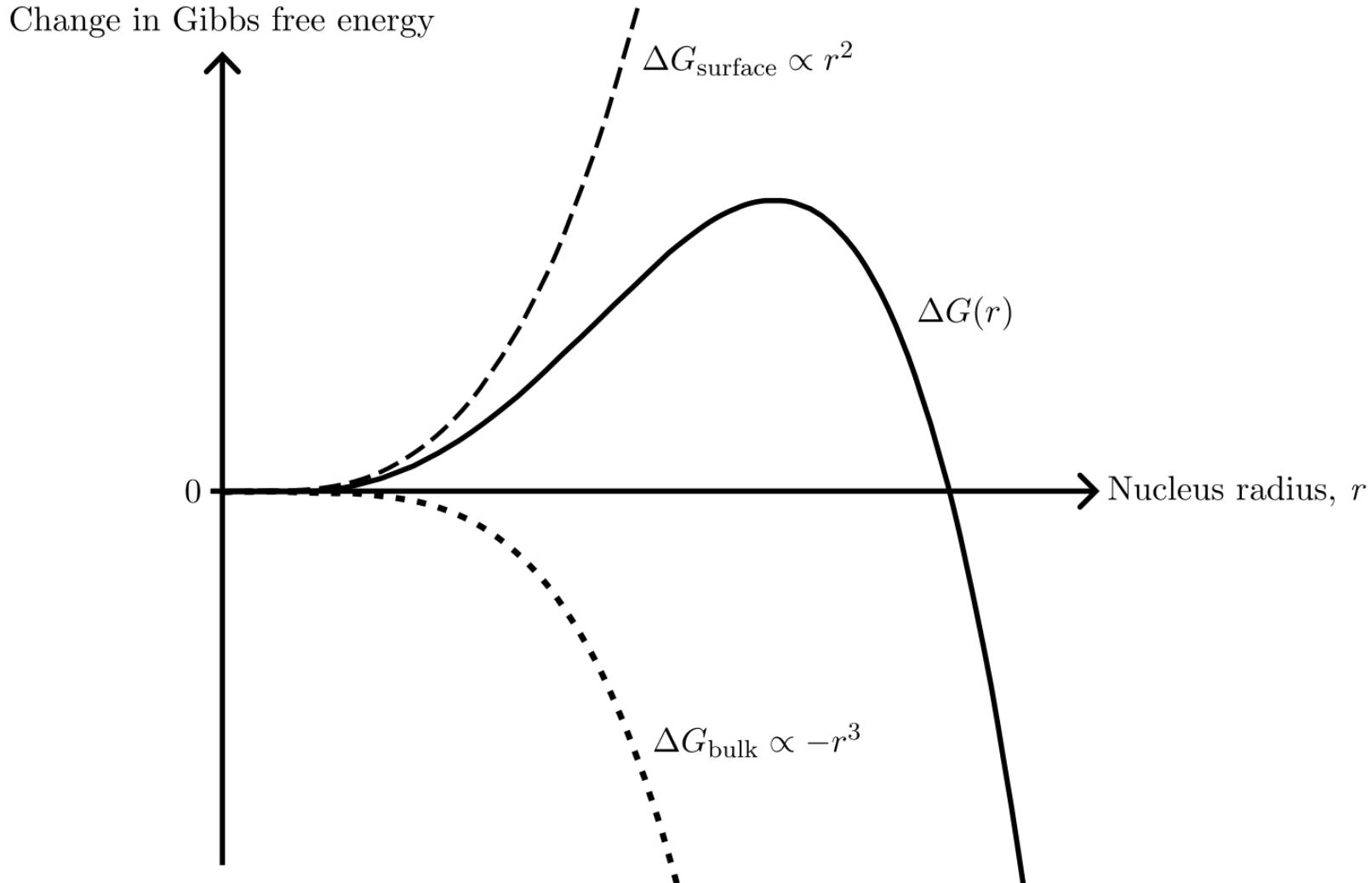
# Nucleation theory



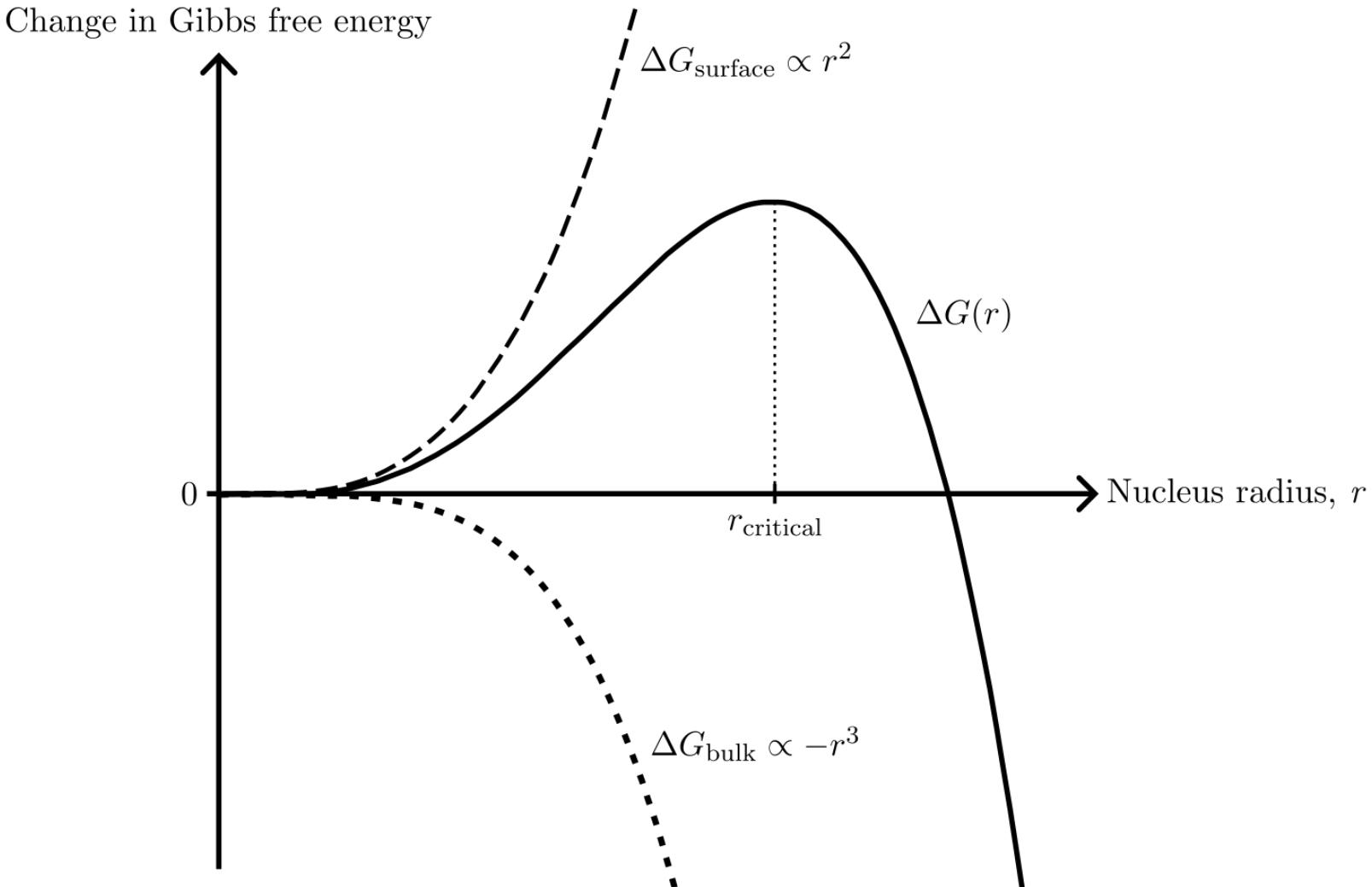
# Nucleation theory



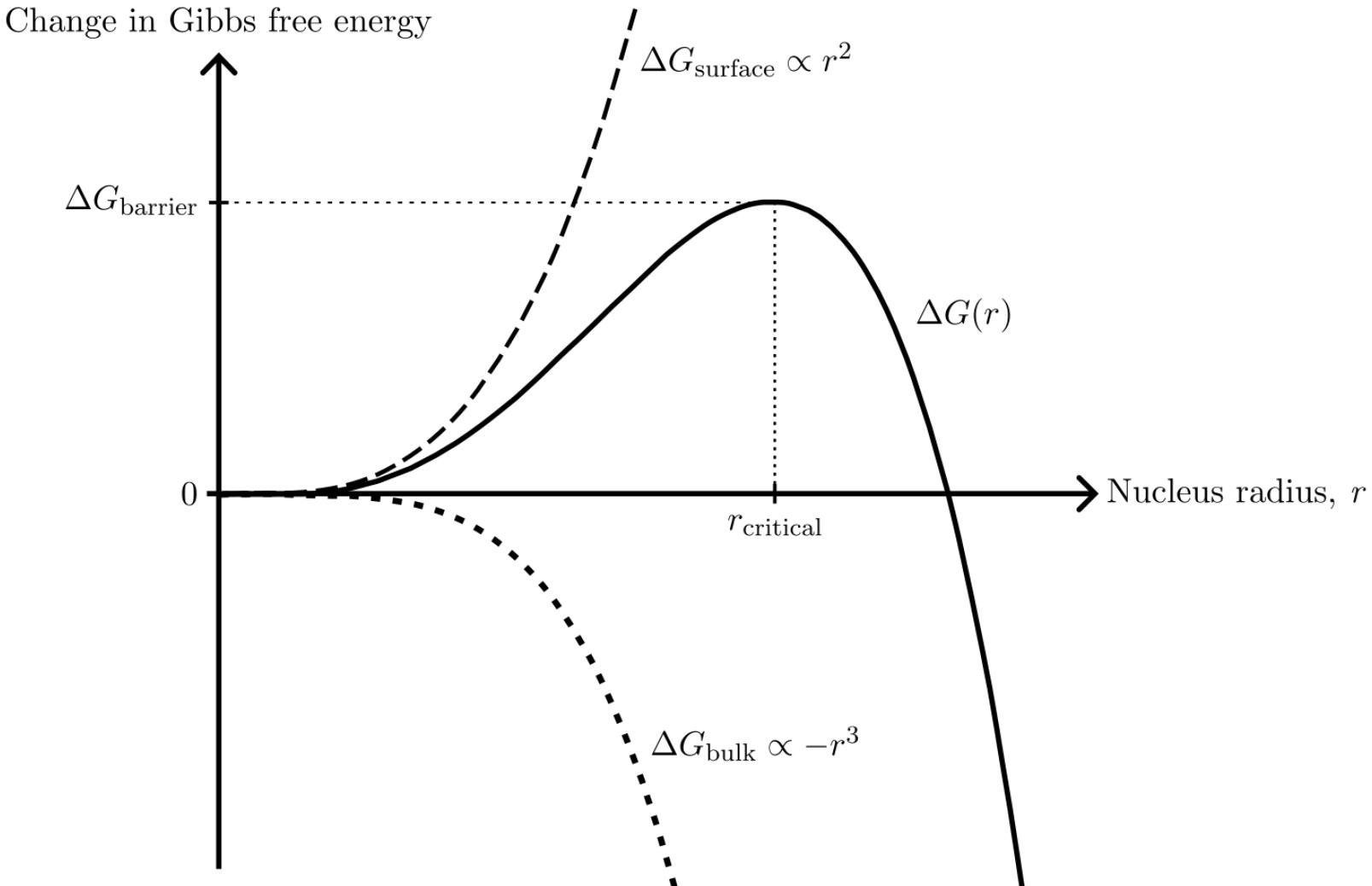
# Nucleation theory



# Nucleation theory

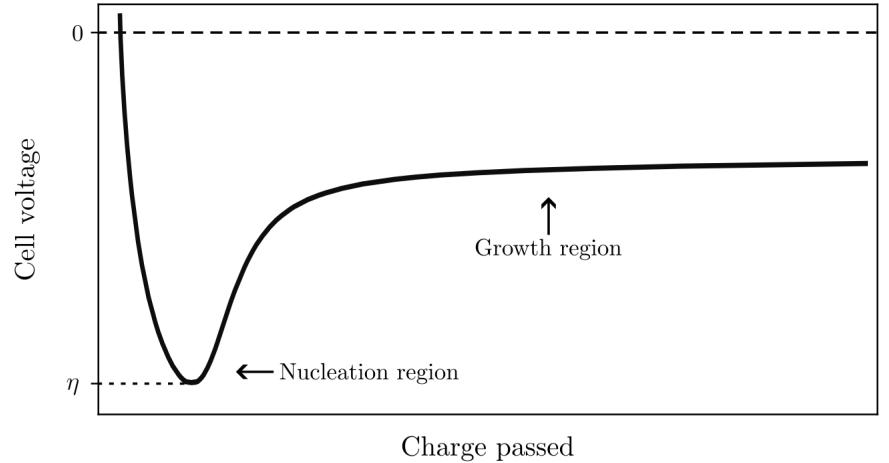
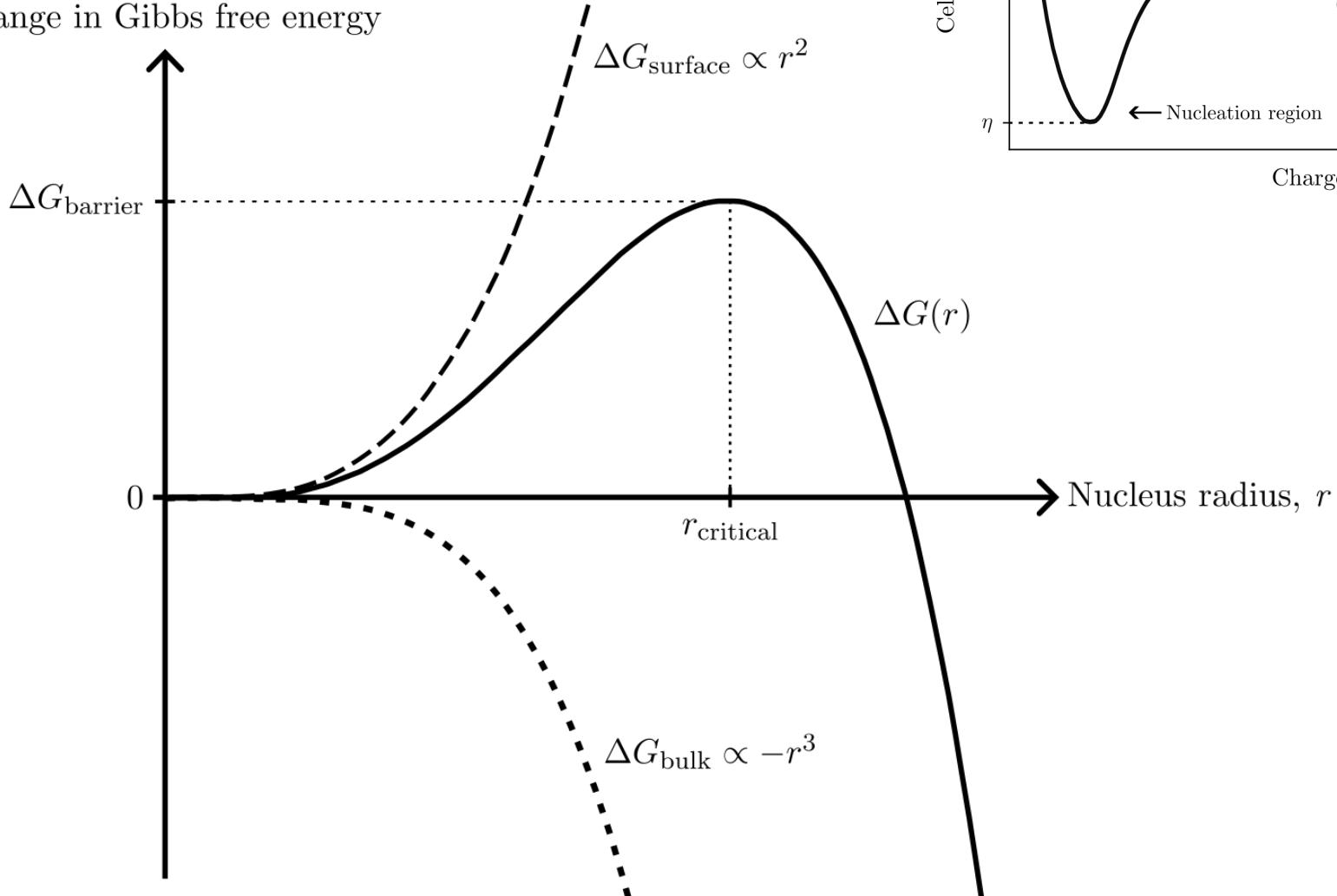


# Nucleation theory



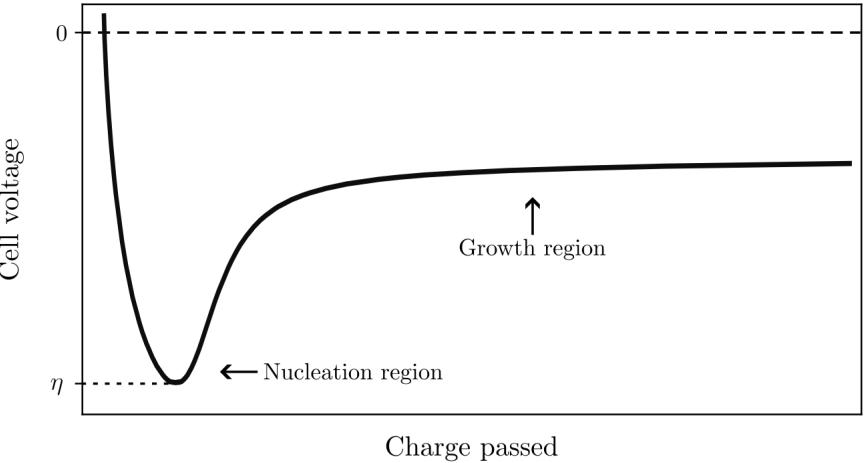
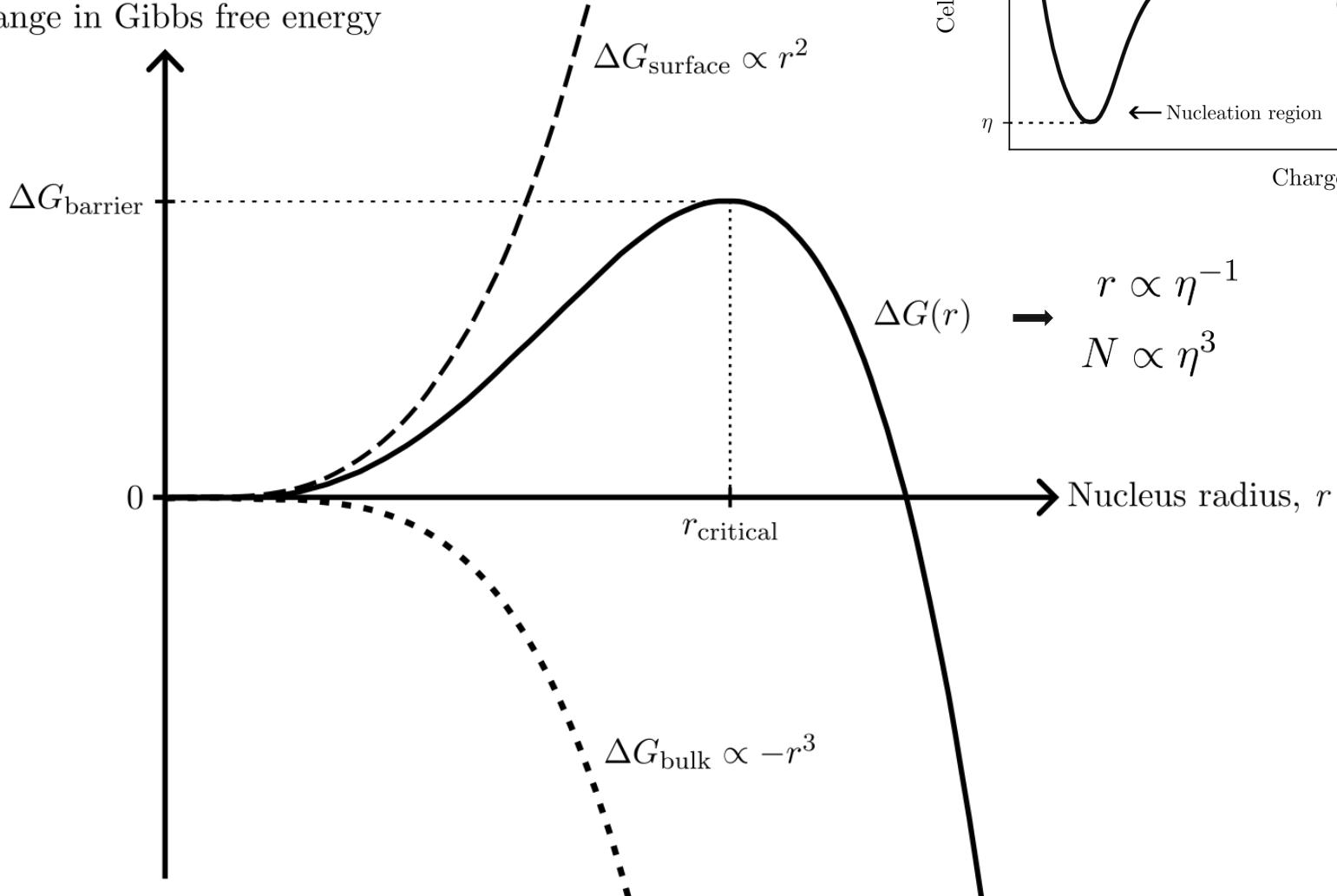
# Nucleation theory

