Supplementary Material

An interpenetrating-polymer-network-based tough ion gel with high humidity resistance for sensitive human motion detection

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TABLE OF CONTENTS

(1) Preparation of the PVDF-HFP/PEA-NSA IPN ion gel and PVDF-HFP/PDMAAm-NSA IPN ion gel

The preparation of the PVDF-HFP/PEA-NSA IPN ion gel is as follows. PVDF-HFP was completely dissolved in 9.24 g of acetone with stirring. The pre-synthesized PEA-NSA was added to the PVDF-HFP solution and dissolved by magnetic stirring for 1 h. Subsequently, [EMIM][TFSI] was added to the PVDF-HFP/PEA-NSA/acetone mixture and dissolved by magnetic stirring for 30 min. Separately, DGBE was dissolved in acetone (1.0 g), and the solution was added to the [EMIM][TFSI]/polymer/acetone solution and magnetically stirred for 30 min to obtain the ion-gel precursor solution. The precursor solution was poured into a mold and heated in an oven at 50 °C for 24 h. The obtained gel was dried further at 70 °C for 24 h to completely remove the acetone for preparing the PVDF-HFP/PEA IPN ion gel. The amounts of the used reagents were shown in the following Table S1.

The preparation of the PVDF-HFP/PDMAAm-NSA was the same as the rhat of the PVDF-HFP/PEA-NSA IPN ion gel, and the only difference is that the PEA-NSA was replaced by PDMAAm-NSA. The amounts of the used reagents for preparing the PVDF-HFP/PDMAAm-NSA IPN ion gel was shown in Table S2.

Table S1 The amounts of the used reagents for the preparation of the PVDF-HFP/PEA-NSA IPN ion gel with different IL contents

Reagents (g)	IL contents in ion gel			
	60%	70%	80%	85%
IL	3.84	4.48	5.12	5.44
Acetone (dissolving polymers)	9.24	9.24	9.24	9.24
Acetone (dissolving DGBE)	1.0	1.0	1.0	1.0
PEA-NSA	1.233	0.925	0.617	0.462
DGBE	0.047	0.035	0.023	0.018
PVDF-HFP	1.28	0.96	0.64	0.48

Table S2 The amounts of the used reagents for the preparation of the PVDF-HFP/PDMAAm-NSA IPN ion gel

Reagents	Amount (g)
IL	5.12
Acetone (dissolving polymers)	9.24
Acetone (dissolving DGBE)	1.0
PDMAAm-NSA	0.620
DGBE	0.020
PVDF-HFP	1.28

(2) Miscibility of PVDF-HFP and PEA-NA in the precursor solution

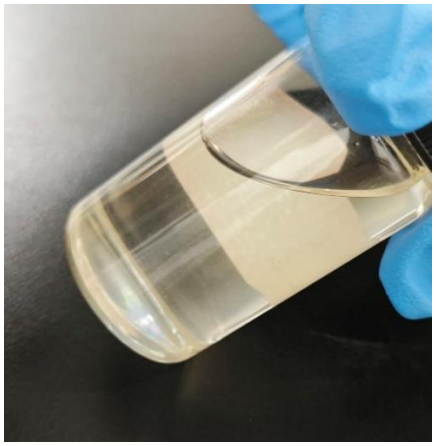

Fig. S1. The IPN ion gel precursor solution composed of PVDF-HFP, PEA-NSA, DGBE, [EMIM][TFSI], and acetone.

(3) Cyclic tensile stress–strain curve of the PVDF-HFP/PEA-NSA IPN ion gels with different IL contents

