Exploring the Feasibility to make a "Paint Battery"

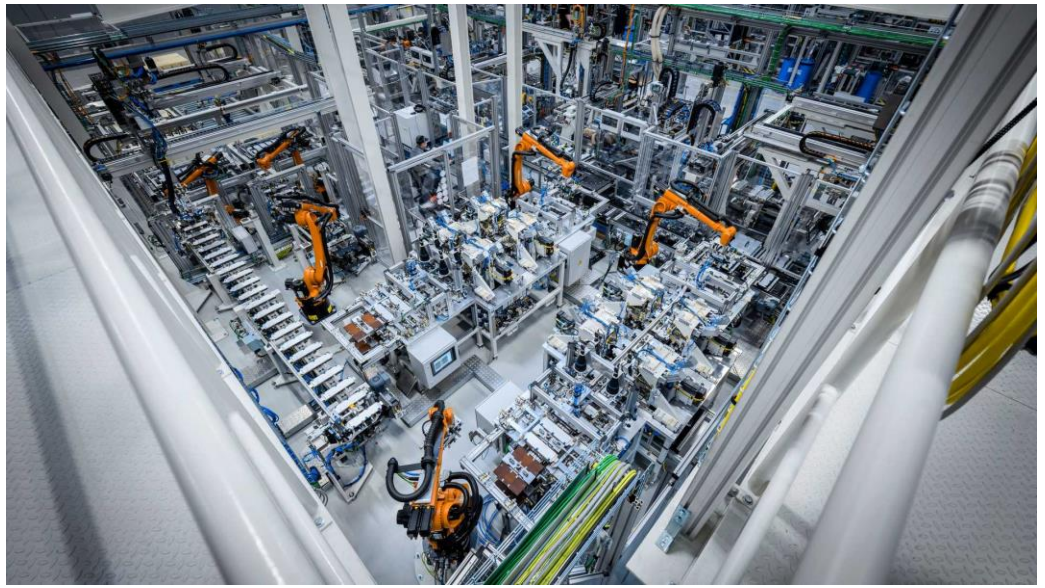
Andreas Grasser, 12.11.2021

Motivation

- Battery production has many steps

→ Battery production separately from actual device assembly

→ More steps, more expensive



Battery production for Mercedes electric cars

Reduction of production steps can lead to lower prices and broader applications (e.g. in small IoT devices)

Long Term Goal

One paint that produces the three layers of a battery by itself:

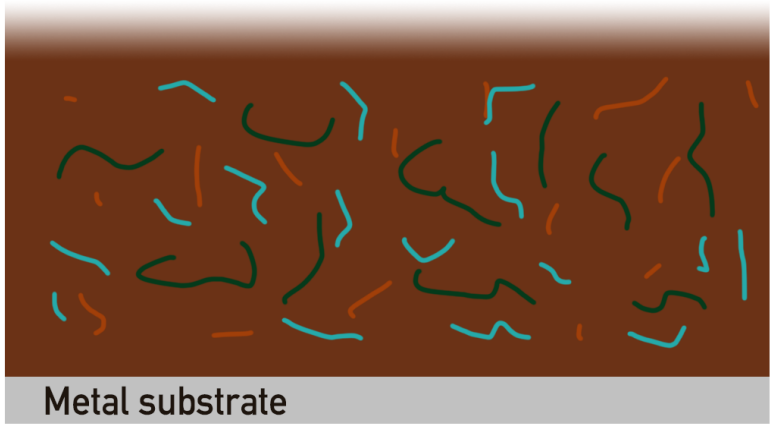
- cathode
- polymer electrolyte / separator
- anode

“Wall paint that forms a battery”

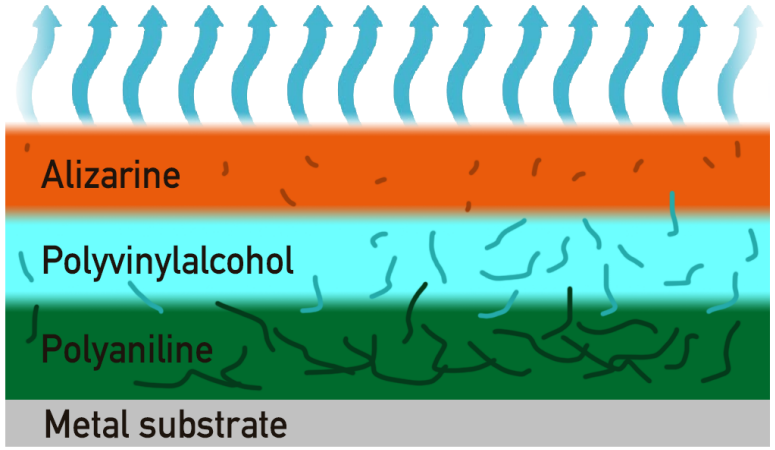
https://www.obi.de

Long Term Goal

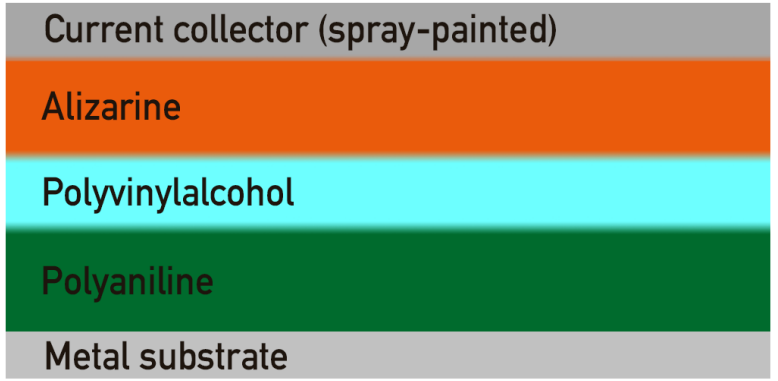
1. Casting of the substrate with paint



2. Evaporation of solvent and self-stratification

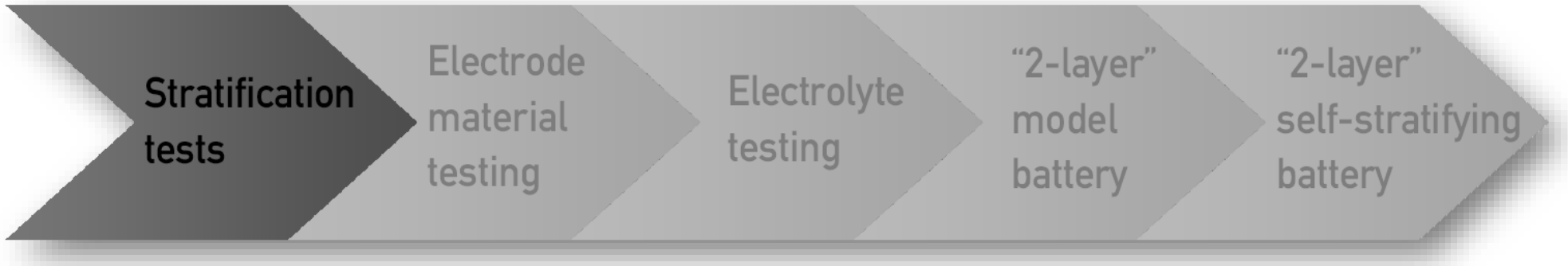


3. Spray-painting the second electrode

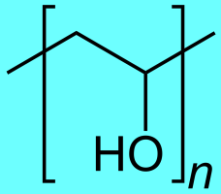
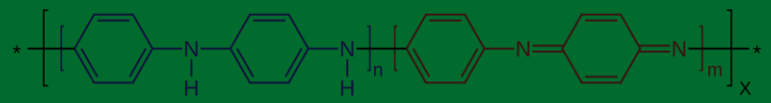


