

# An electrically rechargeable Zn/air coin cell

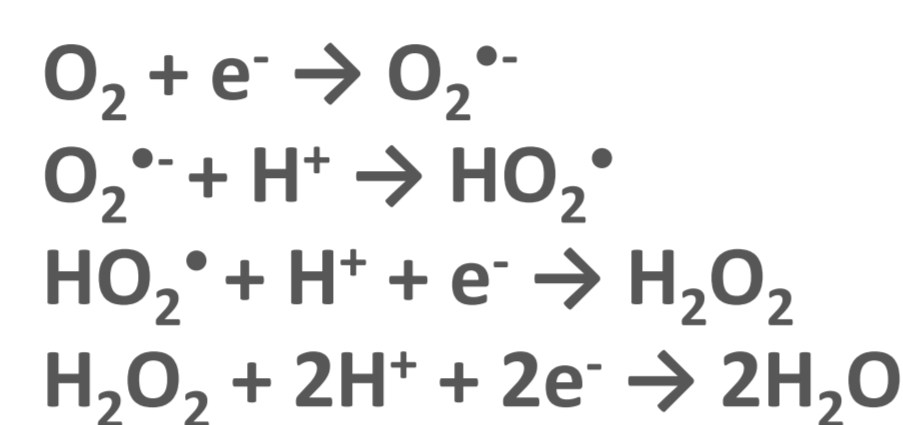
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## Objectives

“LuZi” project aims at the development of a secondary zinc/air battery with appropriate ionic liquid (IL)-based electrolytes. DFI activities focus on development and characterization of active and stable bifunctional cathode catalysts and gas diffusion electrodes (GDE) for the electric rechargeable zinc/air battery.

### Oxygen reaction

ORR reactions in protic IL [1]:



OER reaction mechanisms are not known yet

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## Properties & Strategy

### Advantages of Zn

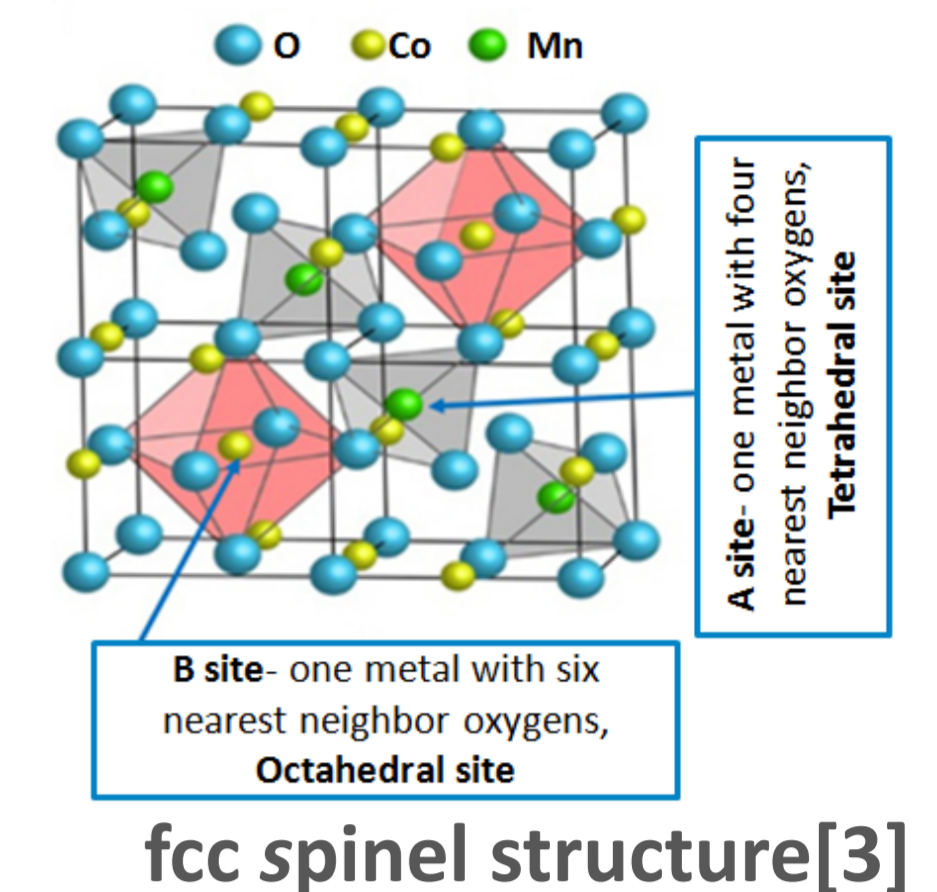
- High energy density of 720 mWh/g<sub>Zn</sub>
- Abundant, cheap and non-toxic