Change in Gibbs free energy



# Nucleation theory

Change in Gibbs free energy



$$\begin{aligned} r &\propto \eta^{-1} \\ N &\propto \eta^3 \end{aligned}$$

# Nucleation theory

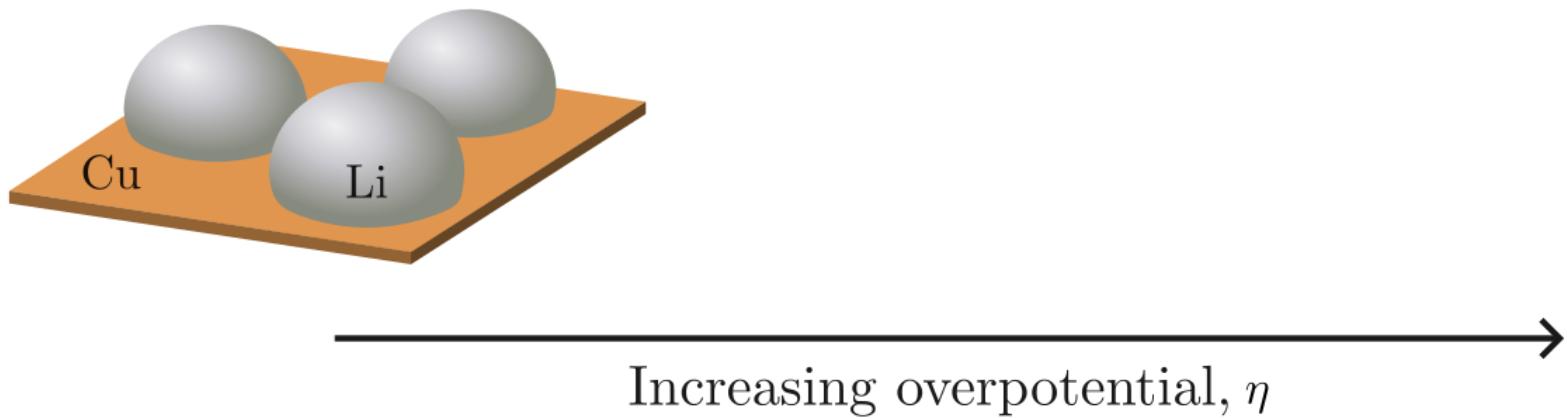
$$r \propto \eta^{-1}$$

$$N \propto \eta^3$$

# Nucleation theory

$$r \propto \eta^{-1}$$

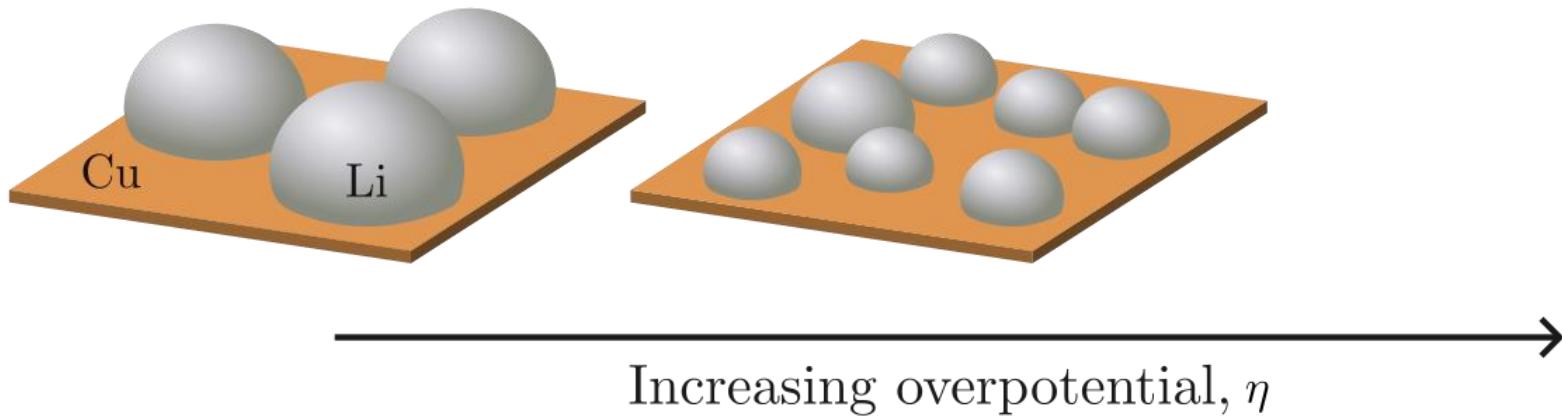
$$N \propto \eta^3$$



# Nucleation theory

$$r \propto \eta^{-1}$$

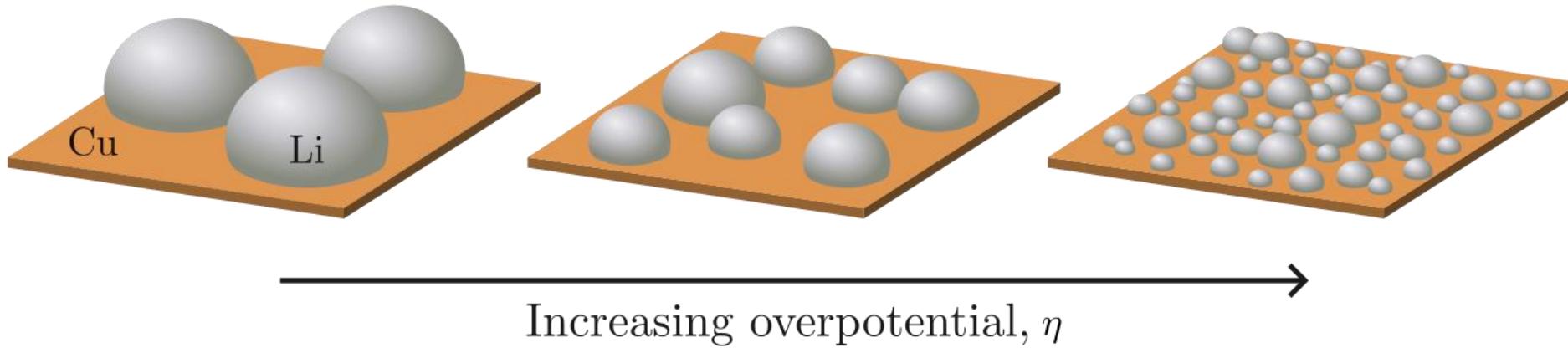
$$N \propto \eta^3$$



# Nucleation theory

$$r \propto \eta^{-1}$$

$$N \propto \eta^3$$



# Scientific questions in this thesis

The shape of the deposition curve

Distribution of the nuclei

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The shape of the deposition curve

- Degree of passivation of the Cu surface
- Deposition current

Distribution of the nuclei

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← Electrochemical measurements

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Distribution of the nuclei

- Pressure between the Li and Cu

# Scientific questions in this thesis

The shape of the deposition curve

- Degree of passivation of the Cu surface
- Deposition current

← Electrochemical measurements

Distribution of the nuclei

- Pressure between the Li and Cu

← Image Li nuclei using SEM

# The C-cell

Cap



Spring



Spacer



Li



Separator



Cu



Gasket



Can



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Spring



Spacer



Li



Separator



Cu



Gasket



Can



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# The C-cell

Cap



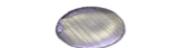
Spring



Spacer



Li



Separator



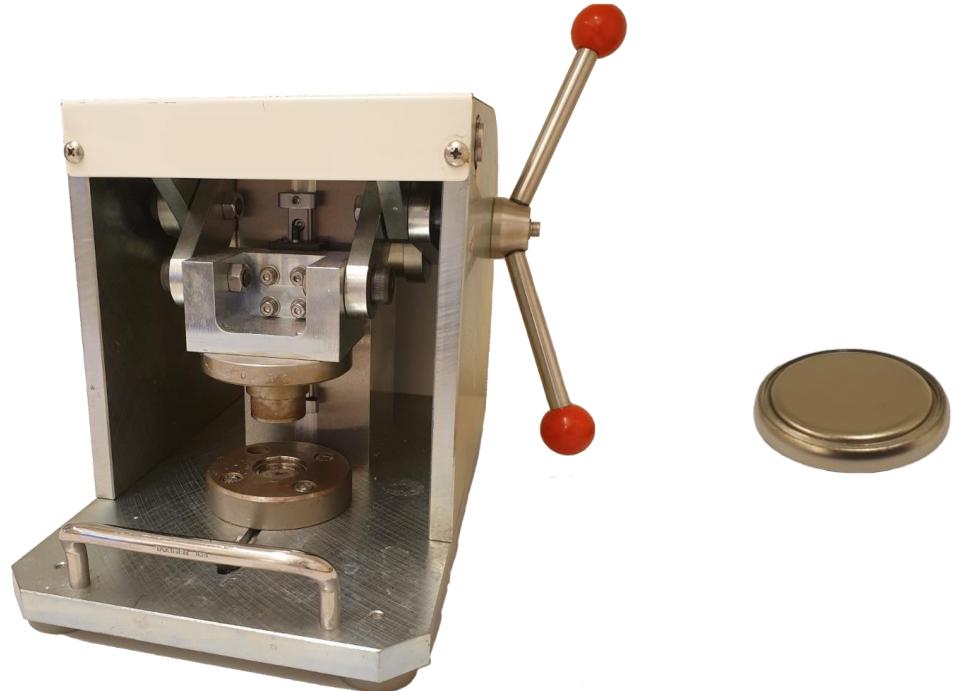
Cu



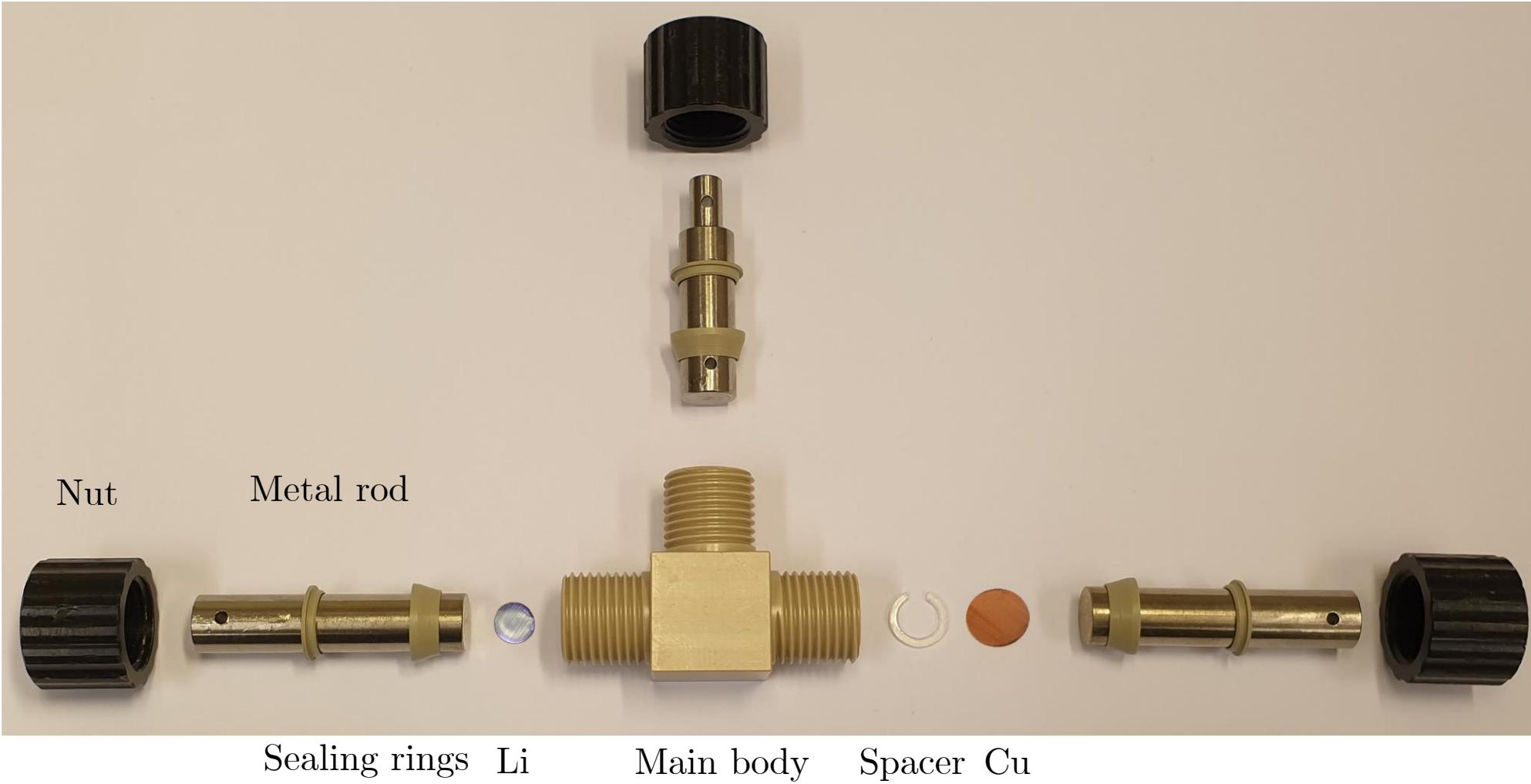
Gasket



Can



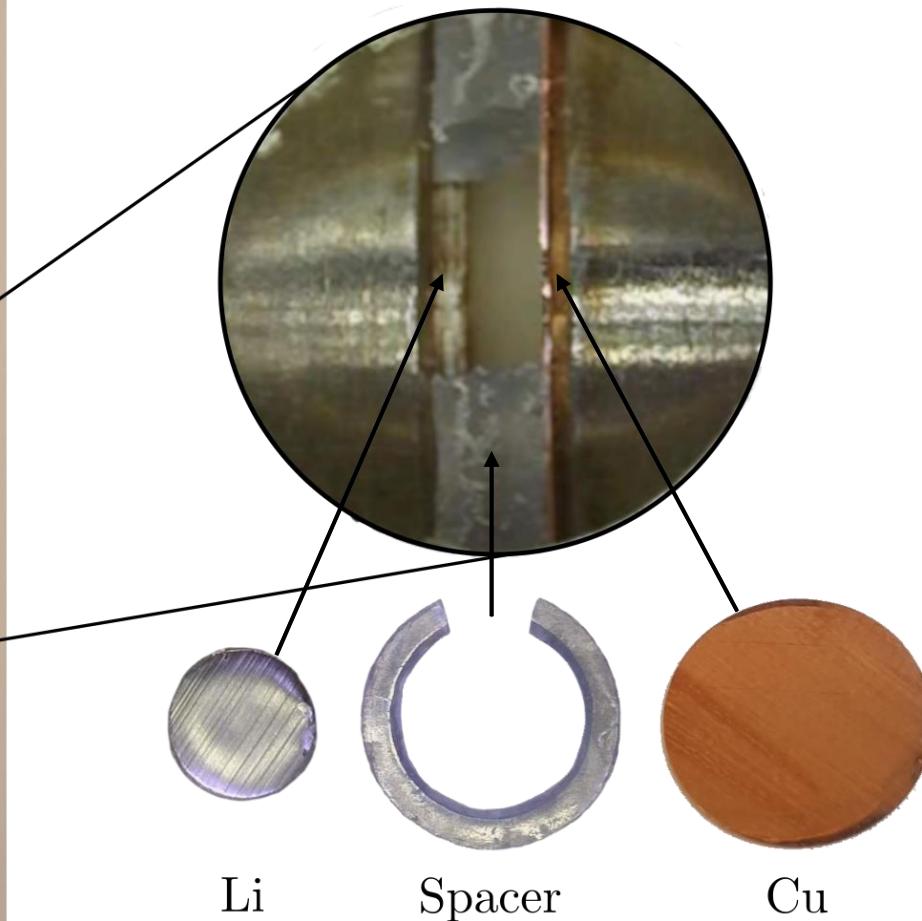
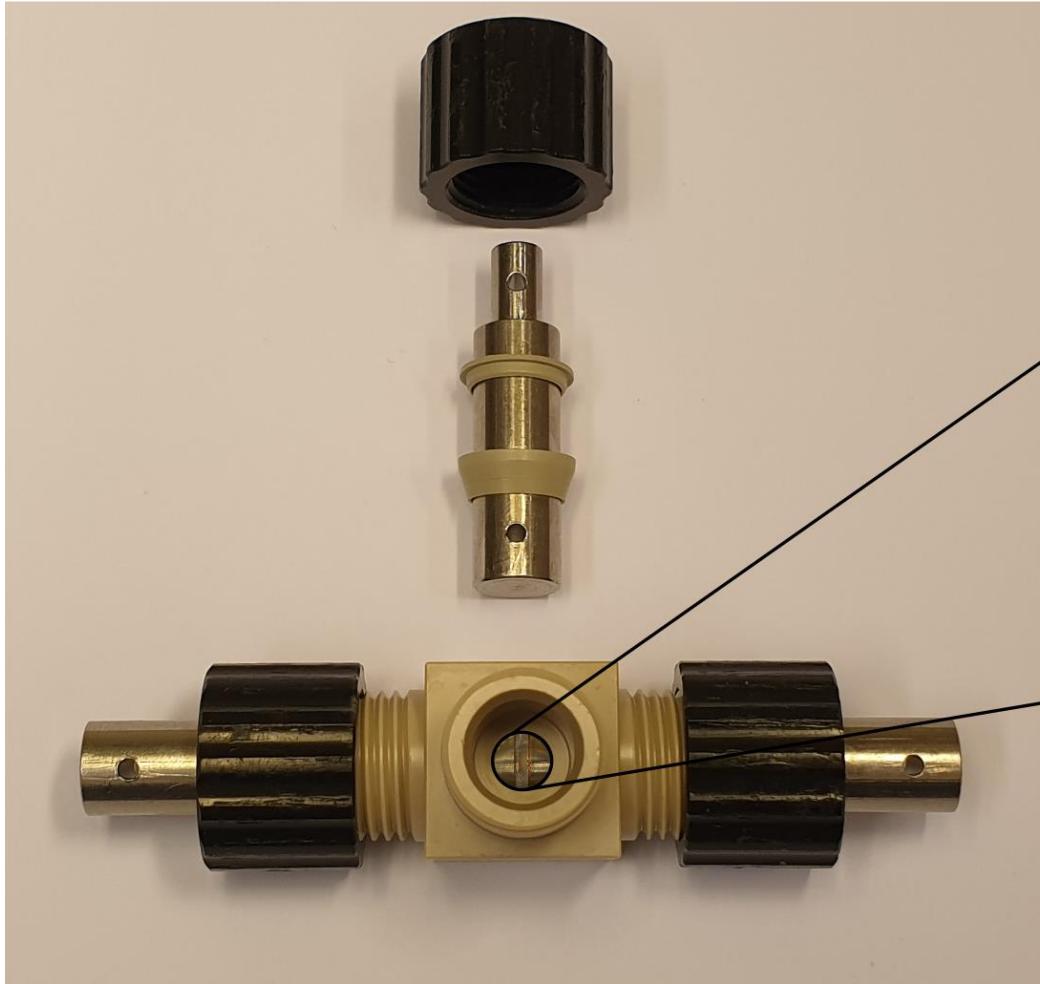
# The T-cell