Possible Steps

- Simple 2-layer stratification experiments
- Testing the electrochemical properties of the electrode materials
- Testing the electrolyte
- Building a complete cell with “traditional” methods
- 2-layer cell using self stratification



Material Focus

Zinc: -0,9V vs Ag/AgCl	Anode	Zinc Alizarin
Conductivity: 10^{-4} S/cm Activ. Energy: 0,1eV	Electrolyte 	Polyvinyl alcohol (PVA)
PANI: 0,2V vs Ag/AgCl	Cathode 	Polyaniline
	Current Collector	Aluminum, stainless steel, Zinc

+ conducting salts:
Sodium perchlorate
Zinc chloride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Contact angle measurements

Measure hydrophility of surface by putting a drop of liquid onto the surface

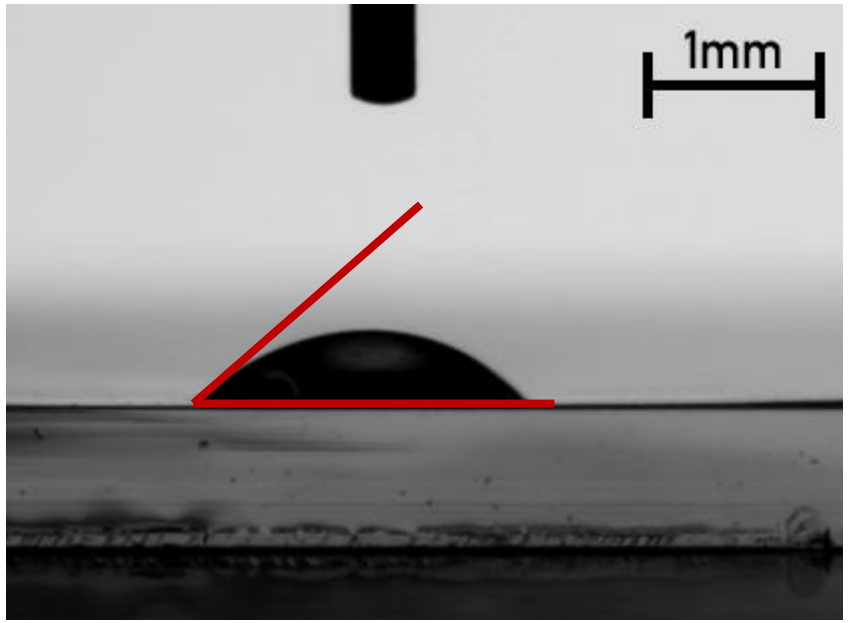
→ possible test for a successful stratification

→ with different liquids: measurement of free surface energy possible

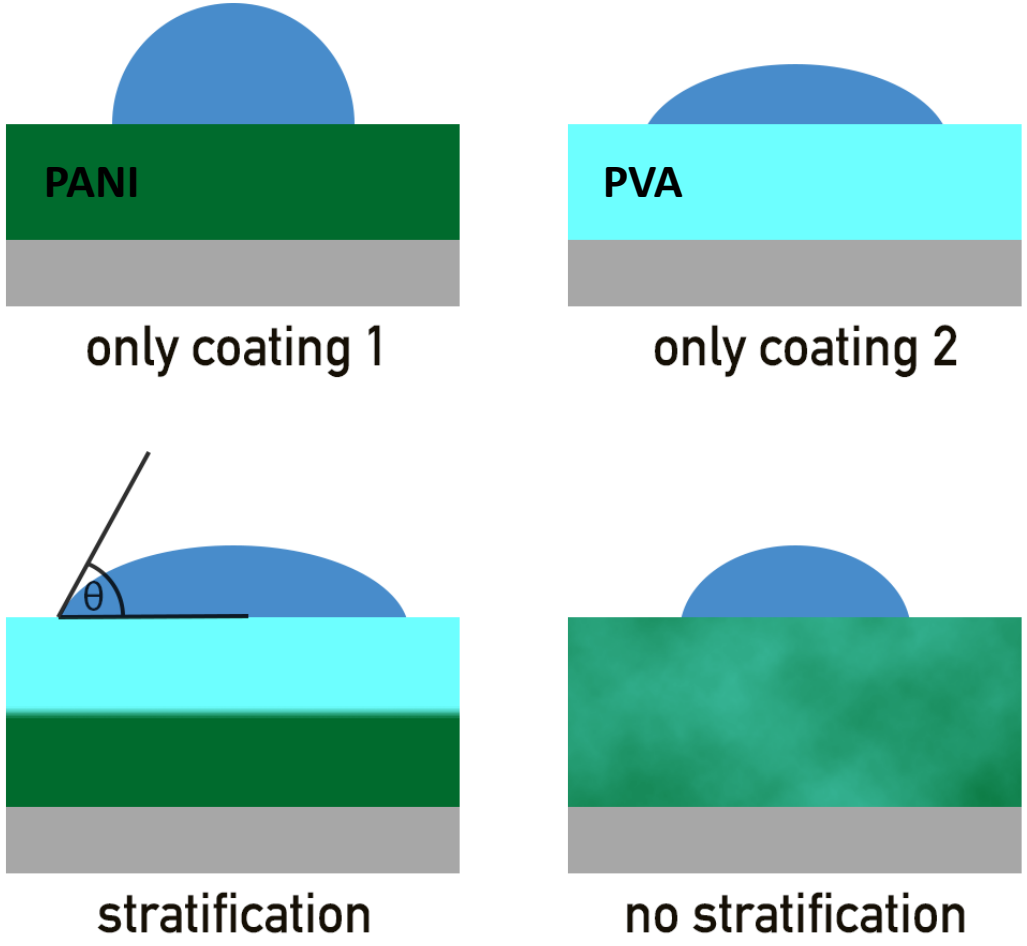
+ Very fast and easy

- Many error sources

  (e.g. soaking into PVA, dirt/fat on surface)

