Electronic Supplementary Information

Ultrathin Self-Powered Artificial Skin

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1. Experimental section

Chemicals. Zinc nitrate hexahydrate ($Zn(NO_3)_2 \cdot 6H_2O$, ≥ 99.0%), hexamethylenetetramine (HMTA) ($C_6H_{12}N_4$, 99+%) and anhydrous hexane were purchased from Aldrich. Zinc nitrate hexahydrate and HMTA were dissolved in deionized water under magnetic stirring for 30 min prior to use. Sylgard 184 PDMS prepolymer and curing agent was purchased from Dow Corning Chemicals.

Synthesis of ZnO nanorods. ZnO nanorods were prepared by using a hydrothermal process. In this synesthetic procedure, we used syringe pumps to enable the continuous addition of the zinc precursor solutions into the hot HMTA solution. In a typical synthesis, the two precursor solutions were prepared by separately dissolving 0.42 g of zinc nitrate hexahydrate in 100 mL of deionized water and 0.24 g of HMTA in 100 mL of deionized water at room temperature. The zinc precursor solution was continuously injected into the HMTA solution with vigorous stirring at 85 °C via a syringe pump at an injection rate of 2 mL/h for 25 min, and the process was finished after 5 min. After centrifugation, the flocculated nanorods were isolated from the supernatant, and washed three times with deionized water to remove the unreacted Zn^{2+} and other ions. The final precipitate was dried at 80 °C and thermally annealed at 400 °C for 2 h in a vacuum to increase crystallinity .

Fabrication of SPAS. In order to fabricate the SPAS, PEDOT:PSS spin-coated (1 step : 500 rpm for 5 s, 2 step : 4000 rpm for 30 s) on slide glass (5 × 5 cm^2) was used as the substrate. The PEDOT:PSS layer was used as an anti-adhesive layer between the PDMS and the glass. Before the PDMS was used (with a curing agent in a ratio of 10:1), PDMS and hexane were mixed to control the film thickness of PDMS with various ratios (PDMS:hexane ratios of 10:0, 7:3, 1:1, and 3:7). The PDMS and hexane mixtures were spin-coated at 3000 rpm for 30 s on the slide glass, and cured on hot-plate under air at 85 °C for 30 min. After PDMS coating, ZnO NRs were arrayed in one direction as a nematic-like ZnO NR film on the PDMS by rubbing with a soft velvet cloth. Thereafter, we repeated the PDMS coating and ZnO NR rubbing procedure to make a one-direction array and close-packed ZnO NR film until desired a number of layers were obtained. 200 nm of silver were then deposited

on top of the SPAS by thermal evaporation. Finally, the conducting wires were connected to the silver electrode as leads for subsequent electric measurement.

For the fabrication of 12 cells array, we soldered a silver wire on each top electrode and then mold the device with PDMS. Each cell was connected in series or parallel for the measurement. When the combination was set, the substrate was bent with 1 mm radius.

Characterization. The calculation of the piezoelectric potential distribution in the BG ZnO NRs was performed via COMSOL Multiphysics® in a finite element method. The morphology and crystalline structure of the ZnO nanorods were characterized with a JEOL JSM-7000F field emission SEM (FESEM; 15 kV). The generated short circuit current and open circuit voltage was measured via a pico-ammeter (Keithley, 6485) and electrometer/high resistance meter (Keithley, 6517), respectively.

2. Supplermentary Figures

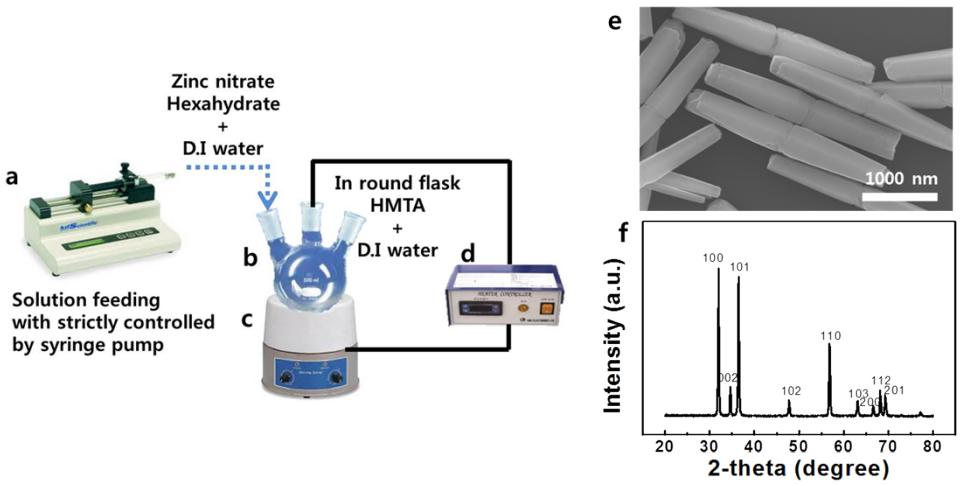

Figure S1. Biaxial-grown (BG) ZnO nanorods synthesis system, SEM image and XRD spectrum. **a,** dual-syringe pump, **b,** three-necks ground flask, **c,** heating-mantle, **d,** thermal controller and thermocouple system, **e,** SEM image of BG ZnO NRs. **f,** XRD spectrum of BG ZnO NRs.