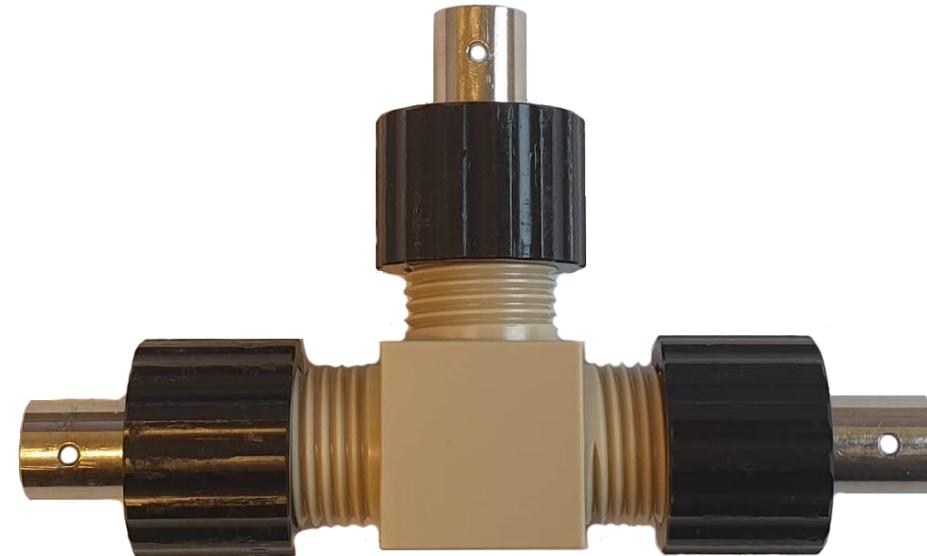
# The T-cell



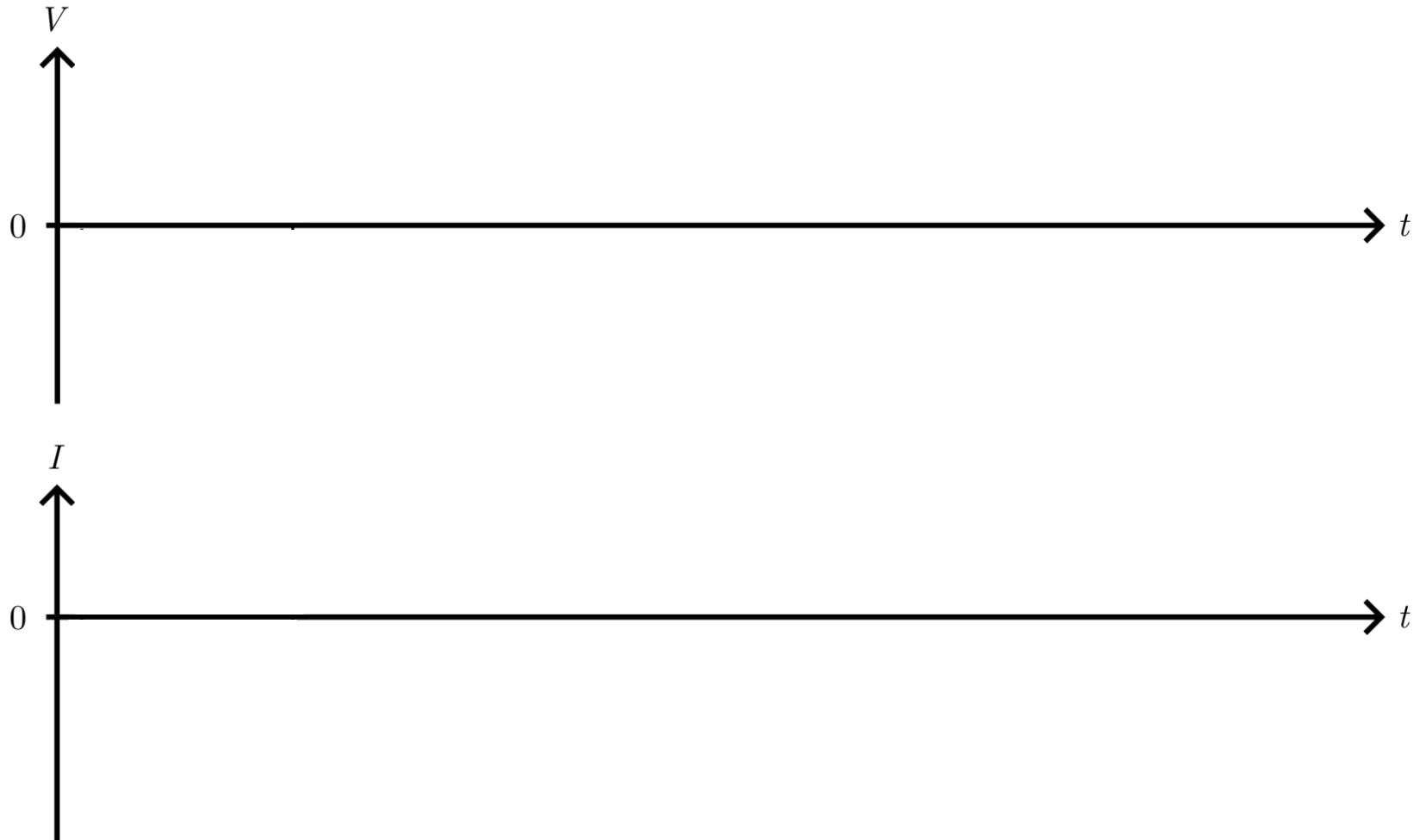
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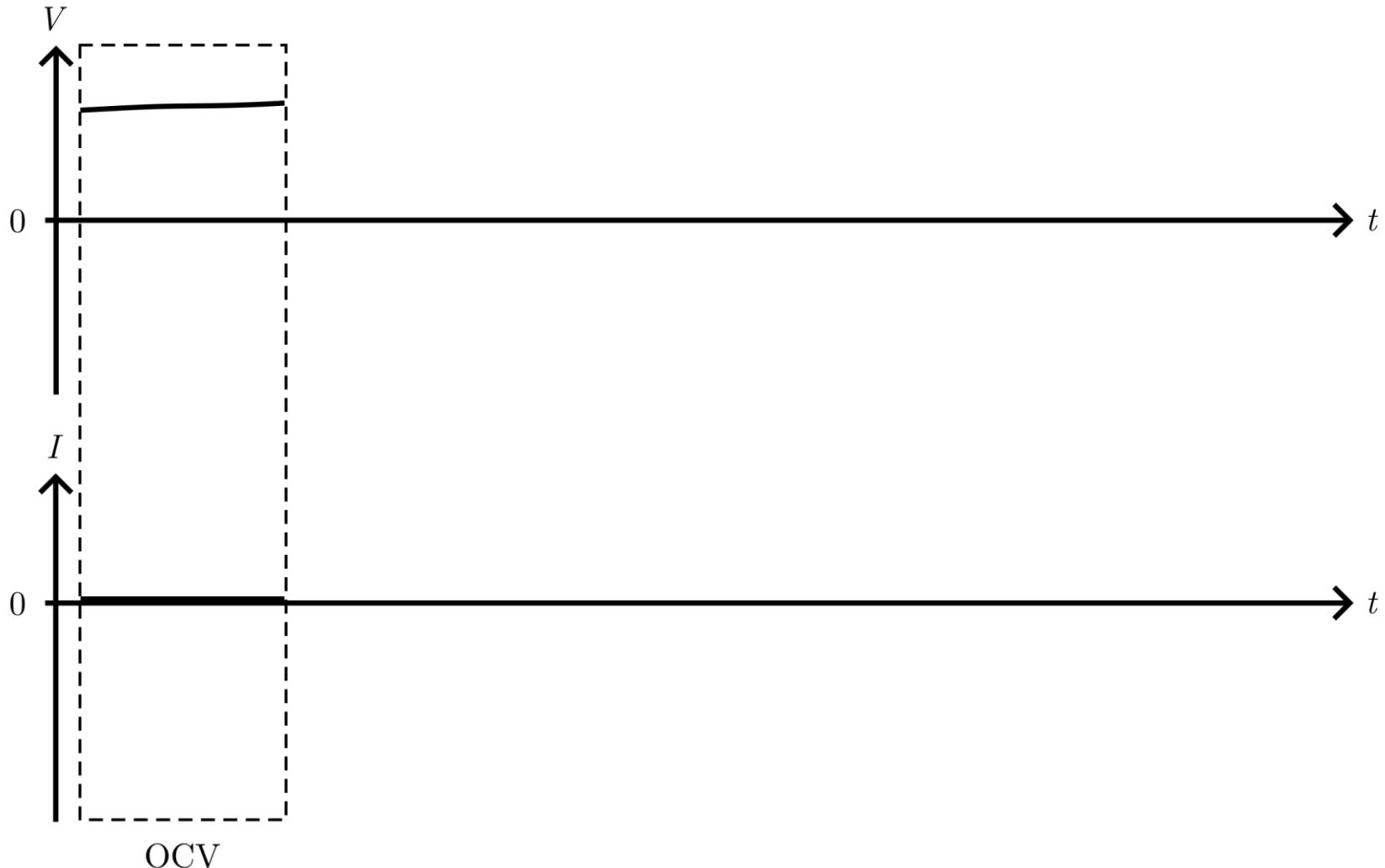
# The T-cell