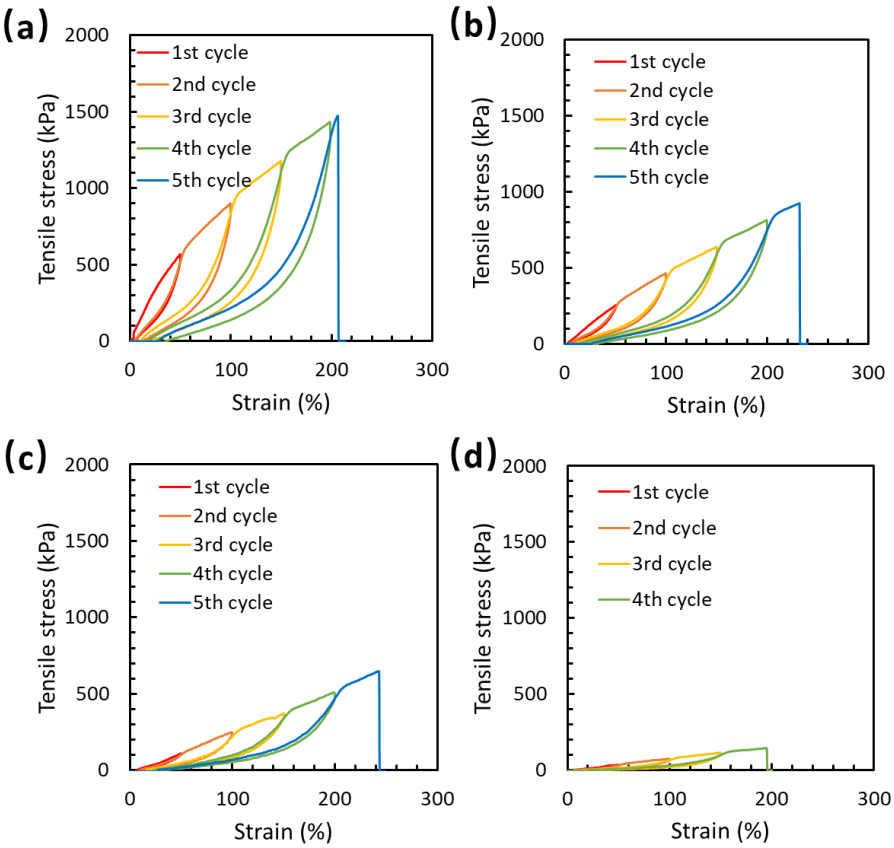

Fig. S2. Cyclic tensile stress–strain curve of the PVDF-HFP/PEA-NSA IPN ion gels with IL contents of (a) 60 wt%, (b) 70 wt%, (c) 80 wt%, (d) 85 wt%.

(4) Characterization of the self-recovering property of the IPN ion gel at ambient temperature

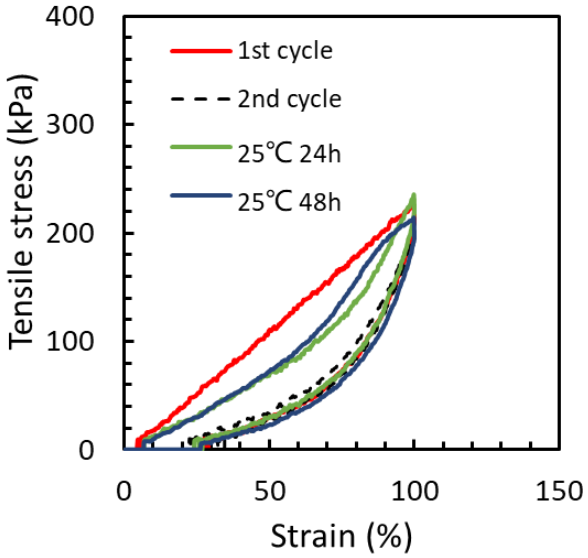

Fig. S3. Cyclic tensile stress–strain curves of the pristine IPN ion gel and the stretched IPN ion gels heated at 25 ℃ for different time. The strain for the stretching is fixed at 100%. The IL content of the PVDF-HFP/PEA-NSA IPN ion gels in this measurement is 80 wt%.

(5) Self-recovery ratios of the stretched IPN ion gels

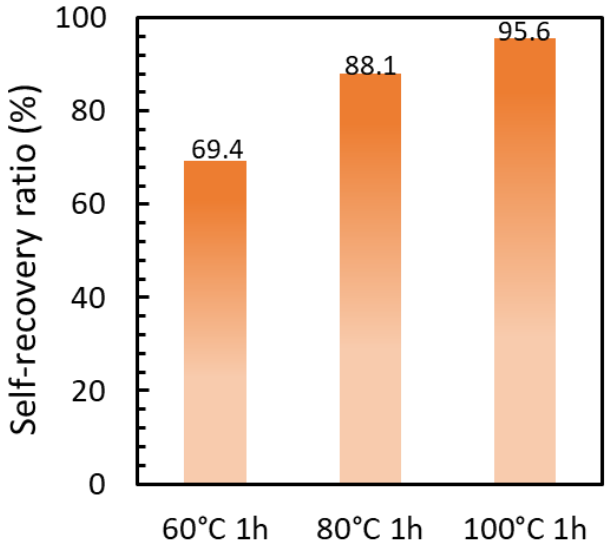

Fig. S4. Self-recovery ratios of the stretched IPN ion gels heated at different temperatures for 1 h.

