Low-cost, High-performing Ion Exchange Membranes For Aqueous Organic/Inorganic Redox Flow Batteries

Xian Yang[1]*, Kang Peng[2], Can Zhao[1], Jin Zhang[1]

[1] Suqian Time Energy Storage Technology Co. Ltd, Huashan Road No. 67, 223800 Suqian, Jiangsu, China

[2] University of Science and Technology of China, Jinzhai Road No. 96, 230026 Hefei, Anhui, China

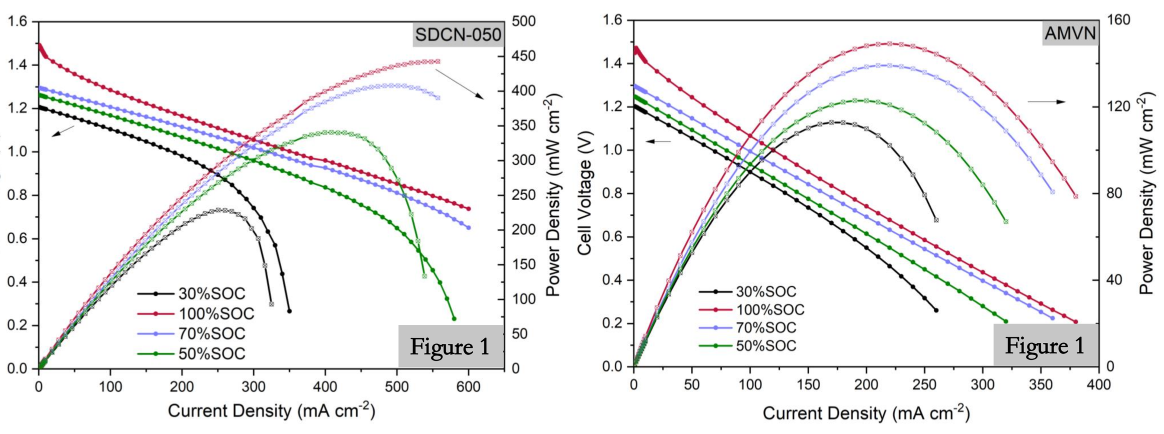
Email: yangxian@energydefender.cn

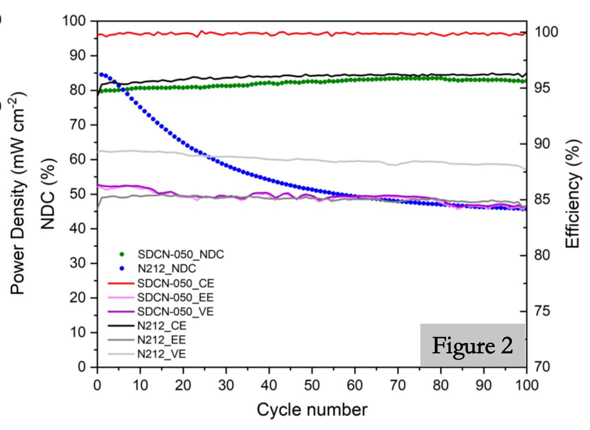
Introduction

Ion exchange membrane is one of the most critical components of redox flow batteries and constitutes the major portion of the total cost. In this proposal, we present a type of ion exchange **membrane SDCN-050** that can be **applied to both aqueous organic/inorganic redox flow batteries**. We successfully demonstrated its **scalability from 5 cm² of a single cell to 43056 cm² of a single cell stack**. The SDCN-050 membrane exhibited better performance than the commercial AMVN membrane in the organic redox flow battery (ORFB), and the commercial N212 membrane in the vanadium redox flow battery (VRFB), respectively.

Single Cell Performance

The polarization curves of the cell assembled with SDCN-050 and AMVN are shown in Figure 1. The peak power density of the cell with SDCN-050 reaches 450 mW·cm^{-2}, which is three times that of the cell with AMVN, also exceeding most reported AEMs in literature[1].