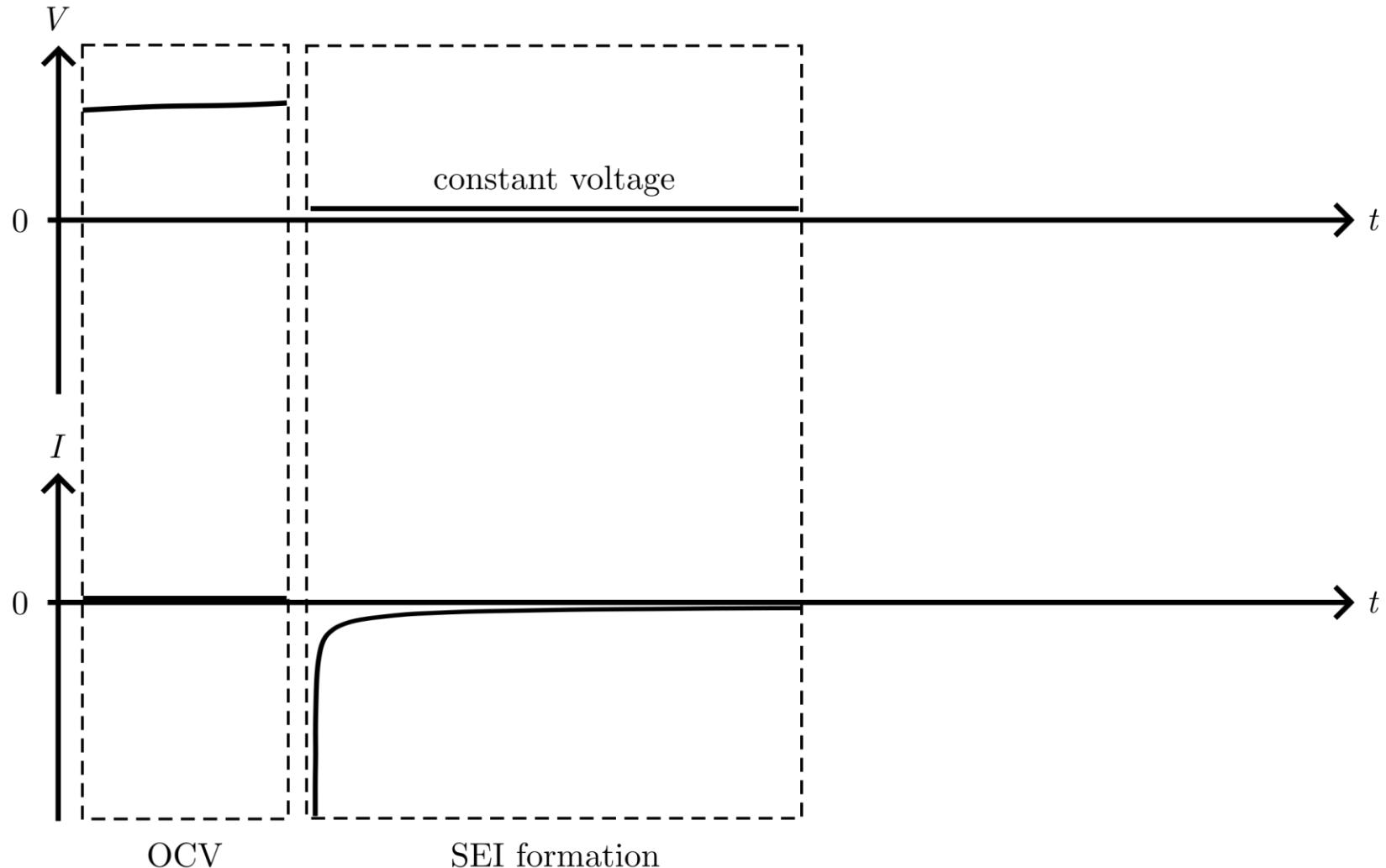
# Deposition protocol



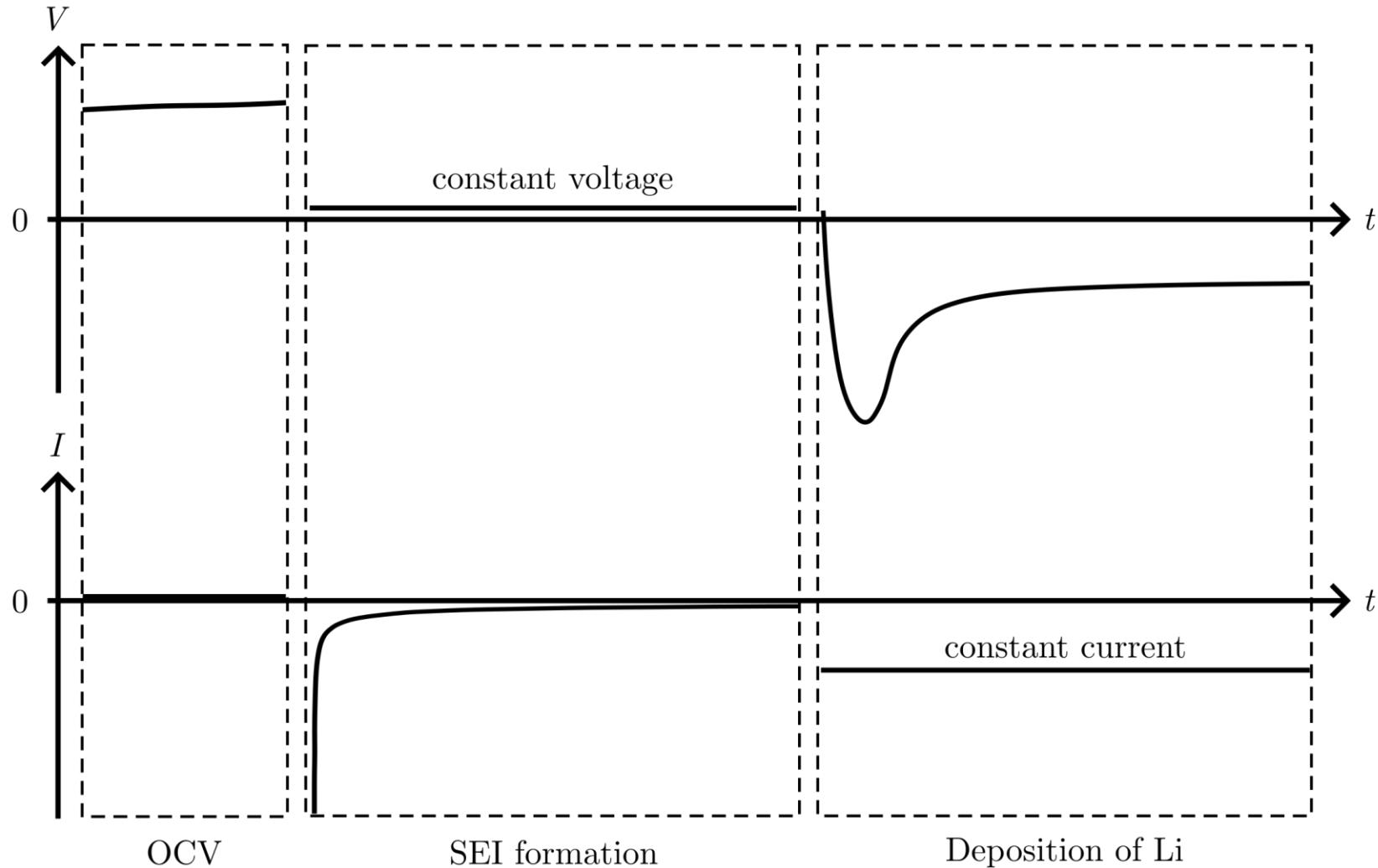
# Deposition protocol



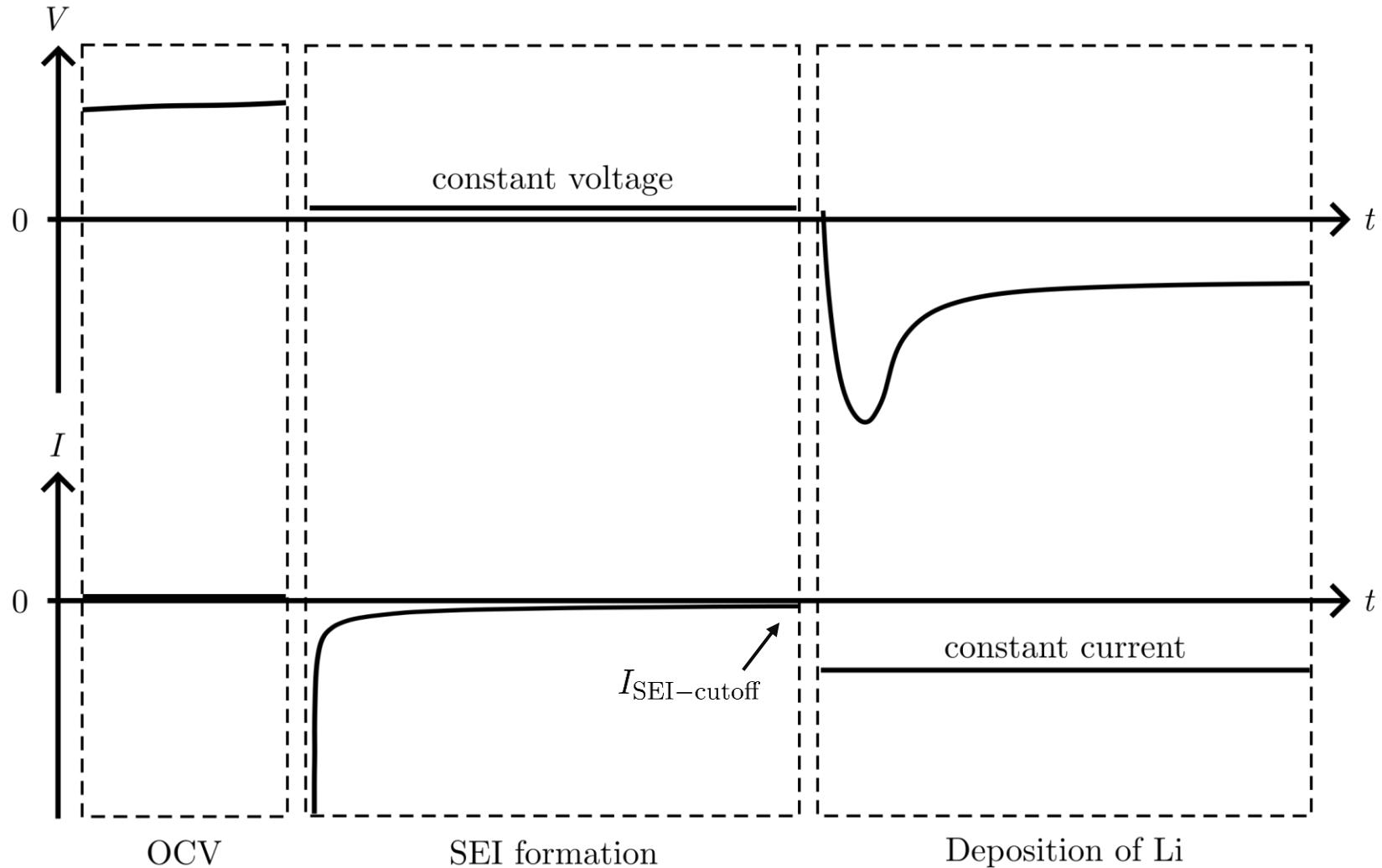
# Deposition protocol



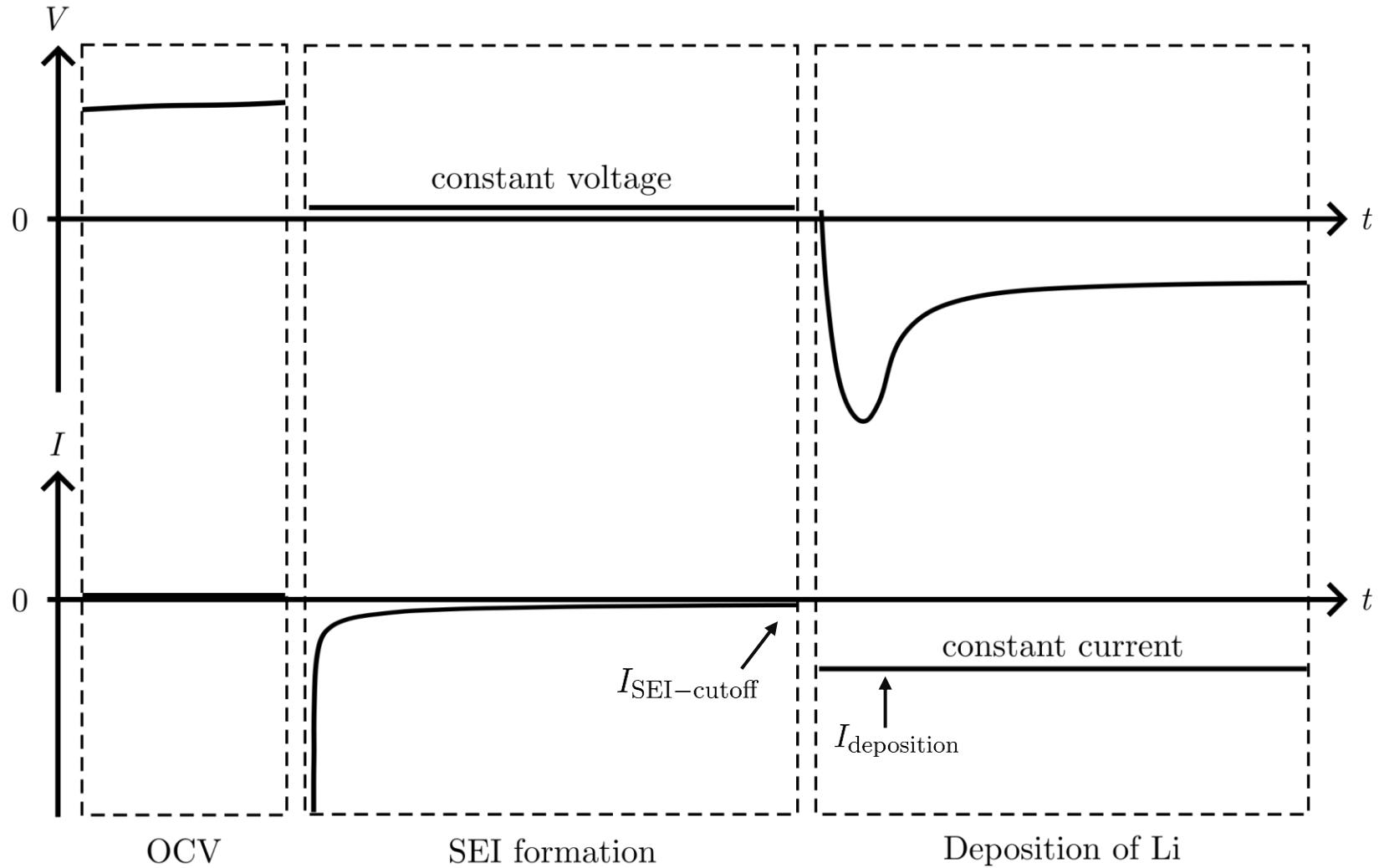
# Deposition protocol



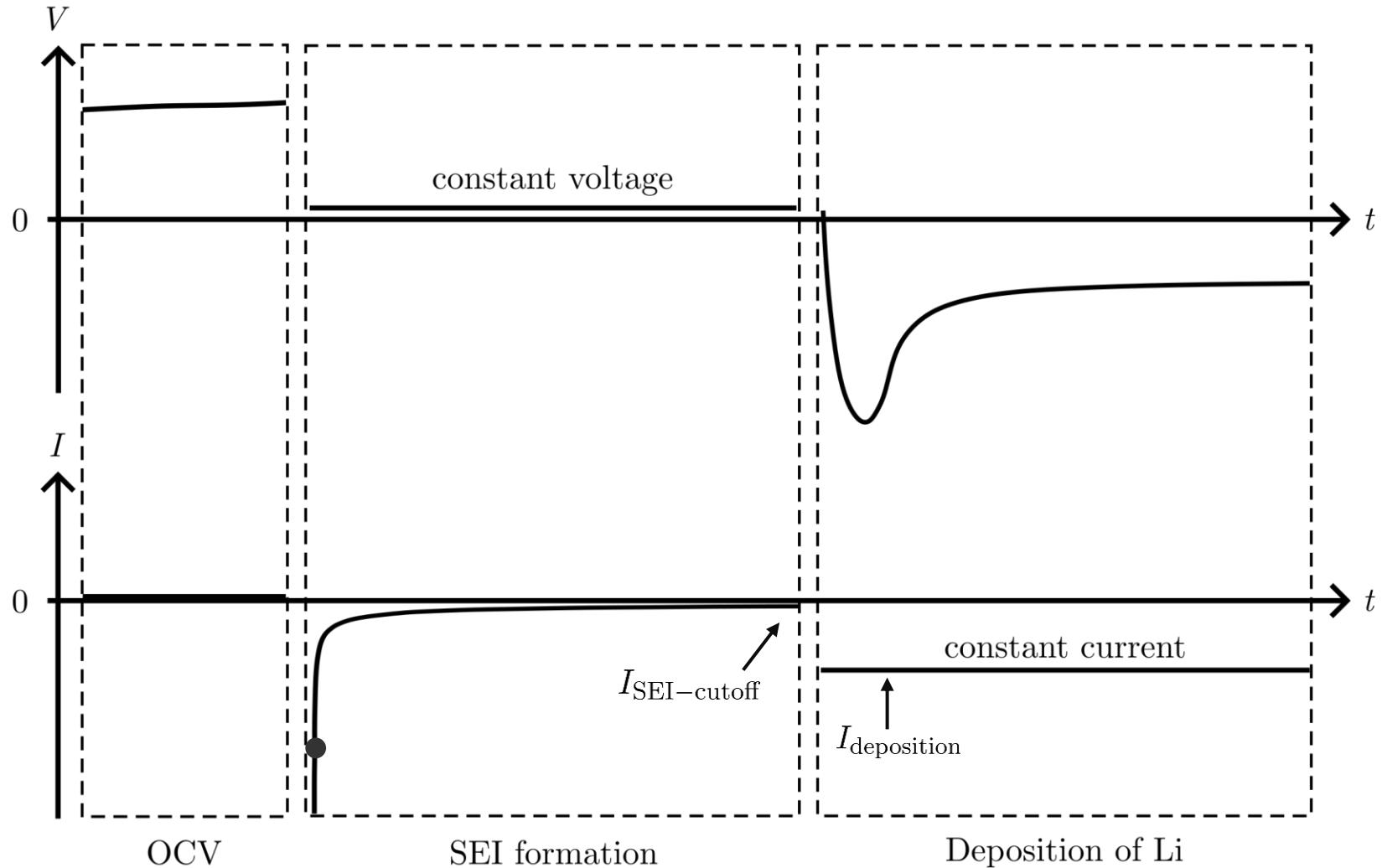
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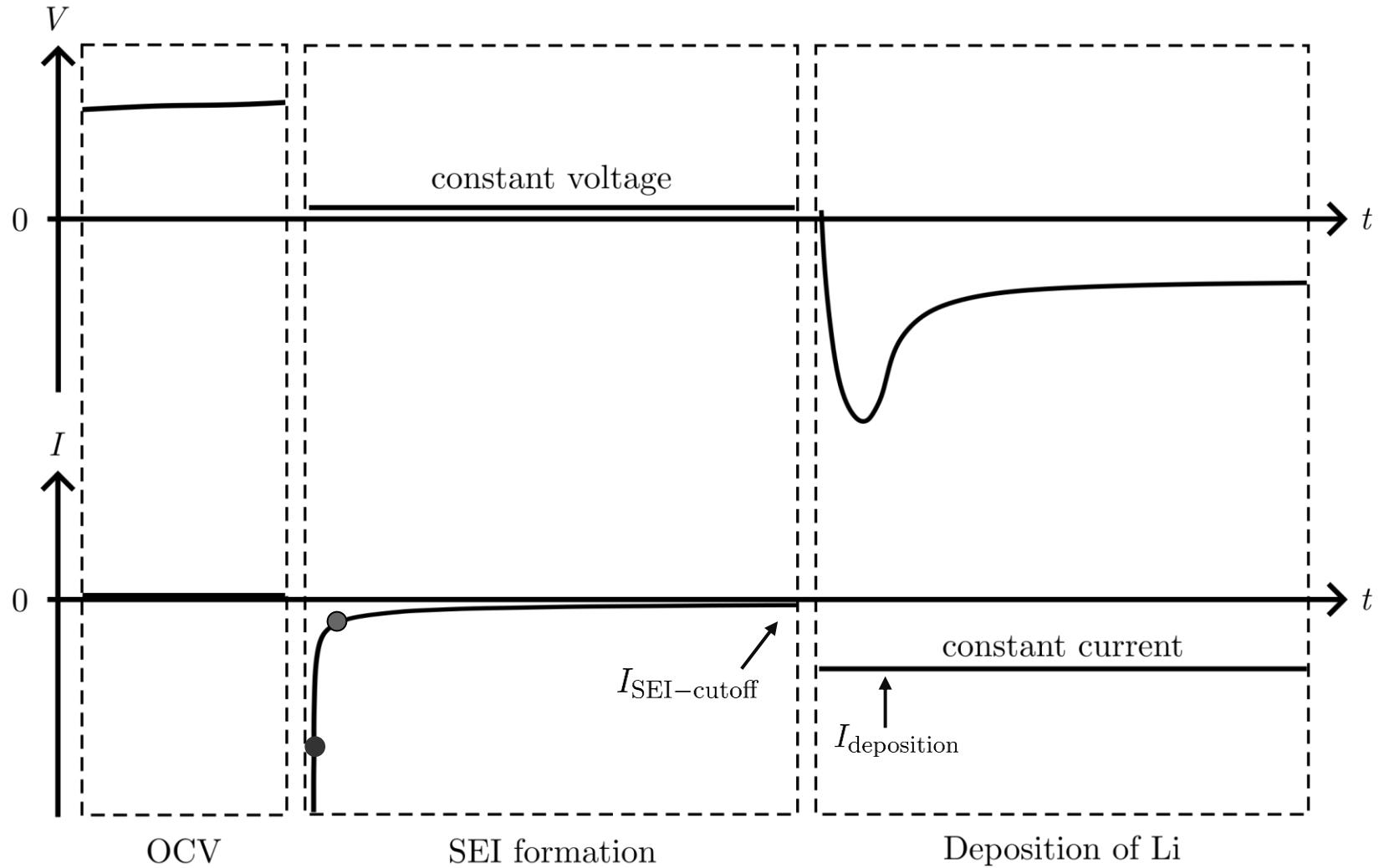
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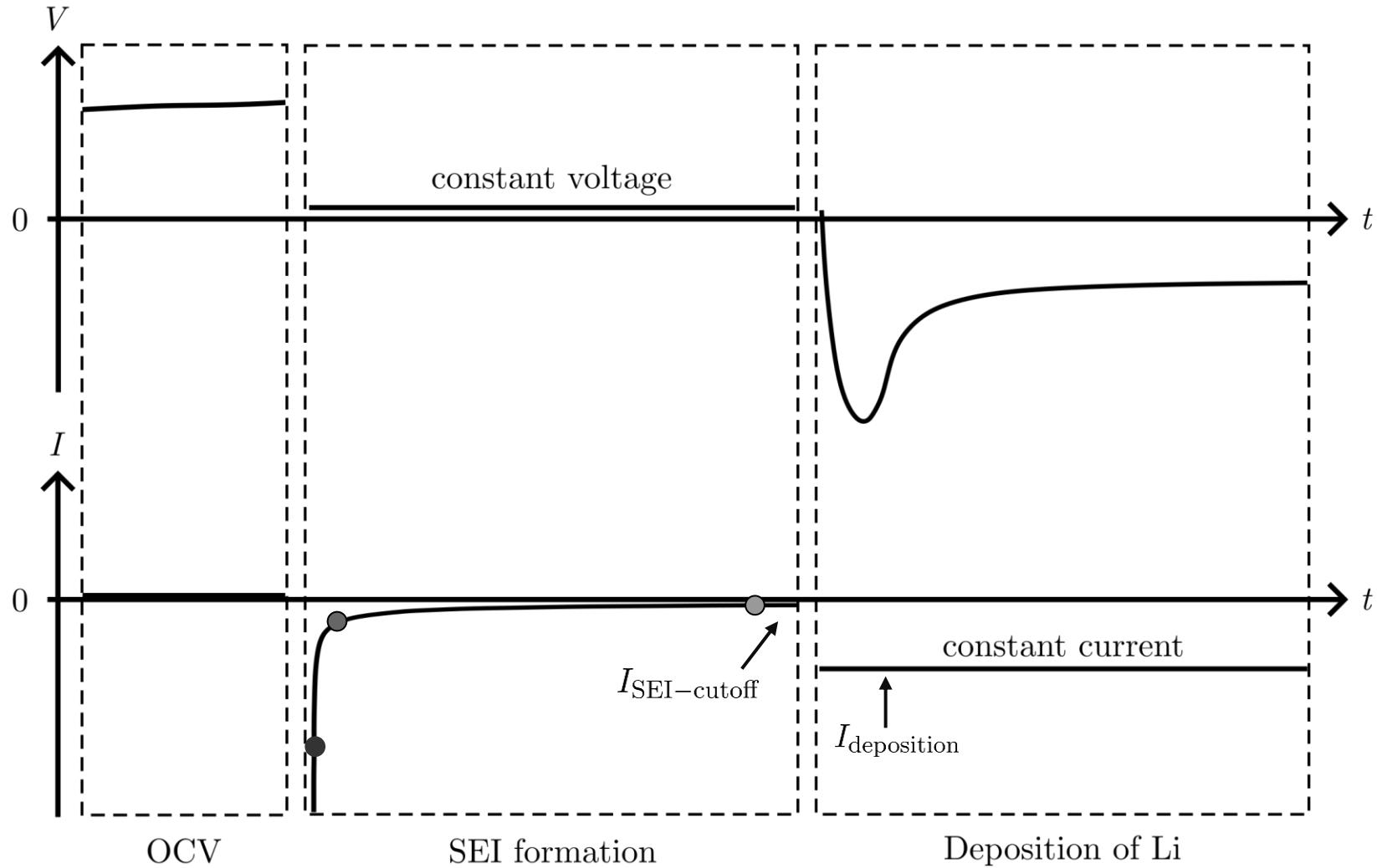
# Deposition protocol



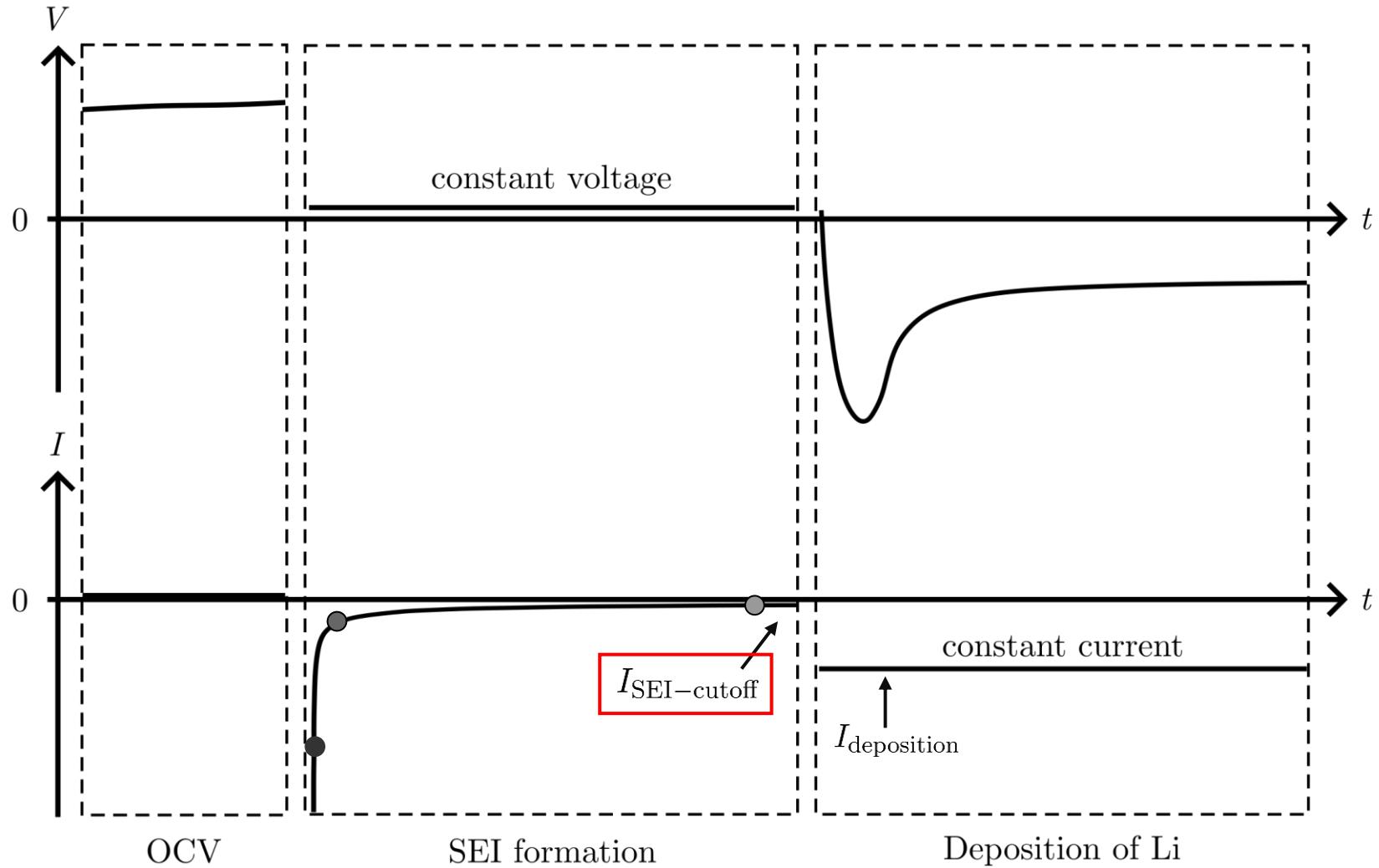
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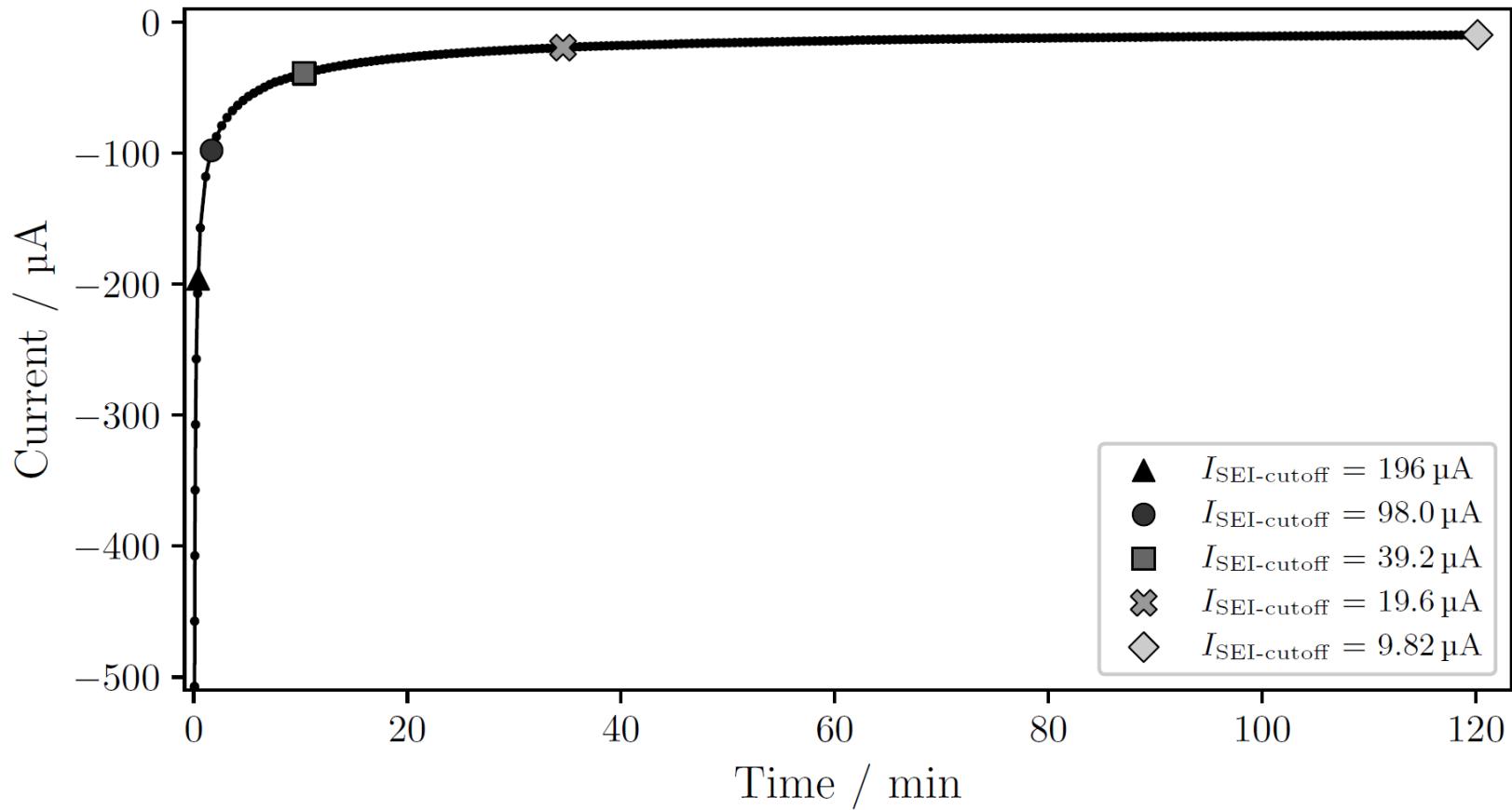
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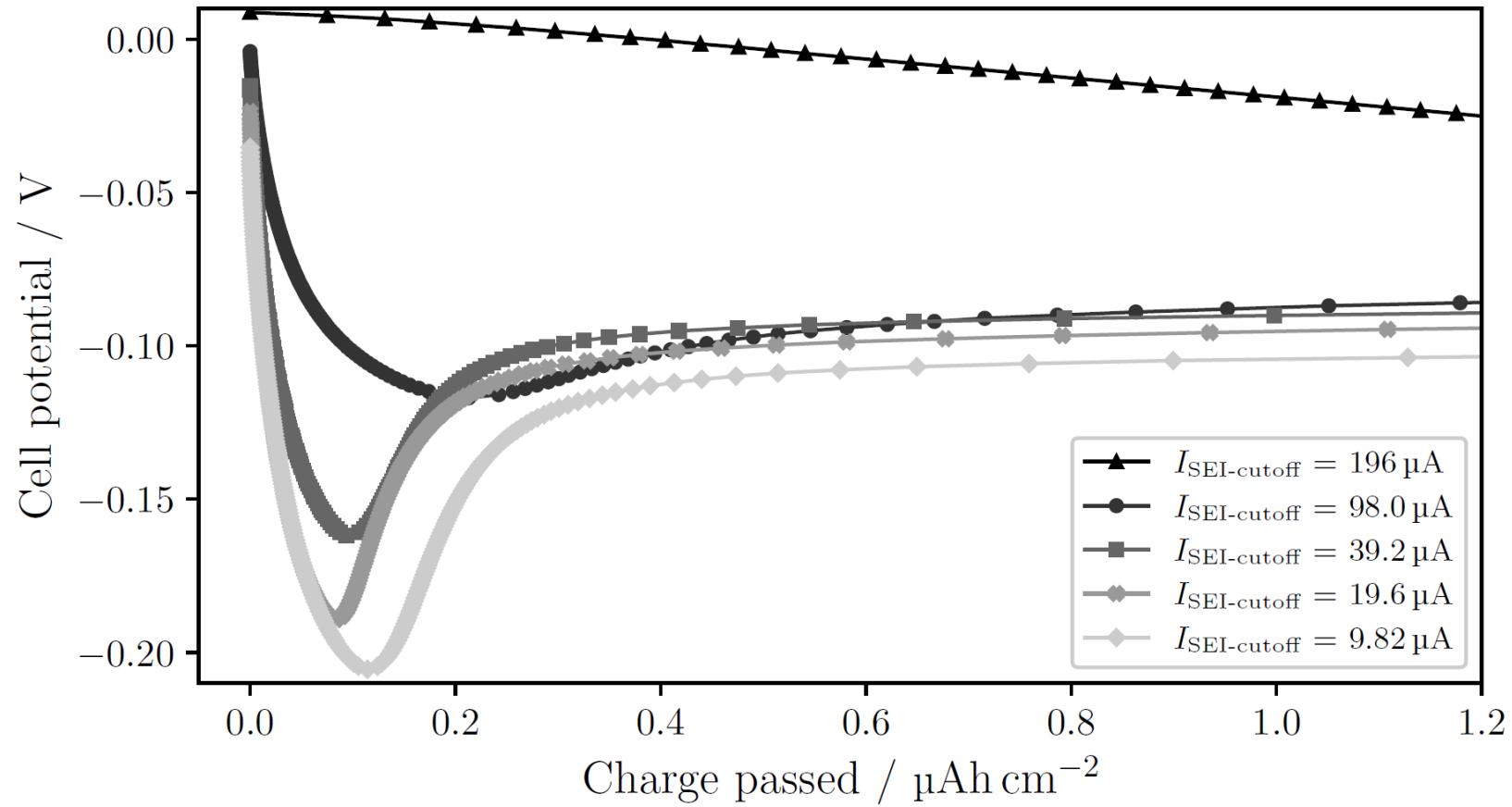
# Passivation of the Cu surface