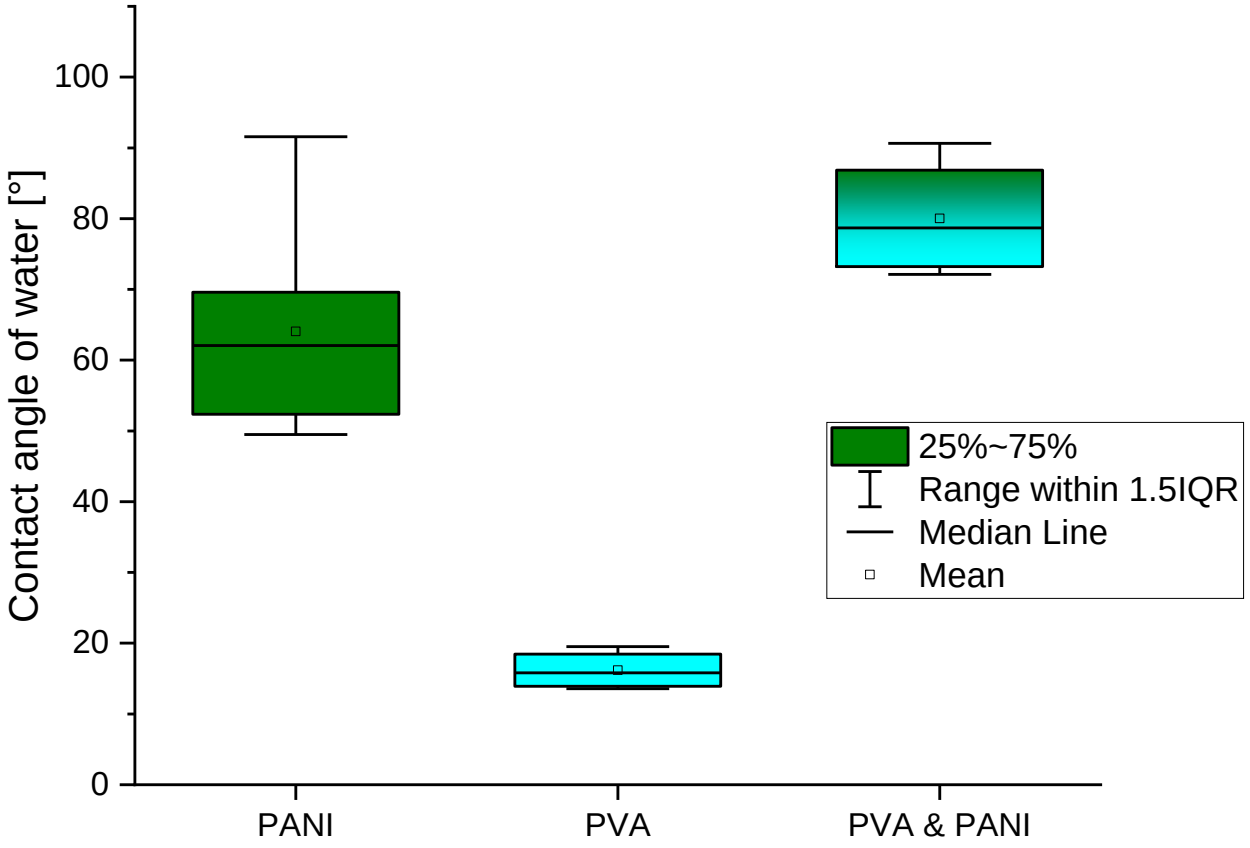


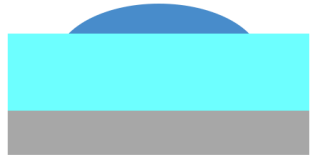
Contact angle measurements

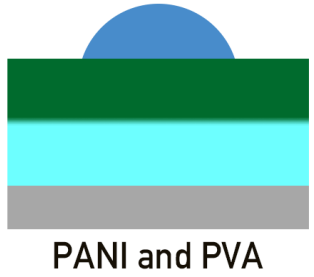


Battery with two layer stratification

- Stratification of Polyaniline + PVA on Aluminum foil?