The cell performance of SDCN-050 tested in the VRFB is compared with that of N212. As shown in Figure 2, the normalized discharge capacity (NDC) of N212 was slightly higher than that of SDCN-050, due to its higher voltage efficiency (VE). However, the capacity of the cell with N212 faded much faster than that of SDCN-050, resulting from its relatively low Coulombic efficiency (CE). As a consequence, the two cells showed **similar energy efficiency (~85%)**, while the cell with **SDCN-050 exhibited no capacity fade** in 100 consecutive charge/discharge cycles.

Membrane	Fenton test	Capacity Fade Rate	CE/%	VE/%	EE/%
AMVN	Before	No fade	99.85	74.37	74.25
	After	0.015%/cycle	99.61	73.82	73.53
FAA-3-50	Before	0.150%/cycle	98.94	69.98	69.24
	After	0.255%/cycle	99.42	66.14	65.77
FAA-3-PE-30	Before	0.025%/cycle	99.62	77.41	77.11
	After	0.138%/cycle	99.00	75.82	75.05
PiperIon80	Before	0.091%/cycle	99.71	81.52	81.28
	After	0.104%/cycle	99.55	70.26	69.95
SDCN-050	Before	No fade	99.80	80.90	80.80
	After	No fade	99.60	80.41	80.09

Fenton test for 570h

Thickness/μm	Electrolyte	Capacity utilization/%	CE/%	VE/%	EE/%
27±2	Organic	89.95	99.57	88.97	88.59
	Vanadium	75.00	99.70	86.22	85.96
36±1	Organic	88.83	99.67	87.00	86.71
	Vanadium	77.70	99.79	85.25	85.07
47±1	Organic	89.33	99.53	84.61	84.29
	Vanadium	79.20	99.86	84.11	83.97
55±1	Organic	88.63	99.62	83.91	83.52
	Vanadium	79.61	99.83	82.96	82.84
60±2	Organic	85.84	99.54	82.77	82.39
	Vanadium	81.05	99.66	82.55	82.27

SDCN-050/100mA·cm^{-2}

Reference

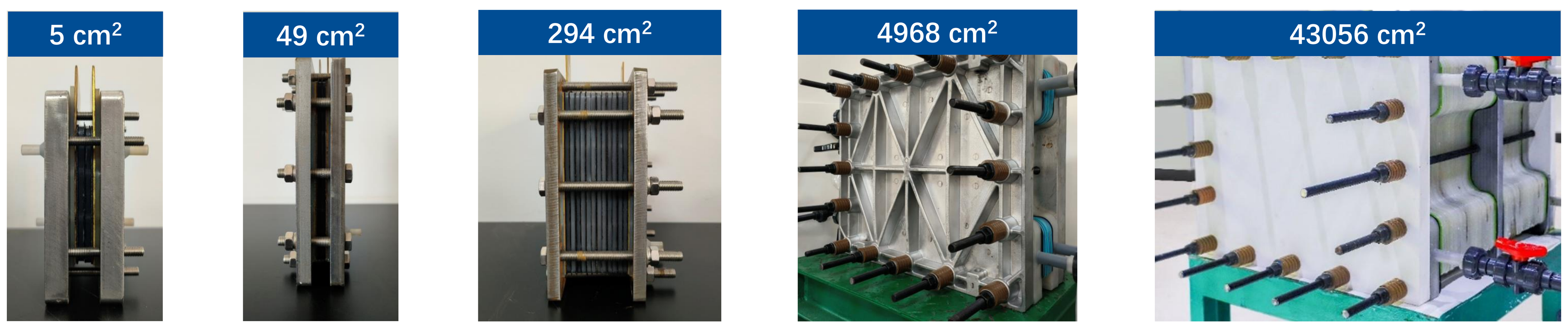
[1] M.T. Tsehaye, X. Yang, et al. "Anion Exchange Membranes with High Power Density and Energy Efficiency for Aqueous Organic Redox Flow Batteries." *Electrochimica Acta*, Vol. 438, 141565, Jan. 2023.

Acknowledgement

We give our wholehearted thanks to our partners at University of Science and Technology of China, for their technical support in polymer design and synthesis.

