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Hochschule Reutlingen
Reutlingen University

Characterization of bipolar membranes and their application in acid-base batteries as electrochemical energy storage

B.Sc. Emina Kurtovic, B.Sc. Maximilian Merkel, B.Sc. Stephan Pflumm, B.Sc. Anastasia Bittner, B.Sc. Tobias Braun, Prof. Dr. Carl-Martin Bell
School of Applied Chemistry, Reutlingen University – M.Sc. Applied Chemistry and M.Sc. Process Analysis and Technology Management

Introduction & methods

Aim of the project

Today, renewable energies are becoming increasingly important. This requires new storage systems, preferably electrochemical ones. Here such a system is investigated for stationary use. This work deals with the identification of a functional and non-hazardous combination of bipolar membrane (BPM), electrolyte and electrode redox pair to design a single cell acid-base flow battery[1].

Milestones

- Characterization of different BPMs by current voltage curves (CVCs) to identify selectivity and water splitting efficiency
- Charging: formation of acid and base by using suitable BPMs
- Discharging: Design of experiments to determine the optimum performance of the acid-base flow battery

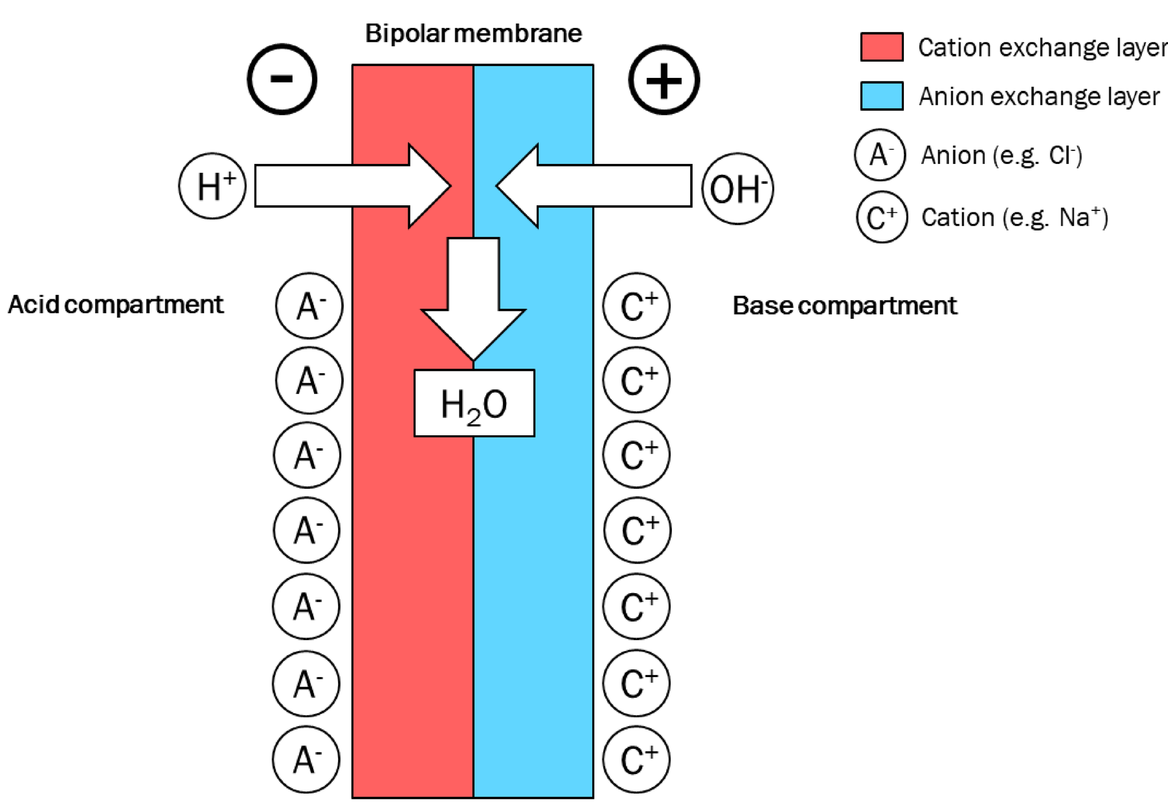


Figure 1: Model of a bipolar membrane as chemical capacitor

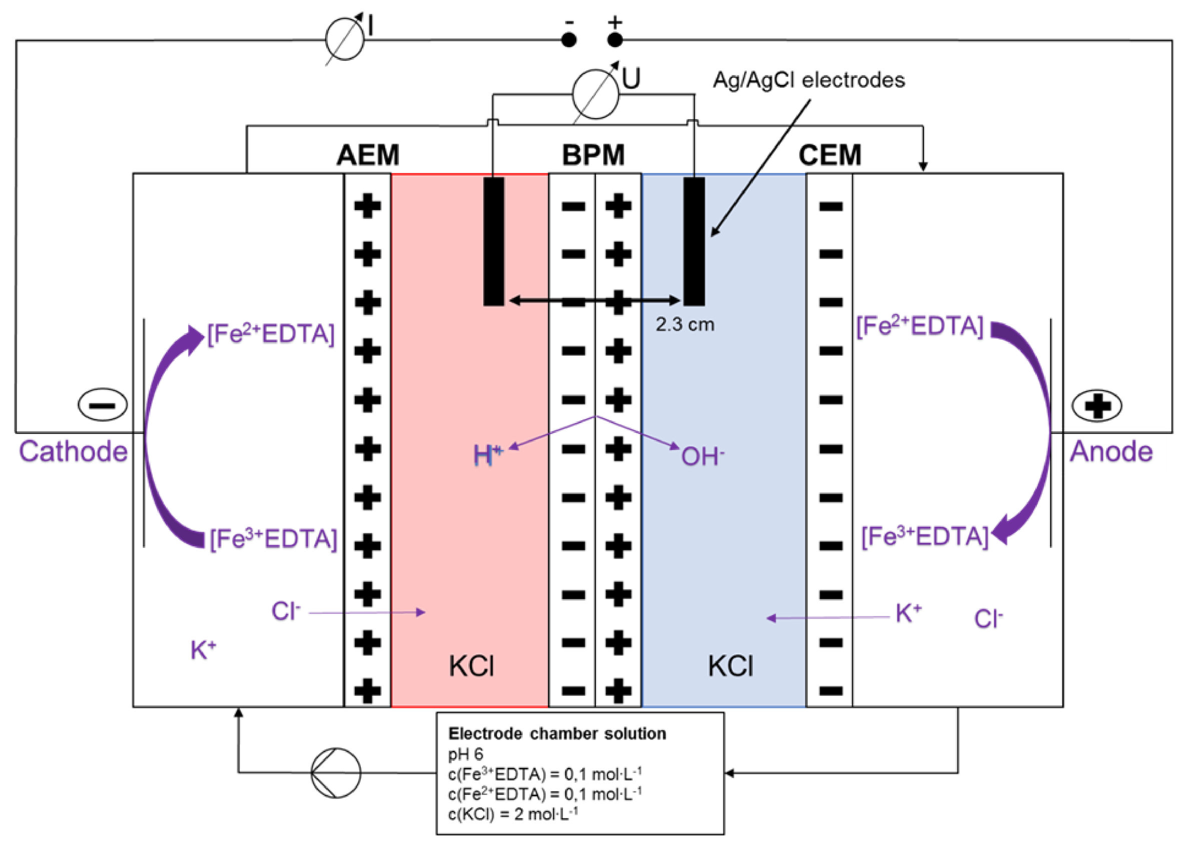


Figure 2: Schematic characterization and charging setup

Results & discussion

Table 1: Limiting current density and slope in water splitting area of different BPMs in 1 mol·L-1 and 2 mol·L-1 KCl. Values obtained of **characterization** of different BPMs by two Ag/AgCl (3 mol·L-1 KCl) without Haber-Luggin-capillaries

Membrane \ Evaluation criteria	Limiting current density [mA·cm-2] 1 mol·L-1 KCl	2 mol·L-1 KCl	Slope in water splitting area [mA·cm-2V-1] 1 mol·L-1 KCl	2 mol·L-1 KCl
fumasep® FBM	1.0	1.3	35.4	51.2
Neosepta® BP-1	1.3	3.0	49.1	73.9
MEGA BPM	7.5	26.0	12.4	20.1
BPM 221019 I	n/a	1.7	n/a	52.0
BPM 040619 II-T	1.5	3.0	38.4	55.3
BPM 040619 II-PP	1.7	3.1	33.3	52.5
BPM 220519 I	n/a	4.5	n/a	40.8
BPM 181019 III	n/a	4.0	n/a	49.0