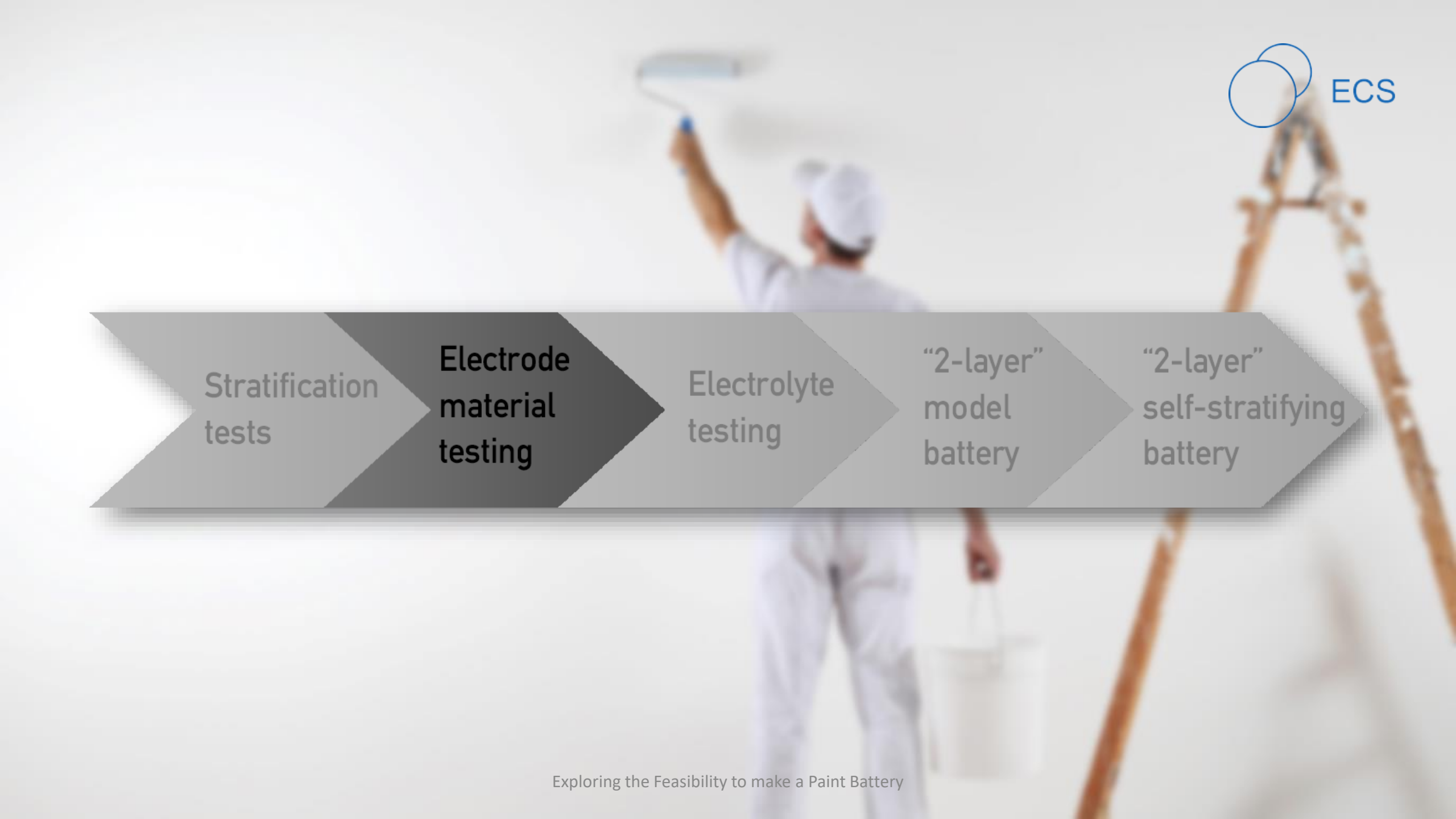






Battery with two layer stratification

- Try the stratification electrochemically using a zinc substrate as anode and Zinc Chloride as conducting salt
- Possible difficulties:
  - Zinc has different surface energy than Aluminum
  - Zn^{2+} /Cl^{-} instead of Na^{+} ions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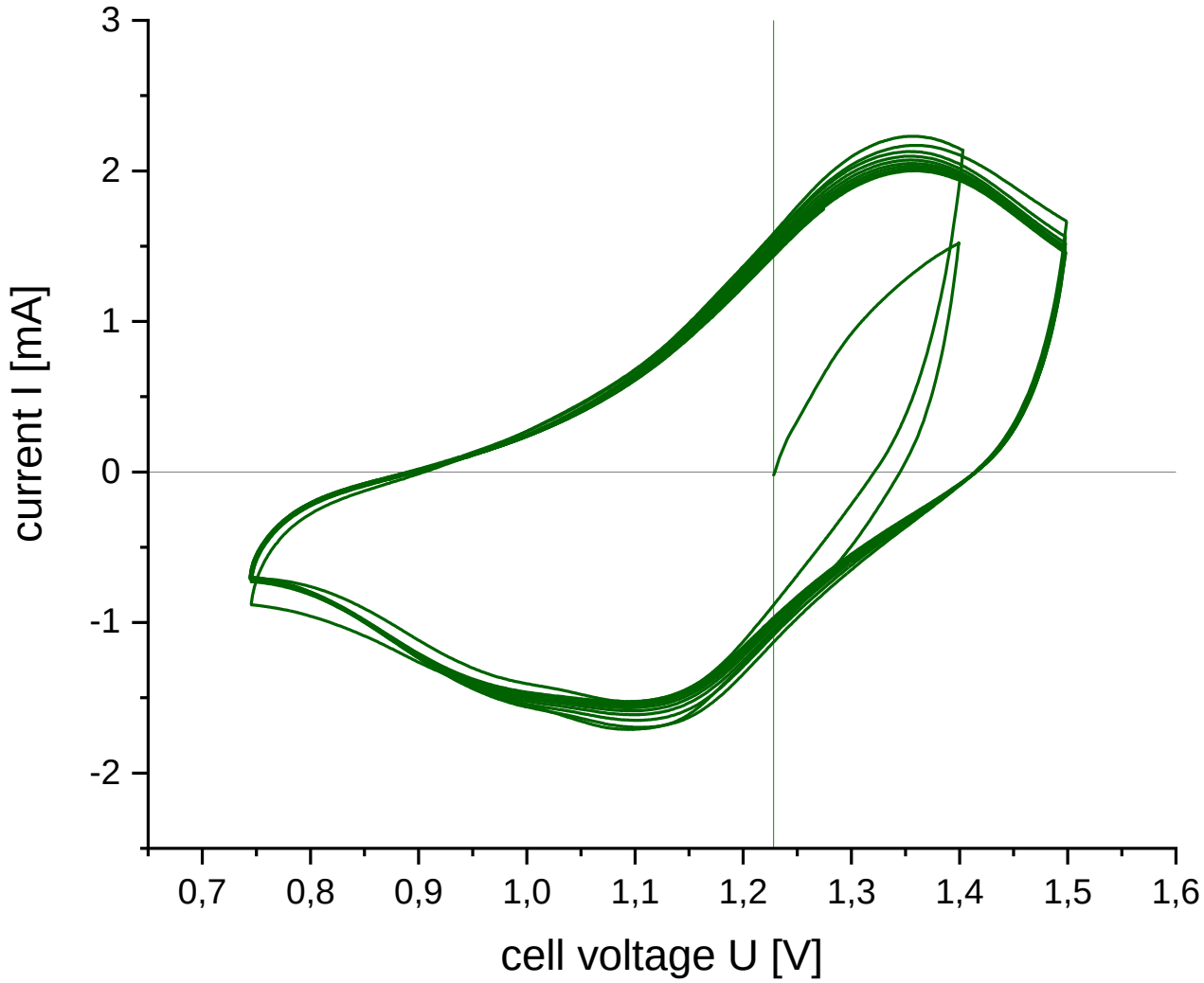
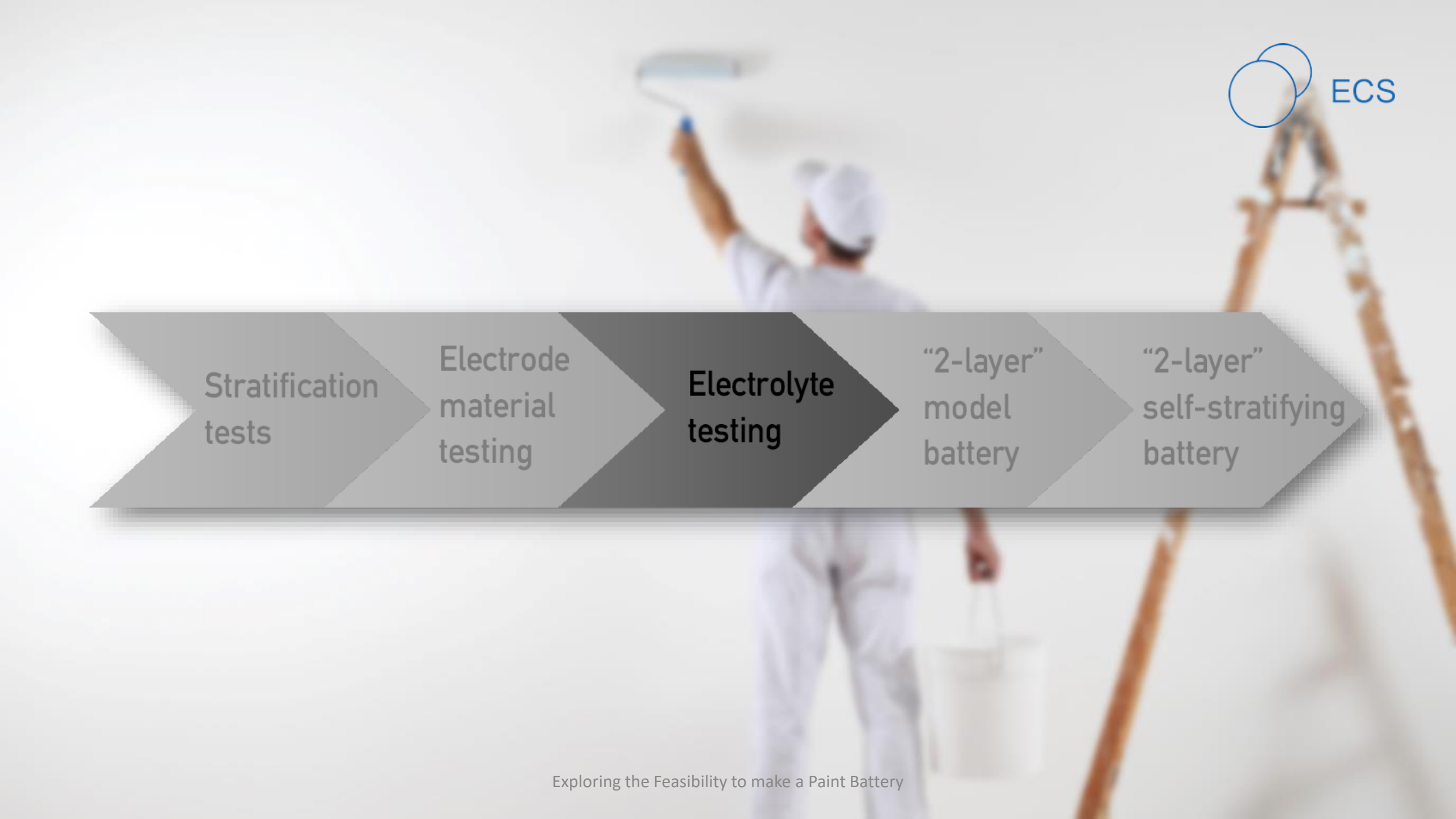
Aqueous Zinc-PANI Battery

- Try a full Zinc-PANI battery in a 3-electrode setup
- Using 1M ZnCl2 aqueous electrolyte