# Passivation of the Cu surface

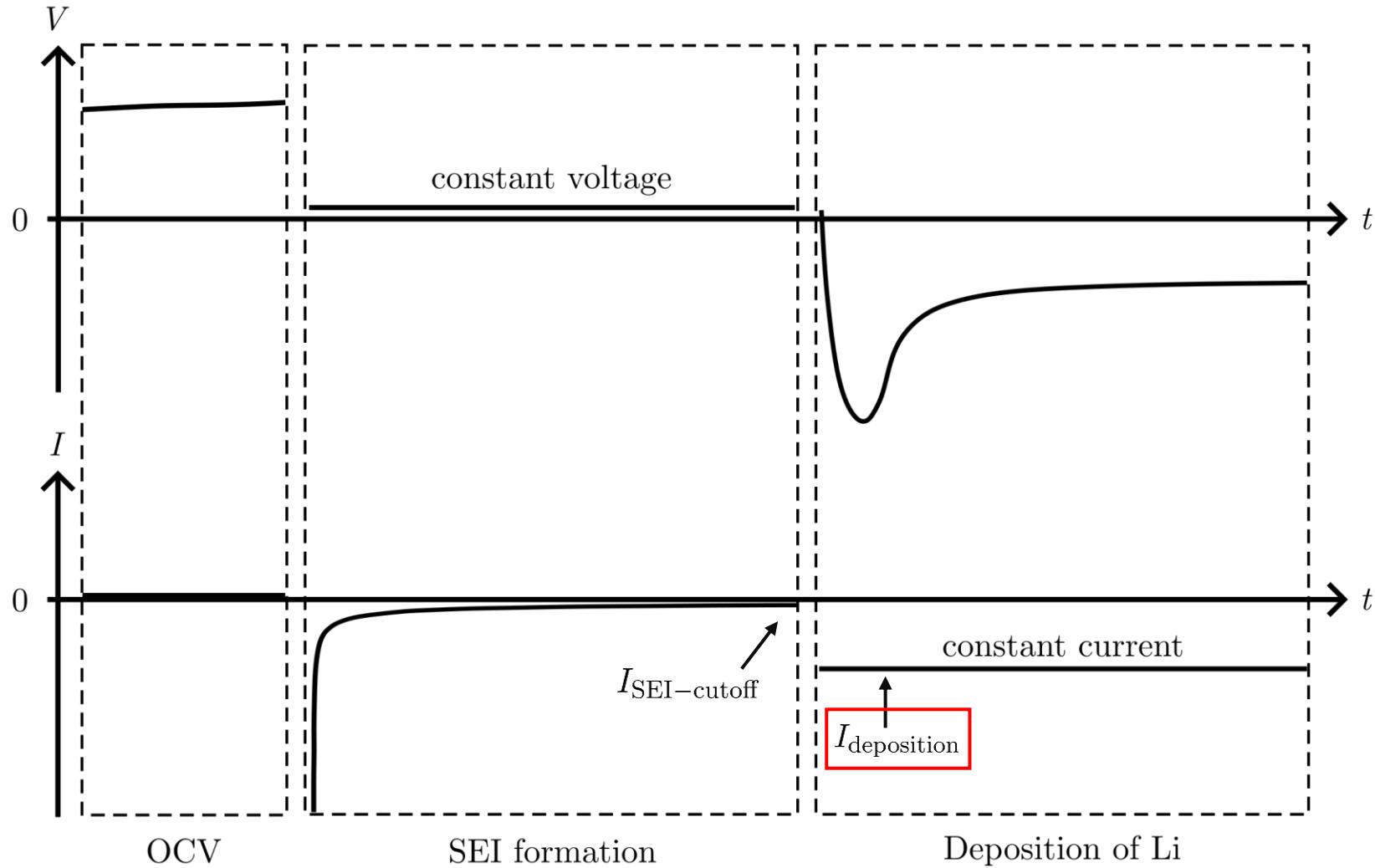


# Passivation of the Cu surface



$I_{\text{deposition}} = 196 \mu\text{A}$

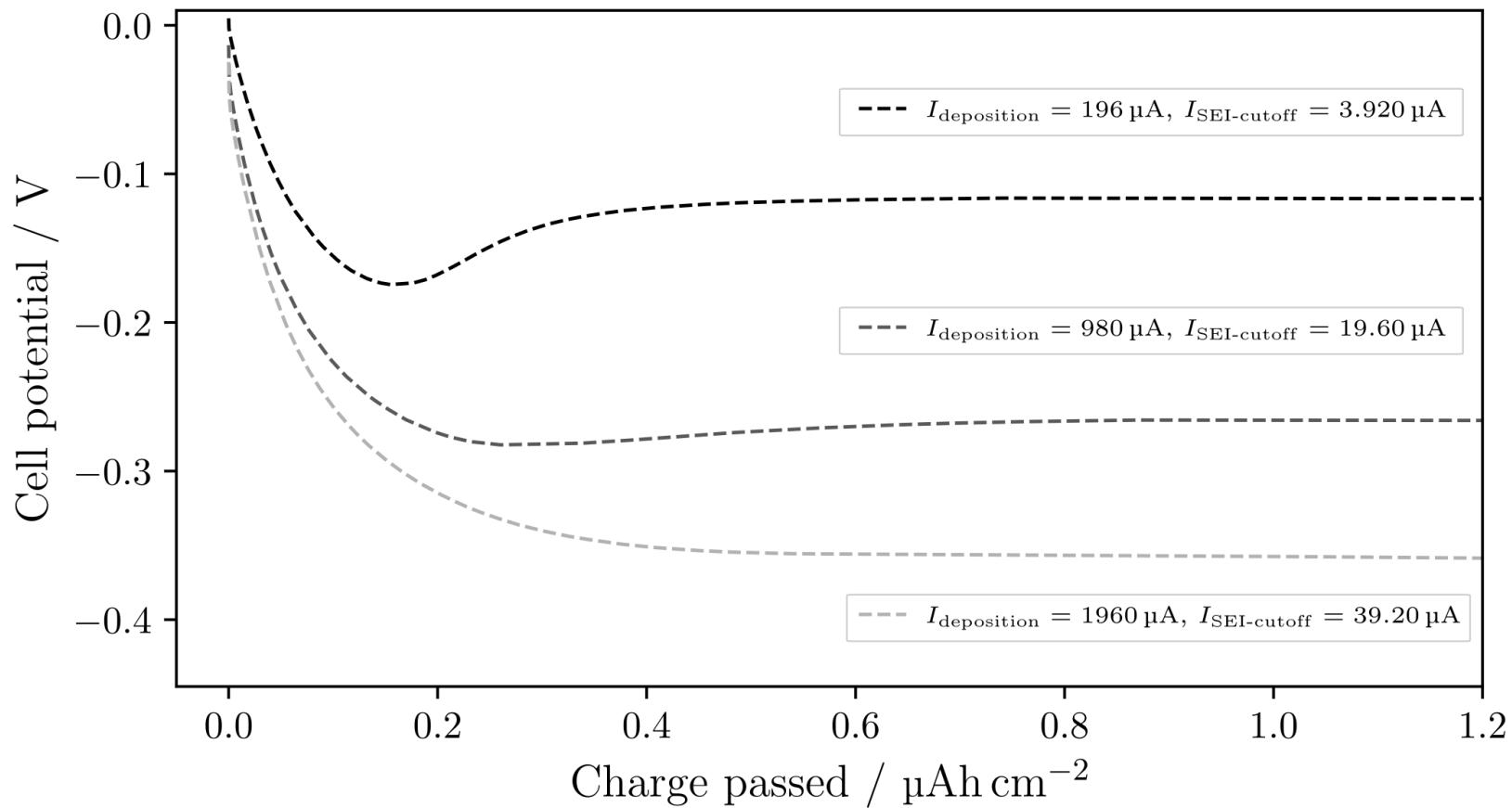
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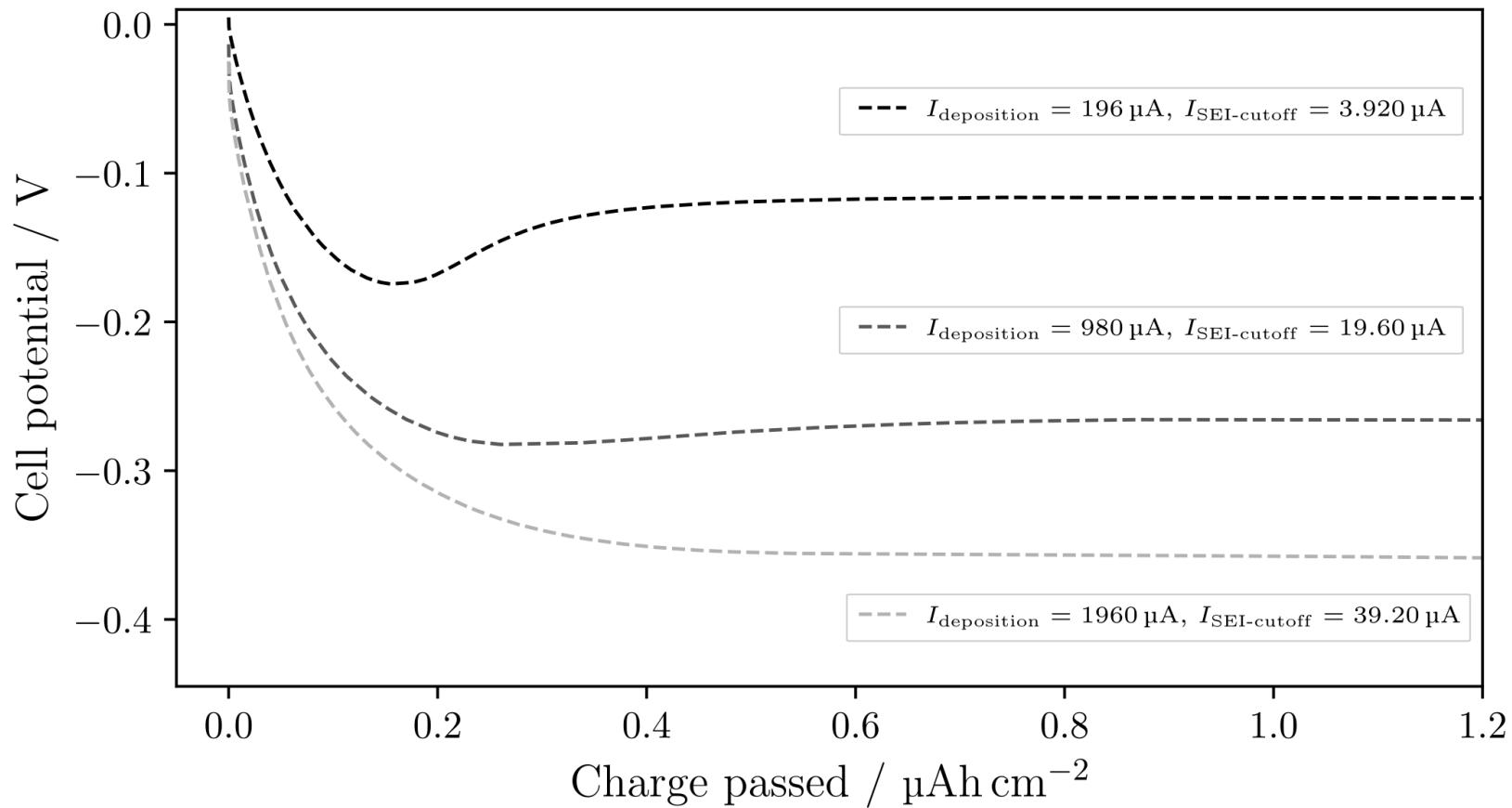
# Deposition current



