Supplementary Information:

Noninvasive and Point-of-Care Screening of Snoring by Breath Monitoring Using Ion-In-Conjugation Polymer-based Humidity Sensors

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Experimental Procedures

Materials: 1, 5-diaminoanthraquinone (1, 5-DAAQ), 2, 6-diaminoanthraquinone (2, 6-DAAQ) and croconic acid were purchased from TCI Chemical Co., Lt.d. N-butyl alcohol and acetone were purchased from Aladdin Industrial Corporation (Shanghai, China). All chemical reagents are analytical grade and used without further purification.

Synthesis of Polymers: Poly (1, 5-diaminoanthraquinone-coronate) (1, 5-PDAC) was prepared through the following method (Fig. 2a): 1, 5-diaminoanthraquinone (1, 5-DAAQ, 238 mg, 1 mmol) and croconic acid (CA, 114 mg, 1 mmol) and n-butyl alcohol (n-BuOH) (25 mL) were added to a flask. The mixture was stirred and refluxed at 130 °C for 24 h. After being filtered and washed with deionized water, the filter cake was washed with acetone in a Soxhlet extractor for 12 h, then with tetrahydrofuran for 24 h. Finally, it was dried under vacuum and dark red powder was obtained. In the same way, poly (2, 6-diaminoanthraquinone-coronate) (2, 6-PDAC) was prepared as black powder (Fig. 2a).

Fabrication of Humidity Sensor: Mix 25 mg of polymer in 1 mL of ethanol and disperse the mixture by ultrasonic treatment to obtain a well-dispersed suspension. Subsequently, the solution was brush-coated onto the Al_2O_3 substrate printed with an Ag-Pd interdigital electrodes (IDES, the channel width and spacing were both 100 μm). Finally, the prepared device was dried under vacuum at 50 °C for 0.5 hours. The Ag-Pd interdigitated electrodes are fabricated by spraying a metal paste onto a ceramic plate by a metal injection system (MJ-10, Beijing Elite Tech Co., Ltd.).

Wireless snoring monitoring device: Motivated by large variation range in impedance, high sensitivity and relatively rapid response time of 1, 5-PDAC, we developed a breath monitoring device which can transmit data to mobile phone. 1, 5-PDAC humidity sensor was integrated in a headphone and connected to a logarithmic amplifier (LOG114EVM, Texas Instruments, USA) which convert low-level current signal (1-1000 nA) to a voltage output (0-5 V). The output signal is measured by an Arduino compatible voltage sensor and collected by a programmable Arduino Uno R3 Board. Then, Arduino sends data to personal computer through USB and to mobile phone through Bluetooth. Commercial breath monitors are from the EEG-1200C from NIHON KOHDEN

CORP. Synchronous monitoring process in attachment video and Figure S10.

Measurements and General Methods: The optical images were captured by a Canon camera. SEM images and element mapping were characterized using a field emission SEM (FESEM) HITACHI Japan (S-4700). XRD measurements were performed with a multiple crystals X-ray diffractometer (X'Pert PRO, PANalytical) with Cu Kα monochromatic radiation source. Fourier transform infrared spectroscopy (FTIR) measurements were conducted by using a VERTEX70. UV-vis absorption spectra were carried out at room temperature (25 °C) with a Shimidazu UV-3600 spectrophotometer. The surface adsorption properties (BET) of four synthetic substances were measured using QUADRASORB evo Gas Sorption Surface Area and Pore Size Analyzer (USA).