→ Working cell with 1,23V OCV

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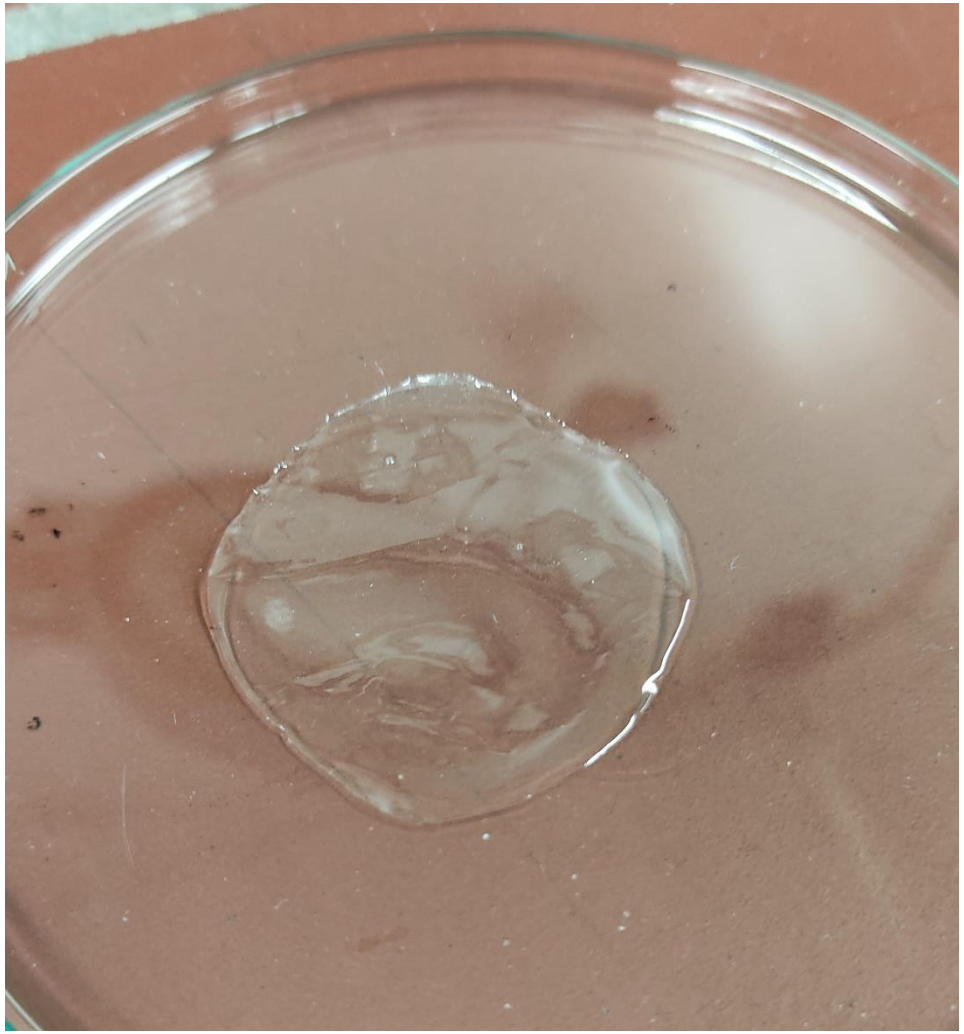
Free standing PVA films

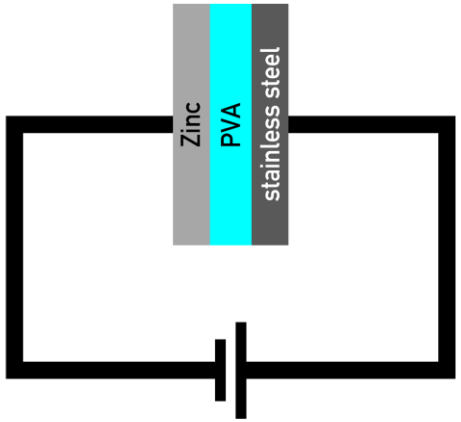
1. Dropcasting PVA-$ZnCl_2$-water solution on glass petri dish
2. Drying at 45°C for ~1h
3. Removing the film with a scalpel
4. Drying at 45°C for ~10min
5. Pressing in coin cell with 45kN

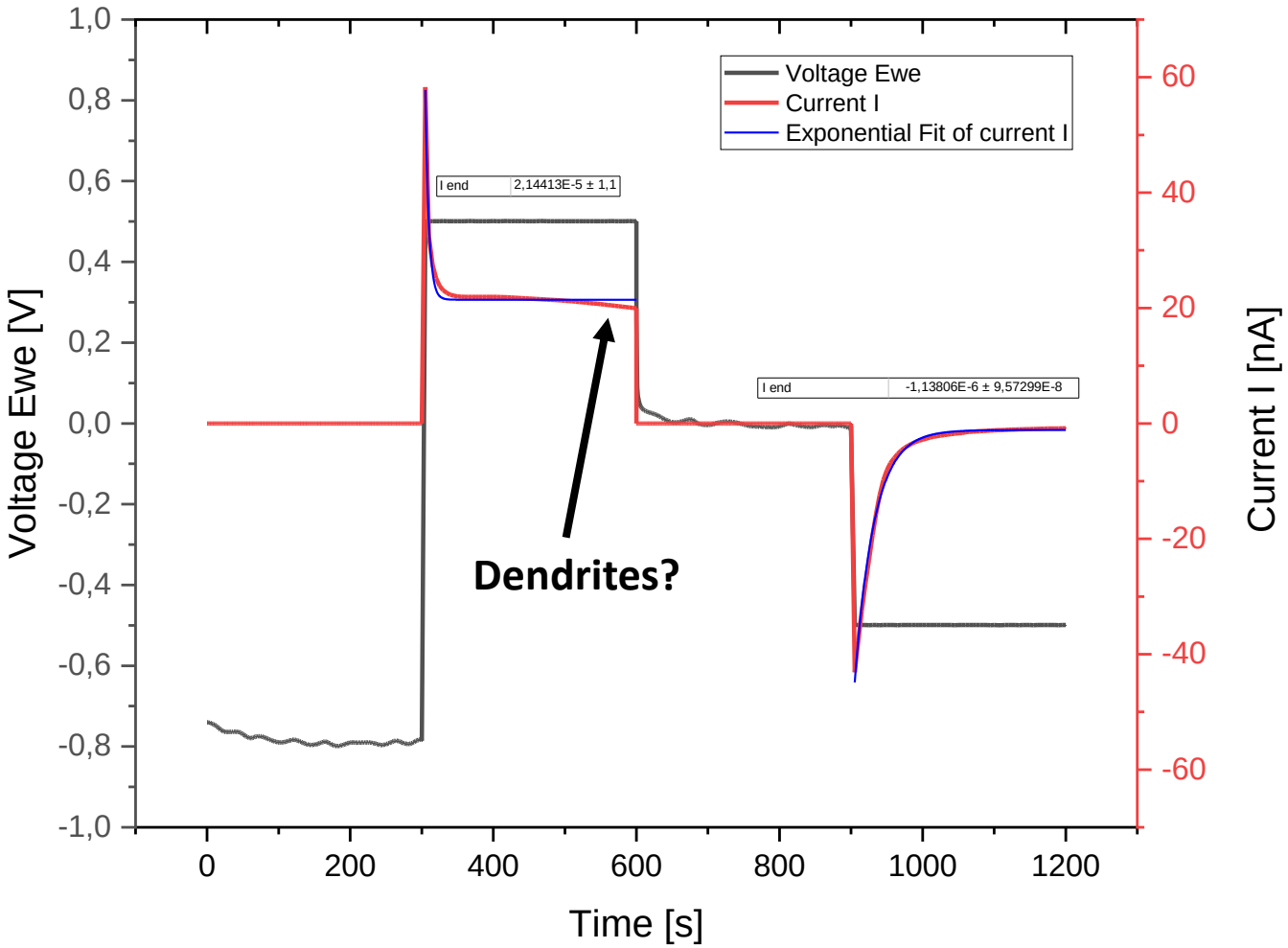


DC polarisation: Can PVA conduct Zinc?