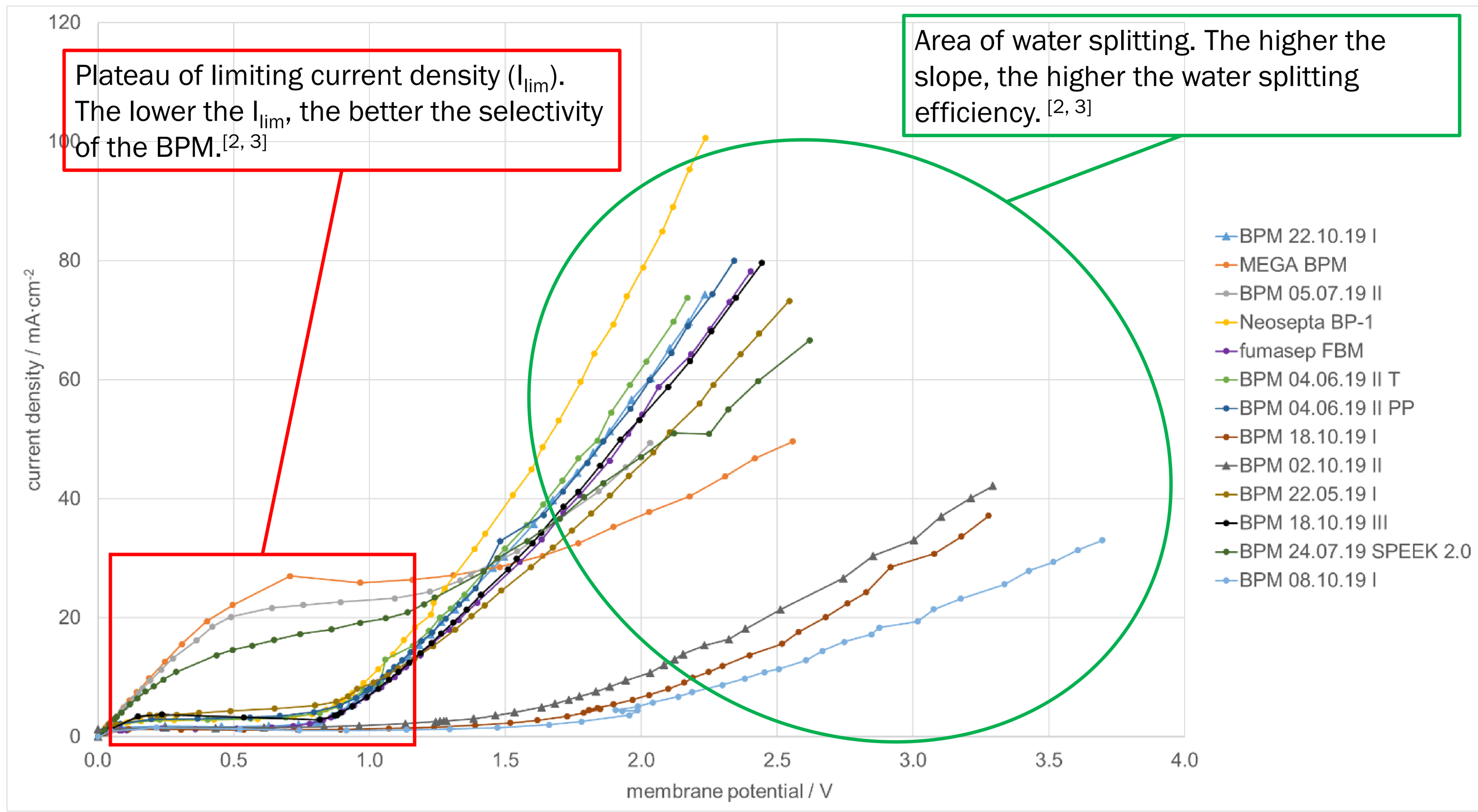


Figure 3: **Characterization** of different BPMs by CVCs in 2 M KCl