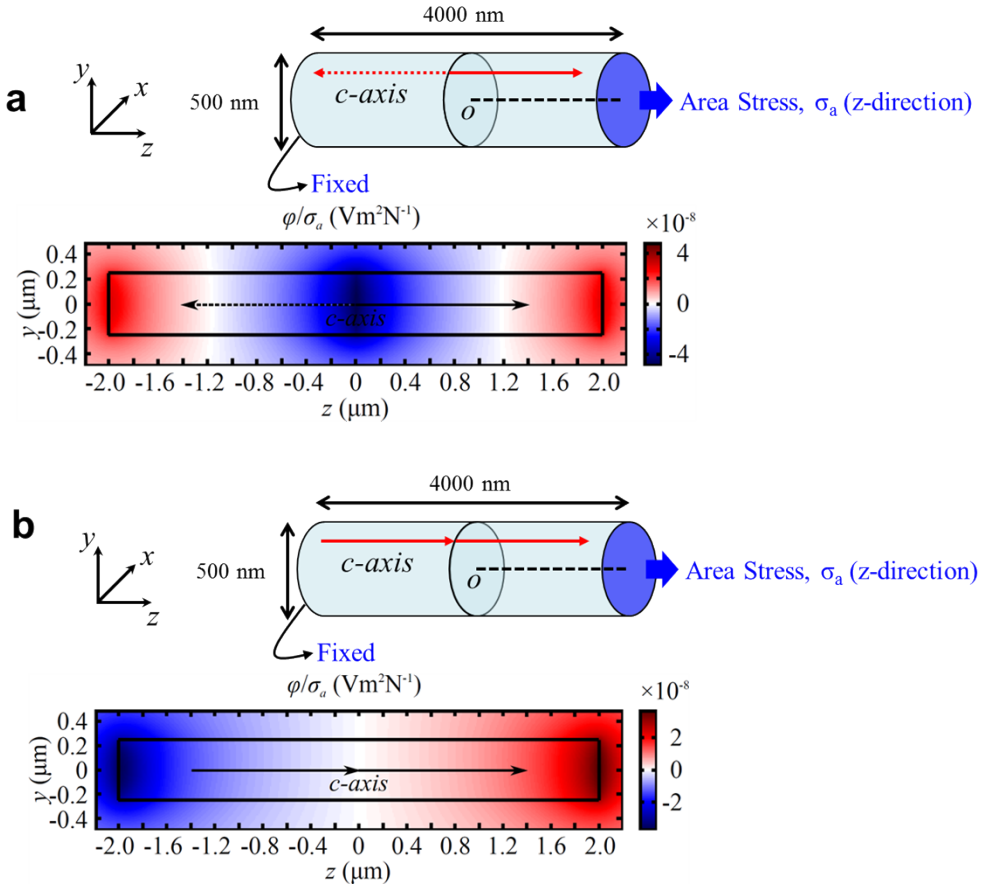

Figure S2. Piezoelectric potential simulation results from applying tensile stress along to the longitudinal direction of ZnO NR. a, two opposite piezoelectric polarizations are generated only along to the longitudinal direction of a BG ZnO NRs. **b,** single piezoelectric polarization is generated only along to the longitudinal direction of an uniaxially grown ZnO NRs. Any piezoelectric polarization along to the transversal direction is not generated in all cases.