# Deposition current



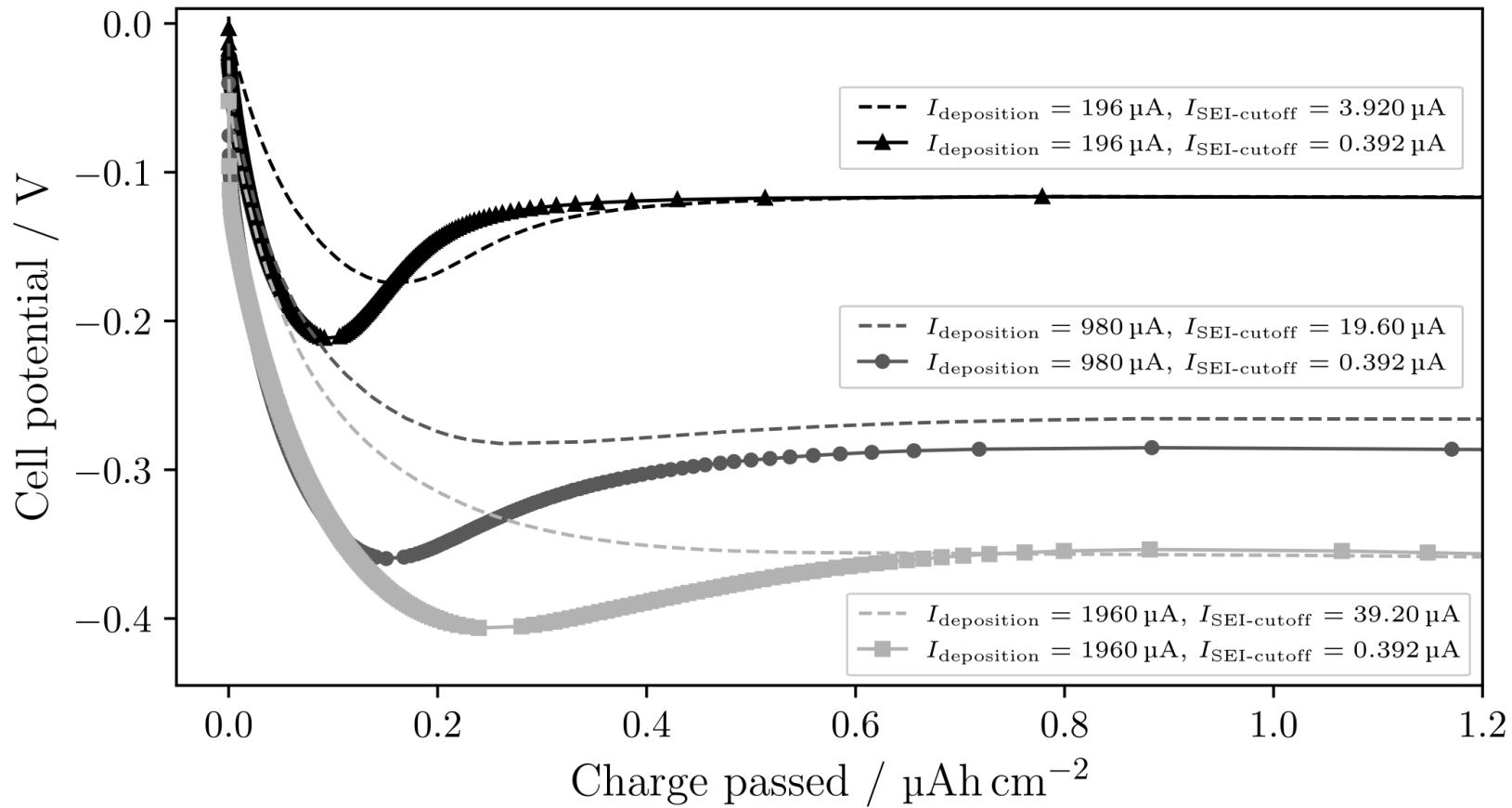
# Deposition current



$$r \propto \eta^{-1}$$
$$N \propto \eta^3$$



# Deposition current with more passivation



$$r \propto \eta^{-1}$$
$$N \propto \eta^3$$



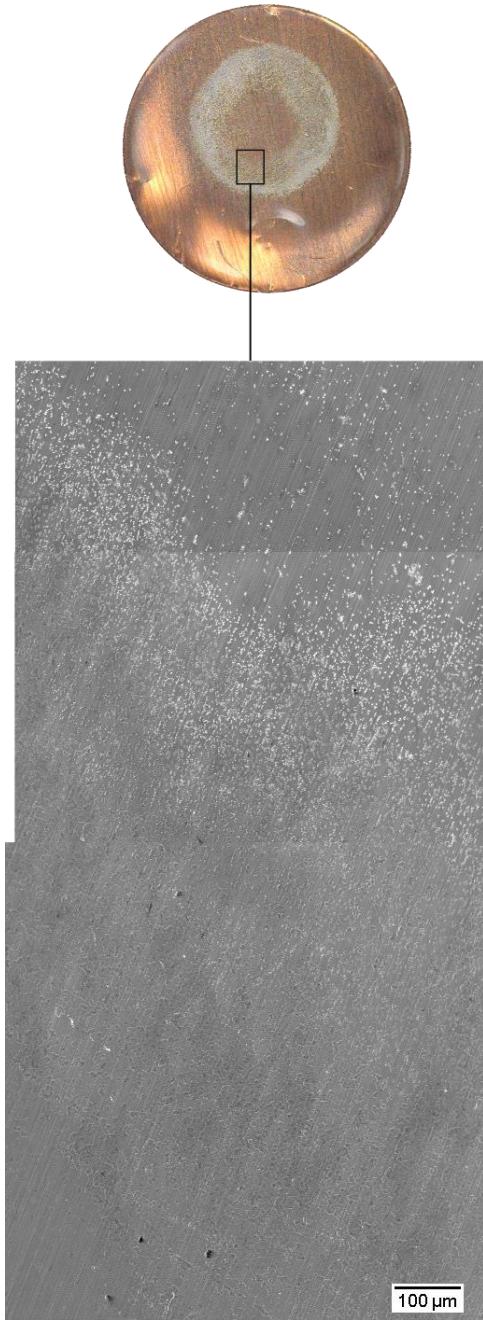
# Pressure effects



# Pressure effects



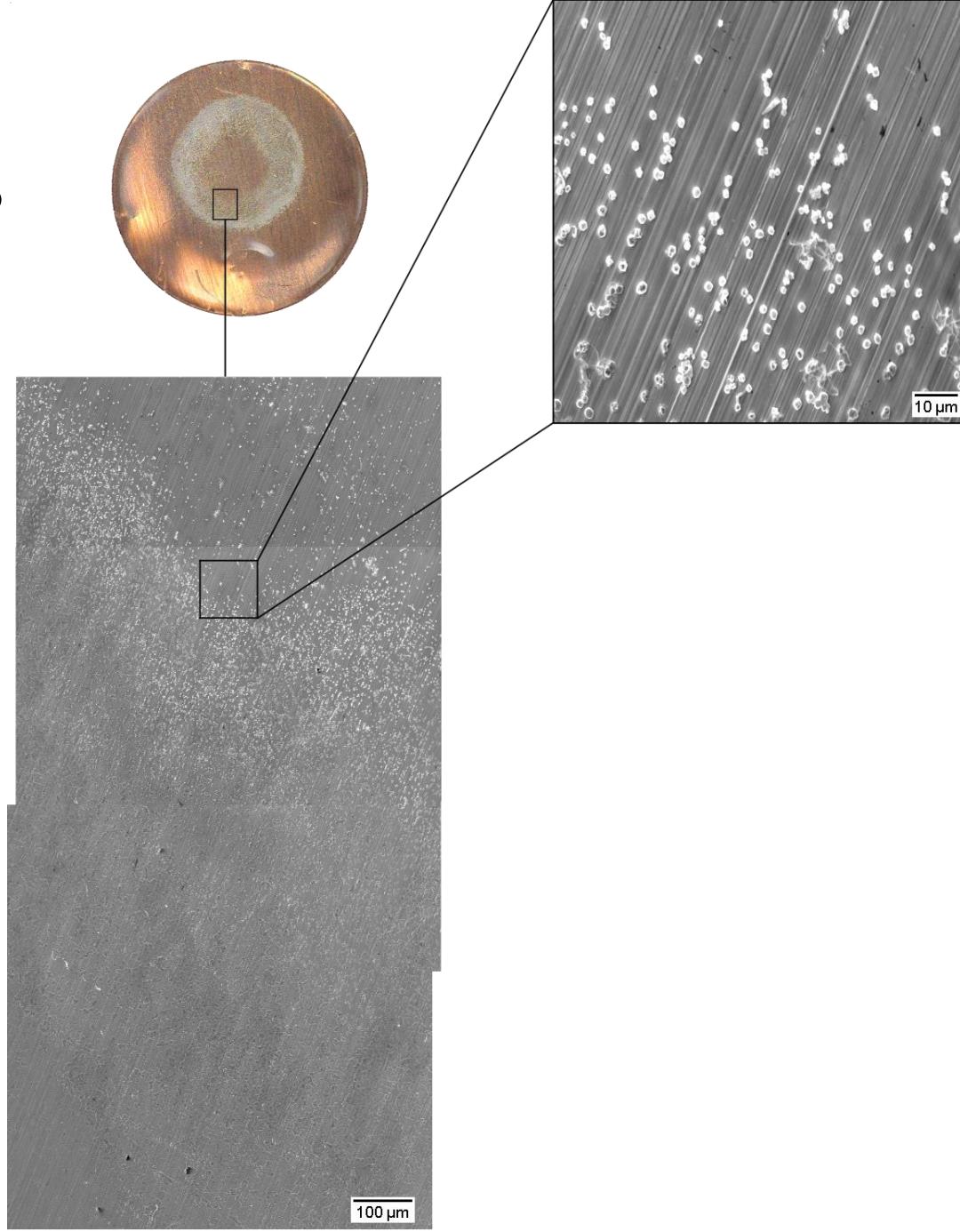
# Pressure effects



25  $\mu\text{Ah}/\text{cm}^2$



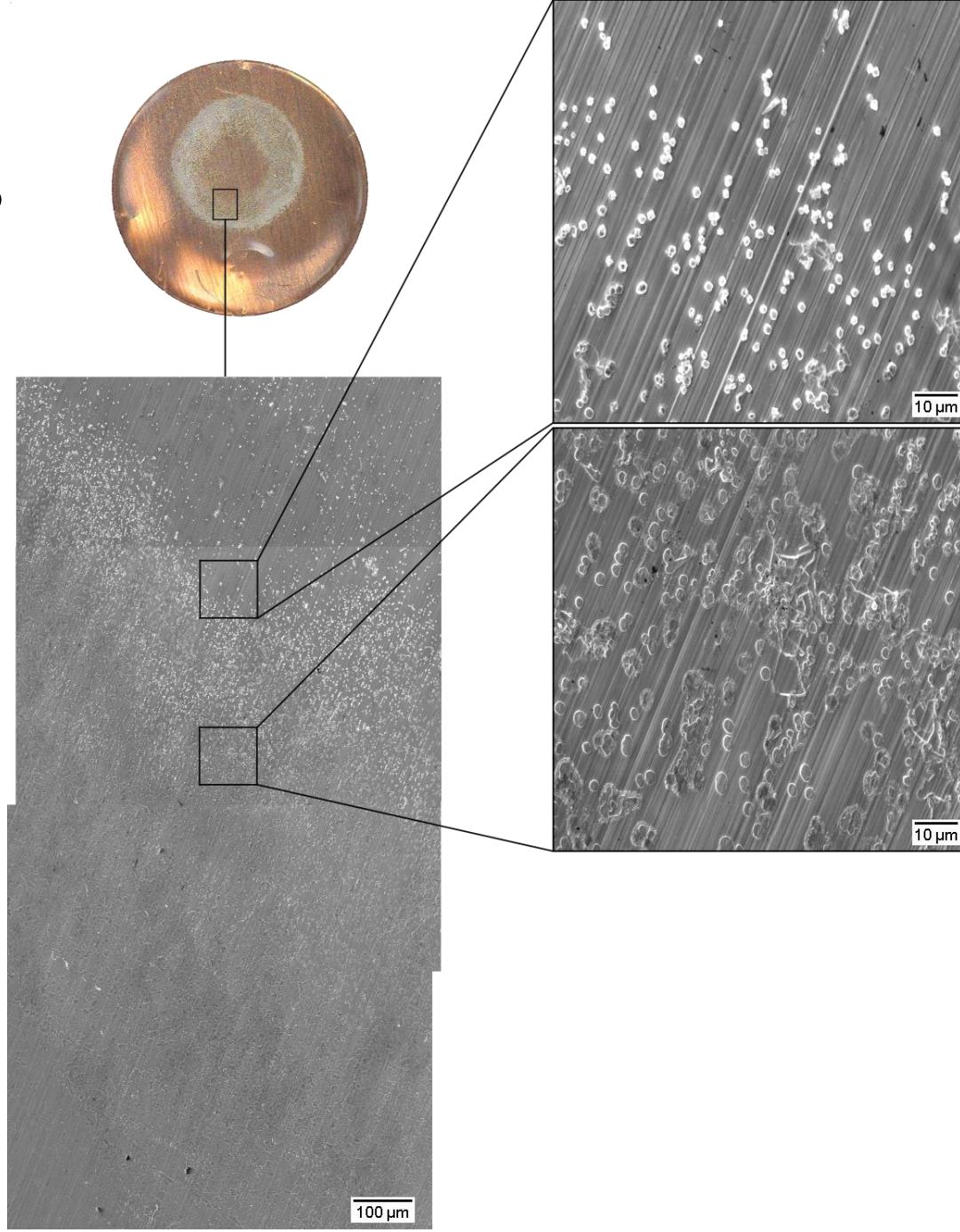
# Pressure effects



$25 \mu\text{Ah}/\text{cm}^2$

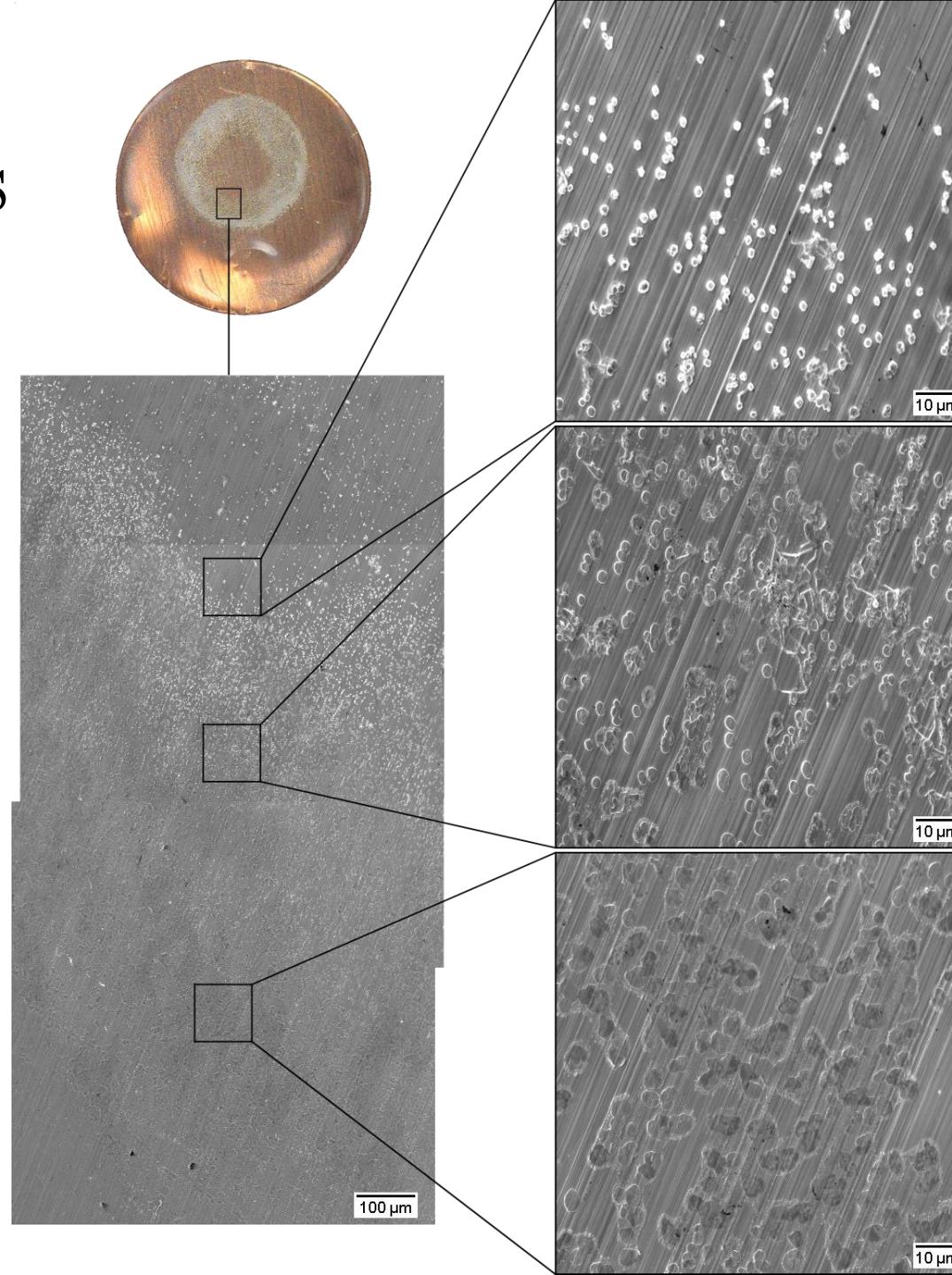


# Pressure effects



25  $\mu\text{Ah}/\text{cm}^2$

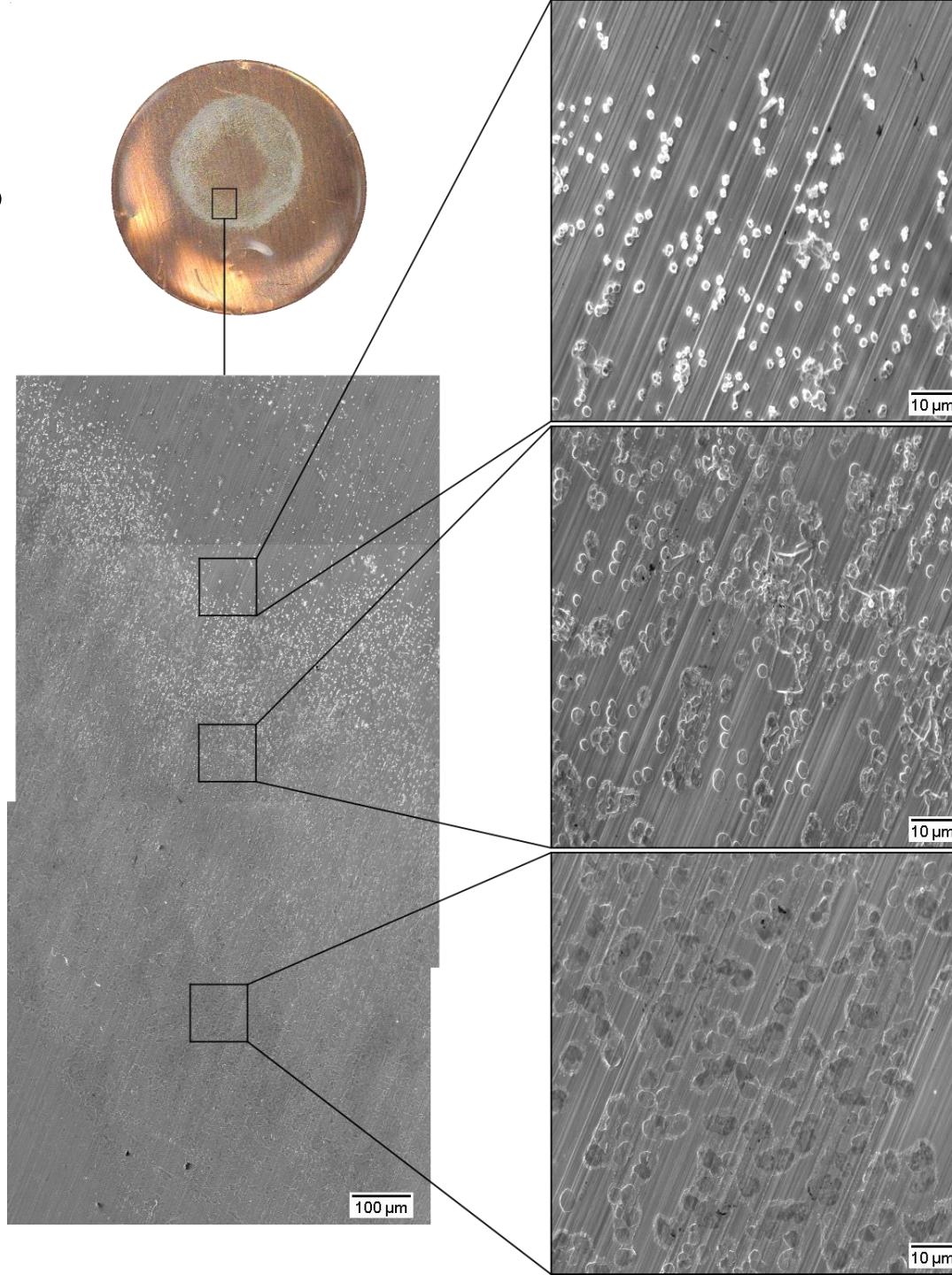
# Pressure effects



25  $\mu\text{Ah}/\text{cm}^2$



# Pressure effects



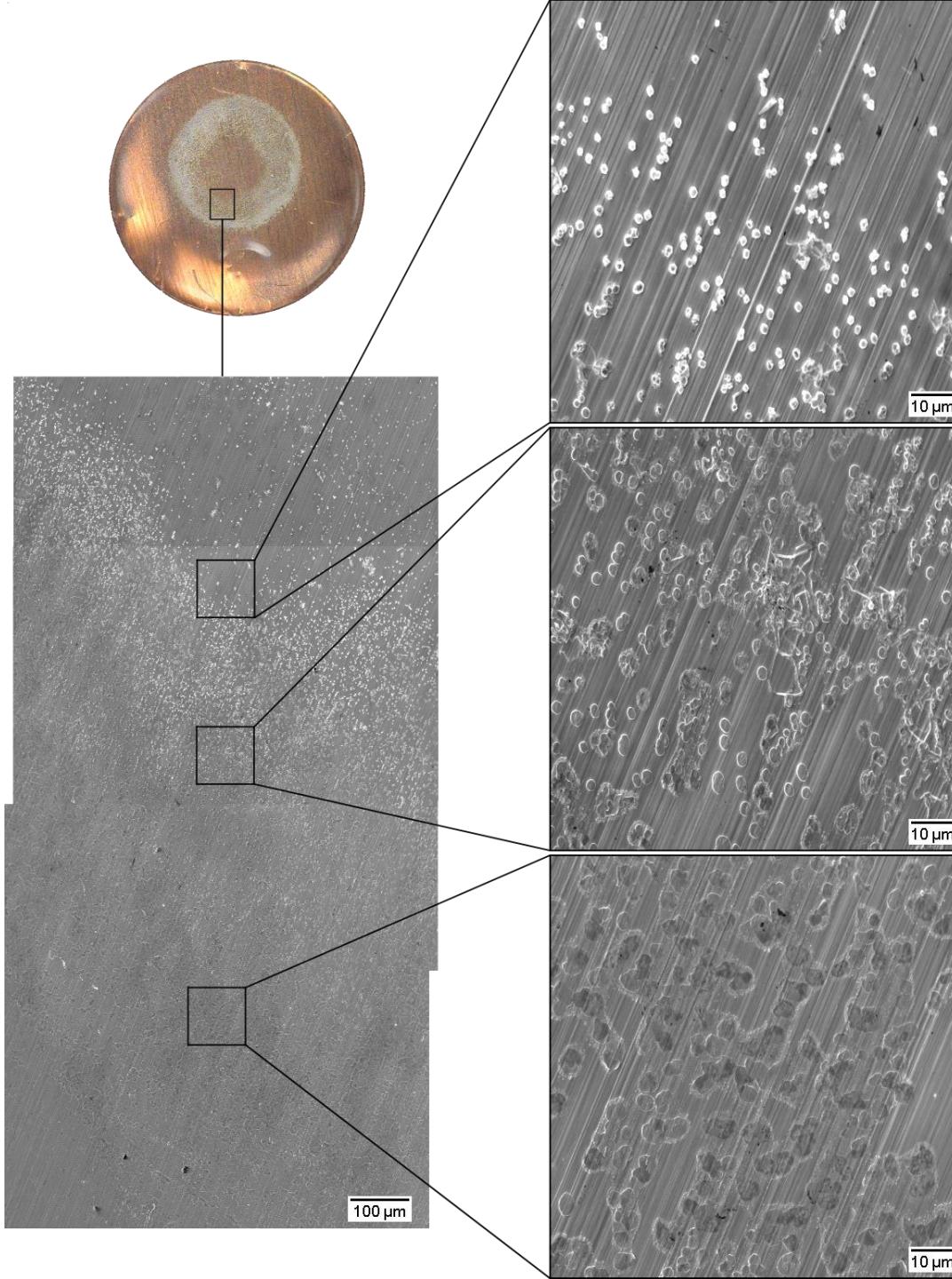
$2r = 1 \mu\text{m}$

$2r = 2 \mu\text{m} \text{ to } 3 \mu\text{m}$

$2r \geq 4 \mu\text{m}$

$25 \mu\text{Ah}/\text{cm}^2$

# Pressure effects



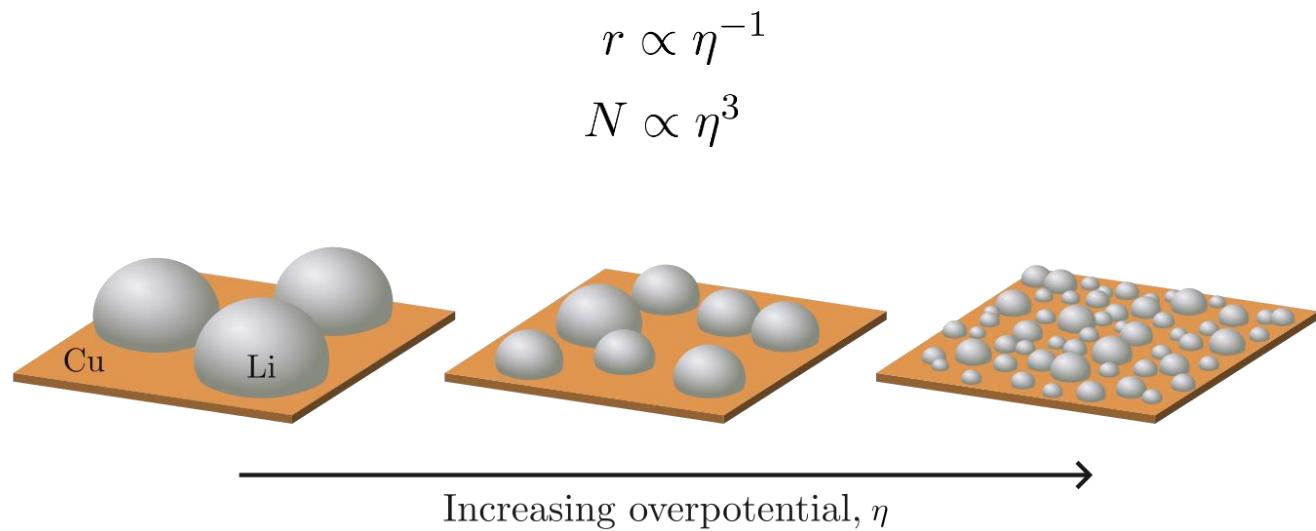
$2r = 1 \mu\text{m}$   
 $N = 0.024 \text{ nuclei}/\mu\text{m}^2$

$2r = 2 \mu\text{m} \text{ to } 3 \mu\text{m}$   
 $N = 0.022 \text{ nuclei}/\mu\text{m}^2$

