Electronic Supplementary Information

Novel Cathodic Electrolyte Based on $H_2C_2O_4$ for Stable Vanadium Redox Flow Battery with High Charge/Discharge Capacities

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Supplementary Figures

Table S1. Cyclic voltammetry data for 1 M V(IV) solution in the sulfuric acid and oxalic acid on the pyrolitic graphite (PG) and carbon felt (CF)

Sample	Anodic peak, I_{pa} [mA]	Cathodic peak, I_{pc} [mA]	ΔEp [mV]	I_{pa}/I_{pc}
Sulfuric acid (PG)	7.946	1.1258	1060	7.058
Oxalic acid (PG)	15.64	14.51	231	1.077
Sulfuric acid (CF)	94.44	27.34	1002	3.454
Oxalic acid (CF)	82.32	59.74	824	1.377

Table S2. Physical and electrical information on the carbon felt used in this study

Item	Parameter
Model	GFA-5
Area weight	430 gm^{-2}
Resistivity	Longit. 2-4 Ωmm
	Transv. 1.5-3 Ωmm
Ash contents	≤ 0.4 %

Table S3. Physical and electrical information on the graphite used in this study

Item	Parameter
Model	G347
Standard grade	TC
Grade kind	Isotropy
Specific gravity	1.85
Specific resistance	11.0 μΩm
Yong's Modulus	10.8 Gpa
Flexural strength	49.0 Mpa
Shore hardness	58
Coefficient of thermal expansion (C.T.E.)	5.5
Thermal conductivity	116 Wmk^{-1}

Table S4. Viscosity of the cathodic electrolytes based on the oxalic acid and sulfuric acid with different vanadium concentrations. (Revolutions per minute: 100 rpm)

Sample	0.1 M V/1 M H_2SO_4	1 M V/1 M H_2SO_4	0.1 M V/1 M $H_2C_2O_4$	0.1 M V/1 M $H_2C_2O_4$
Viscosity (cP)	2.203	2.596	2.165	2.418

