Supporting Information

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A Weavable and Scalable Cotton-Yarn-Based Battery Activated by Human Sweat for Textile Electronics

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**Figure S1.** CVs of the carbon-black-modified electrode in N\(_2\)-saturated (blue line) and O\(_2\)-saturated (red line) NaCl solutions (100 mM) with a scanning rate of 10 mV s\(^{-1}\).
Figure S2. (a) Preparation of carbon black suspension; (b) fabrication of carbon-black-coated cotton yarn with BSA as a binder; (c) contact angle images of the carbon black-coated cotton yarn.

Figure S3. (a) Digital photographs of the carbon-black-modified cotton yarn before and after ultrasonic treatment; (b) conductivity of the carbon-black-modified cotton yarns with/without BSA. The data obtained from three independent experiments (n = 3) are presented as the mean ± SD.
Figure S4. (a) Digital photograph of a cotton yarn partially modified with carbon black; FESEM images of a (b) carbon-black-coated cotton yarn and (c) pristine cotton yarn.

Figure S5. Galvanostatic discharge voltages of CYSABs with the cathode length ranging from 4 to 10 cm. The data obtained from three independent experiments (n = 3) are presented as the mean ± standard deviations.
Figure S6. (a) Cross-sectional SEM image of a Zn-foil-wrapped cotton yarn; EDS mappings of Zn-foil-wrapped cotton yarn in terms of the contained (b) Zn, (c) C, and (d) O elements.

Figure S7. Correlation between the maximum power density of the CYSAB and the NaCl concentration.
Figure S8. Plots of the (a) voltage and (b) current outputs over time at a given external resistance of 50 kΩ.

Figure S9. Galvanostatic discharge curves of the devices with the salt bridge lengths of 0.3 cm and 0.5 cm (n=3), respectively.
Figure S10. (a) Set-up of device saturation experiments; (b) maximum infiltration volumes of three independent CYSABs (n=3).

Figure S11. Open-circuit voltage of a CYSAB activated using a 100 μL NaCl solution under ambient conditions.
**Figure S12.** Correlation between the initial voltage in a galvanostatic discharge curve and the volume of a 100 mM NaCl solution.

**Figure S13.** (a) Galvanostatic discharge curve of a CYSAB activated with an NaCl solution under repeated bending. Insets: photographs of a device in bending and straight states, respectively. (b) A device at the bending state. d indicates the bending diameter.
Figure S14. (a) Voltage and current outputs of a battery pack containing four in-parallel CYSABs under a load of 10 kΩ; (b) photograph of a red LED (minimum driving voltage of 1.5 V) powered with two CYSABs connected in series.
Figure S15. Surface morphologies of carbon-black-coated yarn before (a) and after (b) 16 times of washing. (c) Surface morphology of pristine cotton yarn.

Figure S16. Open-circuit voltage of a CYSAB after repeated washing.
Figure S17. (a) Two cotton yarns with identical lengths containing two (bottom) and three (upper) batteries; (b) photograph showing 50 yarns, each containing 10 continuously fabricated cathode segments.
**Figure S18.** (a) Schematic illustration showing the function of a hydrophobic barrier in a yarn. (b) Photographs of two battery packs (two series-connected CYSABs) with (labelled as “1”)/without (labelled as “2”) a hydrophobic barrier between the two CYSABs. (c) Galvanostatic discharge curves of battery packs 1 and 2. (d) Digital watch powered by a bracelet containing two series-connected CYSABs.
Figure S19. Series of images extracted from a video illustrating the working process of a digital watch powered by 2 in-series CYSABs after the addition of a 100 μL NaCl solution (100 mM) to each device.

Figure S20. Weaving process of an energy fabric with the CYSABs as warp.
Figure S21. (a) Microscopic images of a pristine elastic yarn during various stretching states (elongations of 0% and 50%). SEM images of the (b) pristine elastic yarn and (c) PEDOT:PSS-coated elastic yarn. (d) Cross-section image of the conductive elastic yarn. (e) Contact angle image of the conductive elastic yarn.

A strain sensor was fabricated with a core-sheath-structured elastic yarn, which consists of a polyester fiber sheath and an elastic rubber core. The carbon black suspension was mixed with PEDOT:PSS at a ratio of 1:3 to prepare the conductive ink. The elastic yarn was soaked in the ink, followed by drying at 60 °C for 1 h. The resistance of the strain sensor could be adjusted by repeating the soaking-drying procedures.
Figure S22. (a) Fabric-based strain sensor stitched onto black pants; (b) strain sensor at the stretching state during the on-body test; (c) wireless real-time monitoring of a human while cycling using a smart phone.

Figure S23. Attachment of a fabric-based strain sensor on a human abdomen for respiration monitoring. Inset: a fabric strain sensor in the resting (up) and stretching (bottom) states.
**Figure S24.** Effects of periodic oscillation on sensing performance of fabric-based self-powered sensing system.

