

# A facile strategy for fabricating multifunctional ionogel based electronic skin

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Supporting Information

## **Experimental**

### **Materials**

1-ethyl-3-methylimidazolium chloride ([EMIM]Cl) was purchased from Merger Chemical. Acrylic acid (AA) was purchased from Energy Chemical. Poly (ethylene glycol) diacrylate (PEGDA) and 2-Hydroxy-2 methylpropiophenone (1173) were donated from Tianjing Jiuri Co., Ltd. All chemicals were analytical grade reagents and were used without further purification.

### **Methods**

The [EMIM]Cl ionogel was synthesized by one-pot photopolymerization using AA as the polymer monomer, 1173 as photoinitiator, PEGDA as crosslinking agent, and [EMIM]Cl as ionic liquid. Firstly, AA and [EMIM]Cl were mixed in a certain weight ratio, then 1173 (1 wt% relative to AA) and PEGDA (a certain molar ratio relative to AA) were dissolved in the mixture. The mixture was mixed on a magnetic stirrer at 70 °C for 10 min to obtain a homogeneous solution. The solution was transferred into a

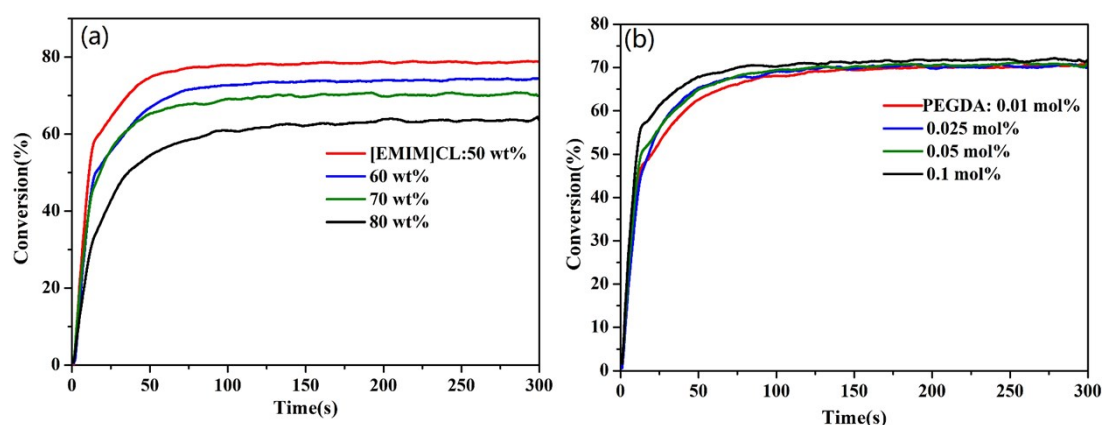
mold made of two glass plates separated by a silicone spacer. Then the solution was irradiated by UV irradiation with the intensity of 80 mW/cm<sup>2</sup> at 365 nm for 180 s to obtain the ionogel. The [EMIM]Cl/water ionogel was fabricated by photopolymerization. The as-prepared [EMIM]Cl/AA/PEGDA/1173 solution was mixed with water in a certain weight ratio. Then the obtained homogeneous solution was irradiated by UV irradiation to obtain an ionogel and the reaction condition was the same as before.

### **Characterization**

The photopolymerization kinetic was collected by RT-FTIR (real time Fourier transform infrared) spectra (Nicolet 5700, Nicolet Instrument, Thermo Company, USA). The sample was sandwiched between two glass pieces and irradiated with UV light. Since the concentration of the reacted double bonds was proportional to the decreased peak area, the percentage of double bond conversion (DC) could be calculated by measuring the peak area at 6160 cm<sup>-1</sup> using the equation:  $DC(\%) = (A_0 - A_t) / A_0$ , where  $A_0$  and  $A_t$  represent the original double-bond peak area and the double bond peak areas after irradiation at time, respectively. The mechanical character and adhesive strength were investigated by a digital tensile machine (E44.104, MTS, China). The resistance was determined using the complex impedance spectroscopy carried out on an electrochemical workstation (CHI 604E, Chenhua Instrument, China). The samples were placed between two pieces of stainless steels electrode. The conductivity of the ionogel was calculated by the Equation  $\sigma = L / (AR)$ , where  $L$  is the thickness of the ionogel,  $R$  is the resistance of the ionogel, and  $A$  is the area of ionogel.

