Supporting information

A Low-cost Sulfate-based All Iron Flow Battery

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Table S1. Viscosity and conductivity of electrolytes of interest.

	Viscosity (mPa·s)	**Conductivity (uS cm^{-1})**
1 M $FeSO_4$	1.36±0.16	5278±28
1 M $FeSO_4$ with 0.1 M EMIC	1.63±0.38	5287±13
2 M $FeSO_4$ with 0.1 M EMIC	3.71±0.36	5468±17

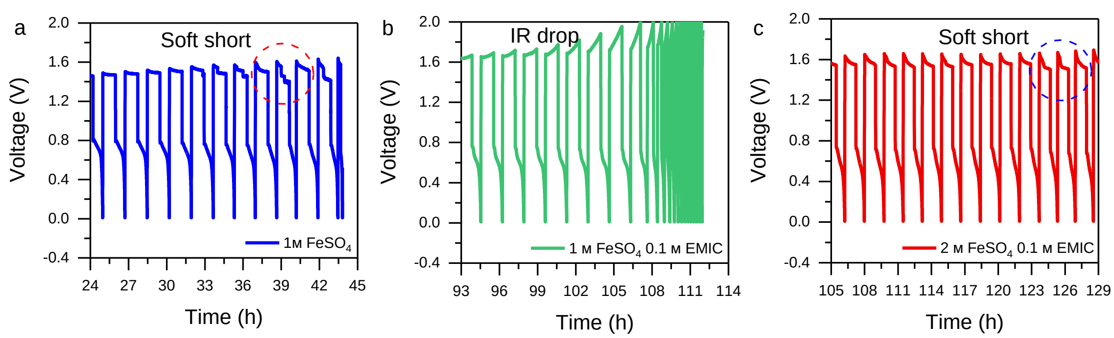

Fig. S1. The charge-discharge profiles of the $FeSO_4$-based AIFBs. The charge-discharge profiles in the final cycles prior to failure for the cells with (a) 1 M $FeSO_4$, (b) 1 M $FeSO_4$ with 0.1 M EMIC, and (c) 2 M $FeSO_4$ with 0.1 M EMIC electrolytes.

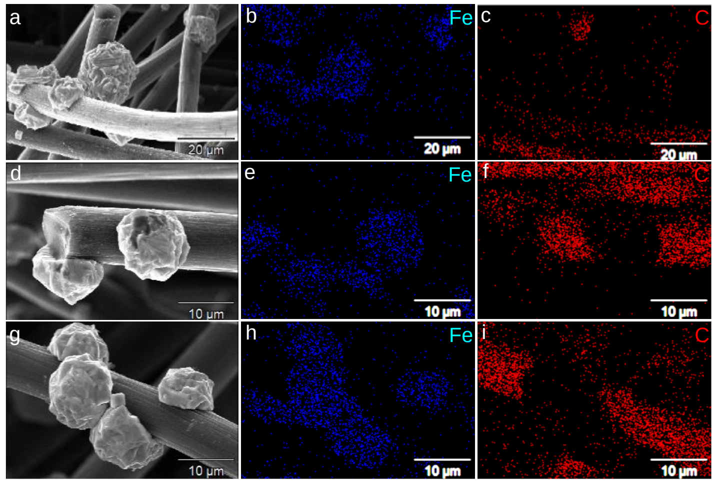

Fig. S2. Iron morphology in the $FeSO_4$-based AIFBs. Iron morphology in the carbon felt in (a)-(c) 1 M $FeSO_4$, (d)-(f) 1 M $FeSO_4$ with 0.1 M EMIC, and (g)-(i) 2 M $FeSO_4$ with 0.1 M EMIC electrolytes. All samples were fabricated at 20 mA/cm^2, one hour.

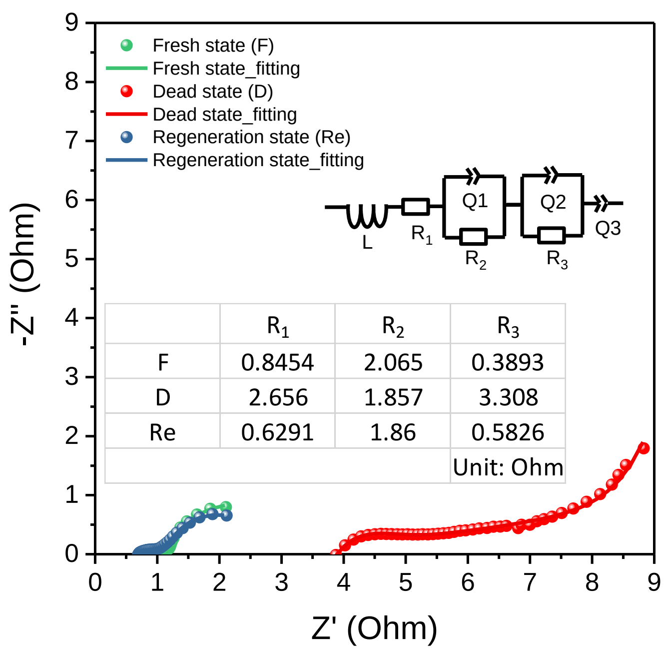

Fig. S3. EIS analysis of the $FeSO_4$-based AIFBs. The EIS curves of flow battery with 2 M $FeSO_4$ with 0.1 M EMIC electrolytes at fresh state, dead state (discharged), and regenerated state. Embedded table exhibited the results of fitting circuit.