### Drawbacks of alkaline Zn/air cell

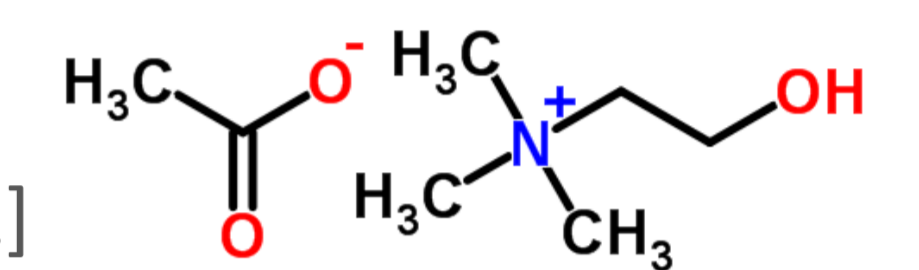
- K<sub>2</sub>CO<sub>3</sub>, dendrite & H<sub>2</sub> formation
- Low energy efficiency (< 60%)
- Electrolyte evaporation

### Strategy & Challenges

- Use of spinel catalysts and protic IL electrolyte
- Triple-phase-boundary formation in GDE with IL [2]
- Low ionic conductivity of IL



fcc spinel structure[3]



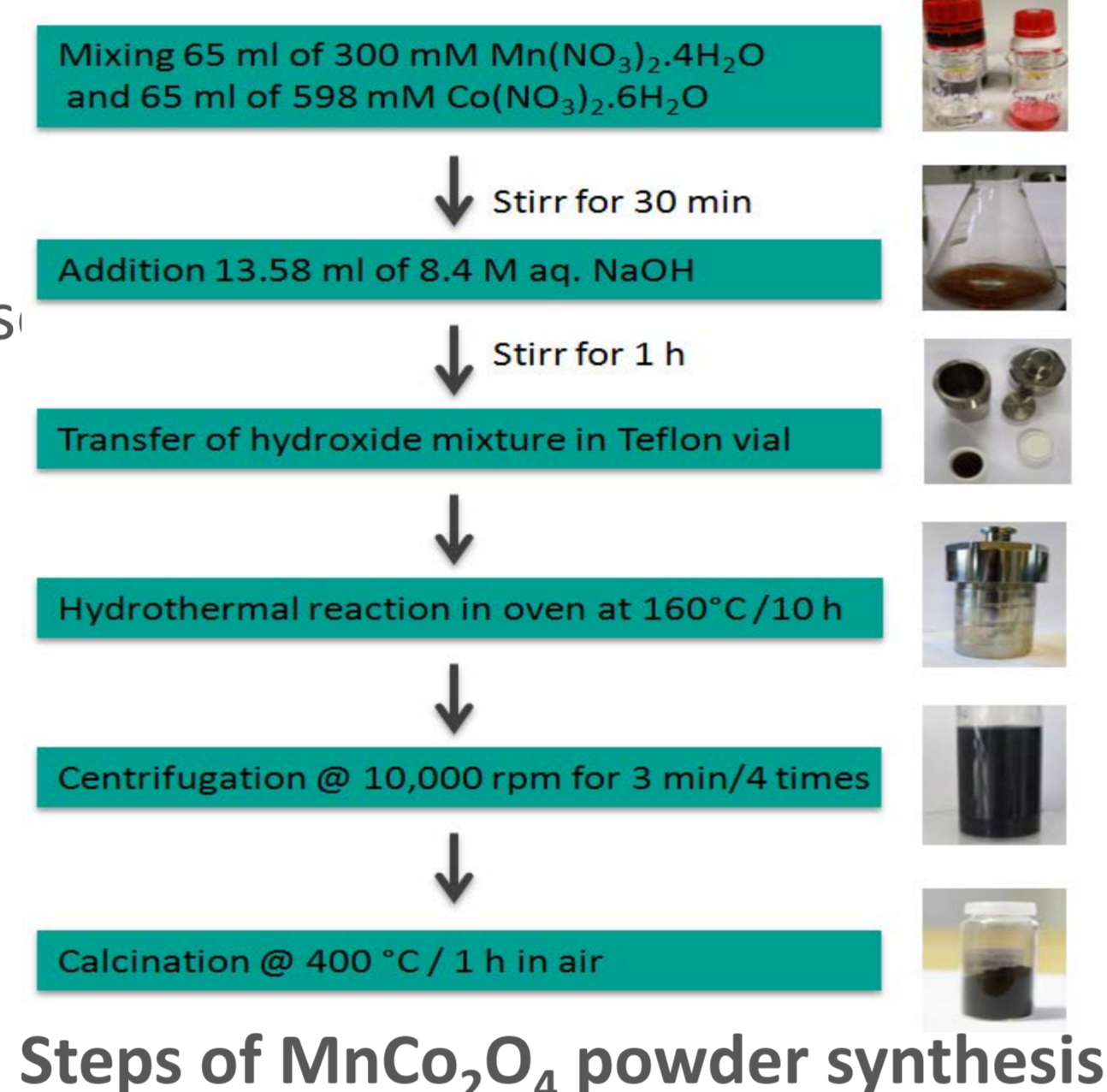
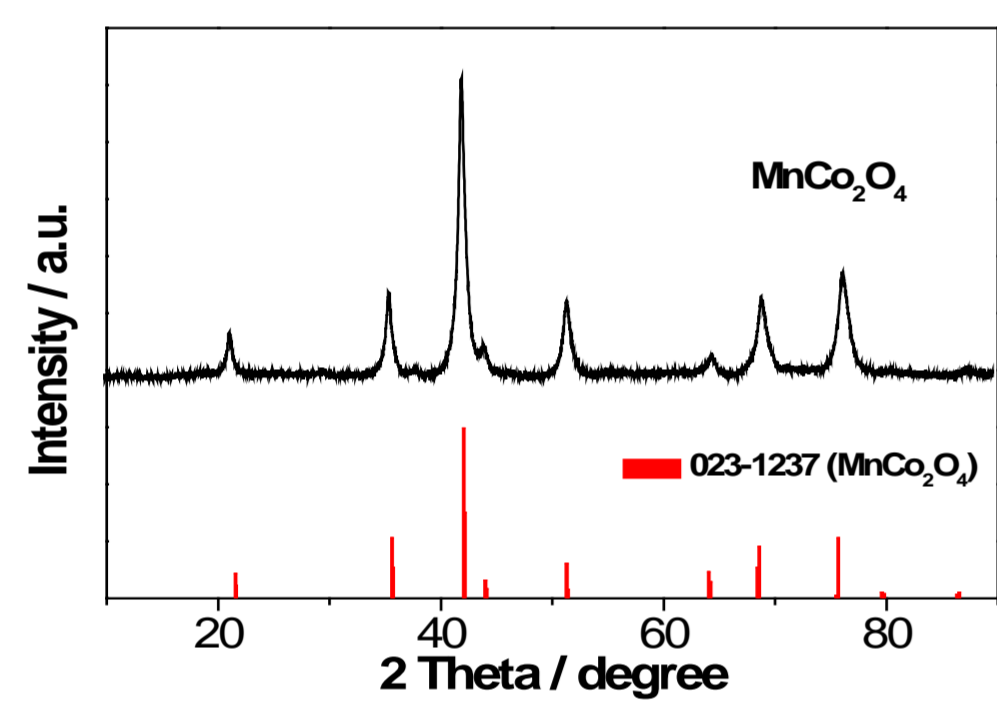
Structure of choline acetate [4]

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## Experimental

### Bi-functional catalyst synthesis

MnCo<sub>2</sub>O<sub>4</sub> (MCO) was prepared by hydrothermal (HT) route. Spinel phase was obtained (see XRD spectra below).

