Next steps in the development of bi-functional Gas-Diffusion Electrodes for Zinc-Air-Batteries

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Introduction

Motivation

- **Zinc-Air-Batteries (ZAB) -** a solution for **midterm energy storage systems** due to their cost structure, safety and abundance of materials**.**
- State-of-the-art **gas-diffusion electrodes (GDE)** challenge the economic feasibility due to the sluggish oxygen reactions ($\eta_{RTE} \approx 60\%$) and the use of expensive bi-functional catalysts.
- Additional: **material stability** under oxygen evolution reaction problematic.

➢ **Existing GDEs need to be optimized for bi-functionality.**

Objective

1. **Identify electrochemical limits of materials**
2. **Optimize pore network** for changing requirements and conditions of oxygen evolution (2-phase-reaction) and oxygen reduction reaction (3-phase-reaction)
3. **Enhance performance by a multi-layer approach**: addition of specialized reaction and gas-diffusion layer.

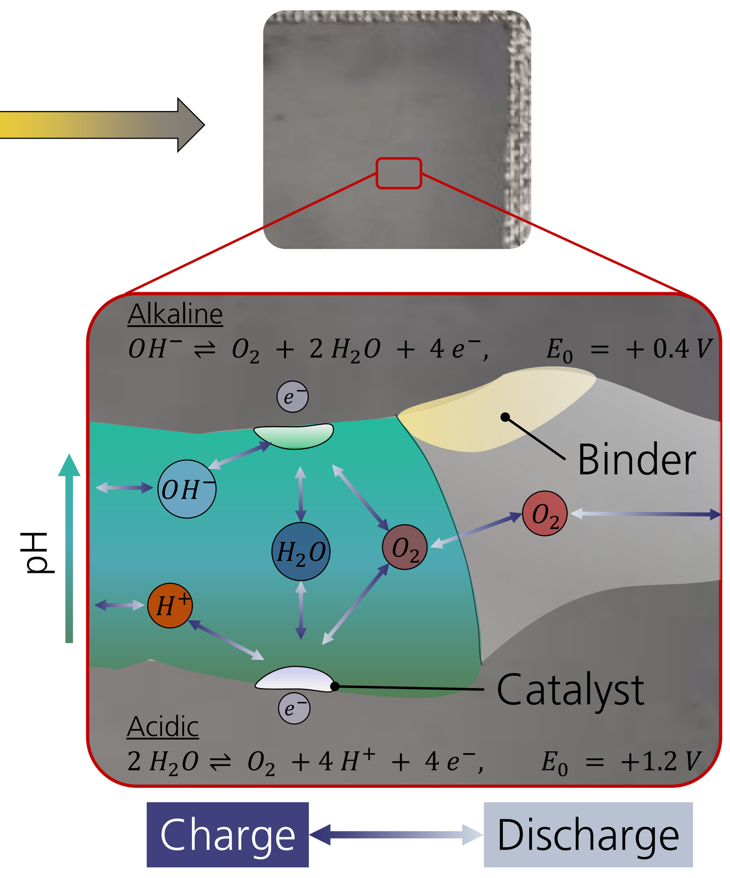
Bi-functional Gas-Diffusion-Electrodes

Manufacturing via dry coating, Reaction and Transport

Pressing & Heat Treatment
Press powder to create electrode and melt binder for mechanical stability

Distribute Powder
Distribute powder evenly on metal mesh

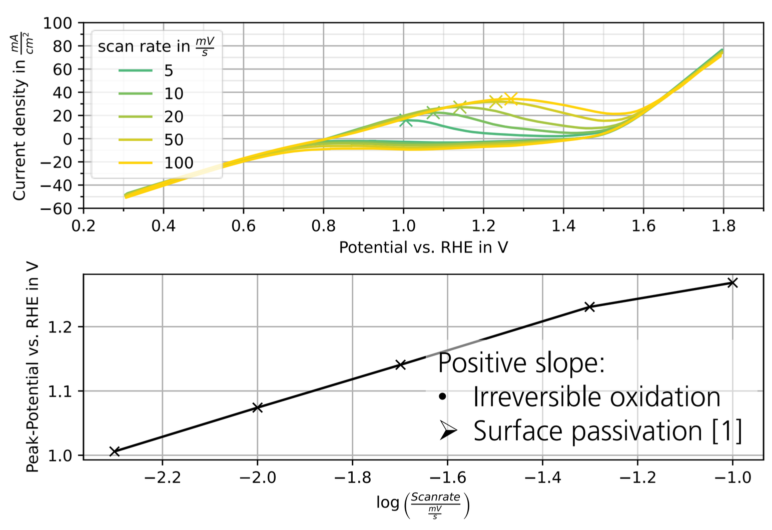
Powder Manufacturing
Prepare mixture of hydrophilic metal powder, catalyst and hydrophobic binder (PTFE)