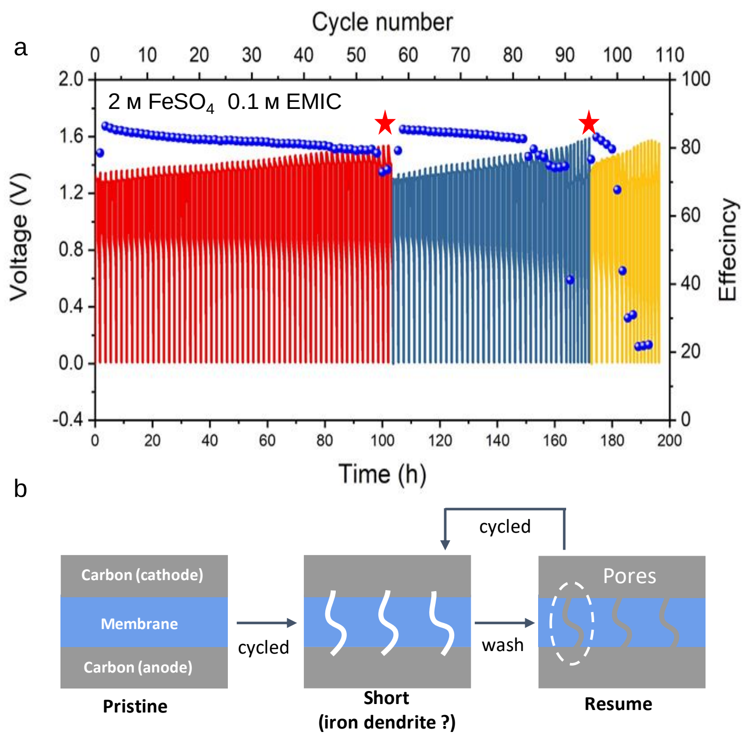

Fig. S4. The charge-discharge profiles of the $FeSO_4$-based AIFBs with traditional set up. (a) Regeneration test with 2 M $FeSO_4$ with 0.1 M EMIC electrolyte, where red stars mean regeneration, and (b) schematic diagram of regeneration with traditional set up.

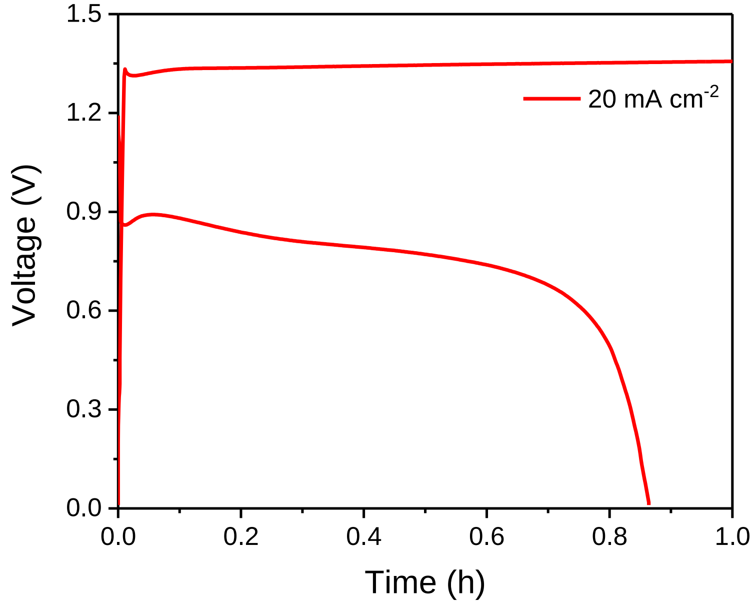

Fig. S5. The 156th cycle charge-discharge profile of the $FeSO_4$-based AIFBs with GF membrane (Fig. 5). The battery was run with 2 м $FeSO_4$ with 0.1 м EMIC electrolyte at a current density of 20 mA cm^{-2}.

