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Electronic supplementary information

Bionic ion channel and single-ion conductor design for artificial skin sensor

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Materials and methods

Materials: sulfuric acid (H_2SO_4), sodium hydroxide (NaOH), potassium hydroxide (KOH), N, N-dimethylformamide (DMF) were purchased from Sinopharm Chemical Regent Co. Ltd. Vertically aligned carbon nanotubes (VA-CNTs) (diameter: 3-10 nm, density: ≤ 0.3 g cm^{-3}; SSA: ~20 m^2 g^{-1}) grown on the silicon substrate (2cm×2cm) and single-walled carbon nanotubes (CNTs) were purchased from NJXF TECH Co. Ltd. Nafion polymer dispersions was purchased from the Dupont.

Preparation of CNTs electrode: 3 mg mL^{-1} gel-like CNTs dispersion was formed by dispersing 120 mg CNTs power in 40 mL DMF solution with 60 min (3 s on and 3 s off), 200W horn sonication treatment in an ice water bath. 3mL as-prepared suspension was casted on glass substrate and evaporated at 40 ℃ for 1 days, obtaining the CNTs electrode.

Preparation of VA-CNTs/Nafion composite electrode: 3 mL Nafion polymer dispersions was casted on glass substrate and evaporated at 50℃ for 30min, and then put the VA-CNTs (including silicon substrate) on the surface of damp-dry Nafion polymer carefully. The VA-CNTs were rooted in Nafion polymer by the effect of permeation, forming the VA-CNTs/Nafion composite. The VA-CNTs/Nafion composite was also dried at 50 ℃ for 1 day and then move the silicon substrate away.

Preparation of electrolyte interlayer Nafion film: Nafion film was prepared by 3 mL casting Nafion polymer dispersions on glass substrate and evaporated at 50℃ for 1 day.

Construction of sensors: Two piece of VA-CNTs/Nafion composite electrode films (20 mm ×5 mm) were laminated on Nafion film (60 mm×5 mm) and then hot pressed at 170 ℃ for 3 h, obtaining VA-CNTs/Nafion composite electrodes- based sensor. The CNTs electrodes-based sensors was constructed by the same process.

Process of replacing the H in VA-CNTs/Nafion composite electrode based sensor with the Na and the K: 1M sodium hydroxide (NaOH) and 1M potassium hydroxide (KOH) solution were prepared in advance. Two sensors were immersed in as-prepared 1M NaOH and 1 M KOH, 60 ℃, 1 day, and subsequently taken out, rinsed by deionized water, dried at 50 ℃.

Sensing Measurement: The top and bottom electrodes of sensor was connected to the electrical wires by the conductive silver adhesives. The two sides of the sensors were fixed on

the motorized translation stages (Beijing Optical Century Instrument Co.LTD. MTS121). The length fixed between the motorized translation stages is 5 cm, while the effective length of sensors is 2 cm. Step motor controlled by computer was used to control the deformation times and the displacement of the sensor. The laser displacement sensor (Keyence, LK-G80) was used to record the displacement of the movable stage along with the time. An electrochemical work station (CHI900D) was connected to the sensor by the electrical wires to collect the output electrical signals from the sensors.

Characterization: SEM images were obtained with Hitach S-4800 filed emission scanning electron microscope. TGA was analyzed by SII Exstar6000 instrument. The strain-stress curve was obtained by Shimadzu AXS-X 500N.

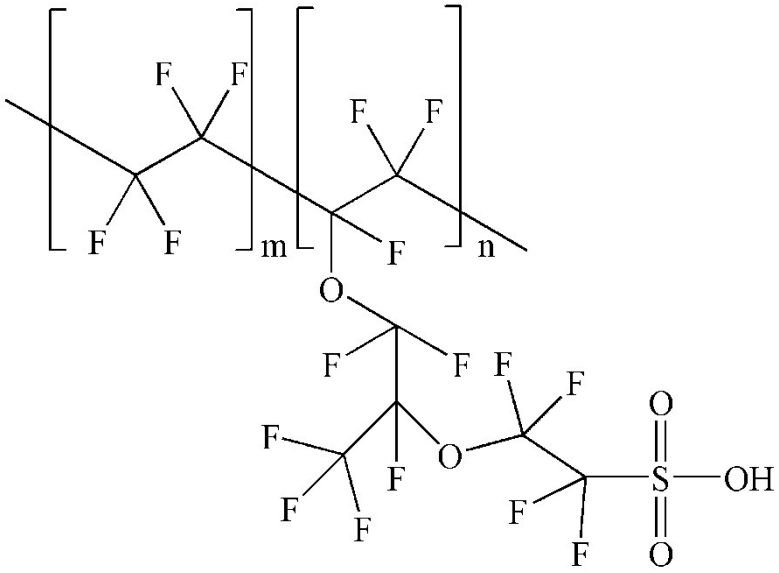

Fig. S1. Molecular structure of Nafion. It is perfluorosulfonic acid/PTFE copolymer with a sulfonic acid group in the side chain.

