Supporting Materials

Constructing Bifunctional Electrodes of FeCeO with Tunable Carbon Decoration from Waste Plastics for Efficient Energy Storage and Oxygen Evolution Reaction

Shizhen Zhang [a], Xu Hou [a, b, *], Jing Huang [a], Li Yin [a], Enxian Yuan [c, *]

[a] School of Chemical Engineering, Changchun University of Technology, Changchun, Jilin, PR China

[b] Advanced Institute of Materials Science, Changchun University of Technology, Changchun, Jilin, PR China

[c] School of Chemistry and Chemical Engineering, Yangzhou University, Yangzhou, Jiangsu, PR China

[*] Corresponding author:

Xu Hou: houx@ccut.edu.cn

Enxian Yuan: exyuan@yzu.edu.cn

S1. Details about the reactants

(1) $Ce(NO_3)_3$, $Fe(NO_3)_3$, oxalic acid, methanol, ethanol and tetramethylammonium hydroxide with the analytical purity were purchased from Rhawn Reagent Company (Shanghai, China).

(2) Polyethylene (PE) and polypropylene (PP) were purchased from Huachuang Plastics (Guangdong, China).

(3) Real waste plastics (RWP) were the gathering of the packaging bags, plastic bags, bottle caps, plastic gloves, plastic bottles, and straws. The waste plastics were cleaned by the ethanol, and dried at room temperature for 12 h; then, it was mixed and crushed into the powders for the experiment tests.

S2. Details about characterization methods

(1) SEM images were obtained on an JSM-7610F scanning electron microscope equipped with a OxfordX-Max50 energy-dispersive X-Ray spectroscopy attachment.

(2) TEM images were obtained on a JEM-2100 microscope equipped with an energy-diffusive X-Ray spectroscopy attachment.

(3) XRD patterns were obtained at a rate of 5 °/min in the range of 5-90 ° on a Rigaku instrument, which was equipped with a Cu Kα radiation source.

(4) N_2 physisorption test was performed on a specific surface area and porosity analyzer (ASAP 2020). The sample (50 mg) was first degassed at 350 °C for 24 hours and then exposed to N_2 at -196 °C. The specific surface area was obtained by Brunauer-Emmett-Teller (BET) method. N_2 absorption at a relative pressure (P/P_0) of ca. 0.99 was used to determine the total pore volume.

(5) H_2-TPR (hydrogen temperature programmed reduction) tests were performed by a Micromeritics AutoChemII2920 chemisorption analyzer. As a typical H_2-TPR test, the sample (100 mg) was charged in a quartz tube reactor. Firstly, it was pretreated under Ar flow at 300 °C for 2 h. Secondly, it was cooled to and maintained at 100 °C under Ar flow until TCD signal was constant. Finally, it was heated to 750 °C under hydrogen (H_2 10 vol% in Ar) flow with a heating rate of 10

°C/min. The hydrogen consumption was monitored by a thermal conductivity detector.

(6) TG-DSC tests were carried out on an HCT-1 thermogravimetric and differential scanning calorimetry analyzer in 100-800 °C with a heating rate of 10 °C/min under air.

(7) Raman spectra were obtained on a Lab Ram HR-evolution with an excitation laser of 532 nm.

(8) XPS spectra were obtained on a photoelectron spectrometer (ESCALAB 250Xi) equipped with an Al Kα source gun.

(9) The actual contents of Fe and Ce in FeCeO were determined by an inductively coupled plasma (ICP) optical emission spectrometer (Optima 7300DV) by completely dissolving FeCeO in the mixture of HCl and HNO_3 at 50 °C.

(10) The electrochemical tests for energy storage were conducted in 6M KOH electrolyte using a three-electrode system. Before the experiment, the nickel foam (length 2 cm; wideness: 1 cm; thickness: 1.5 mm) was ultrasonically washed with hydrochloric acid, isopropanol, ethanol, and water for 30 min, individually. First, the ink was prepared by dispersing the prepared materials (8 mg), carbon black (1 mg) and polyvinylidene fluoride (1 mg) into N-methylpyrrolidone (80 μL) via the ultrasonic treatment. Second, the ink was dropped onto the nickel foam within an area of 1 × 1 cm, and the mass loading of the prepared materials was 2-3 mg. Final, the capacitance was evaluated in 6M KOH electrolyte by a three-electrode system on a CHI660E electrochemical workstation. The prepared nickel foam was used as the working electrode, graphite rod was used as the counter electrode, and Hg/HgO was used as the reference electrode. Cyclic voltammetry (CV), galvanostatic charge/discharge (GCD), and electrochemical impedance spectroscopy (EIS) were measured. The specific capacitance C (F/g) was obtained from the GCD curve via Equation S1:

$$C = \frac{I \times \Delta t}{m \times \Delta U} \qquad (S1)$$

where I was the constant discharge current (A), Δt was the discharge time (s) of potential change, and m (g) was the mass of the prepared materials in the substrate.

(11) The electrocatalytic OER tests were tested in 1M KOH electrolyte solution using a three-electrode system. Before the experiment, the nickel foam (length 2 cm; wideness: 1 cm; thickness: 1.5 mm) was ultrasonically washed with hydrochloric

acid, isopropanol, ethanol, and water for 30 min, individually. First, the ink was prepared by dispersing the sample (5 mg) into the solution consisting of Nafion (50 μL), ethanol (712.5 μL) and deionized H_2O (237.5 μL) via the ultrasonic treatment. Second, the ink was dropped onto the nickel foam within an area of 1 × 1 cm, and the mass loading of the sample was 1.2-1.5 mg. Final, the OER activity was evaluated in 1M KOH electrolyte solution by a three-electrode system on a CHI660E electrochemical workstation. The prepared nickel foam was used as the working electrode, graphite rod was used as the counter electrode, Hg/HgO was used as the reference electrode. Linear scanning voltammetry (LSV) was measured at a scanning rate of 5 mV/s. The potential was calibrated using a reversible hydrogen electrode (RHE) with the equation $E(RHE) = E(Hg/HgO) + 0.098 + 0.059\ pH$. The voltage was then compensated according to the equivalent circuit (iR, 90%) to obtain LSV curves.