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Thin Film Technology
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Simulation-based Optimization of Mass Transport Processes in Thermal Drying in the Recycling Process of Lithium-Ion Batteries

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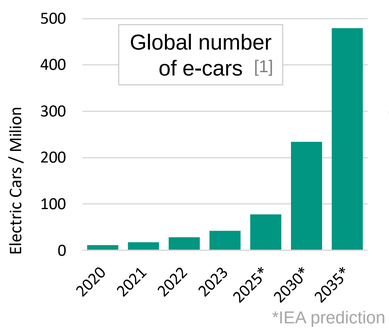
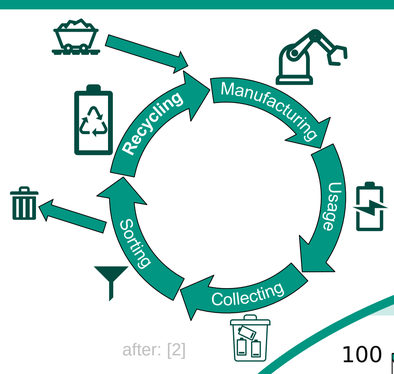
Lab-scale thermal drying model developed

Motivation



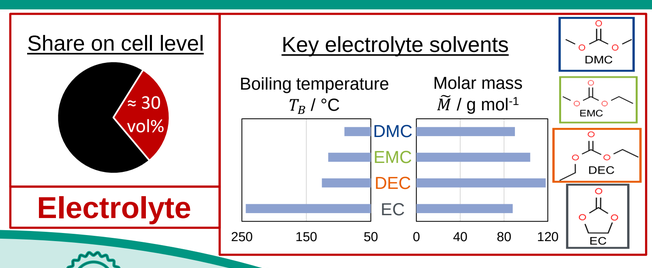


Recycling in Circular economy

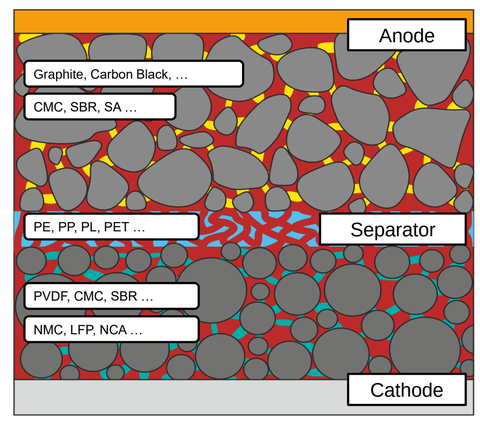
Safety ↑ Simplicity ↑ Efficiency ↑

Key challenges
- Material cost and shortage
- Recovery rates by legislation

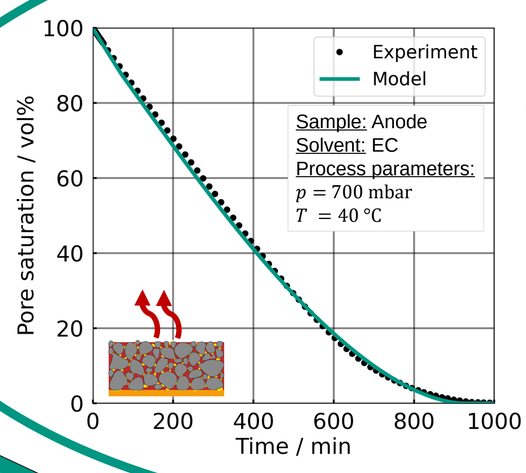
Components



- Hazard of health damage, fire, explosion, …
- Adverse effects on various downstream processes

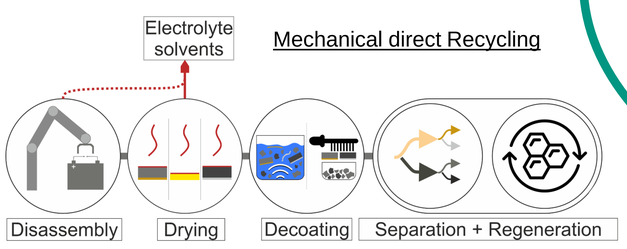


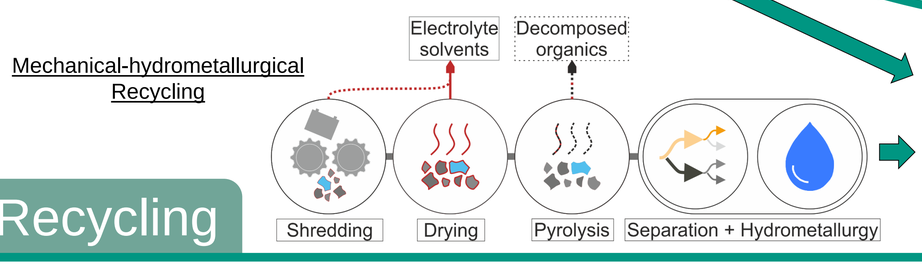
Achievements



- Mass transport **model**
- **Validation** through **experiments** in a magnetic suspension balance