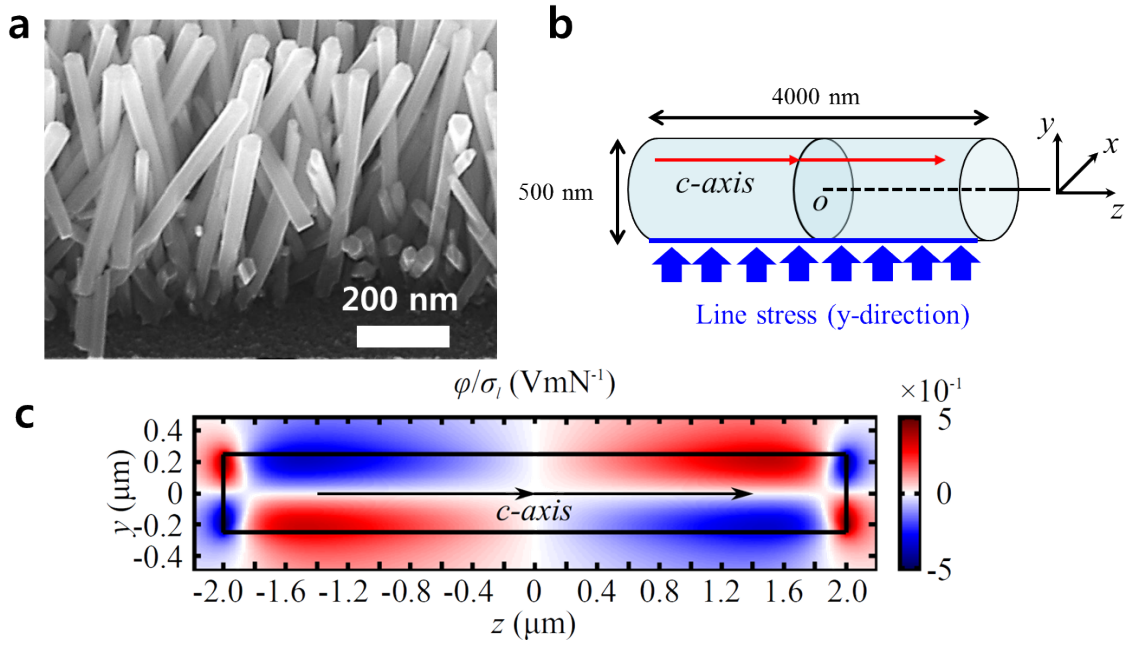

Figure S3. Unidirectional growth of ZnO NRs on seed layer and piezoelectric potential simulation result. a, SEM image of ZnO NRs grown on seed layer. It has only one preferential growth direction. **b,** Schematic diagram representing a ZnO NR. The orientation of *c*-axis of ZnO in each domains of the cylinder is drawn as a red-colored arrow. The direction of the Cartesian coordinates is shown, with *O* denoting the origin on the cylinder-bisecting vertical plane. **c,** The piezoelectric potential of a ZnO cylinder where the c-axis is unidirectionally aligned under the equal stress. In b to f, black-colored arrows and solid lines depict the direction of the *c*-axis and the ZnO cylinder boundaries, respectively.

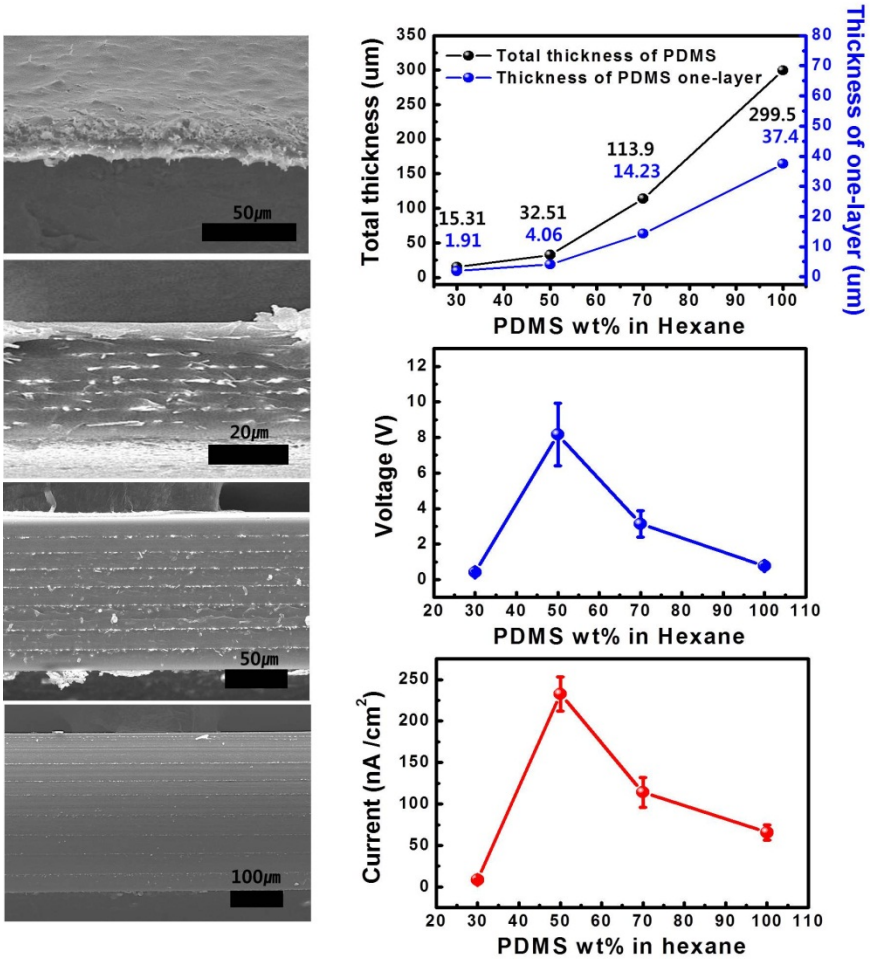

Figure S4. Influence of PDMS thickness that was controlled with PDMS : Hexane mixing ratio on output voltage and current. All PDMS films were curried on hot-plate at 85 °C for 120 min in air. (PDMS spin-coating conditions: 500 rpm for 5 s and then 2500 rpm for 25 s) a-d, Cross section by SEM (all sample was consisted with 7 layers of SPAS). **a,** 30 wt% of PDMS in hexane. **b,** 50 wt% of PDMS in hexane. **c,** 70 wt% of PDMS in hexane. **d,** 100 wt% of PDMS **e,** total and one SPAS thickness change depending on PDMS/hexane ratio. **f and g**, Output voltage and current measurement peaks with changing of PDMS/hexane ratio (wt%).