**Figure S25.** (a) Galvanostatic discharge curves of CYSABs fabricated with polished (black curve) and unpolished (red curve) Zn foils; (b) plots of the open-circuit voltage against time for the CYSABs fabricated with polished (black curve) and unpolished (red curve) Zn foils.
Figure S26. Effects of the NaCl solution pH on the open-circuit voltage and galvanostatic discharge voltage of the CYSABs. The data obtained from three independent experiments ($n = 3$) are presented as the mean ± standard deviations.

Figure S27. Effects of the current on the galvanostatic discharge behaviors of the CYSABs with continuous electrolyte supply.
Figure S28. Schematic illustration of a working CYSAB to analyze the role of the carbon-black-coated fiber and salt bridge depending on their locations and the corresponding electric circuit.

**Electron transfer between sweat and the carbon black nanoparticles**

Increasing the length of the carbon-black-coated yarn immersed in sweat facilitated a more effective oxygen reduction catalytic area for the battery cathode. At the same time, a high concentration of salt ions, large oxygen reduction area, and large solid-liquid contact area facilitate electron transfer, which is one of the considerable advantages of using a longer carbon-black-coated thread as a battery cathode.
**Figure S29.** Photographs of a red LED powered by the curl/randomly coiled CYSABs.
Figure S30. Time-dependent turning on of the LEDs due to the successive transport of liquid along the cotton yarns.
| Battery Category | Electrode Materials | Separator & Sweat Reservoir | Anode & Cathode Reactions | Maximum Output Voltage | Weavability | Washability (in water under stirring) | Reusability | Large-Scale Production | Device Type | Applications | Ref. |
|------------------|---------------------|----------------------------|--------------------------|------------------------|------------|-------------------------------------|------------|------------------------|-------------|-------------|------|
| Zn-air           | Zn foil - carbon black powder | Cotton yarn | Anodic: Zn - 2e\(^-\) → Zn\(^{2+}\)  
Cathodic: O\(_2\) + 2H\(_2\)O + 4e\(^-\) → 4OH\(^-\) | ~1.0 V | Yes | Yes | Yes | Yes | Yarn & Fabric | Power for an LED and a wearable strain sensor | This work |
| Zn-air           | Zn foil - MWCNTs/ SWCNTs powder | Paper | Anodic: Zn - 2e\(^-\) → Zn\(^{2+}\)  
Cathodic: O\(_2\) + 2H\(_2\)O + 4e\(^-\) → 4OH\(^-\) | 0.81 V | No | No | Not provided | No | Patch | Powering wireless heart-rate sensor/biosensing | 1 |
| Zn-Cu            | Zn foil - Cu foil | Super-hygroscopic material | Anodic: Zn - 2e\(^-\) → Zn\(^{2+}\)  
Cathodic: 2H\(_2\) + 2e\(^-\) → H\(_2\) | 0.57 V | Not provided | Not provided | Not provided | No | Patch | Powering a red LED | 2 |
| Mg-Ag/AgCl       | Mg sheet - Ag/AgCl ink | Cellulose paper | Anodic: Mg - 2e\(^-\) → Mg\(^{2+}\)  
Cathodic: 2AgCl + 2e\(^-\) → 2Ag + 2Cl\(^-\) | ~1.5 V | No | Not provided | No | No | Detachable electronic module | Wireless communication/heart rate sensor | 3 |
| System          | Electrolyte | Anode | Cathode | Charging | Application               |
|-----------------|-------------|-------|---------|----------|---------------------------|
| Zn-air          | Zn foil, PANI and CNT filter paper | Zn - 2e\(^{-}\) \rightarrow Zn\(^{2+}\) | \(O_2 + 2H_2O + 4e^{-} \rightarrow 4OH^{-}\) | Not provided | Not provided | No | Patch | Charging for supercapacitors 4 |
| Zn-flake filters | Zn flake inks-Ag\(_2\)O inks | Zn - 2e\(^{-}\) \rightarrow Zn\(^{2+}\) | Ag\(_2\)O + 2e\(^{-}\) \rightarrow 2Ag + O\(_2\) | ~1.2 V | Not provided | Not provided | Not mentioned | No | Patch | Powering a temperature sensor 6 |
| Mg-Ag/AgCl      | Mg foil-silver ink paper | Mg\(^{2+}\) | 2AgCl + 2e\(^{-}\) \rightarrow 2Ag + 2Cl\(^{-}\) | ~1.6 V | No | No | No | No | Patch | Sweat conductivity monitoring 5 |
| Mg-Ag/AgCl      | Mg foil-silver ink paper | Mg\(^{2+}\) | 2AgCl + 2e\(^{-}\) \rightarrow 2Ag + 2Cl\(^{-}\) | ~1.6 V | No | No | No | No | Patch | Sweat conductivity monitoring 5 |

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