(6) Mechanical properties of the ion gels after placed in different humidities

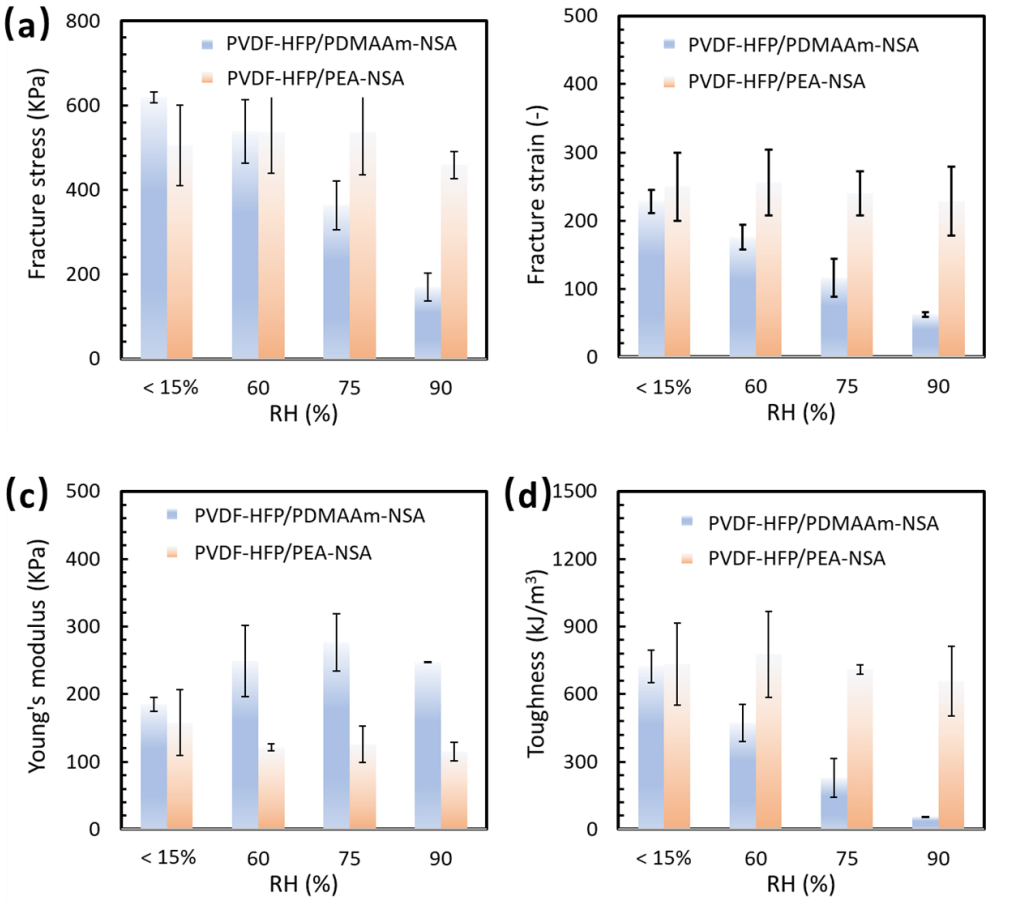

Fig. S5. (a) Fracture stress, (b) fracture strain, (c) Young's modulus, and (d) toughness of the ion gels after placed in different humidities for 8 h.

(7) Long-term stability of IL content and water ratio in the IPN ion gel

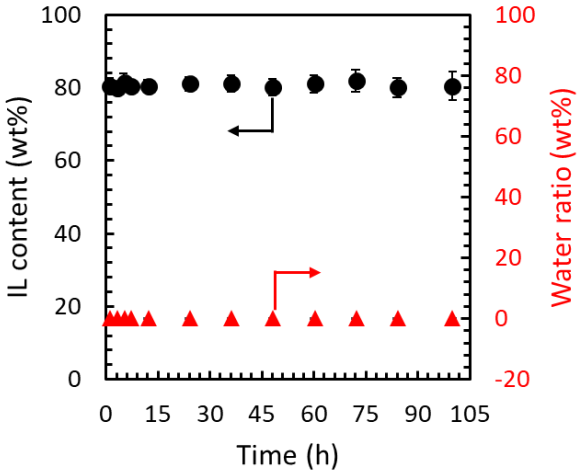

Fig. S6. Long-term stability of IL content and water ratio in the IPN ion gel containing 80 wt% IL at 90% RH.