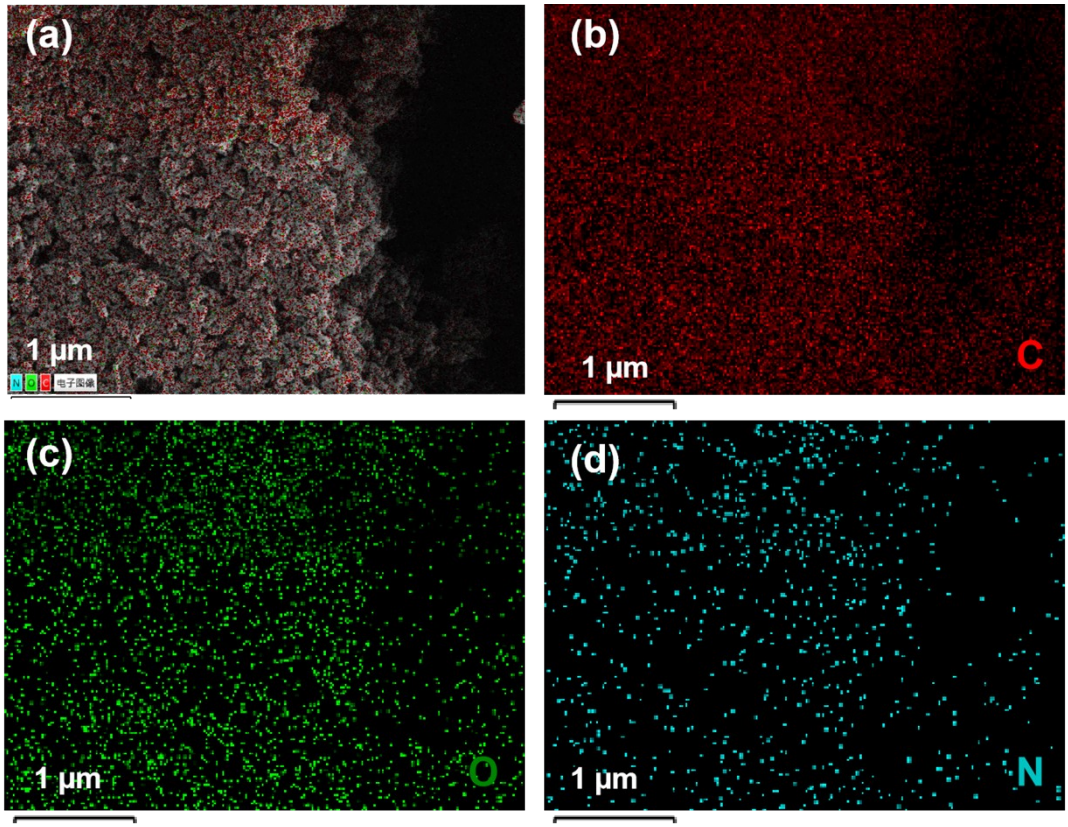

Fig S1. (a-d) EDX mapping images of 1, 5-PDAC.