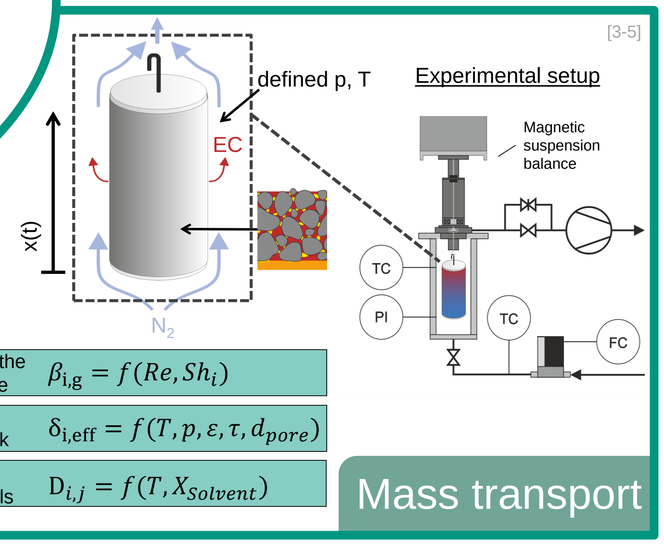
Recycling

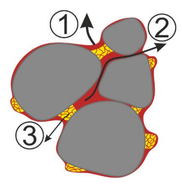




- Current collectors, cell casings
- Active Material Cathode / Anode

Mass transport



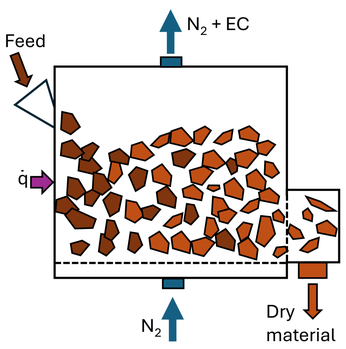


1. Mass transport in the external gas phase $\beta_{i,g} = f(Re, Sh_i)$
2. Mass transport in the porous network $\delta_{i,eff} = f(T, p, \varepsilon, \tau, d_{pore})$
3. Mass transport in absorbing materials $D_{i,j} = f(T, X_{Solvent})$

Transition to a **real-application** thermal drying model – a parameter study

Dryer

Convection dryer batch process



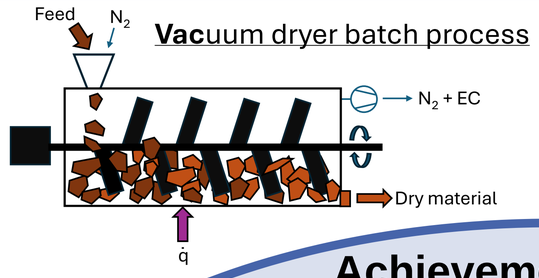
Default parameters	Conv.	Vac.
p / mbar	1000	50
T / °C	40	40
$Y_{EC,in}$ / -	0	0
sgt* / s^{-1}	0.1	0.002
α_g / W m^{-2} K^{-1}	150	20
α_w / W m^{-2} K^{-1}	20	200
wbr* / -	0.1	0.5

*sgt: specific gas throughput

$$[sgt] = \frac{\dot{m}_{N_2}}{m_{solids}}$$

*wbr: wall-bulk-ratio

$$[wbr] = \frac{\tau_{wall}}{\tau_{bulk}}$$

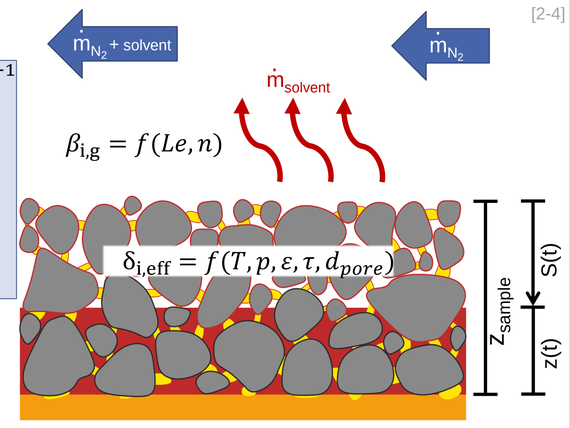


- Virgin battery material
- Steady-state process
- α_{gas}, α_{wall} pre-defined (depending on dryer)
- $\beta_{i,gas}$ through Lewis-analogy with n = 1/3
- Single component solvent
- No capillary transport
- 1st, 2nd drying stage

$$\beta_{i,t} = \left(\frac{1}{\beta_{i,g}} + \frac{s(t)}{\delta_{i,eff}}\right)^{-1}$$