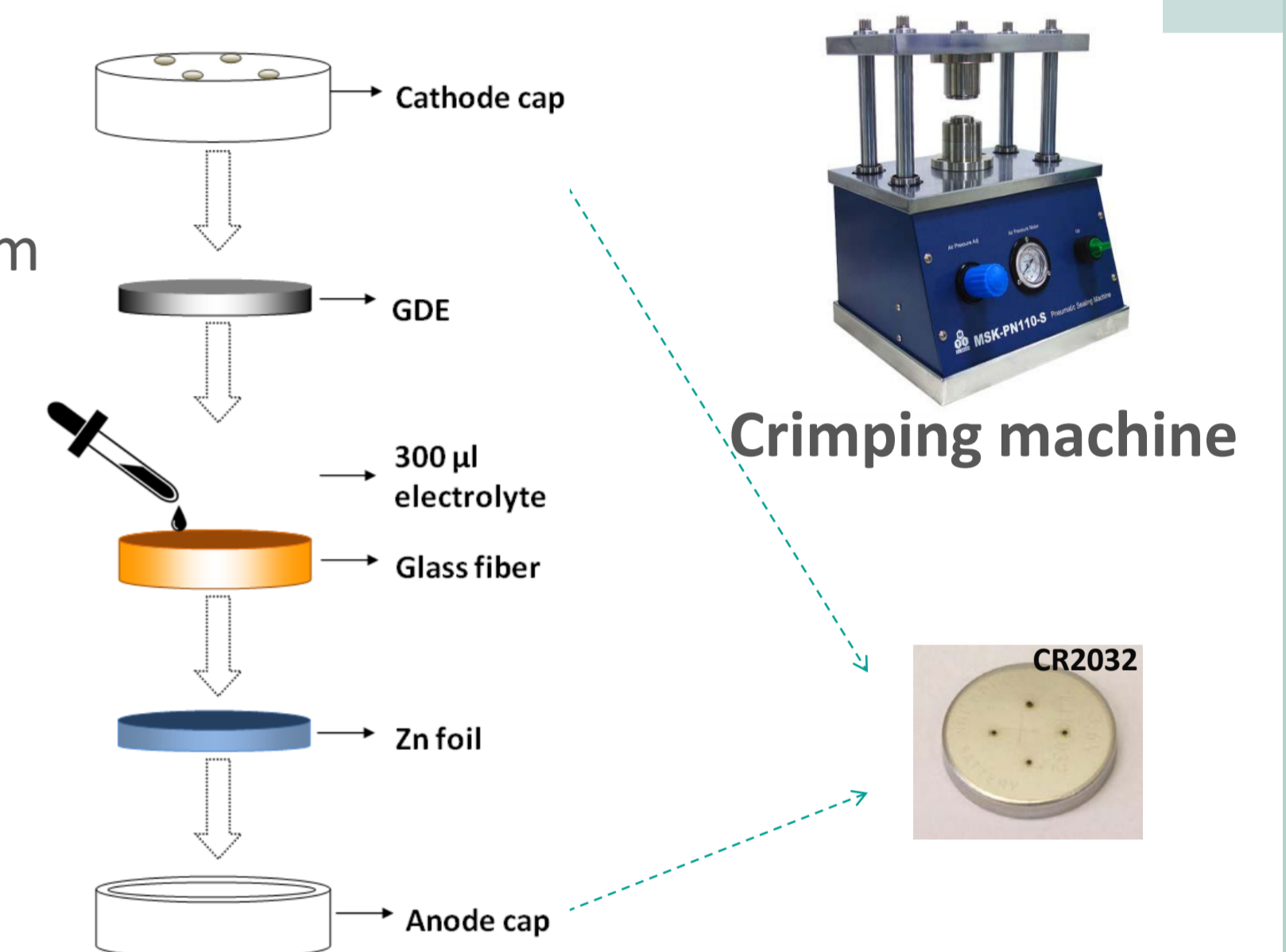


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## Coin cell fabrication

### Parameters

- Electrodes, separator size: 18 mm
- Catalysts loading: 1 mg<sub>MCO</sub> cm<sup>-2</sup>
- Volume of electrolyte: 300 μl
- 4 x air holes size: ~0.5 mm
- Crimping pressure: 7 bar