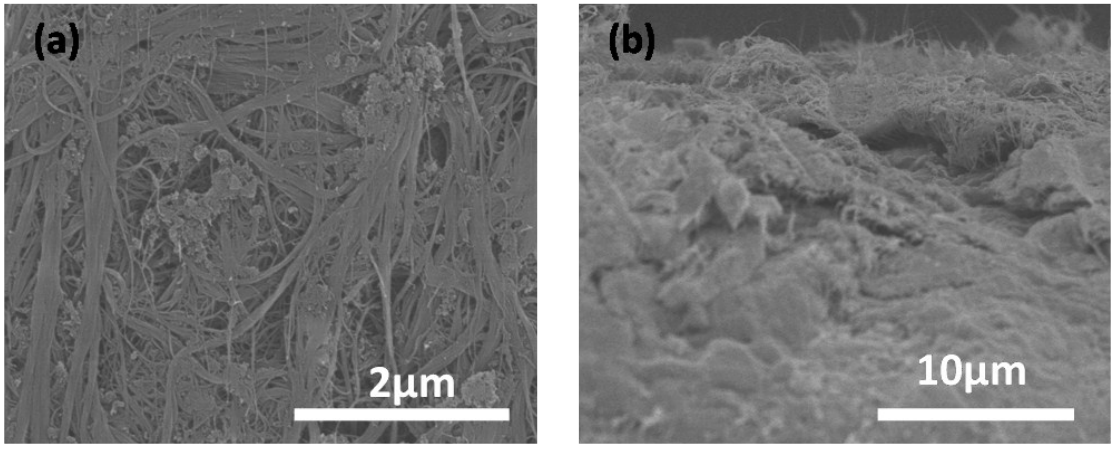

Fig. S2. (a) Surface and (b) cross-section images of the CNTs electrodes-based sensors.

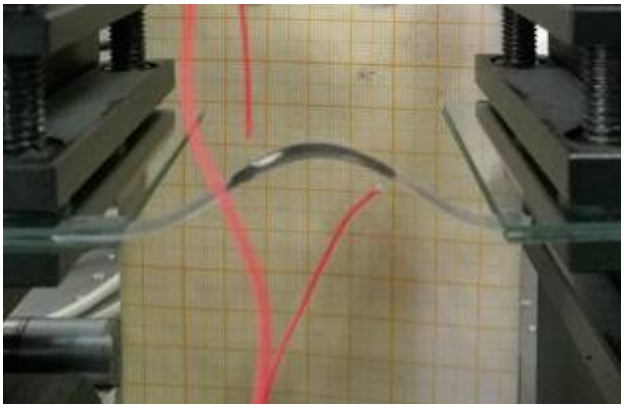

Fig. S3. Testing setup for the bending sensing. The two sides of the sensors were fixed on the movable stage with a step motor to compress the sample. When the step motor produce

displacement, the sensor buckle to generate a bend shape.