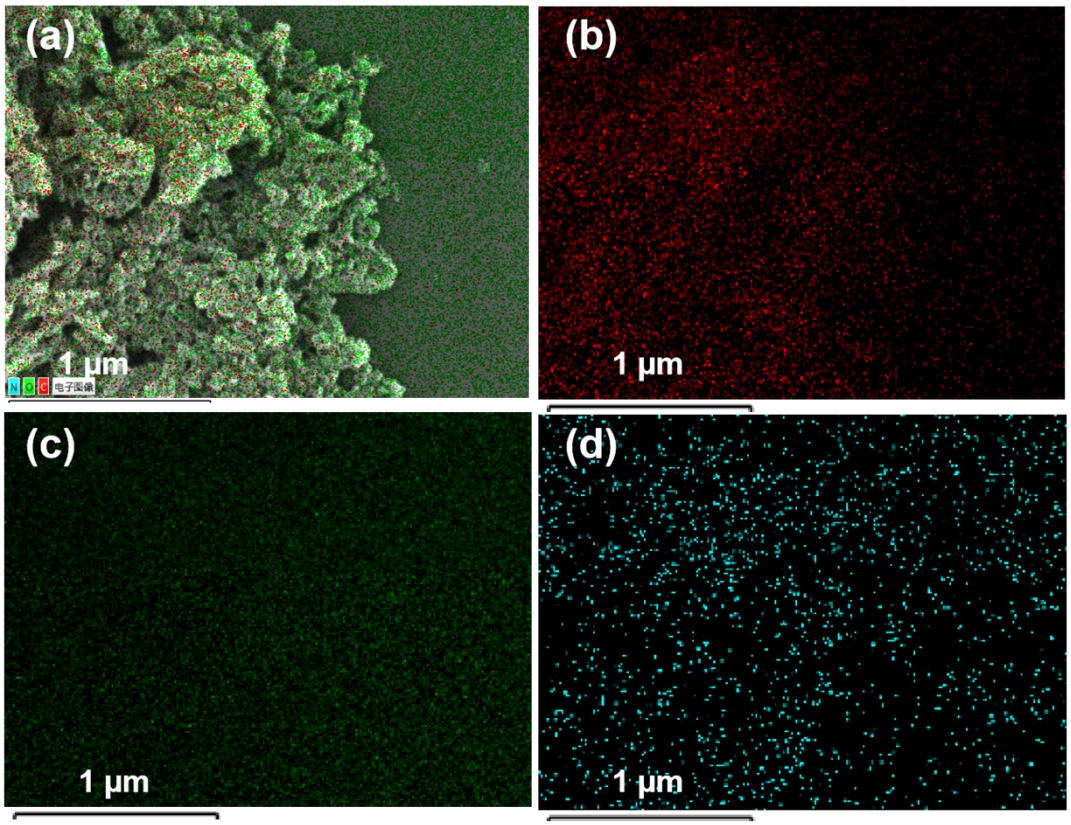

Fig S2. (a-d) EDX mapping images of 2, 6-PDAC.

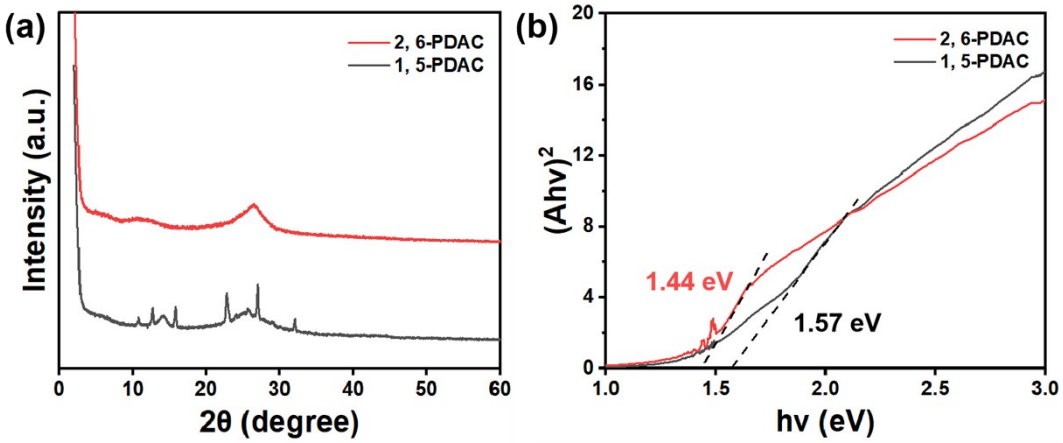

Fig S3. (a) Powder X-ray diffraction of 1, 5-PDAC and 2, 6-PDAC. (b) The Tauc plots of 1, 5-PDAC and 2, 6-PDAC.