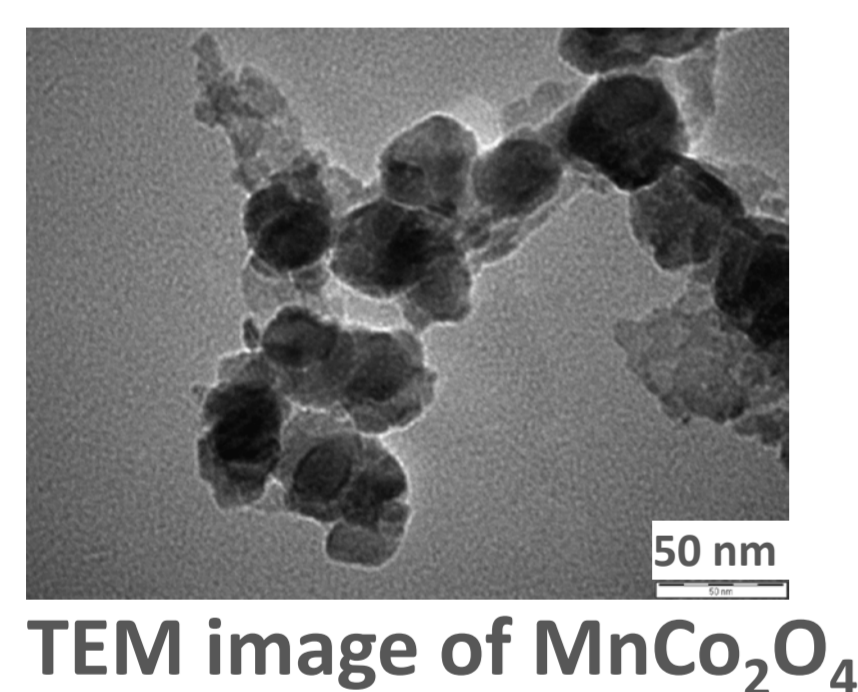
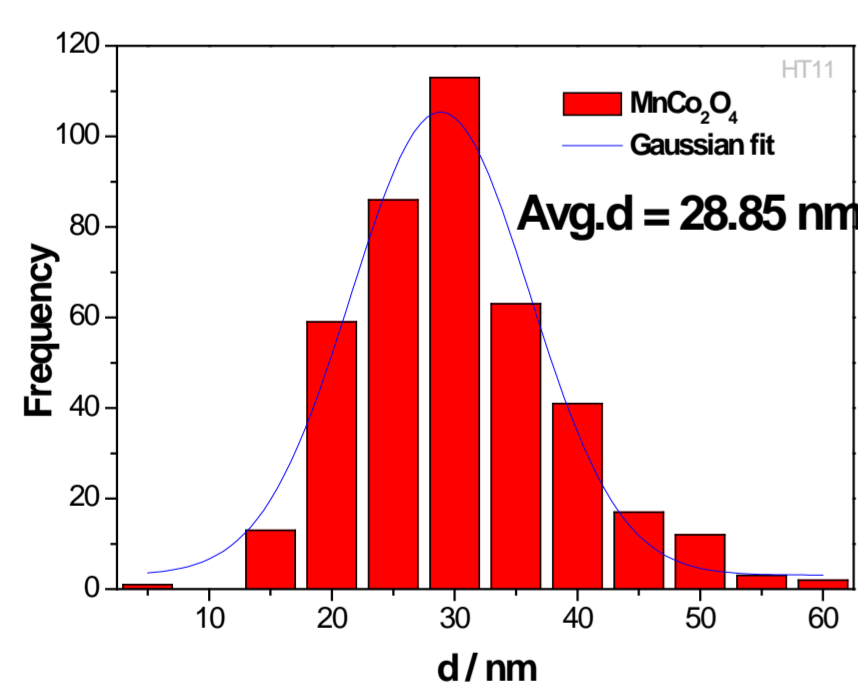