Up-Scale Process

The SDCN-050 membrane was tested in single cells and cell stacks, which shows consistent performance in operating cells at scale from 5 cm² to 43056 cm². The CE is improved upon scaling up because the cell stack employs a totally different cell design from the lab-scale cell. The decreased capacity utilization and energy efficiency with the increasing cell size are mostly related to the concentration polarization. **The 43056 cm²-stack has been running for four months.**

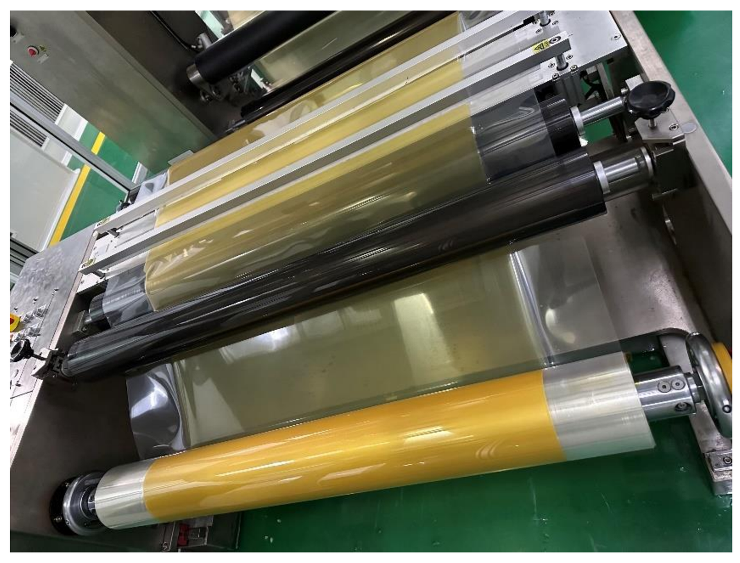


Active Area/cm²	Electrolyte	Capacity Fade Rate	Capacity Utilization/%	CE/%	VE/%	EE/%
5	Organic	0.002%/cycle	87.66	99.62	84.36	84.04
5	Vanadium	0.05%/cycle	78.56	99.92	83.53	83.46
49	Organic	0.002%/cycle	89.72	99.69	83.60	83.33
49	Vanadium	0.03%/cycle	77.76	99.88	84.07	83.97
294	Organic	0.003%/cycle	81.90	98.60	82.20	81.00
294	Vanadium	0.06%/cycle	76.14	98.34	84.10	82.70
4968	Organic	0.002%/cycle	79.50	99.90	81.58	81.50
4968	Vanadium	0.08%/cycle	65.60	99.90	81.24	81.16
43056	Organic	0.059%/cycle	78.36	99.99	81.30	81.30
43056	Vanadium	0.09%/cycle	79.58	99.90	82.40	82.32

Cost Estimation

The cost of the raw materials for the production of the polymers for per square meter SDCN-050, is listed in the table below, excluding the membrane preparation process and other added costs. The total cost for the raw materials is around US$150 m^{-2}, which is quite promising for industrial applications.

Name	Cost per m² (CNY)
Raw material 1	131.75
Raw material 2	93.00
Raw material 3	4.07
Raw material 4	4.26
Raw material 5	29.40
Raw material 6	365.60
Raw material 7	0.96
Raw material 8	13.50
Raw material 9	240.50
Raw material 10	56.4
Raw material 11	0.72
Raw material 12	23.88
Raw material 13	0.20
Raw material 14	48.12
Total cost	1012.36 (~US$150)



Summary

In collaboration with our partners at University of Science and Technology of China and taking into account the different operating conditions for organic and inorganic RFBs, we developed a type of anion exchange membrane (SDCN-050), which is specially designed for use in RFBs. It features low resistance, high selectivity, high mechanical strength, and long-term stability. Its low resistance ensures a high peak power density of 450 mW·cm^{-2}. When used in VRFB, the **coulombic efficiency of the cell with SDCN-050 reached 99.9%**, resulting in excellent capacity retention. The estimated cost of the raw materials for SDCN-050 is around US$150 m^{-2}. In addition, **SDCN-050 shows consistent performance in operating cells at all scales**. We believe our work will greatly benefit the flow battery community and provide potent membrane candidates for the future market.