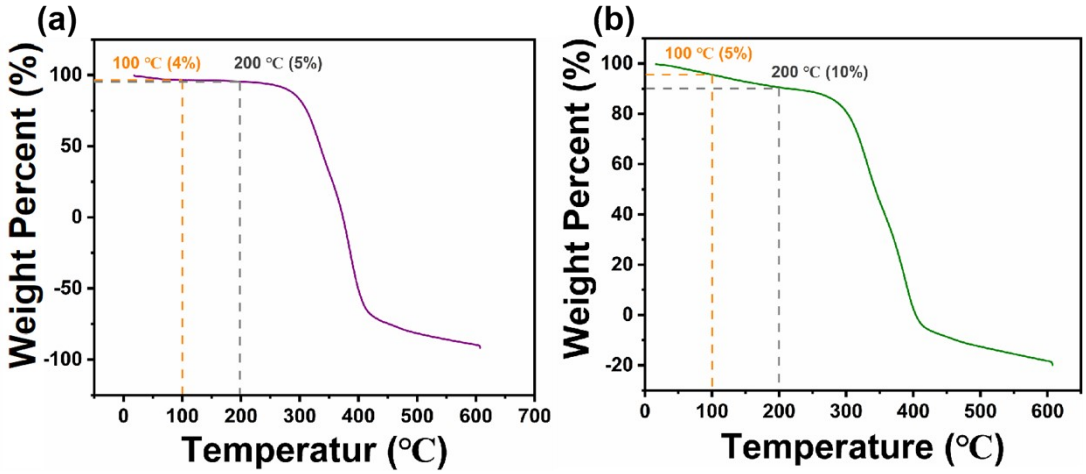

Fig S4. TGA curves of (a) 1, 5-PDAC and (b) 2, 6-PDAC.

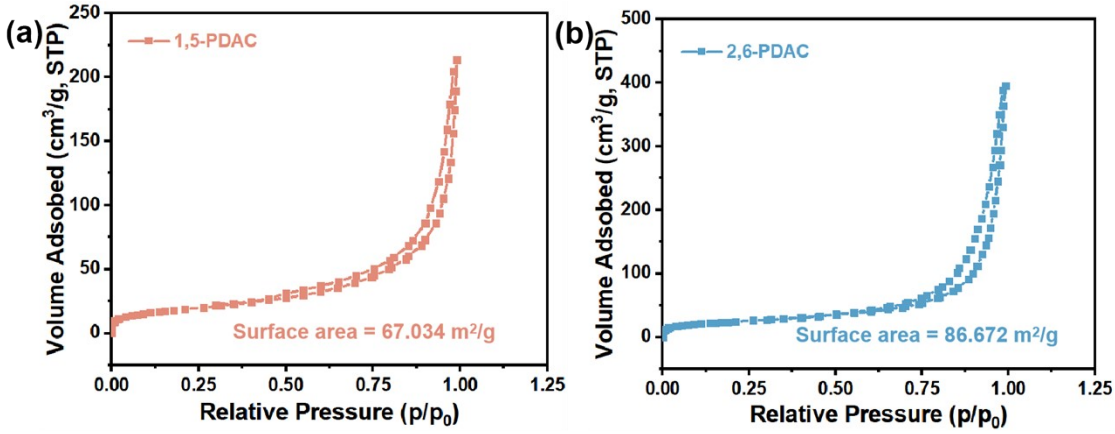

Fig S5. N_2 adsorption isotherm measured at 77.3 K of (a) 1, 5-PDAC (b) 2, 6-PDAC.