- Using one stainless steel and one zinc contact and apply 0,5V and -0,5V to the electrolyte
- Zn-ion current of 21,4nA

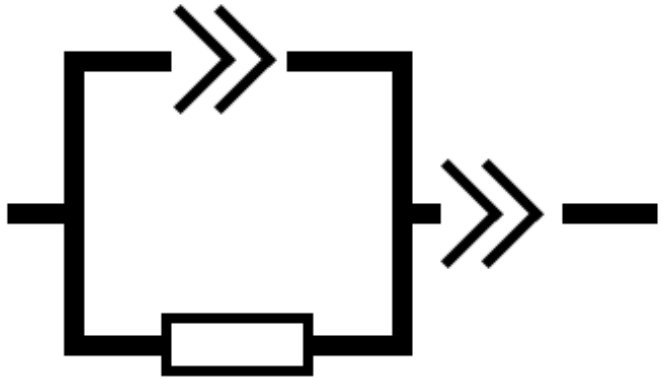
→ PVA can conduct Zinc-Ions!

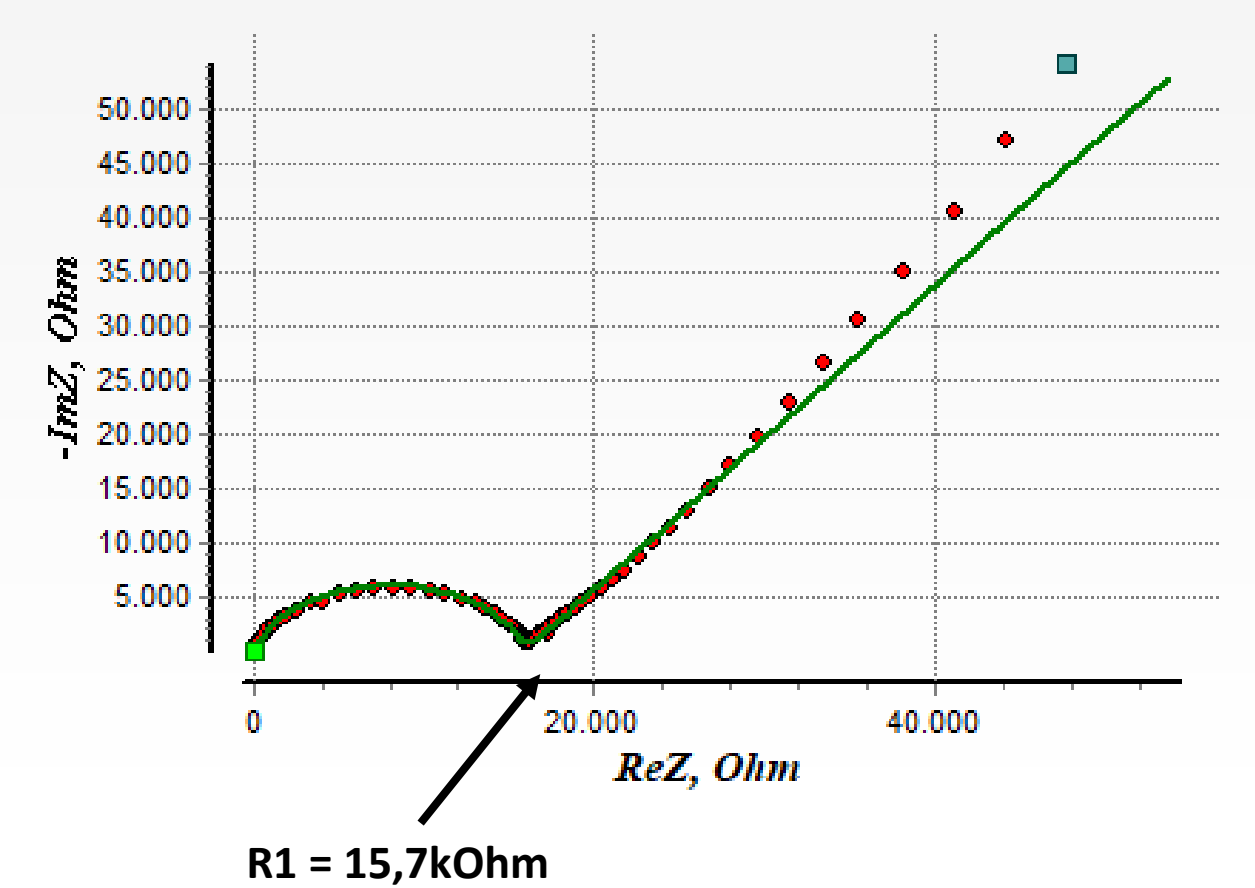




Impedance spectroscopy

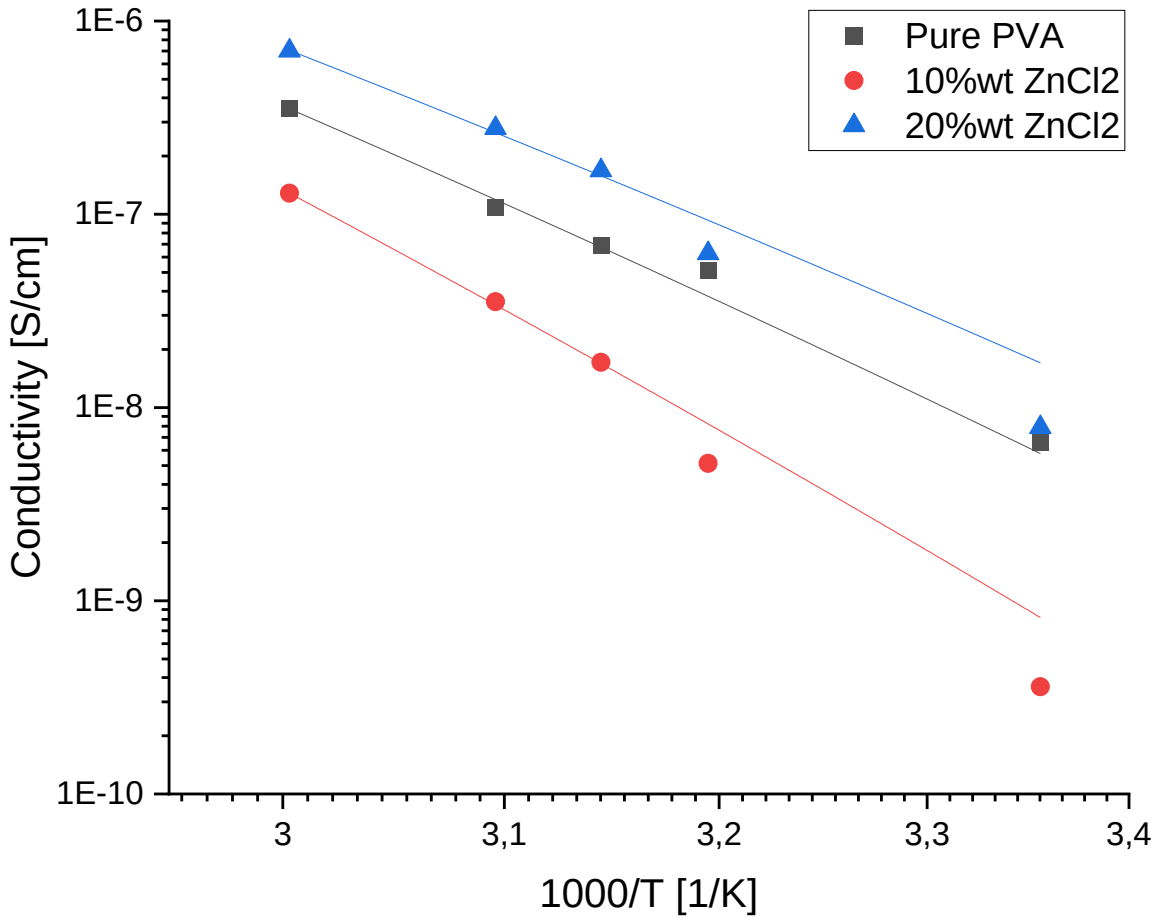
- Using stainless steel contacts for blocking conditions
- Fitting with following circuit:





ZnCl2 Concentration in PVA

- Strong dependence of the conductivity on the temperature
- But still very low conductivity of max. $7 \cdot 10^{-7}$ S/cm
- Activation Energy: $Ea \approx 0{,}7eV - 1eV$



New PVA with longer polymer chains

Most papers use longer chain PVA for the films

Problem:

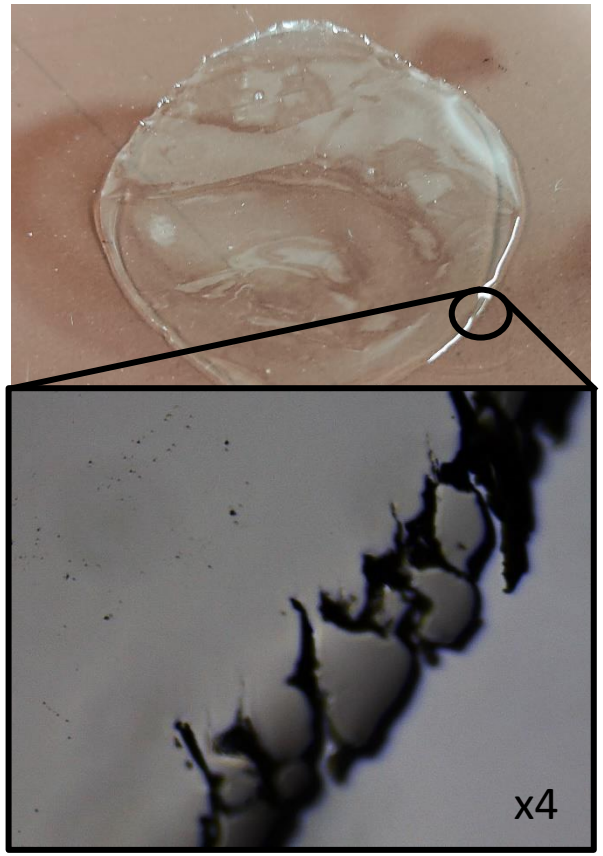
No smooth films with the new longer chain PVA!

→ Longer stirring?

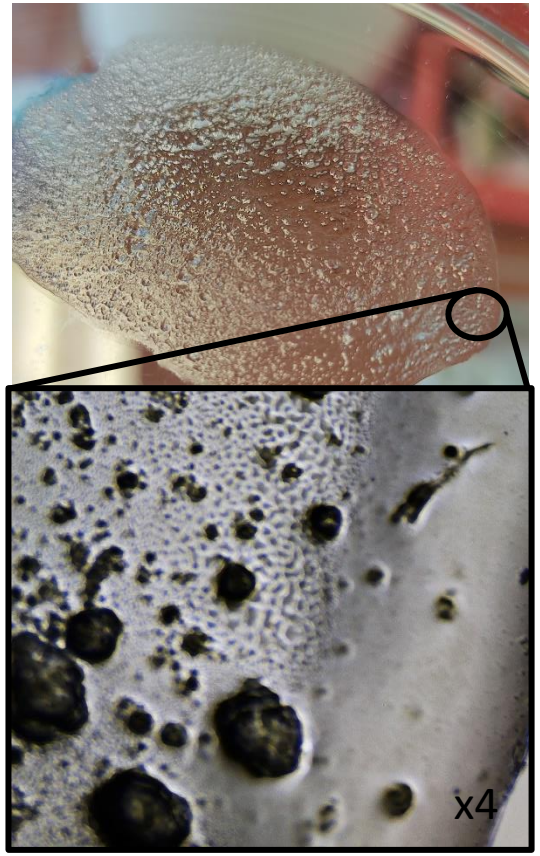
→ More water?