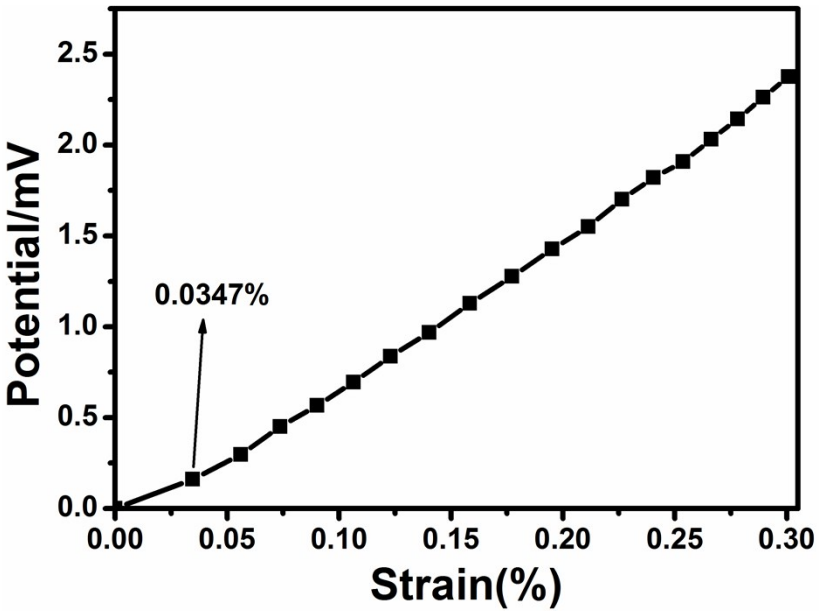

Fig. S4. Potential as a function of the bending strain for VA-CNTs electrodes-based sensors

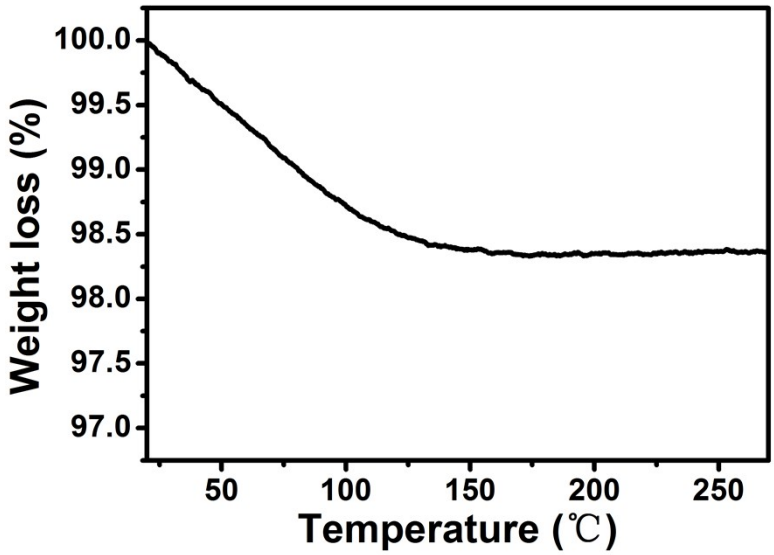

Fig. S5. The thermogravimetric analysis (TGA) curve of sensors. The weight loss in the temperature range from 20℃ to 135℃ is about 1.5%, finally leveling off to a constant. This is ascribed to the loss of absorbed water stably existing in sensors.

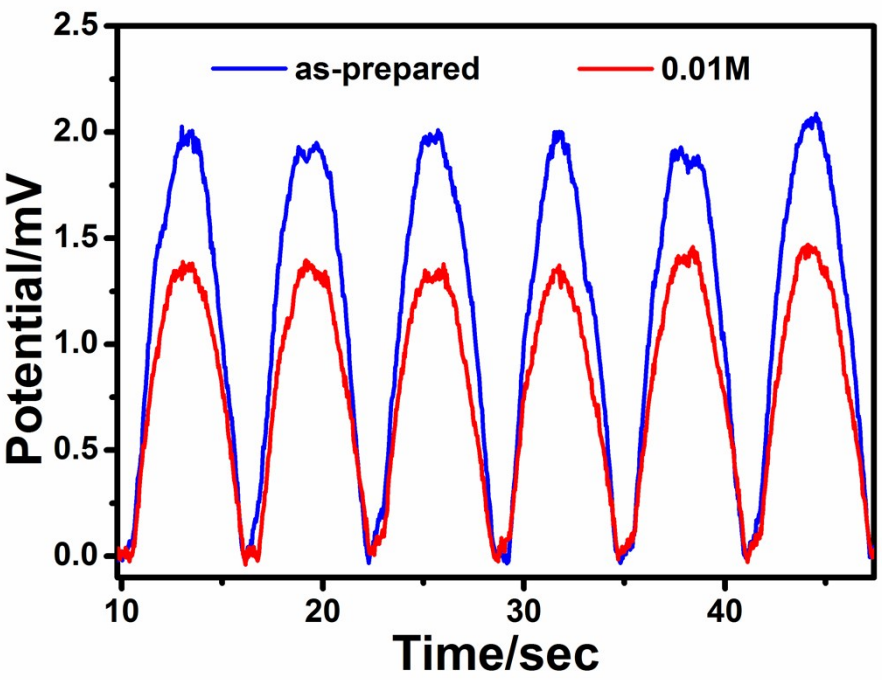

Fig. S6. Sensing performance of the sensor with different concentrations of hydrions (H^+). As-prepared sensor (blue line) and the sensor with 0.01 M H^+ (red line).