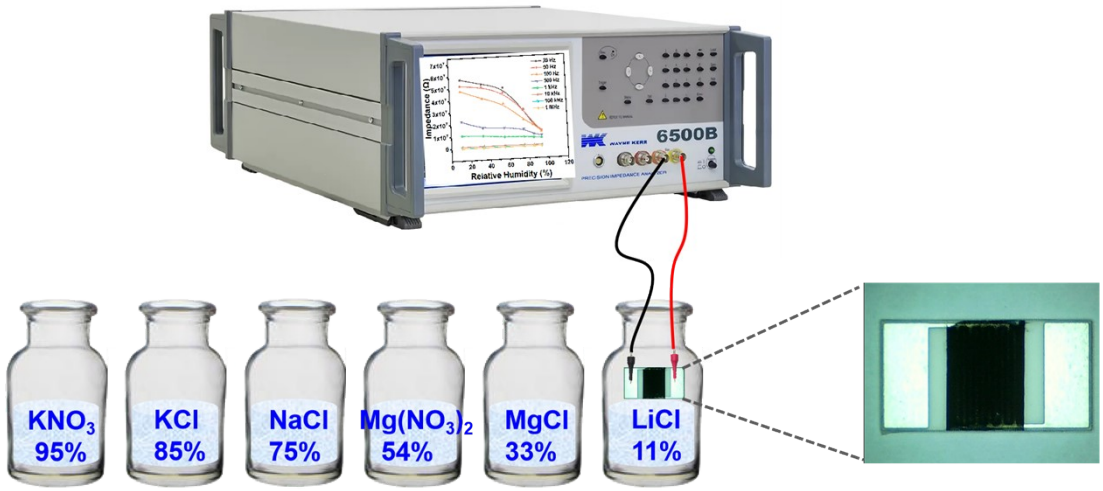

Fig S6. The schematic diagram of the testing equipment and the photos of 1, 5-PDAC and 2, 6-PDAC humidity sensors.

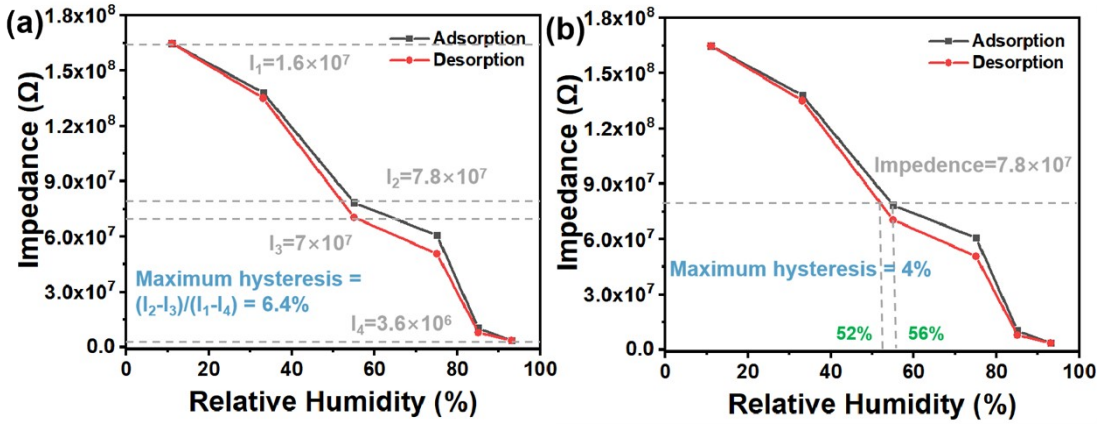

Fig S7. Two definitions of the hysteresis: (a) The relative impedance discrepancy when the relative humidity is ascending/descending to the same value. (b) Maximum of RH(Z)-RH'(Z), where RH(Z) and RH'(Z) refer to the relative humidity at the same impedance when the humidity is scanning ascendingly and descendingly. In this paper, we use method (a).

