

Supplementary information

Experimental details

Preparation of RuO₂/AZO

The RuO₂/AZO samples were synthesized by a microwave-assisted hydrothermal method using aluminum nitrate nonahydrate (Al(NO₃)₃·9H₂O, High purity chemicals, 99.9%), zinc nitrate hexahydrate (Zn(NO₃)₂·6H₂O, High purity chemicals, 99.9%) and ruthenium chloride hydrate (RuCl₃·xH₂O, Sigma-aldrich) as raw materials. A mixture of deionized water and isopropanol was used as solvent. The pH of the precursor solution was controlled by concentrated hydrochloric acid (HCl, Burdick&Jackson, 37%). All the chemicals were used without further purification.

The molar ratio of aluminum to zinc to ruthenium was 1:9:1.1. For the synthesis of AZO, Zn(NO₃)₂·6H₂O, Al(NO₃)₃·9H₂O and RuCl₃·xH₂O were dissolved in a solution composed of isopropanol and deionized water, having the isopropanol-to-water volume ratios of 4:1. Concentrated hydrochloric acid was added drop-wise into the above solution until pH reached 0.1. The resulting solution was transferred and sealed in a Teflon vessel; then placed in a microwave reactor (Model MARS6, CEM Corp., USA). The reaction temperature was raised to 170°C, maintained for 20 min; then cooled down to room temperature. The resultant powder was washed with deionized water and dried, then annealed at 350, 400, and 500°C under oxidative atmosphere for 1 h to get RuO₂/AZO powder.

Measurements

The crystal structure of obtained RuO₂/AZO was monitored with X-ray powder diffractometer (XRD, (Rigaku Ultima IV Diffractometer) with graphite-monochromator equipped with Cu K α radiation; operating at 40 kV and 40 mA. The particle size and morphology were observed using field-emission scanning electron microscopy (FE-SEM, Tescan Mira 3 LMU FEG, 20kV) and transmission electron microscopy (TEM, Tecnai G2 T-20S, FEI & JEM-3011 HR, JEOL) equipped with energy-dispersive X-ray spectroscopy (EDS). The Brunauer-Emmett-Teller (BET) surface area was measured by nitrogen adsorption/desorption at 77.3 K. Before measurement, all the samples were degassed for 30 min at 90°C, and evacuated for 4 h at 200°C. X-ray photoelectron spectroscopy (XPS) was carried out with an AXIS-NOVA (Kratos Inc., UK) system using Al-K α (150W) radiation. The cathode was formulated by mixing RuO₂/AZO powder and PTFE in a weight ratio of 8:2 dispersed in isopropanol and deionized water (1:1 v/v). The obtained slurry was spread on SUS mesh as a gas diffusion layer as well as a current collector, followed by vacuum drying at 120°C for 12 h. The electrolyte was 1 M LiNO₃ dissolved in a N,N-dimethylacetamide (DMAc). Li foil was used as an anode, and coin cells (CR2032 type) were assembled in an argon-filled glove box.

Electrochemical measurements were carried out using the galvanostatic cycling method with a WBCS-3000 battery cyler (WonAtech). The applied current density was 0.02 mA/cm², and cut-off voltage was 2.0 - 4.4 V vs. Li/Li⁺.

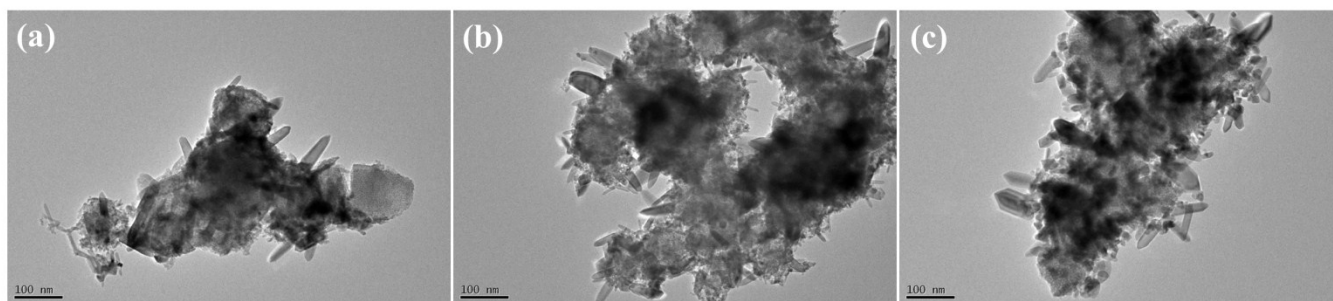


Fig. S1 (a) TEM images of RuO₂/AZO annealed at (a) 350°C (b) 400°C and (c) 500°C

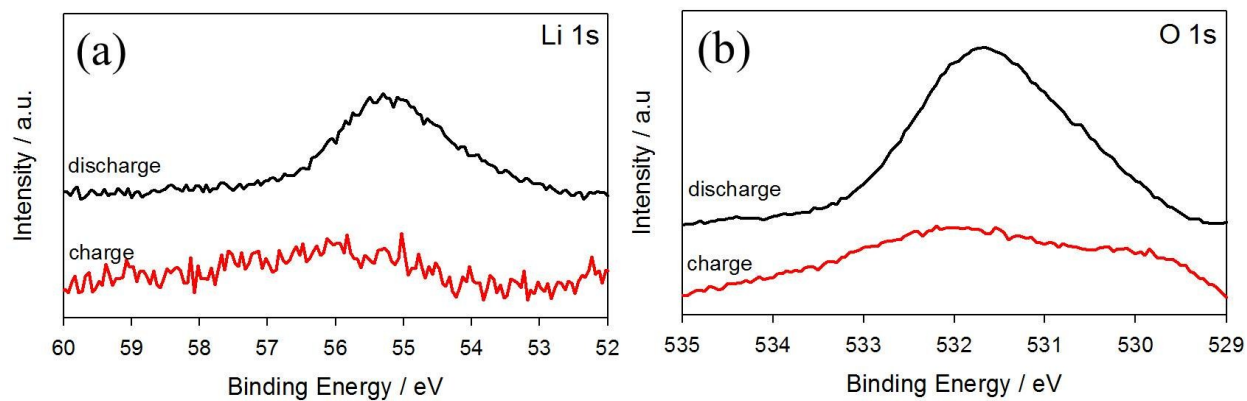


Fig. S2 XPS analysis of amorphous RuO₂/AZO: (a) Li 1s spectra and (b) O 1s spectra after the first discharge and charge

Table S1 BET analysis of RuO₂/AZO annealed at different temperature

	350°C	400°C	500°C
Specific surface area (m ² /g)	17.1	35.0	90.9
Pore volume (cm ³ /g)	0.046	0.050	0.095