Electronic Supplementary Material (ESI) for Chemical Communications.

Supporting Information

An Intrinsically Stretchable and Compressible Zn-Air Battery

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Experimental Section

Synthesis of sodium polyacrylate hydrogel electrolyte.

A beaker of concentrated sodium hydroxide solution (27 mL, 25 M, Alfa) was prepared using de-ionized water and consequently dropped into an aqueous solution of purified acrylic acid monomer (54 mL, 47 wt%, Macklin) with a slow speed within 12 h. Additionally, the ammonium persulfate (0.78 g, ThermoFisher) was added into the neutralized solution and stirred for 0.5 h. A degas procedure was performed to remove the dissolved air in the solution. Further treatment in an oven at 40℃ for 30 h allows free radical polymerization. Finally, the as-polymerized hydrogel was dried in an 80 ℃ oven and then soaked in a mixed solution (500 mL) of zinc acetate (0.2 M, Macklin) and potassium hydroxide (6 M, Alfa) for up to 2 days.

Fabrication of the Au foil

The Au foil was fabricated by the following procedures. Firstly, a gold alloy is gradually thinned by running it through rollers, until 0.05 mm thickness is achieved. Then, the stretched gold is cut into square pieces of about 6 cm^2, placed between sheets of washi paper (extremely fine paper soaked in alkali) and pounded for 4-5 stages till it is thinned to 120 nm.

Fabrication and electrochemical characterization of the rechargeable ZAB

The Zn anode was electrodeposited on a CNT paper (width: 1 cm; length: 5 cm) at -0.8 V vs. Zn foil for 20 min in zinc sulfate (1 M). The Au foil (120 nm) was attached onto a CNT paper (25 um) as cathode, and then pricked by tiny nails with the diameter of 200 um, and the hole density is one per 0.25 mm^2. The surface of the CNT paper is highly waterproof, thus possess a highly hydrophobic surface with well-retained ORR activity. The anode and cathode were paved on the PANa film electrolyte (thickness: 2.7 mm), which also served as a separator. LSV and discharge of the as-assembled ZAB were tested by a CHI760E potentiostat, where the charge & discharge cycle tests were performed by LAND-CT2001A.

Experimental details of stretching and compressing electrochemical tests

Stretching: The newly assembled batteries (width: 1 cm; length: 5 cm) were packaged first, fixed tight on the self-made stretching tester designed with a linear motor, connected to a CHI760E potentiostat, and then slowly, uniformly stretched to 100%, 200%, 300%, respectively, controlled by a single chip microcomputer. The relative electrochemical measurements were conducted after.

Compressing: The as-assembled batteries were put on a uniform platform and connected to a CHI760E potentiostat first. Then, before stabilization for a while, a set of weight blocks were placed onto the ZABs, respectively. The average thicknesses of the compressed cells were measured after to calculate the strain of the ZABs before electrochemical measurements.

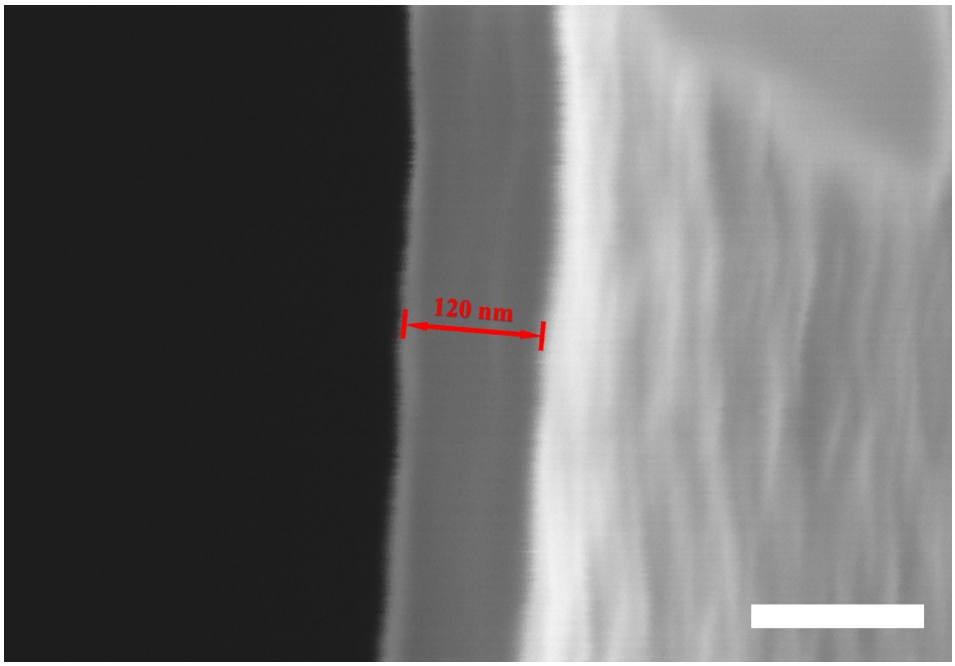

Figure S1. Cross profile of the thin Au foil. Scale bar: 150 nm.

According to the scale bar of the SEM image, the thickness of Au foil is about 120 nm.

Table S1. Cost comparison of noble-metal-based oxygen catalysts.

Catalyst	*Catalyst cost ($ / cm²)*	*Charge Potential (V)*	*Discharge Potential (V)*	*Current Density (mA / cm²)*
[a]RuO_2 + Pt/C (20%)[1]	1.78	2.25	1.00	5.0
[b]IrO_2 + Pt/C (20%)[2, 3]	0.16	1.50	1.35	1.0
[c]Commercial RuO_2	0.52	/	/	/
thin Au macro foil	0.013	2.05	1.20	2.0

a) [a]Cost was calculated by a catalyst loading of 10 mg/cm^2.

b) [b]Cost was calculated by a catalyst loading of 0.2 mg/cm^2 of Pt/C (20%) and 0.27 mg/cm^2 of IrO_2.

c) [c]Cost was calculated by a catalyst loading of 2 mg/cm^2.

d) All costs referred to Sigma Aldrich at www.sigmaaldrich.com on 13rd March, 2020.

Table S2. Comparison of electrochemical performance of our ZAB (Zn-air Battery) with previously reported ZABs in terms of current density, time per cycle, cycle time, stretchability and compressibility.

Ref.	Electrolyte	Current density mA cm^{-2}	Time per cycle min	Cycle time h	Stretch-ability	Compress ibility
This work	**PANa**	**1**	**22**	**10**	**Intrinsic 300%**	**Intrinsic 85%**
1[4]	PVA	2	10	6	×	×
2[5]	PVA	0.5	20	12	×	×
3[6]	PVA-PEO	2	60	10	Extrinsic 300%	×
4[7]	Cellulose	1	20	10	×	×
5[8]	PVV/PVA GPE	0.5	10	24	×	×
6[9]	PVA	2	20	24	×	×
7[10]	A hydrogel polymer (unspecified)	1	10	8.3	×	×

As can be seen from Table S2, a majority of the reported flexible ZABs did not provide electrochemical data under strain. We developed the first intrinsically stretchable and compressible ZAB which has never been reported in all published articles. Without electrochemical tests under compressive strain, the resistance of flexible ZAB cannot be reflected. In this article, the electrochemical performance is even slightly enhanced under the compressive strain of up to 85%, compared with the empty load specimen, which proves adequate novelty of this work.

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