Table S2. Flow batteries performance comparison

Ref	Iron salt	Main topic	membrane	Current density [mA cm^{-2}]	Capacity [mAh cm^{-2}]	Cycle number
[1]	$FeCl_2$	Influence of electrolyte additives, temperature, and pH on improving the coulombic efficiency of the iron electrode.	No full-cell cycling performance.			
[2]	$FeCl_2$	Ligands effects on stabilizing Fe(III) in aqueous solution.	No full-cell cycling performance.			
[3]	$FeCl_2$	Iron electrodeposition in a deep eutectic solvent.	Daramic 175 microporous separator	5	5	16
[4]	$FeCl_2$	Evaluation on full-cell cycling performance.	AEM (Tokuyama A901, 11 µm thickness)	40	3.3	50
[5]	$FeCl_2$	MWCNT slurry electrode.	Not mentioned	75	0.5	12
[6]	$FeCl_2$	Internal rebalancing system.	Daramic separator with PVA coating	100	100	<120
[7]	$FeCl_2$/$FeSO_4$	Influence of supporting electrolytes on iron plating reaction.	No full-cell cycling performance.			
[8]	$FeCl_2$/$FeSO_4$	Negative electrode engineering.	Daramic separator	40	20	6
[9]	$Fe_2(SO_4)_3$	Influence of Fe salts, separators, Fe electrodes, and supporting electrolytes on AIFB.	No full-cell cycling performance.			
[10]	$FeSO_4$	Cost analysis.	No full-cell cycling performance.			
This work	$FeSO_4$	High-concentration $FeSO_4$-based electrolyte.	Microporous membrane	20	20	>800

Table S3. Prices of the redox compounds

Chemical	Molecule weight [g mol^{-1}]	Price [$ kg^{-1}]	n	Ur[$ Ah^{-1}]
V_2O_5 [a)]	182	11.7	2	0.079
$FeCl_2$ [b)]	126.75	0.086	1	0.00041
$ZnCl_2$ [b)]	225.21	2.17	2	0.0091
$FeSO_4$ $7H_2O$ (anode)[c)]	278.02	0.05	2	0.00026
$FeSO_4$ $7H_2O$ (cathode)[c)]	278.02	0.05	1	0.00052

[a)] Reference [11]; [b)] Reference[12]; [c)] Quoted from Shandong Jiulong Qingjiang Water Purification Technology Co., Ltd.

Table S4. Prices of supporting electrolytes

Chemical	Molecule weight [g mol^{-1}]	Price [$ kg^{-1}]	Use [$ Ah^{-1}]
H_2SO_4 [a)]	98	0.075	0.00099
KCl [b)]	74.45	0.26	0.0014

$C_2H_5NO_2$ [b]	75.07	1.88	0.011
EMIC (anode) [c]	146.62	1	0.00049
EMIC (cathode) [c]	146.62	1	0.000985

[a] Reference [11]**;** [b] Reference [12]; [c] Quoted from Shanghai Yuchuang Chemical Technology Co., Ltd.

Table S5. Prices of electrode materials

Electrode material	Price [$ m^{-2}]	U_{em} [$ m^{-2}]
Carbon felt [a]	70	70
Copper mesh [a]	48	48
Carbon felt [b]	154.7	154.7
Carbon felt [c]	70	70

[a] Reference [11]**;** [b] Reference [12]; [c] Reference[13]

Table S6. Prices of the membranes

Membrane	Price [$ m^{-2}]	U_m [$ m^{-2}]
Nafion 117 cation-exchange membrane [a)]	500	500
PBI porous membrane [b)]	50	50
Microporous membrane [c)]	10	10
Glass fiber separator [d)]	0.1	0.1

[a)] Reference [11]; [b)] Reference [12]; [c)] Reference [13]; [d)] Quoted from Qingdao Rockpro Composites Co., Ltd.

Table S7. Electrolyte costs of All-V, Zn-Fe, and $FeSO_4$/EMIC RFBs

	U_e [$ Ah^{-1}]	V_{eff} [V]	C_e [$ kWh^{-1}]
All-V [a)]	0.08064	1.26	64
Zn-Fe [b)]	0.021	1.4	15
$FeSO_4$/EMIC [c)]	0.00304	0.9	3.37

[a] Reference [11]; [b] Reference [12]; [c] The price information and detailed calculation are shown in **Table S3** and **Table S4**.

Table S8. Stack costs of All-V, Zn-Fe RFBs and $FeSO_4$/EMIC.

	U_{em} [\$ m^{-2}]	U_m [\$ m^{-2}]	U_b [\$ m^{-2}]	U_s [\$ m^{-2}]
All-V [a]	140	500	55	695
Zn-Fe [b]	154.7	50	55	259.7
$FeSO_4$/EMIC [c]	70	10.1	55	135.1

[a] Reference [11]; [b] Reference[12]; [c] The price information and detailed calculation are shown in **Table S5**, and **Table S6**.

Table S9. Energy density analysis of All-V, Zn-Fe RFBs and $FeSO_4$/EMIC flow battery.

	V_{eff} [V]	Catholyte	Anolyte	Catholyte/Anolyte ratio [vol%]	Energy density [Wh L^{-1}]
All-V [a]	1.26	1.5 M VO^{2+}	1.5 M V^{3+}	1:1	25
Zn-Fe [b]	1.4	2 M $FeCl_2$	1 M $ZnCl_2$	1:1	37

$FeSO_4$/EMIC [c)]	0.9	2 м $FeSO_4$	2 м $FeSO_4$	2:1	32

[a)] Reference [11]; [b)] Reference[12]; [c)] This work.

Reference

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