- Serial connection of mass transfer resistances
  - Within sample,
  - Surface

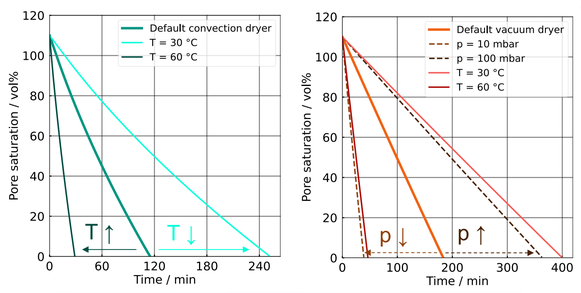
Model & Assumptions



Achievements

- Highly **flexible** model for different **dryer** setups
- Identified **critical process** and **material** properties
- **Instructions** on **drying** procedure
- **Multicomponent** system (EC, DEC)
- Validation through existing **industrial dryers**

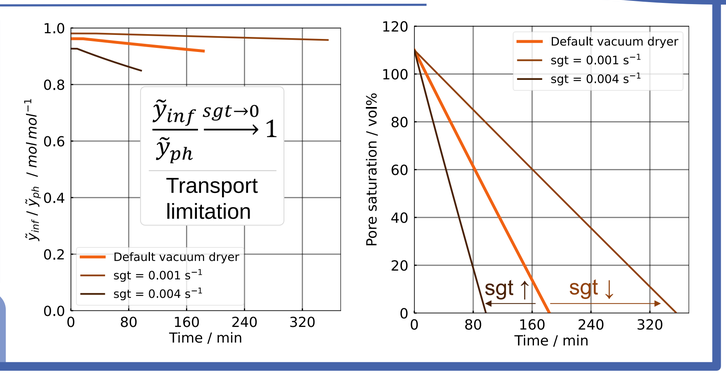
Next Steps



p ↓ , T ↑ ⇒ $time_{dry}$ ↓

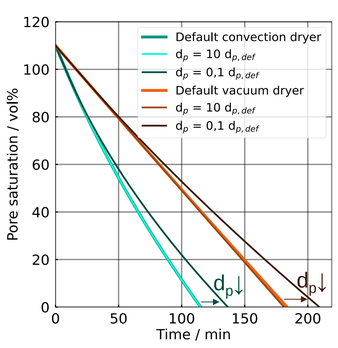
Temperature **limitation**: T < 60 °C
⇒ Unwanted **decomposition** reactions

Feasibility of different process conditions?
⇒ **Cooperation** with **industry**, get **economical** data



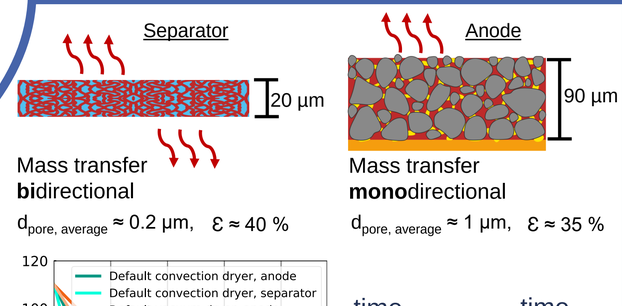
Process properties

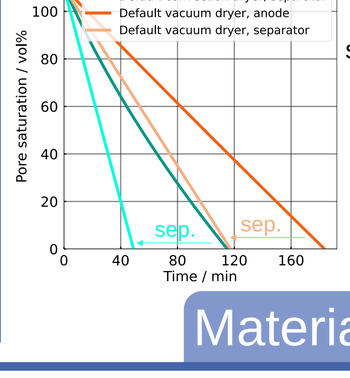
Material properties



Pore size:
only **minor** effects on drying time at small pore diameters

Effect of Knudsen-diffusion in small pores!





$time_{dry}$ separator < $time_{dry}$ anode, cathode

If possible: **separate** material before drying

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Next Steps

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[1] ZSW, IEA. (2024). Anzahl von Elektroautos weltweit von 2013 bis 2023 und eine Prognose bis 2035. Statista. Statista GmbH. Zugriff: 26. Februar 2025. https://de.statista.com/statistik/daten/studie/168350/umfrage/bestandsentwicklung-von-elektrofahrzeugen/
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