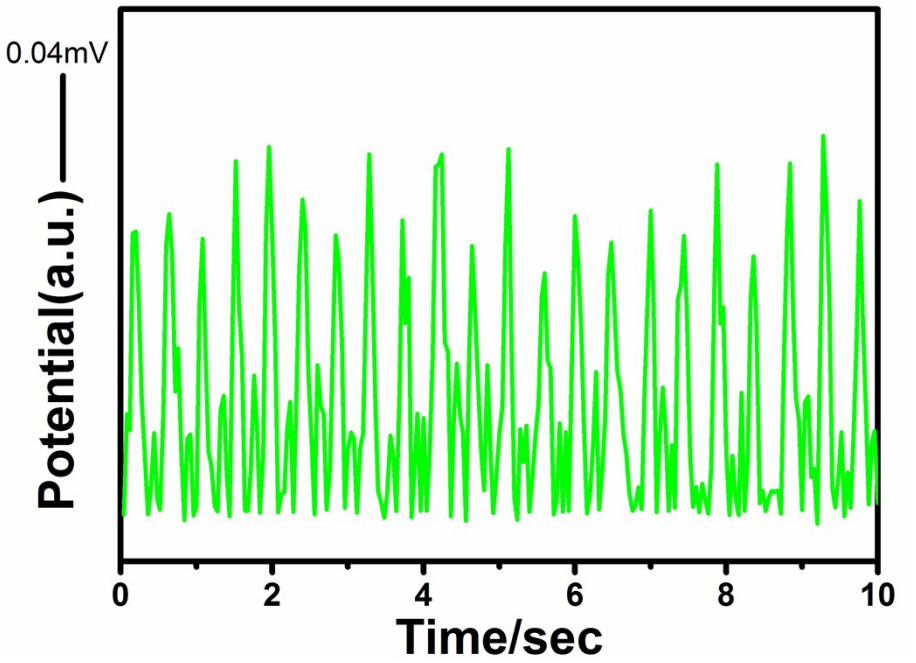

Fig. S7. Higher pulse rate which is 132 times min^{-1} after intense exercise

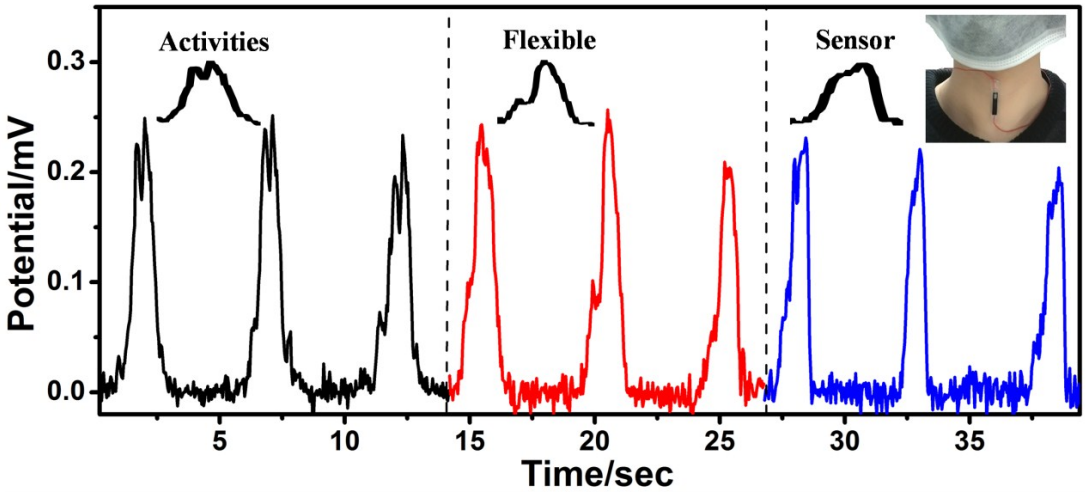

Fig. S8. Response signals recorded upon speaking "activities", "flexible", "sensor", respectively. The inset curves in the top left corner are fitted from the testing data.