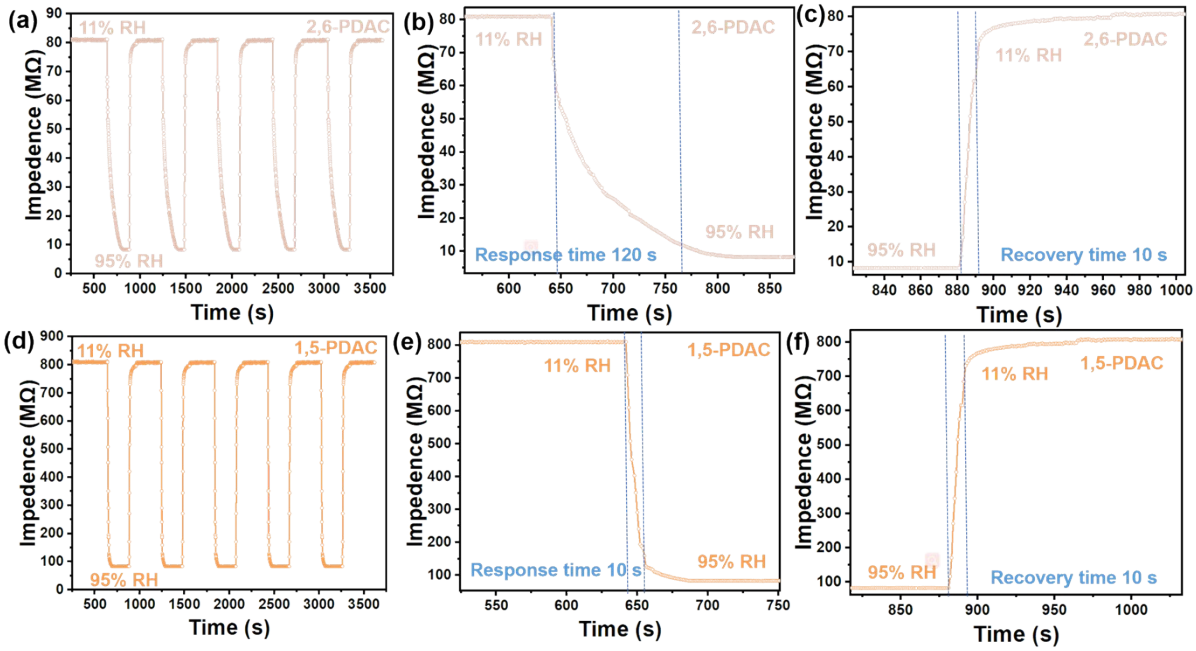

Fig S8. The repeatability characteristic of (a) 2, 6-PDAC humidity sensor and (d) 1, 5-PDAC humidity sensor at the humidity varied from 11% to 95% RH; The response and recovery time of (b), (c) 2, 6-PDAC humidity sensor, (e), (f) 1, 5-PDAC humidity sensor.

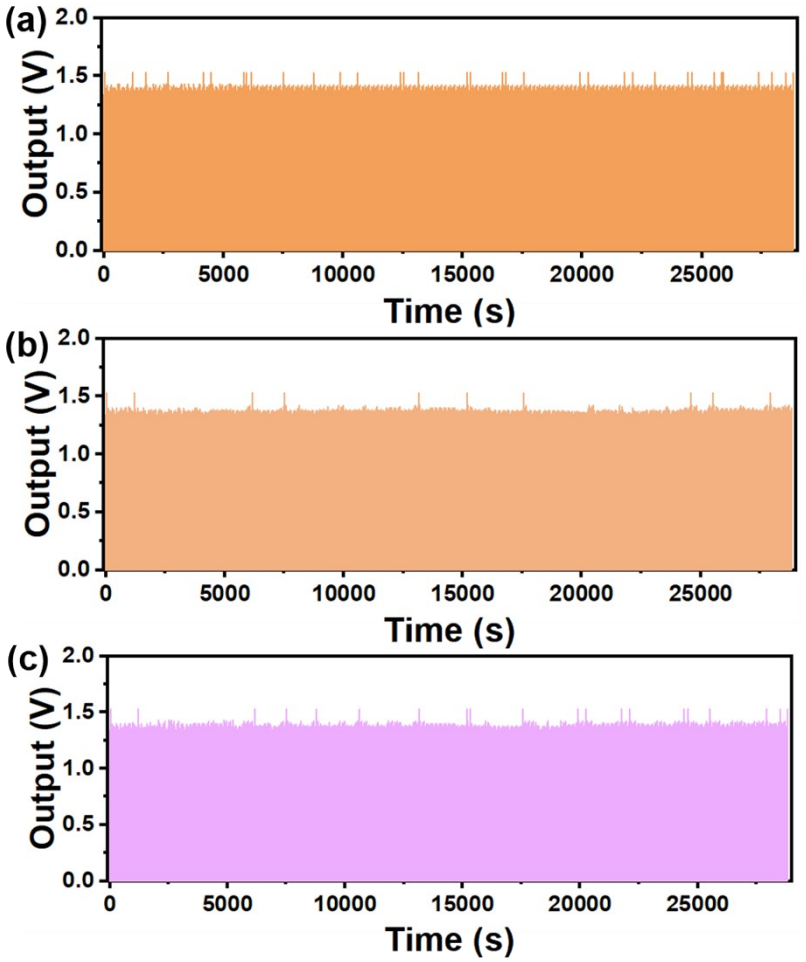

Fig S9. The cycle time stability of 28800 s (8 hours) of the normal breath.