(8) Long-term stability of ionic conductivity of the IPN ion gels

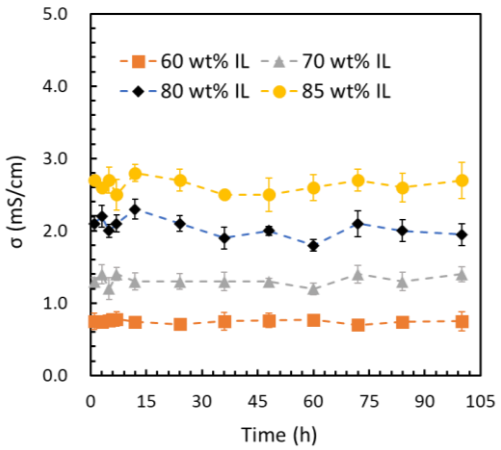

Fig. S7. Long-term stability of ionic conductivity of the IPN ion gels with varying IL contents at 90% RH.

(9) Measurement of the cytotoxicity of the IPN ion gel

Cell Culture

Human neuroblastoma SH-SY5Y cells were purchased from Selleck Chemicals and incubated in culture dishes containing medium (DMEM/F12 with 10% FBS and 1% antibiotics) until they reached an appropriate density and incubated in a 37°C, 5% CO_2 incubator. Then the cells were passaged by digestion with trypsin (0.25% Trypsin-EDTA), centrifuged at 1000 rpm for 5 minutes, and resuspended in fresh culture medium. The resuspended cells were then seeded into 96-well plates, and 100 μL of PBS was added to the outer wells to maintain humidity and incubated at 37°C for 24 h.

Live-Dead Staining

For live-dead staining experiments, after treatment for 24 hours, Calcein AM and PI were mixed with the detection buffer at a ratio of 1:1000. The original liquid in the 96-well plates was discarded, and the newly prepared detection mixture was added. The plates were then incubated at 37°C for 30 minutes. Subsequently, the plates were observed under an inverted fluorescence microscope to count the number of live and dead cells.

Cell Counting Kit-8 (CCK8) Assay

Different concentrations of the material (100, 50, 25, 12.5, 6.25, 3.125 μg/mL) were added to experimental groups, while control groups received fresh medium. Plates were incubated for another 24 h. CCK8 solution was mixed with medium (1:10) and added to each well, followed by 30 min incubation at 37°C. Absorbance was measured using a microplate reader.

(10) Measurement of the antibacterial property of the IPN ion gel

In this experiment, the material used was the second-generation pure Escherichia coli (*E. coli*). A bacterial loop was used to pick up a bacterial bead, which was then added to 2 ml of LB broth (0.25g LB broth powder + 10ml ultrapure water) and cultured for 18 hours. Subsequently, 18 ml of buffer solution (0.137 g potassium dihydrogen phosphate + 0.284 g disodium hydrogen phosphate + 100 ml ultrapure water) was added. First, 50 μL of the original bacterial suspension was added to 4950 μL of buffer solution, then from this bacterial suspension, 500 μL solution was taken and added to 4500 μL of buffer solution. A 250 ml conical flask and a transparent glass slide (1.5*1.5 cm) were placed in a high-pressure reactor for sterilization for 1 hour, then cooled to room temperature and placed in a super-clean workbench for later use. Three IPN gel samples, each measuring 1.5*1.5cm, were cut and evenly placed on one side of a small glass slide. Using a pipette, 100 μL of the prepared bacterial liquid was evenly dropped onto the sample, and after the bacterial liquid was evenly distributed, another glass slide was placed over the sample. Sterile tweezers were used to place the glass slide into a conical flask, repeating this step three times to add three samples to the conical flask. The mouth of the conical flask was sealed with plastic film and placed in an incubator at constant temperature for cultivation for 3 hours. After 3 hours, the conical flask was removed, and 15 ml of pre-prepared sterilized buffer solution was added to the conical flask, then sealed and ultrasonically treated for 10 minutes. After sonication, 200 μL of the solution was dripped into a petri dish and evenly coated, then placed in an incubator at constant temperature for 24 hours. For the control group, 300 μL of the prepared bacterial liquid was directly diluted with buffer solution to 15 ml, 200 μL of which was added to a petri dish and evenly coated, then placed in an incubator at constant temperature for 24 hours.

(11) A schematic of the bending angle of the finger joint

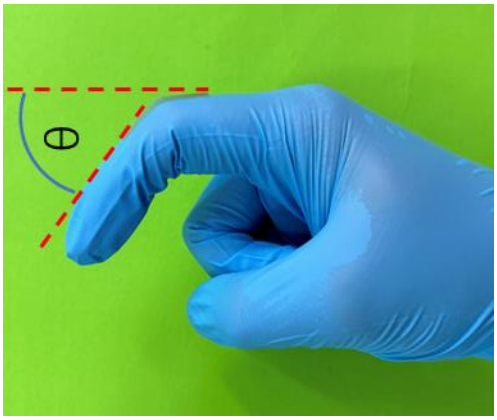

Fig. S8. A schematic of the bending angle of the finger joint.