→ **Higher temperature!**

PVA with Mw 9.000



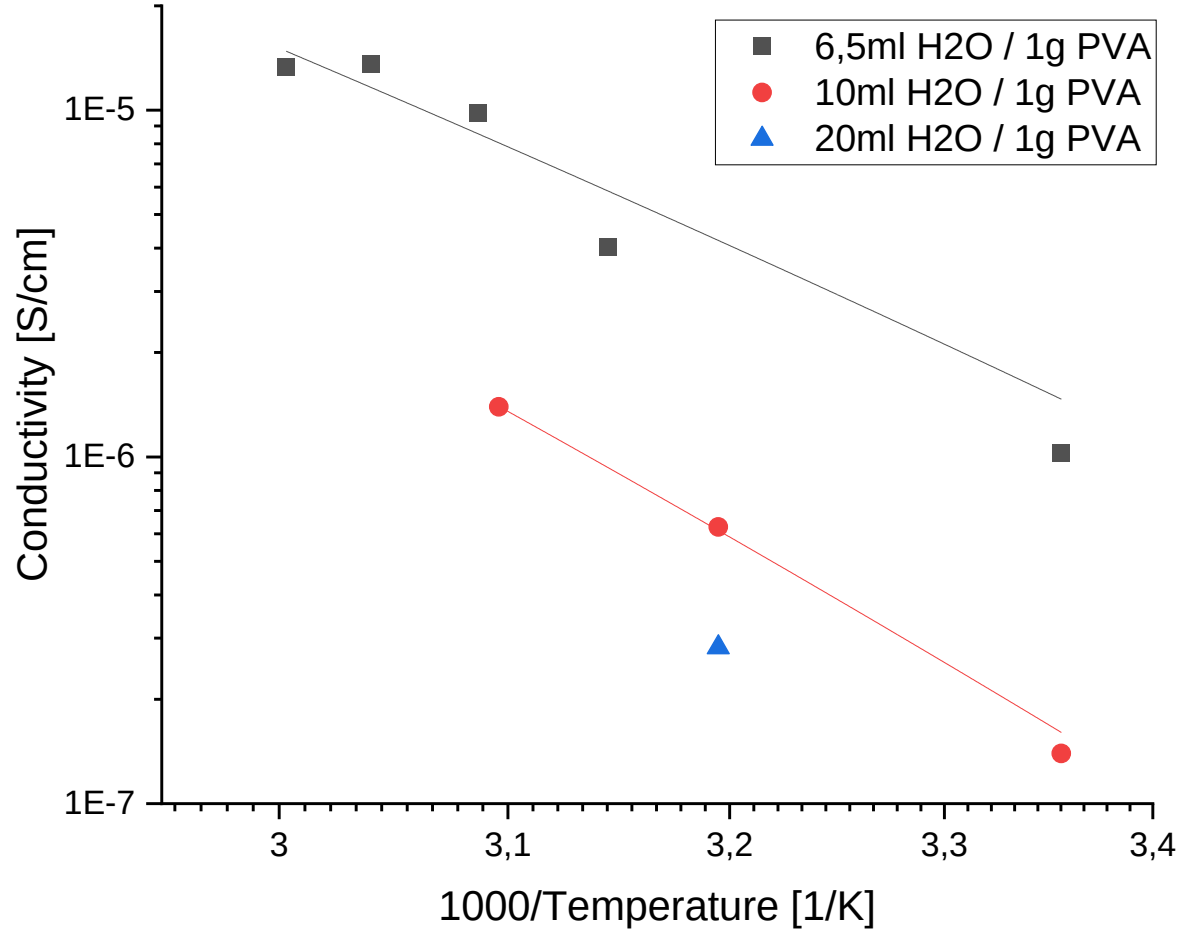
PVA with Mw 90.000

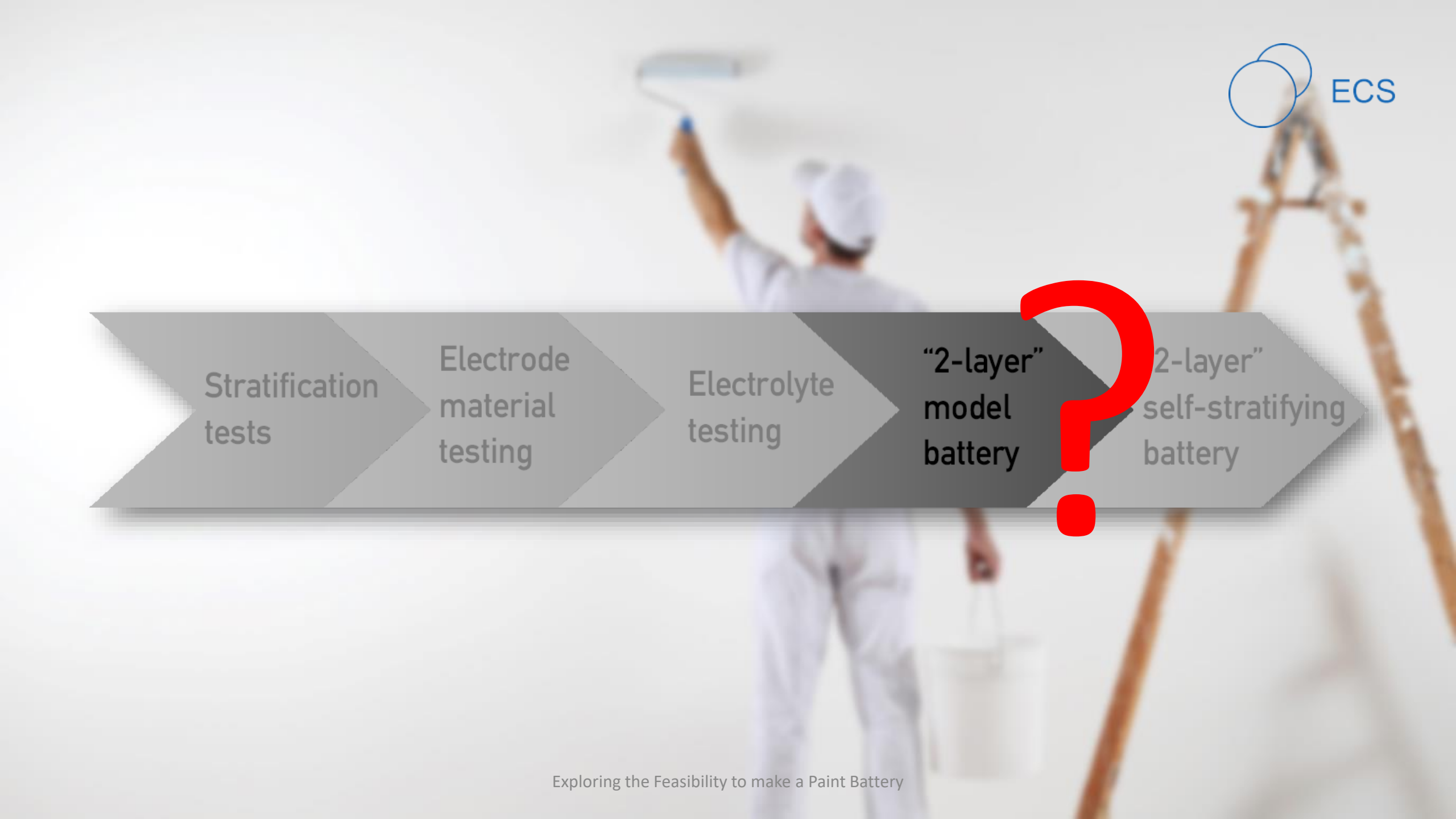


Amount of Water in PVA-solution

Using a 80:20 PVA-ZnCl2 mixture and varying the amount of water for the dropcast solution

→ Lower conductivity for higher amount of water in solution (because of thinner films?)

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Current Problems

- No smooth films with the new longer chain PVA

✓ Higher temperature for mixing

- Still low conductivity of films and no redox-peaks for Zinc-PVA-PANI cell

→ Better contacting?

→ Some water needed in PVA?

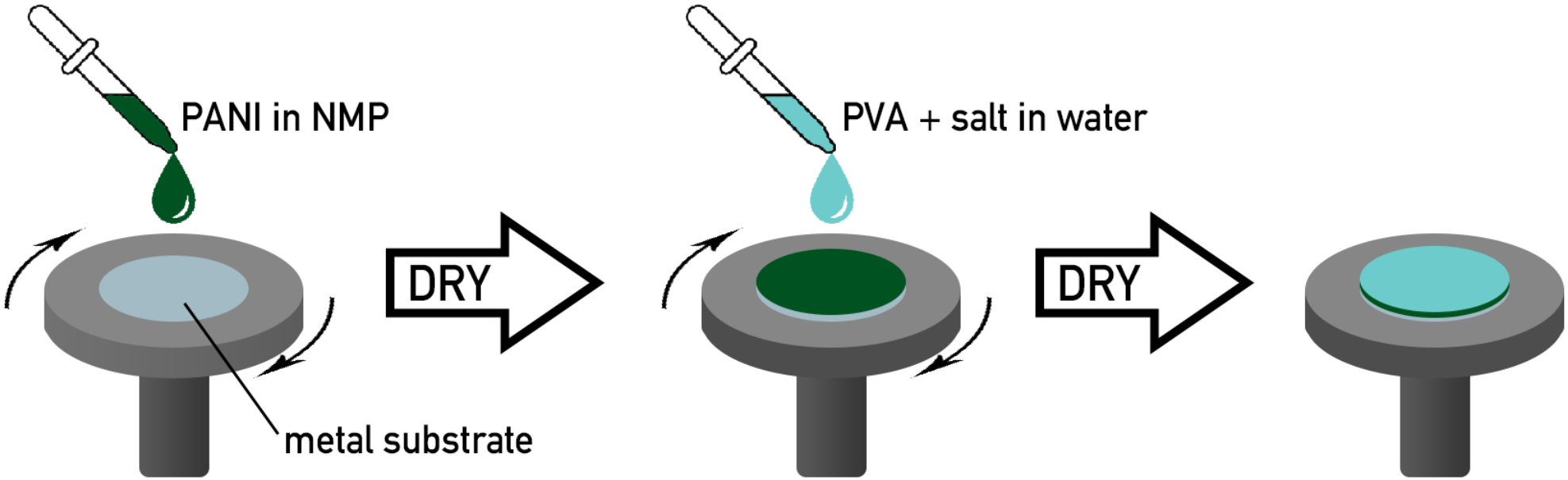
Further Plans?

- Examine PVA-ZnCl2 electrolyte
  - Water content by FTIR spectroscopy?
  - Conductivity in relation to the film thickness?
  - Different cathions/anions?
  - Equivalent circuit?

- Build a working PVA-PANI-Zinc battery by using traditional techniques
  - Pressing coincells?
  - Dropcasting/spincoating layers directly on top of each other?

- Or something else?

Manual Battery



Manual Battery

- Using DIY 3D-printed spin coater