Schematic representation of Zn/Air coin cell assembly

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## Results

### Catalyst development

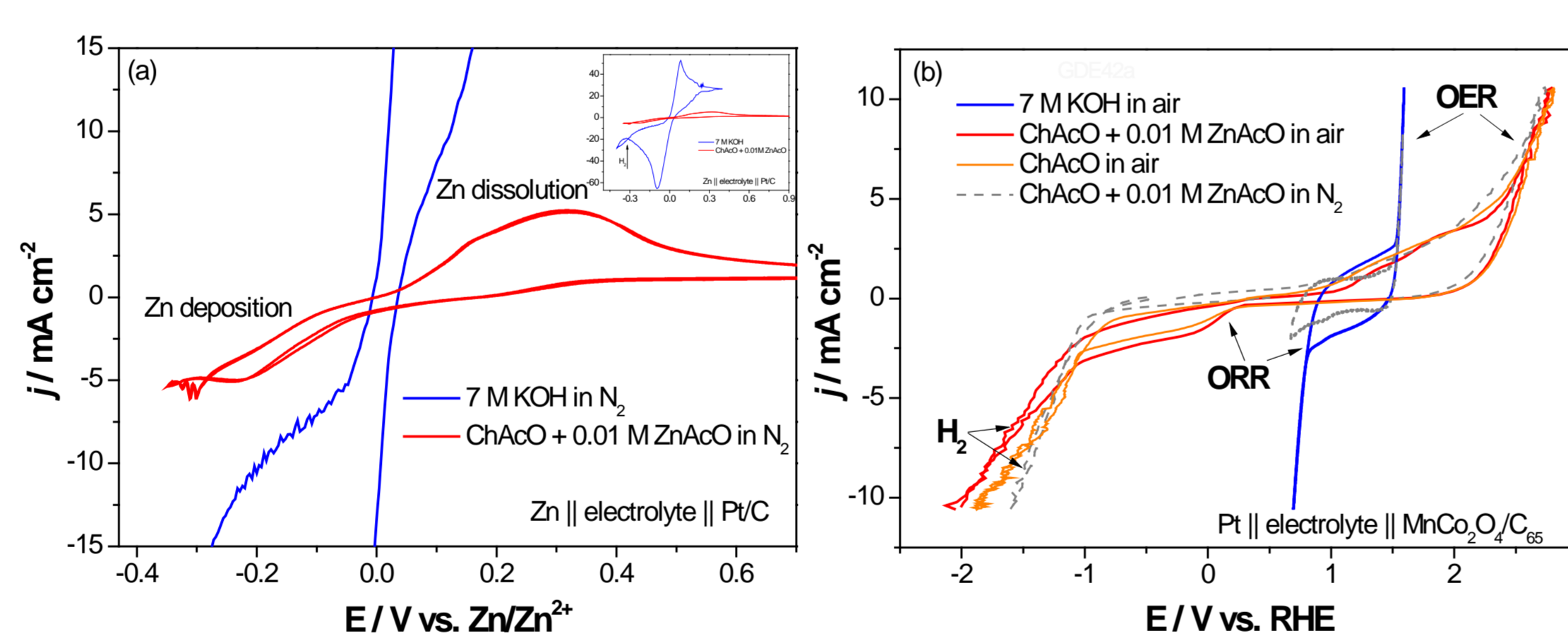

 TEM image of MnCo<sub>2</sub>O<sub>4</sub>


Partial size distribution histogram

### Catalyst powder

- Uniform nano-sized particles
- d<sub>avg.</sub> = 26 nm
- Good distribution (Gaussian fit)
- Irregular shape

### Half cell tests


 CV of (a) Zn and (b) MnCo<sub>2</sub>O<sub>4</sub>/C<sub>65</sub> @ 10 mVs<sup>-1</sup> in KOH and ChAcO