Fig. 4 : Übersicht Energieverbraucher bei Ladung der AB-Batterie

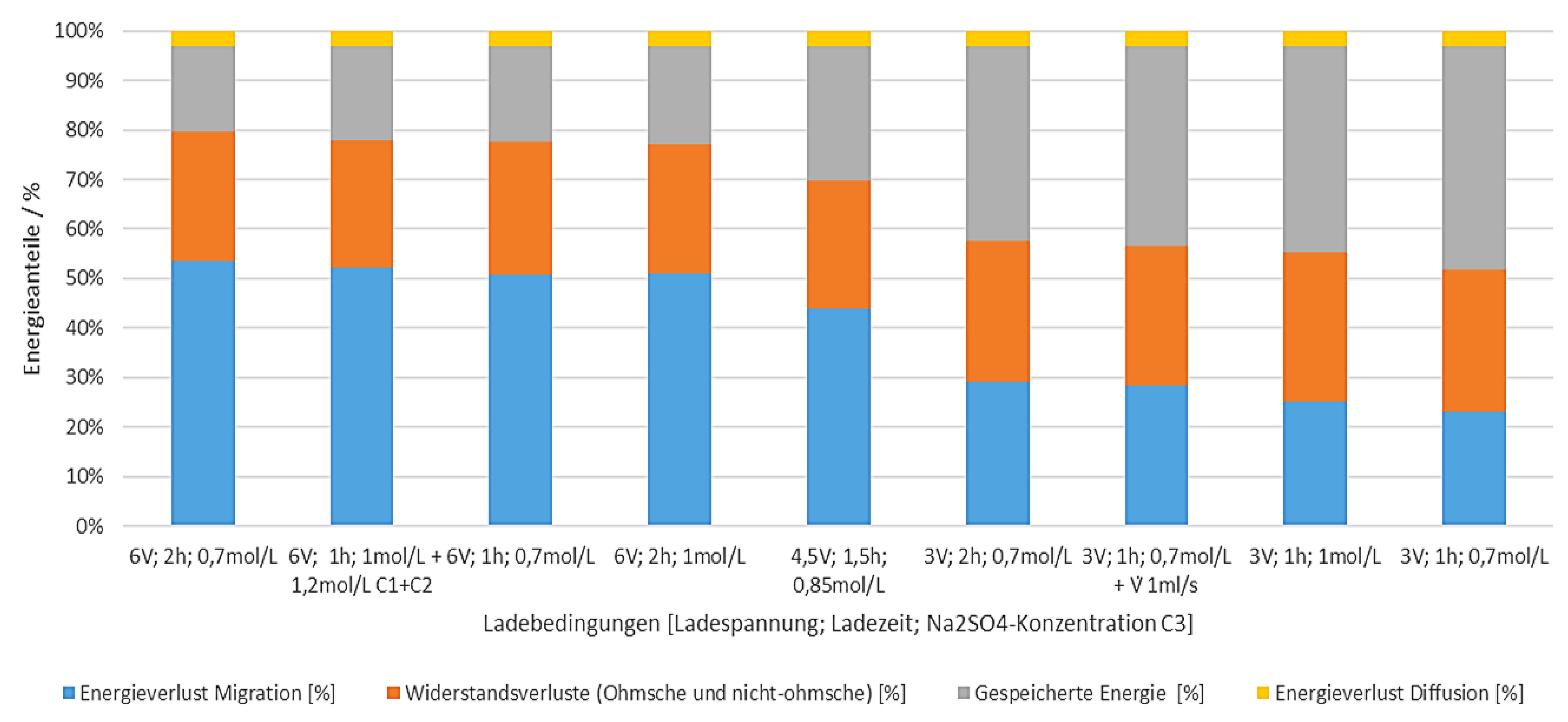
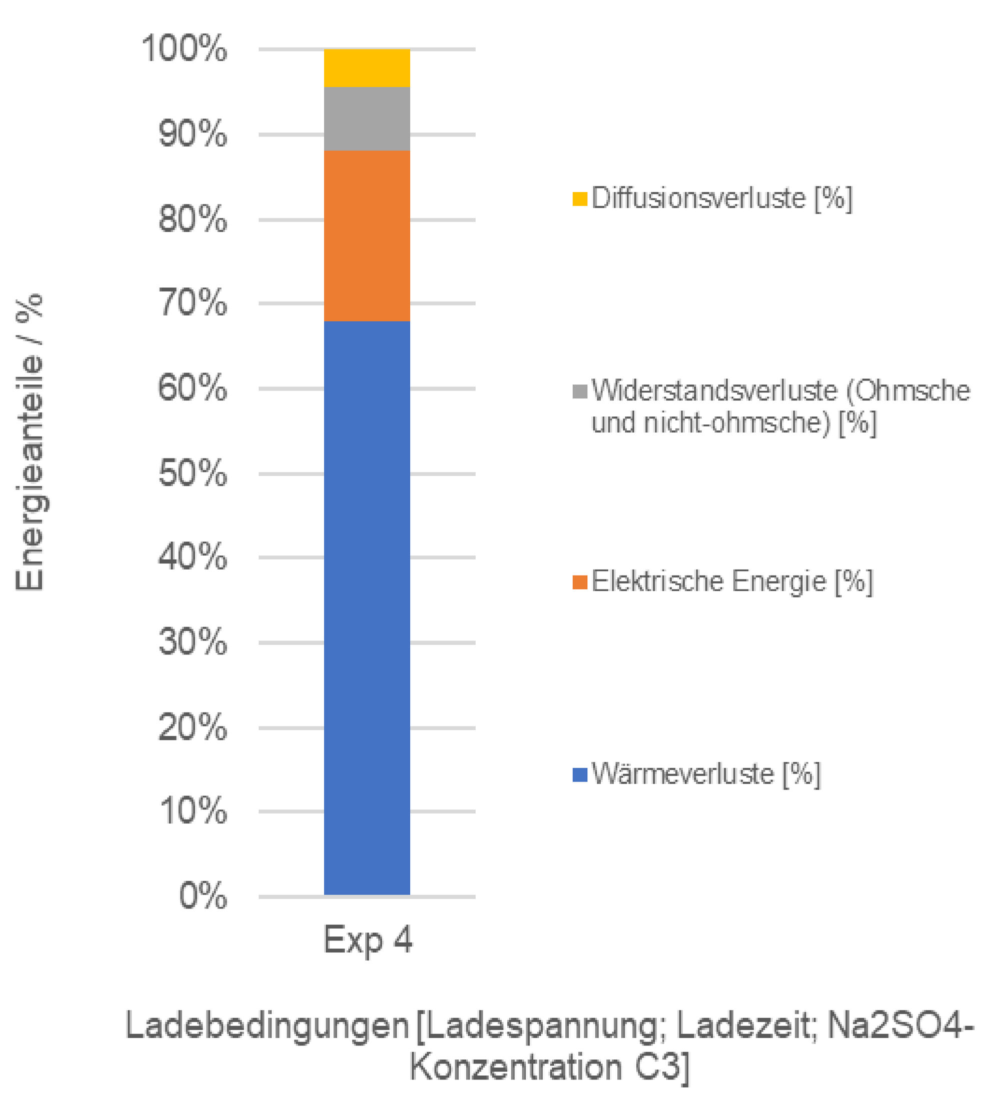