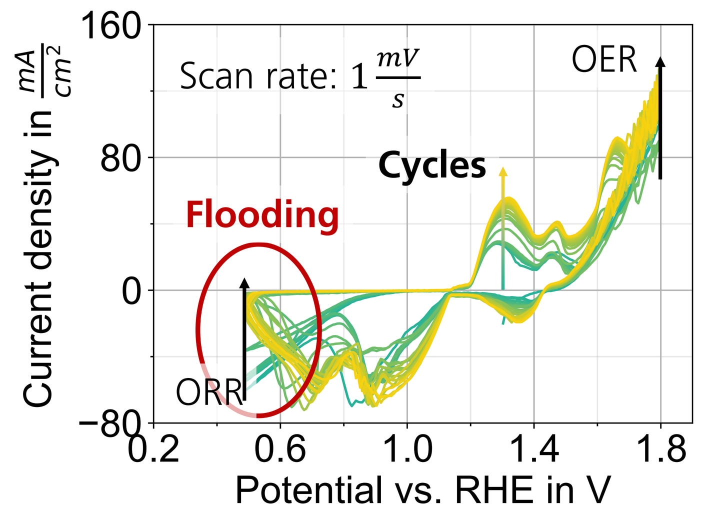
Material Stability

Cyclic-Voltammetry studies in 6M KOH

Nickel GDE
90wt.% Ni – 10 wt.% PTFE



Silver GDE
90wt.% Ag – 10wt.%PTFE



- Potential for OER (U>1V vs. RHE) is demanding for used materials
  ➢ e.g. typical used Carbon decomposes @ *U > 1.3 V* vs. RHE [1]
- Ni and Ag show good performance but degrade quickly

Multilayer

Pore Network

Architecture Design

State-of-the-art Alkaline **Monolayer** GDE — KOH — Reference

Electrolyte Variation

Acid **Monolayer** GDE — H_3PO_4

- No CO_2 Absorption
- Better O_2 Solubility
- Material stability

Current

Addition of a **Gas-Diffusion-Layer**
- No electrolyte breakthrough

*Partner Advent

Multilayer GDE
GDE+**GDL**
Alkaline or Acid

Addition of an acidic **Gel-Polymer-Electrolyte**:
- Electrolyte retention
- Reduce gas crossover

*Partner Politecnico di Torino

Multilayer GDE
GDE+ **Acidic GPE**

Addition of an alkaline **Gel-Polymer-Electrolyte**:
- Zn-Electrode needs alkaline conditions
- bipolar-cell

*Partner CIC energiGUNE

Multilayer GDE + Bi-layer GPE
- Improved η_{RTE}
- Electrochemical stable in conditions of secondary ZABs
- Optimal wetting for OER and ORR conditions