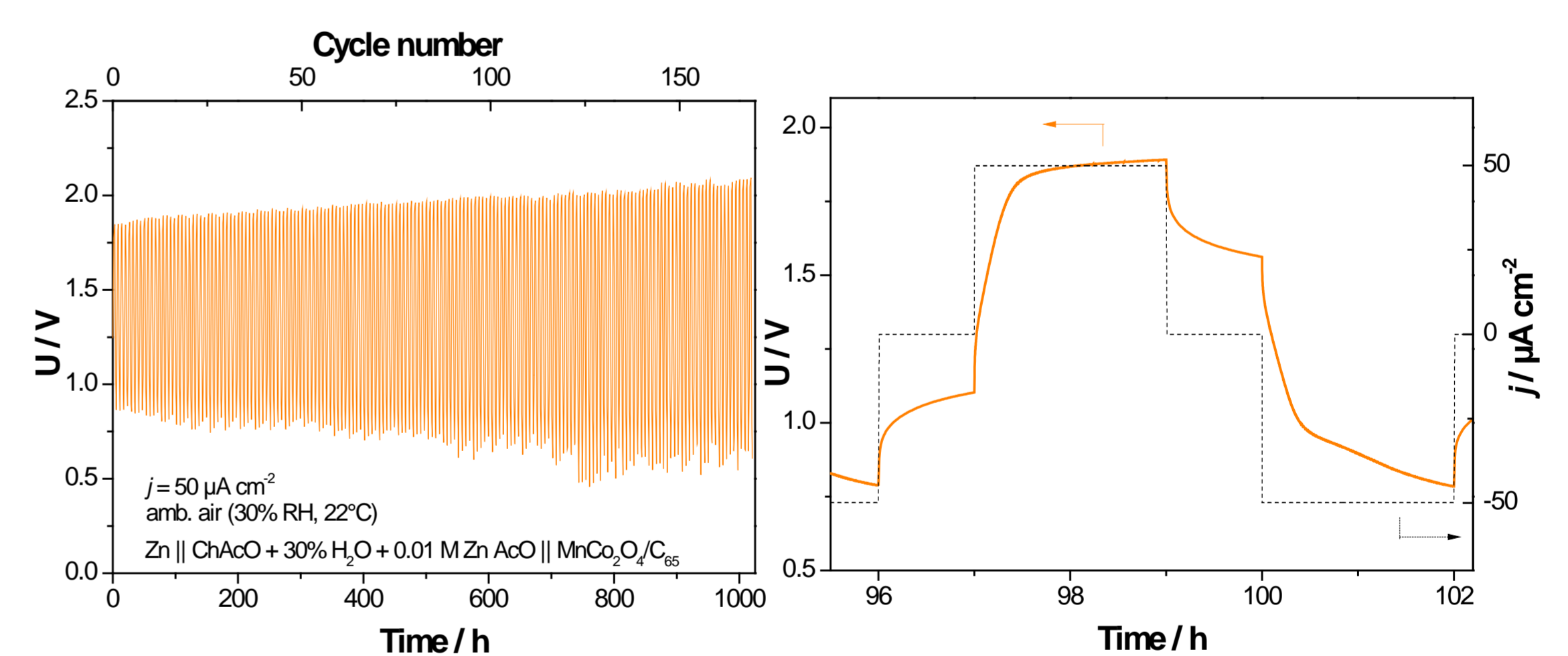
### Zn deposition/stripping

- Fast kinetics and quasi-reversible process in KOH
- x10 higher current density than in ChAcO
- Overpotential at j<sub>max</sub> (ΔE<sub>ChAcO</sub> > ΔE<sub>KOH</sub>)

### ORR/OER

- Fast kinetics in KOH
- for ORR, x3 higher current density than in ChAcO
- Lower reaction rate in ChAcO than in KOH
- ΔE<sub>ChAcO</sub> >> ΔE<sub>KOH</sub>

### Full cell


 Cyclic stability profile (6 h/cycle) @ 50 μA cm<sup>-2</sup> in choline acetate + 30% H<sub>2</sub>O

### Coin cell test results

- Relatively fast kinetics in ChAcO compared to other ILs such as DEMA, EMiM...
- η<sub>energy</sub> = 55%, η<sub>columbic</sub> = 100%
- Reversible discharge capacity = 100 μAh
- Average cell voltage<sub>Avg.</sub> = 0.75V (discharge) & 1.9V (charge)
- High cycling ability rate under ambient conditions

## Conclusions

- Successful synthesis of nano spinel MnCo<sub>2</sub>O<sub>4</sub> by hydrothermal method.
- Feasibility of Zn/air coin cell charge/discharge was demonstrated with protic ChAcO under ambient conditions (30% RH @ RT) for the first time.
- Very good cycling ability for >1000 h @ 50 μAcm<sup>-2</sup> with ChAcO electrolyte.
- At 100 μA cm<sup>-2</sup>, specific cell capacity of 725 mAhg<sub>Zn</sub><sup>-1</sup> was achieved for one single discharge step which is close to theoretical value (810 mAhg<sub>Zn</sub><sup>-1</sup>)

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## References

- [1] D. A. Walsh, A. Ejigu, J. Smith, P. Licence, Phys. Chem. Chem. Phys., 15 (2013) 7548
- [2] P. Ingale, M. Sakthivel, J.-F. Drillet, J. Electrochem. Soc., 164 (2017) H5224
- [3] www.cdti.com
- [4] www.chemspider.com/Chemical-Structure.9818719

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