$2r \geq 4 \mu\text{m}$   
 $N = 0.016 \text{ nuclei}/\mu\text{m}^2$

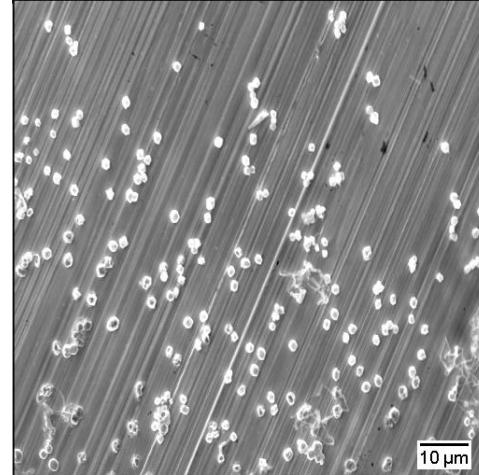
25  $\mu\text{Ah}/\text{cm}^2$

# Pressure effects



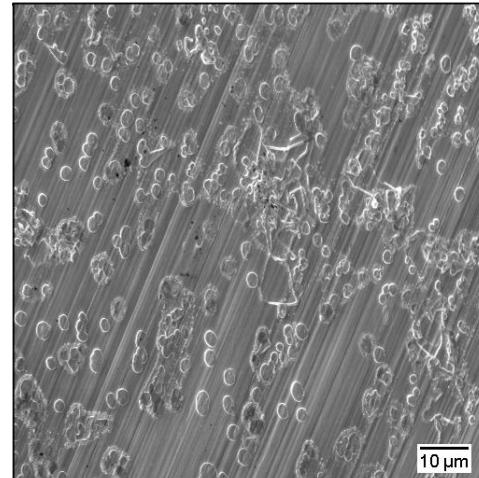
$$r \propto \eta^{-1}$$

$$N \propto \eta^3$$



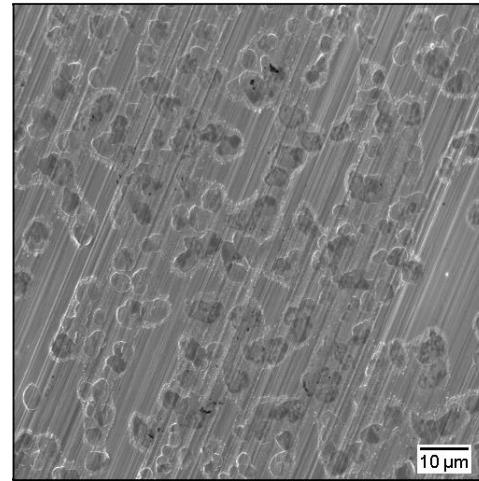
$$2r = 1 \text{ } \mu\text{m}$$

$$N = 0.024 \text{ nuclei}/\mu\text{m}^2$$



$$2r = 2 \text{ } \mu\text{m} \text{ to } 3 \text{ } \mu\text{m}$$

$$N = 0.022 \text{ nuclei}/\mu\text{m}^2$$



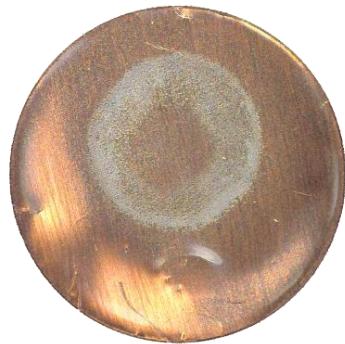
$$2r \geq 4 \text{ } \mu\text{m}$$

$$N = 0.016 \text{ nuclei}/\mu\text{m}^2$$

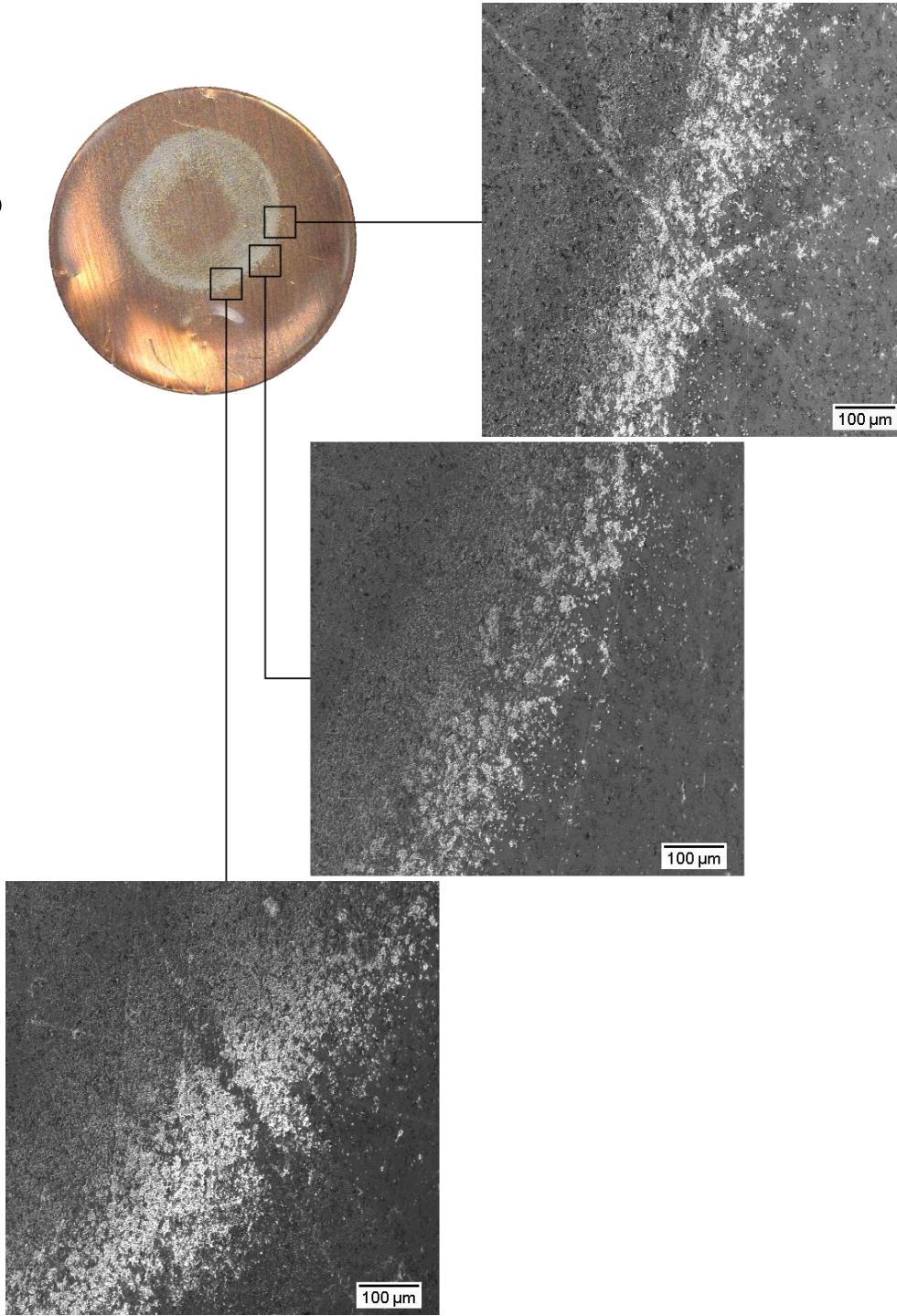
$$25 \text{ } \mu\text{Ah}/\text{cm}^2$$