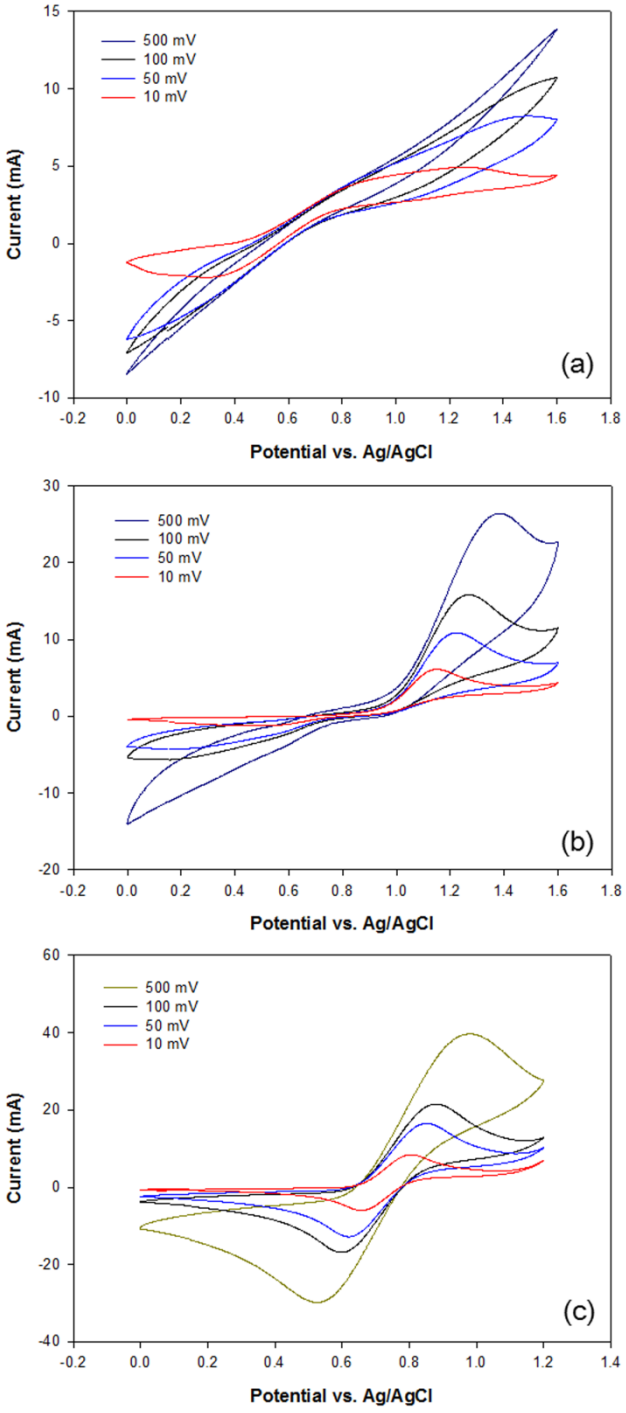

Figure S1. Cyclic voltammetry (CV) curves of 0.1 M vanadium solution dissolved in distilled water (a), 1 M sulfuric acid (b), and 1 M oxalic acid (c) at the pyrolitic graphite depending on different scan rates

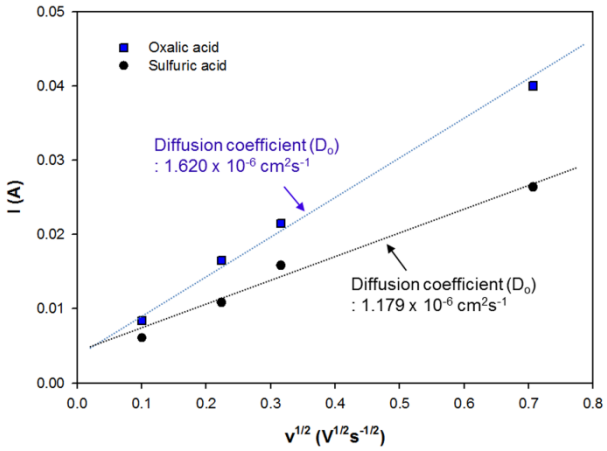

Figure S2. Plots of the anodic peak current vs. the square root of scan rates ($v^{1/2}$) for the cathodic electrolytes (0.1 M vanadium) based on 1 M oxalic acid and 1 M sulfuric acid

The diffusion coefficients of the solutions with oxalic acid and sulfuric acid were obtained from following equations, (1) reversible redox couple and (2) irreversible redox couple [1]:

$$i_p = 2.69 \times 10^5 n^{3/2} A C D_0^{1/2} v^{1/2} \quad (1)$$

$$i_p = 2.99 \times 10^5 n^{3/2} \alpha^{1/2} A C D_0^{1/2} v^{1/2} \quad (2)$$

where i_p is the peak current, n is the number of electrons transferred in the reaction, A is the working electrode area, C is the bulk concentration of primary reactant, D_0 is the diffusion coefficient, and v is the scanning rate.

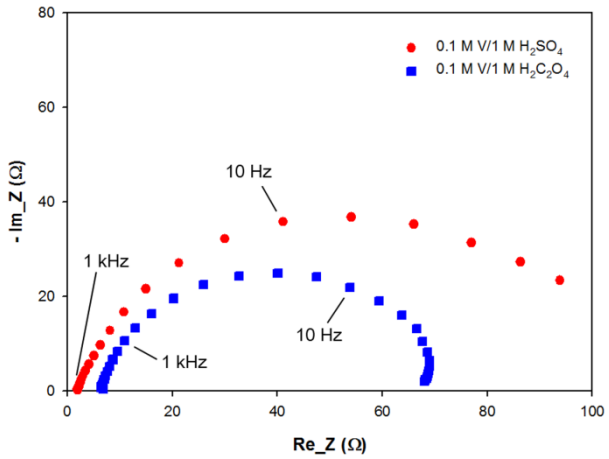

Figure S3. Impedance spectra of the cathodic electrolyte based on the oxalic acid and sulfuric acid with the frequency range from 0.1 Hz to 1 MHz (Working and counter electrode: Pt, reference electrode: Ag/AgCl)

References

1. Z. He, Z. Li, Z. Zhou, F. Tu, Y. Jiang, C. Pan, and S. Liu, *J. Renewable Sustainable Energy* 2013, ***5***, 23130