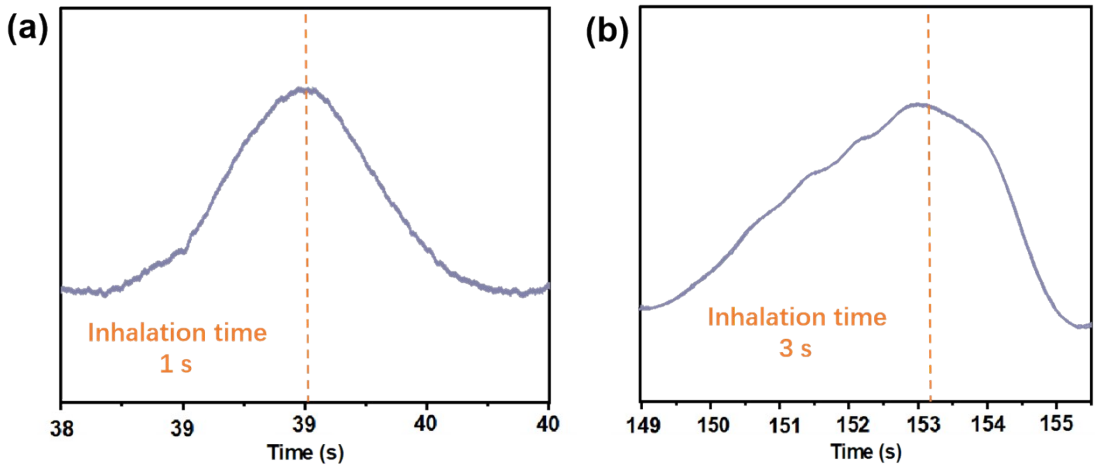

Fig S10. The magnify of breathing time in state of (a) normal breath and (b) snore.

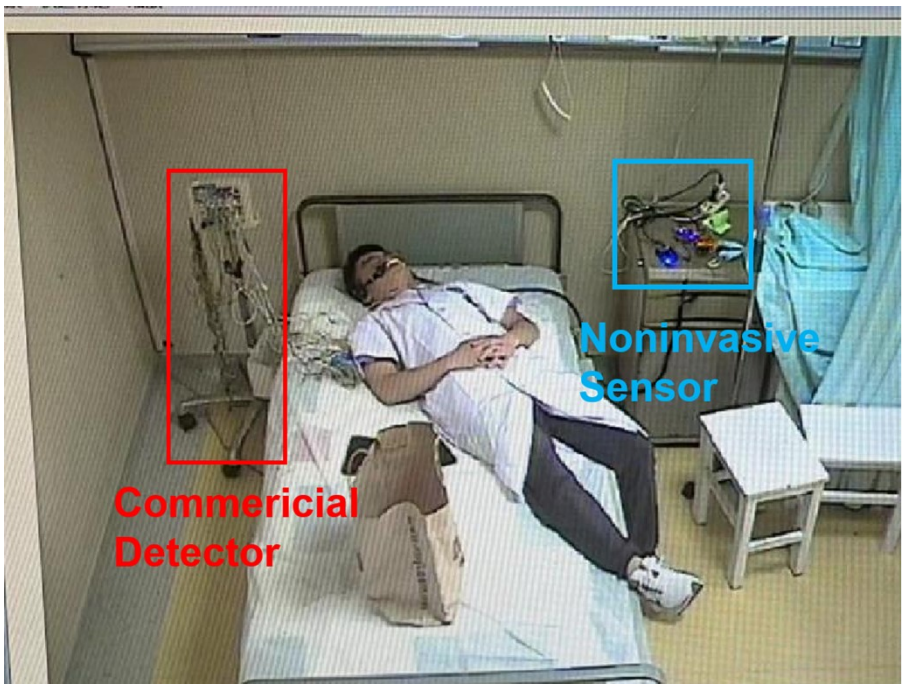

Fig S11. Schematic diagram of synchronous breath detection.