Goal

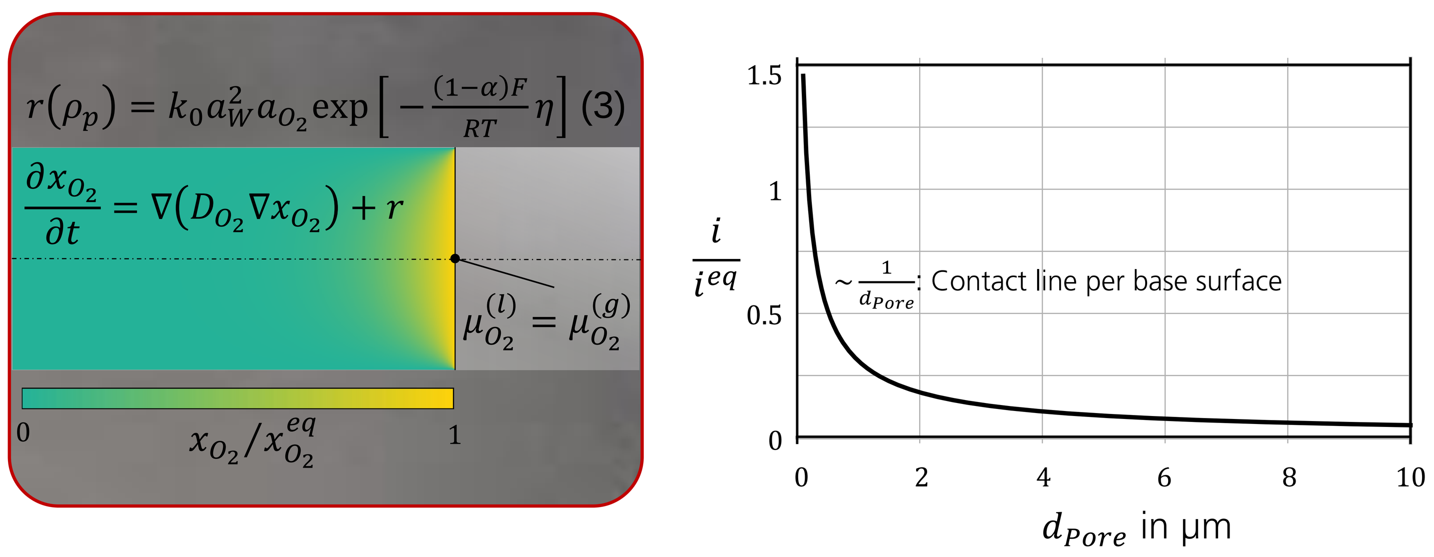
Use optimized monolayer GDE

Optimize Pore Network

Model development

Simple models for an informed GDE Design

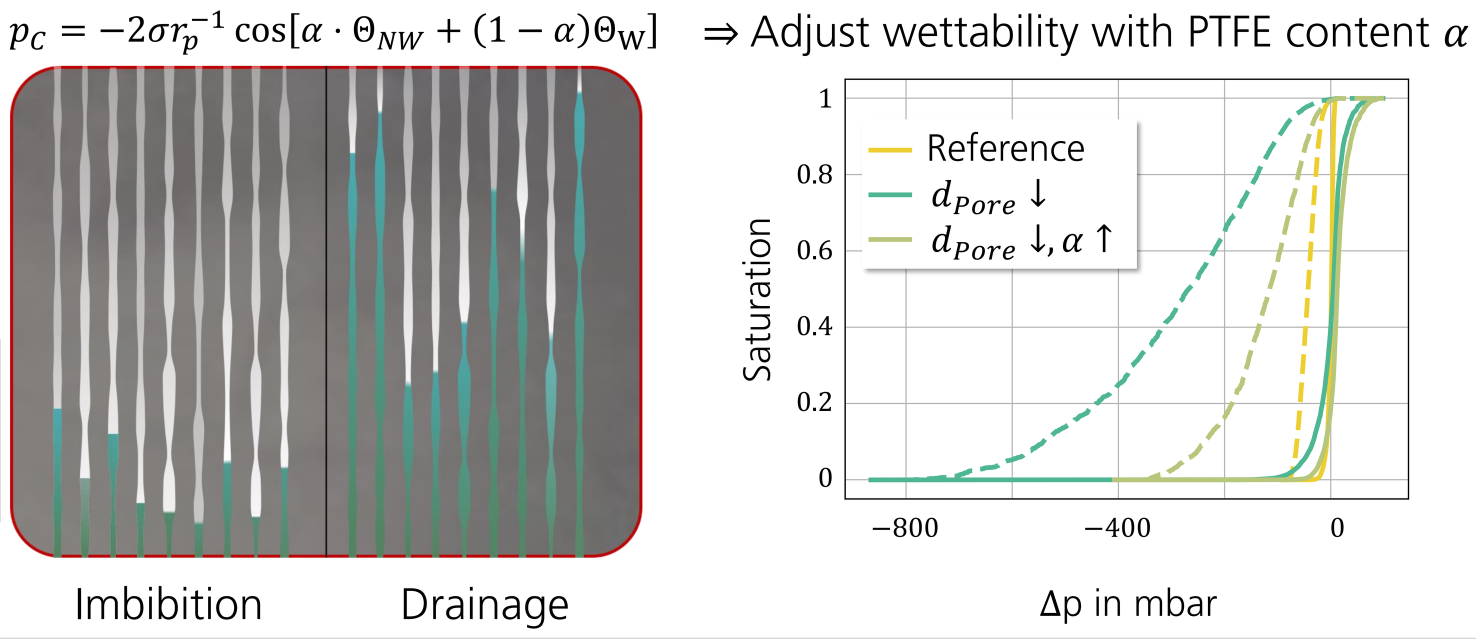
① Oxygen Transport and Reduction Reaction in a cylindrical pore (2D)



⇒Small pores perform better because reaction only happens close to the contact line

② Modelling of wetting degree: Randomly generated parallel pores p_cS curves with mixed wettability

$p_C = -2\sigma r_p^{-1} \cos[\alpha \cdot \Theta_{NW} + (1-\alpha)\Theta_W]$ ⇒ Adjust wettability with PTFE content α



References

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(2)Rohe, M., et al. (2019). "Processes and Their Limitations in Oxygen Depolarized Cathodes: A Dynamic Model-Based Analysis."
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Summary

- To achieve a economical viable ZAB for midterm storage state-of-the-art electrodes need to be improved to overcome their shortcomings: low η_{RTE} & material stability.
- In the **HIPERZAB** project first steps are done to follow two approaches:
  1. Use model based insides to improve the monolayer GDE
  2. Extend the monolayer architecture

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