# Pressure effects

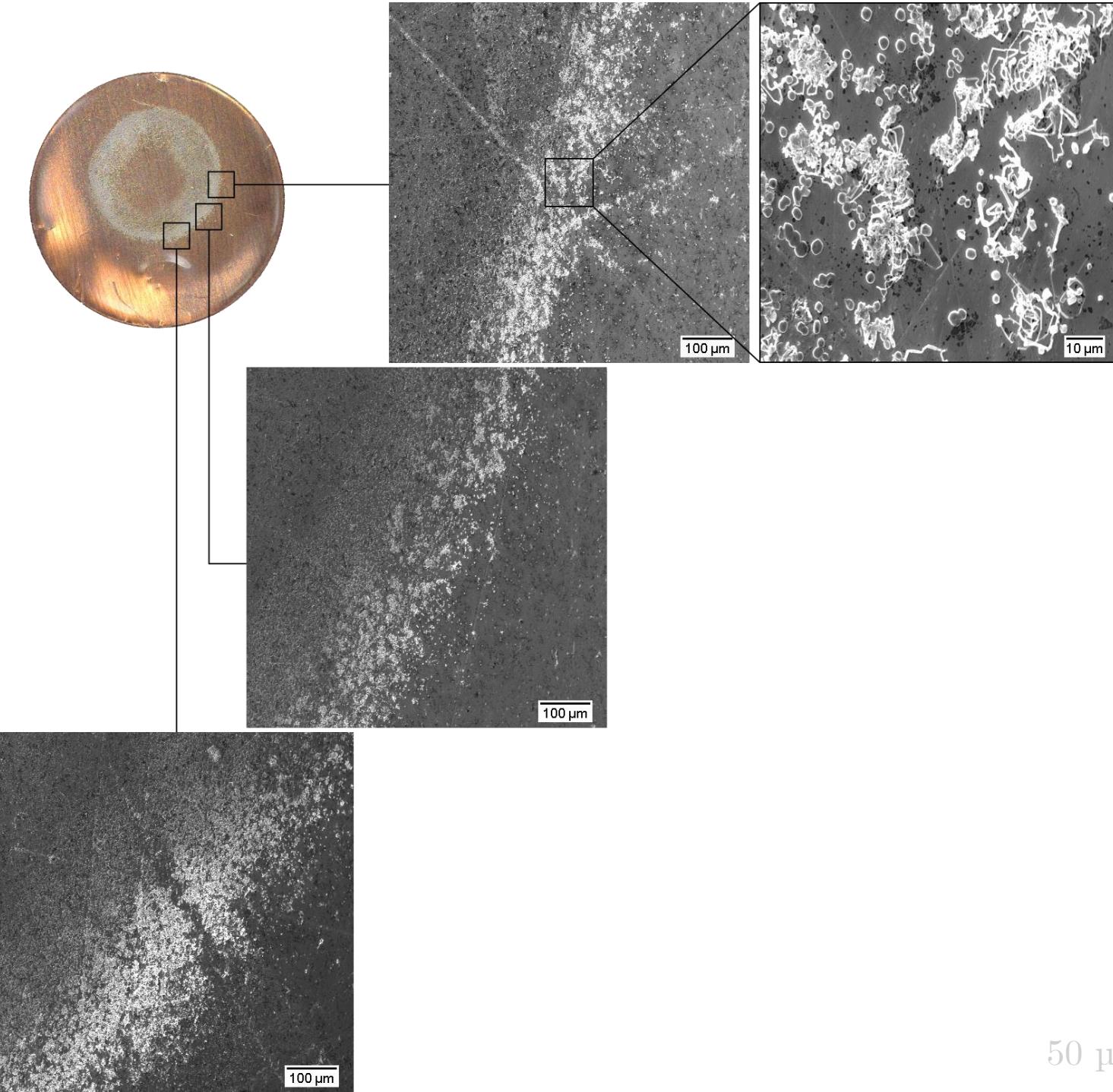


# Pressure effects

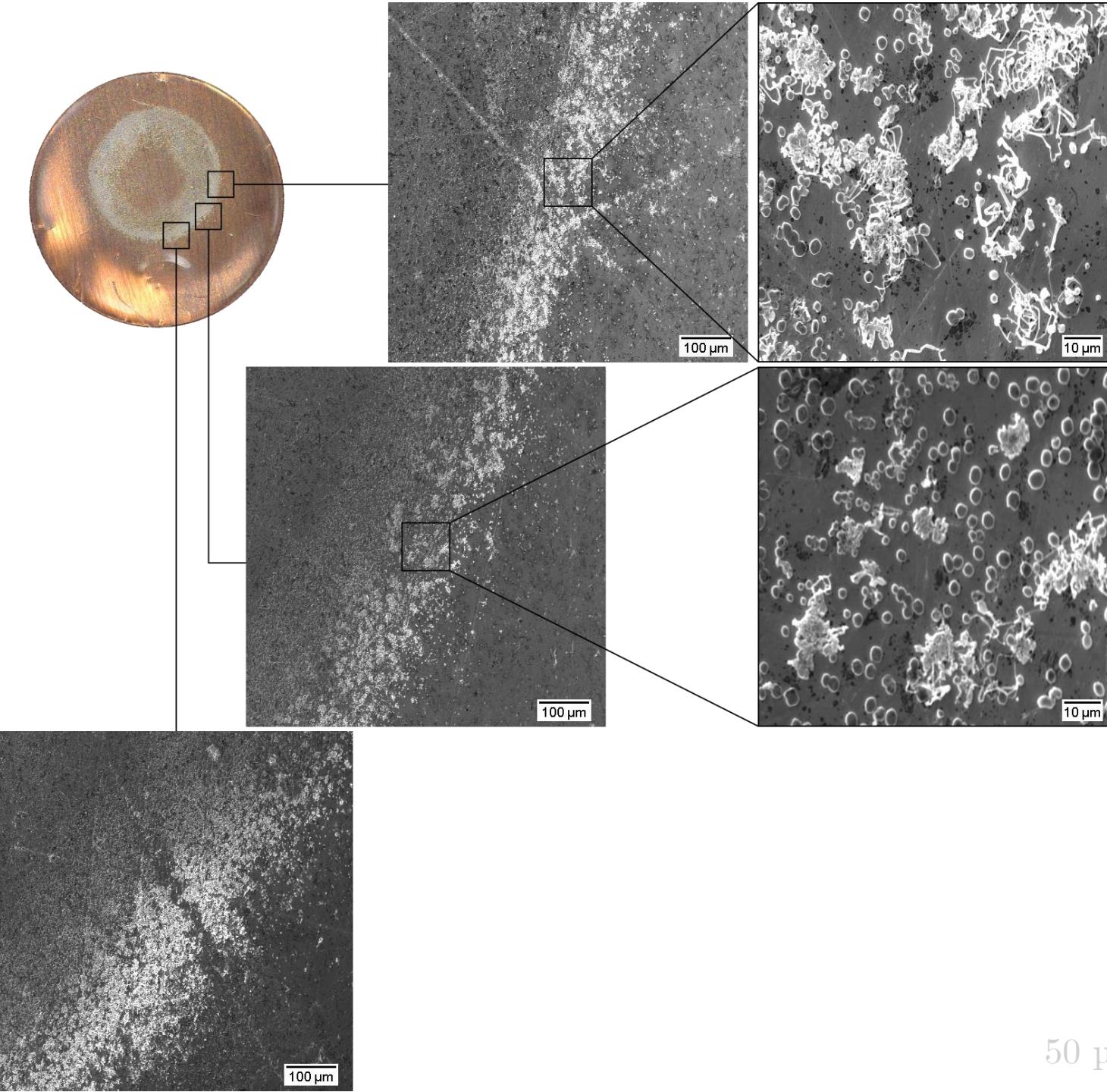


50  $\mu\text{Ah}/\text{cm}^2$

# Pressure effects



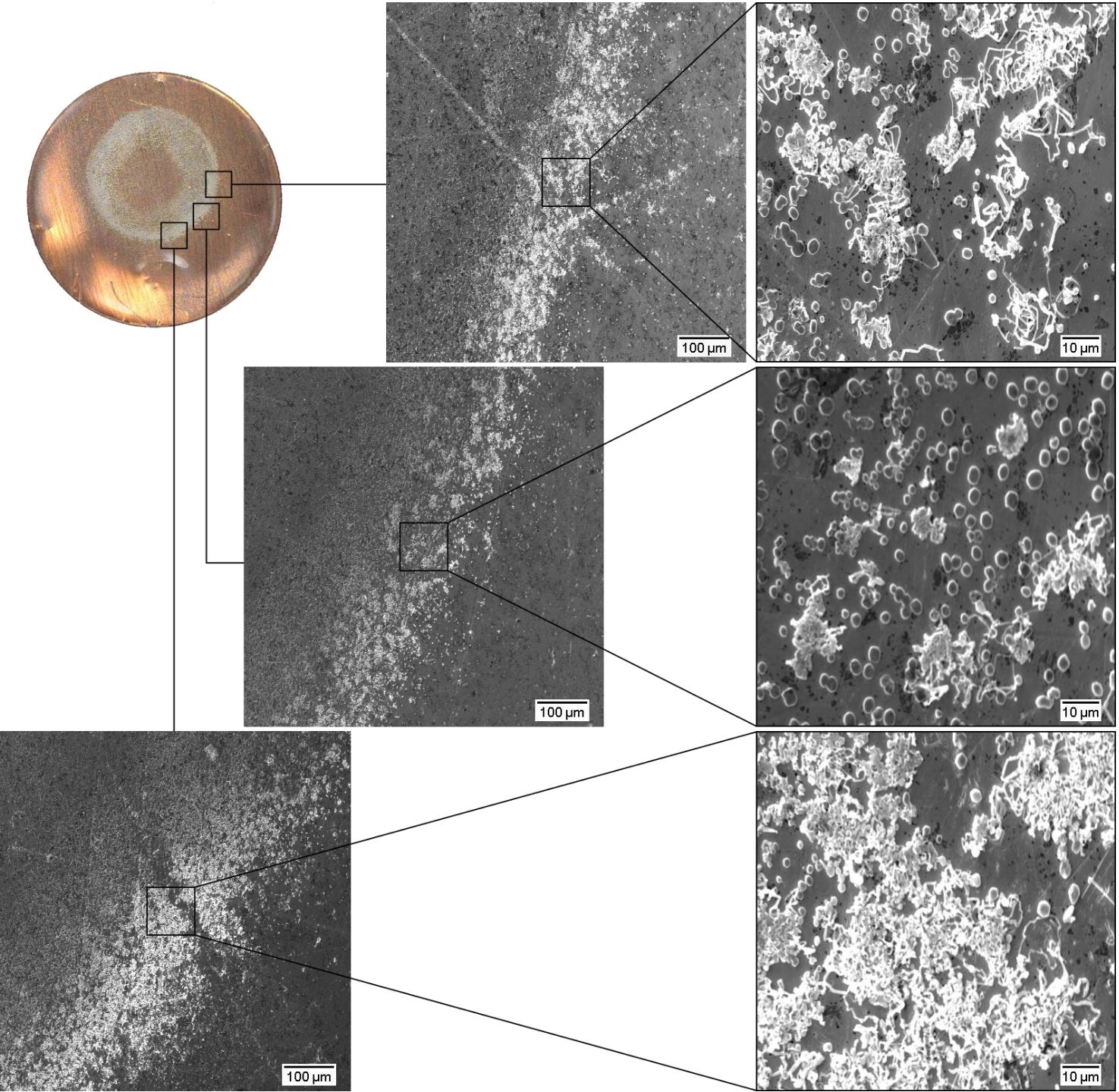
# Pressure effects



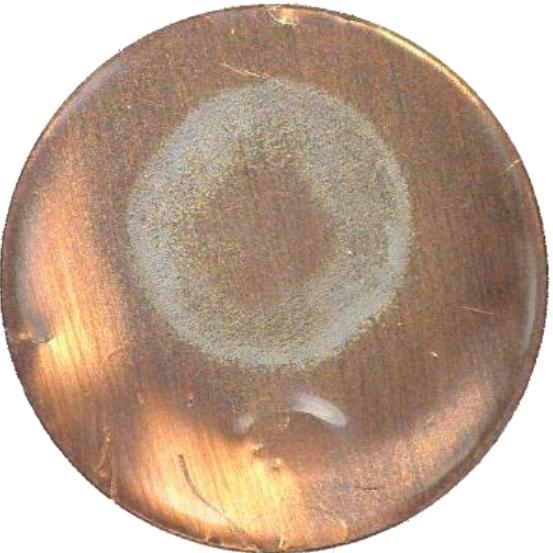
50  $\mu\text{Ah}/\text{cm}^2$



# Pressure effects



# Pressure effects



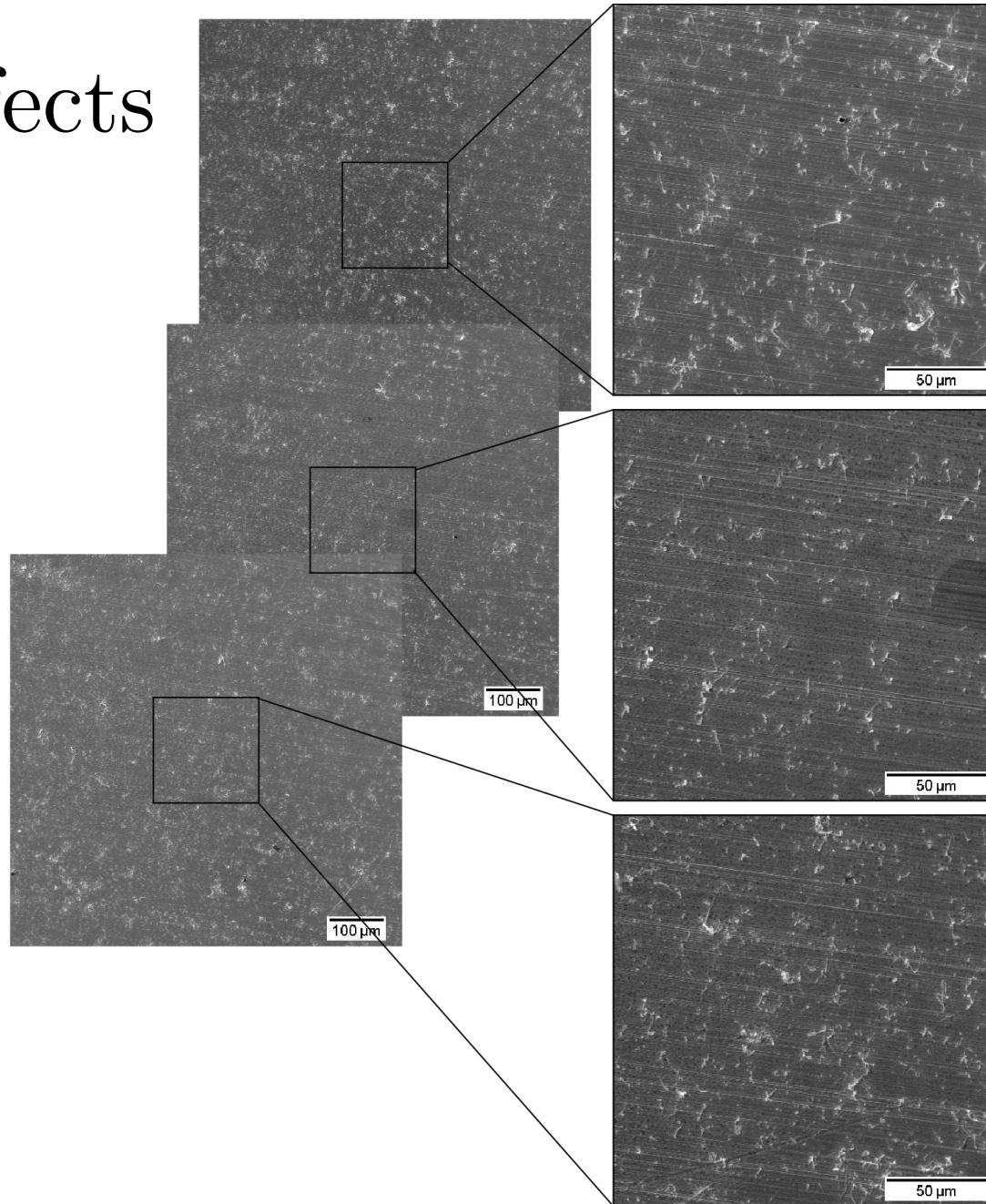
Wave spring



# Pressure effects

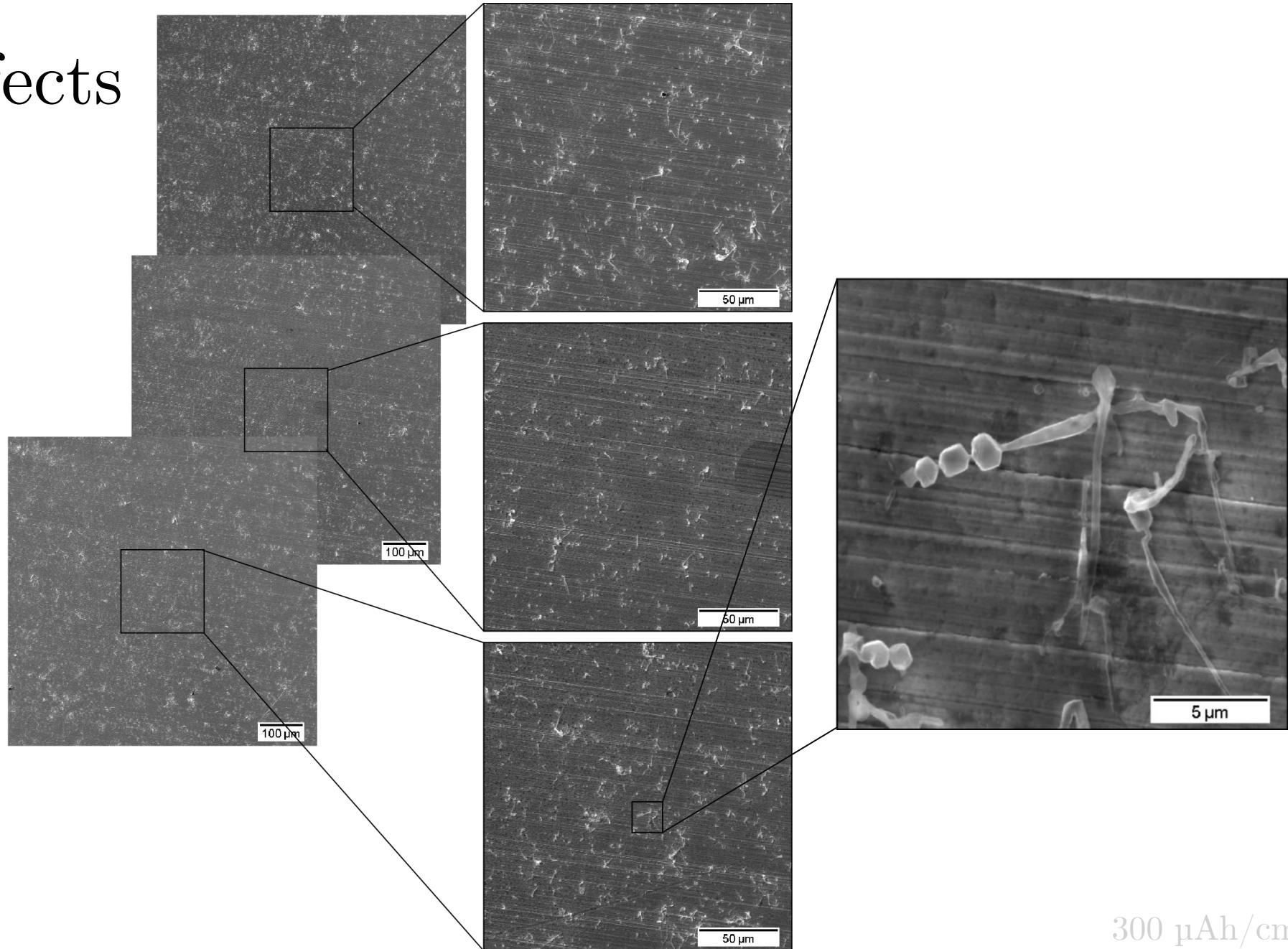


# Pressure effects



300  $\mu\text{Ah}/\text{cm}^2$

# Pressure effects

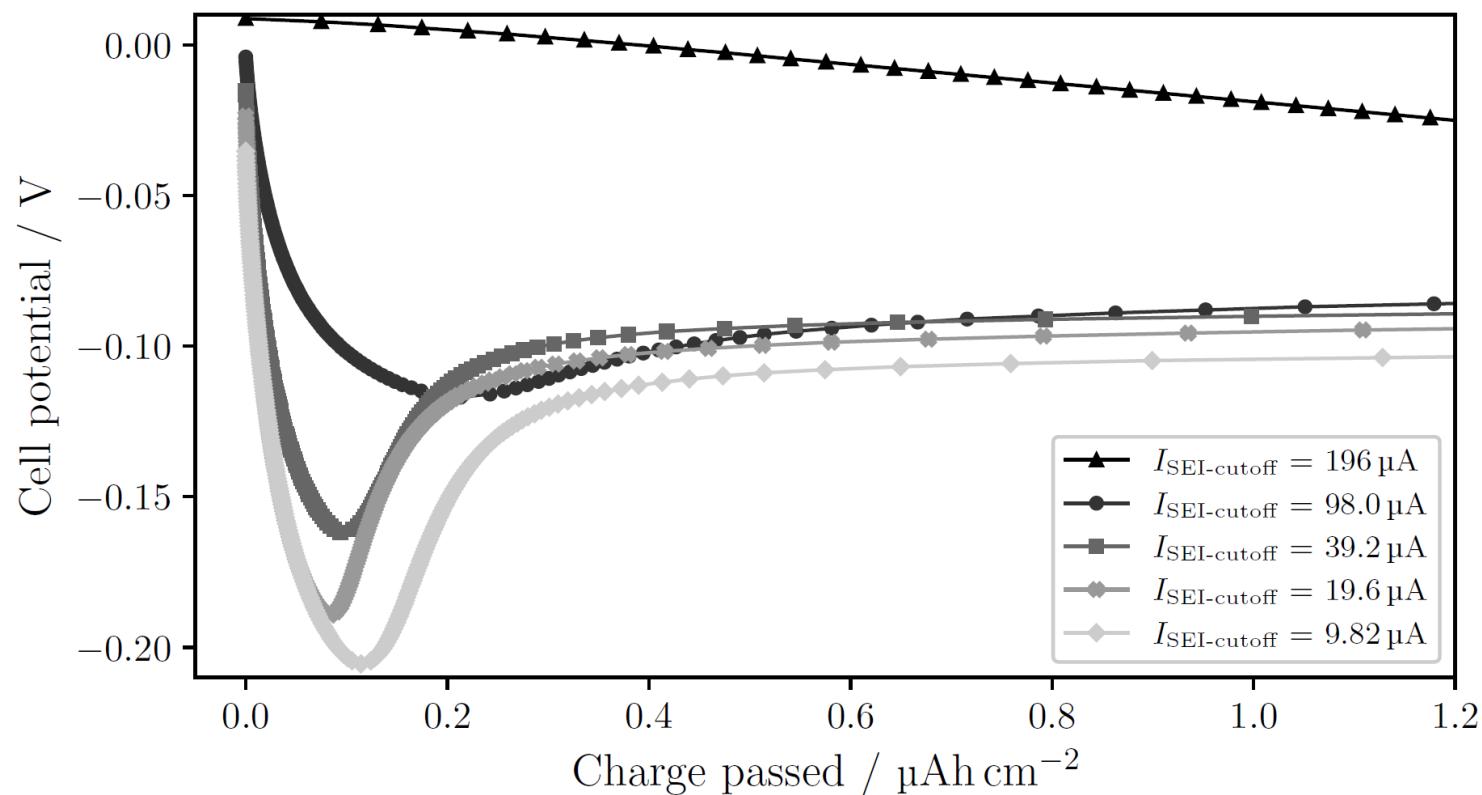


$300 \mu\text{Ah}/\text{cm}^2$



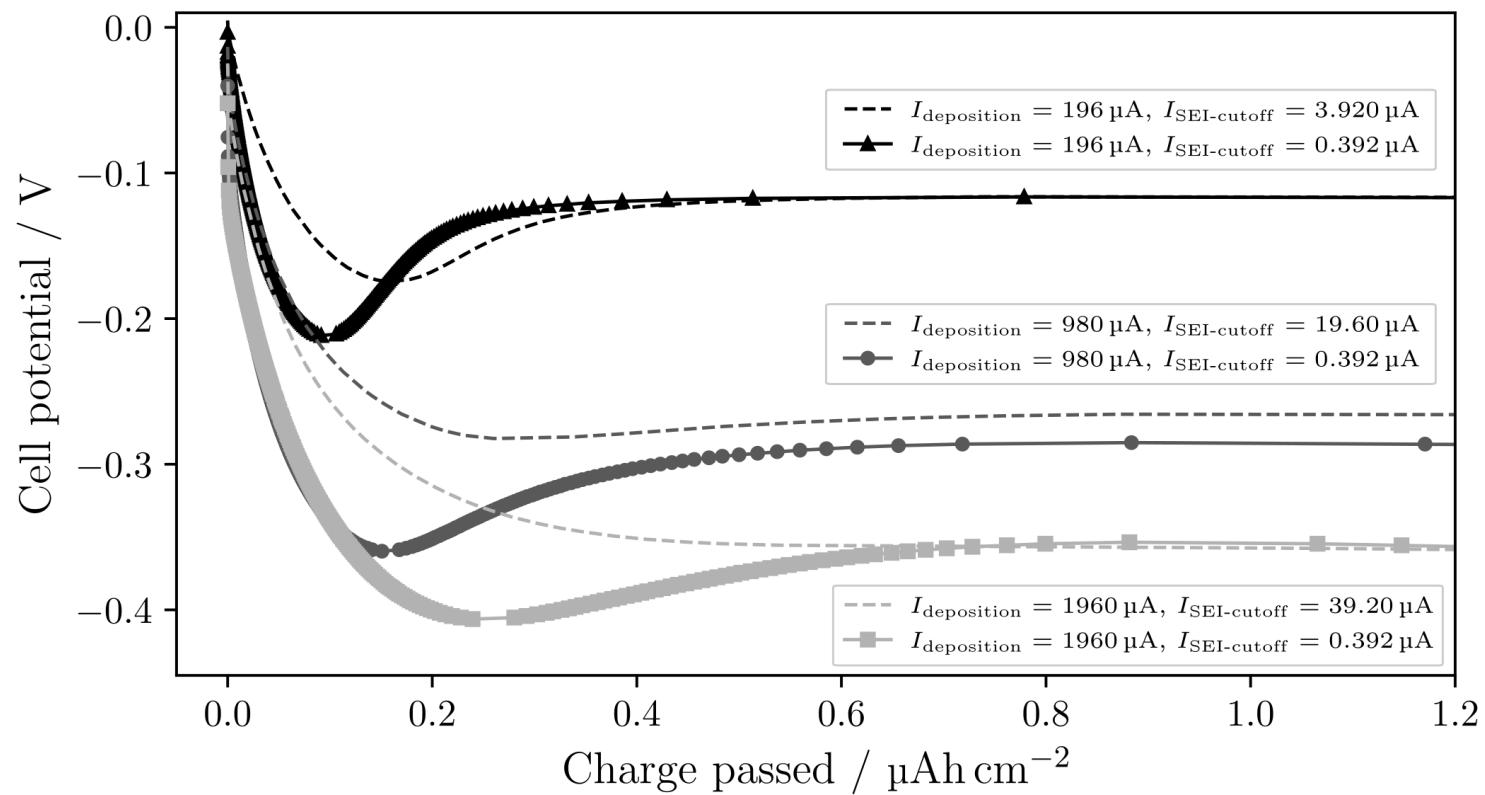
# Conclusions

1) More instantaneous nucleation can be induced by passivating the surface more before deposition.



# Conclusions

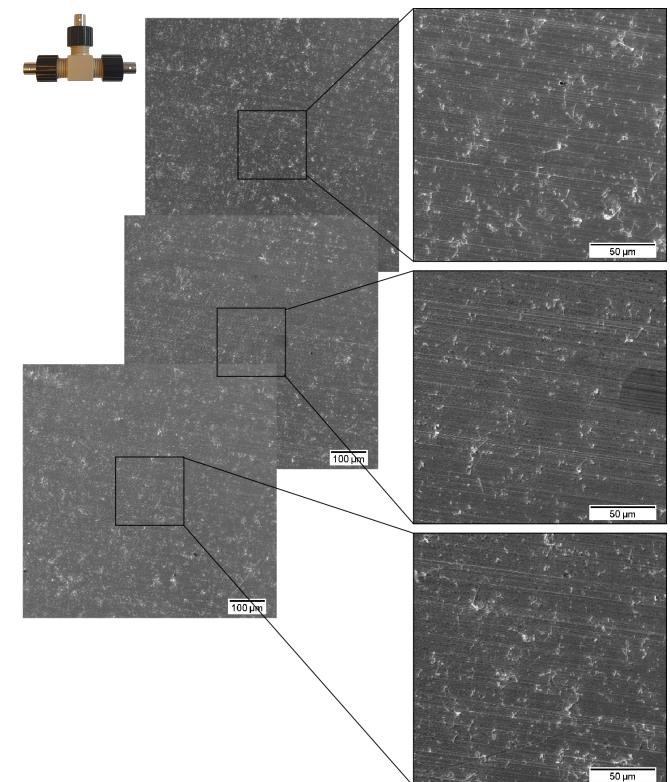
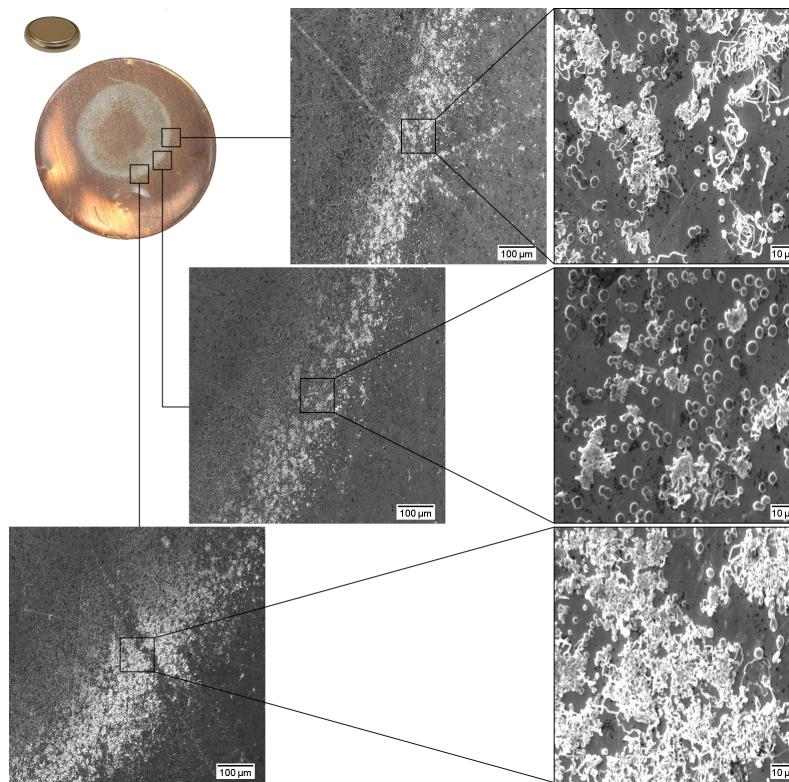
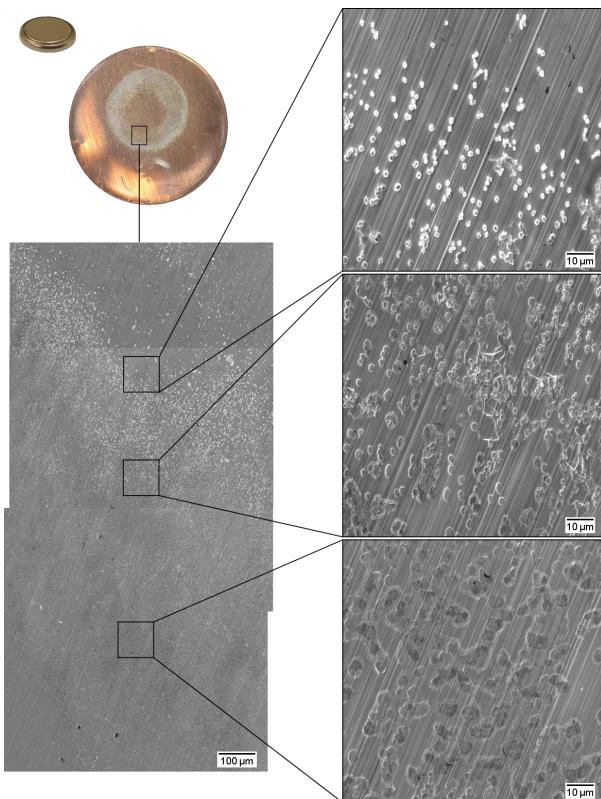
2) For larger deposition currents, a larger overpotential is seen. This should result in smaller nuclei with larger areal density.



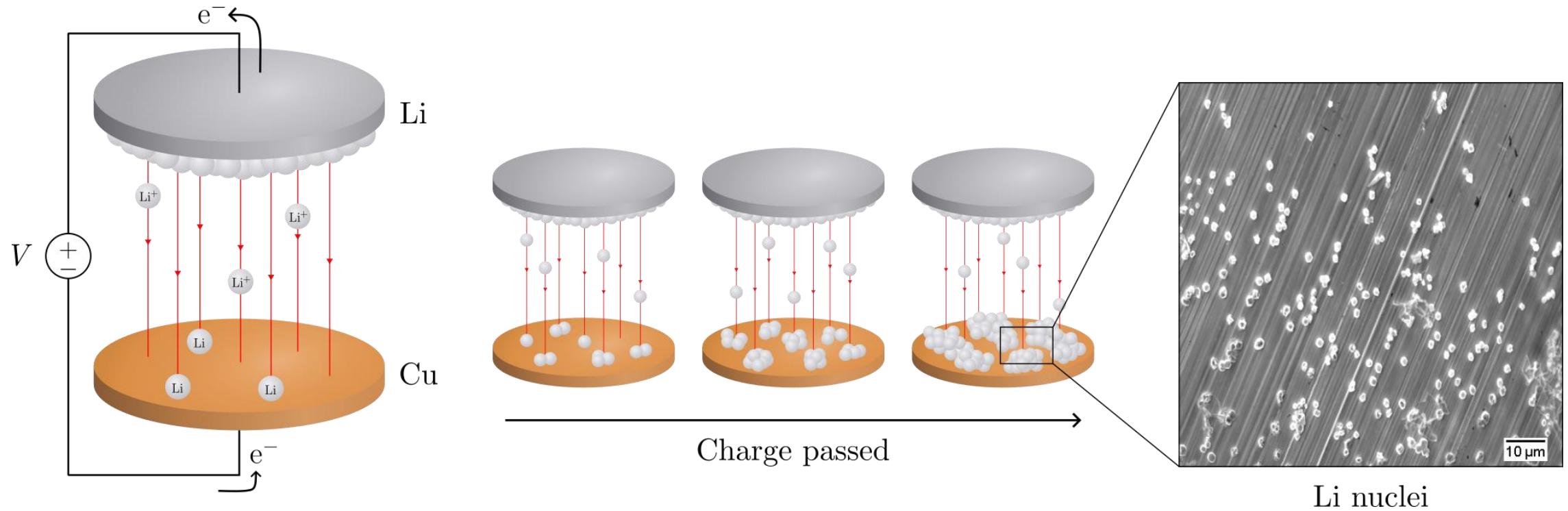
$$r \propto \eta^{-1}$$
$$N \propto \eta^3$$

# Conclusions

3) Uniform pressure between the electrodes is essential to achieve uniform deposition in Li-metal batteries.



Thank you for listening!



# Electrochemical Deposition of Lithium on Copper

Gottfrid Olsson

2024-05-29