Fig. 5 : Übersicht Energieverteilung bei Entladung der AB-Batterie



Conclusion & outlook

- Large differences in the performances of the characterized BPMs
- Low power density (0.5 kW·m-3) and energy density (0.9 kWh·m-3) of acid-base flow battery in comparison to other battery types (e.g. Redox flow, Li-ion or lead batteries)[4]
- Relevant energy losses in charging due to electromigration through anion exchange membrane of protons
- Large energy loss in discharging through heat formation in bipolar membrane I neutralization reaction

Battery type		Evaluation criteria: Power density [kW·m-3]	Energy density [kWh·m-3]
Acid-base flow battery	This work	0.5	0.9
	Xia [29]	0.75	/
Vanadium redox flow battery [4]		/	20-60
Lead-acid battery [4]		/	25-65
Li-ion battery [4]		/	190-375

Table 2: Comparison of the properties of different battery types available

[1] J. Xia, G. Eigenberger, H. Strathmann, and U. Nieken, “Flow battery based on reverse electrodialysis with bipolar membranes: Single cell experiments,” Journal of Membrane Science, vol. 565, pp. 157–168, DOI: 10.1016/j.memsci.2018.07.073, 2018
[2] A. M. Ashrafi, N. Gupta, and D. Neděla, “An investigation through the validation of the electrochemical methods used for bipolar membranes characterization,” Journal of Membrane Science, vol. 544, DOI: 10.1016/j.memsci.2017.09.026, 2017
[3] T. T. Bejerano, E. Korngold, and R. Messalem, “New bipolar membrane setup for high current densities,” Desalination and Water Treatment, vol. 56, no. 6, pp. 1421-1426, DOI: 10.1080/19443994.2014.950339, 2015
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