The light transmittance spectra was characterized by a UV spectrometer (UV2310II, Shanghai, Tianmei, China) with the sample thickness of 1 mm. The thermal analysis were obtained from thermogravimetric analyses (TGA) (Q500, TA Instruments, New Castle, DE) via scanning a temperature range from 30 °C up to 600 °C (10 °C min<sup>-1</sup>) under nitrogen environment and differential scanning calorimeter (DSC) (Q2000, TA Instruments, New Castle, DE) with a scan rate of 10 °C min<sup>-1</sup> under nitrogen environment, respectively. The sensing performances of the ionogel was obtained by a Keithley 2400 sourcemeter.

## Results and discussion

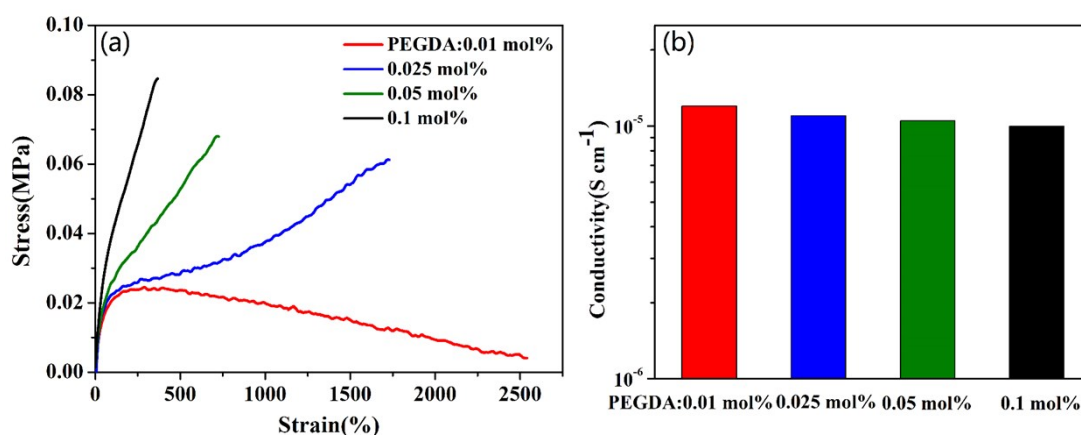


**Fig. S1** (a) Double bond conversions of the AA with various [EMIM]Cl concentration.

(b) Double bond conversions of the AA with various PEGDA concentration.

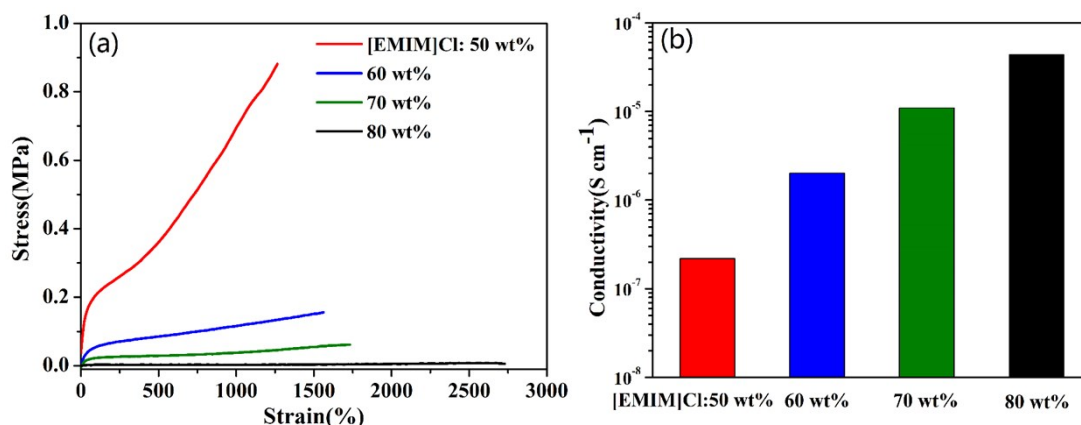
The progress of the reaction can be characterized by detecting the conversion of the double bond by RT-FTIR equipped. As shown in Fig. S1(a), all the polymerizations reached equilibrium within 180 seconds, suggesting it is a very facile and quick preparation strategy. The monomer conversion of all the samples is above 60%, indicating that this is an effective reaction process. However, the addition of ionic liquid

reduced the conversion of acrylic acid. This because that the increase in ionic liquid reduced the concentration of the reactive monomers and hindered the movement of the monomers. As demonstrated in Fig. S1 (b), the addition of PEGDA did not significantly affect the reaction rate and conversion of acrylic acid.



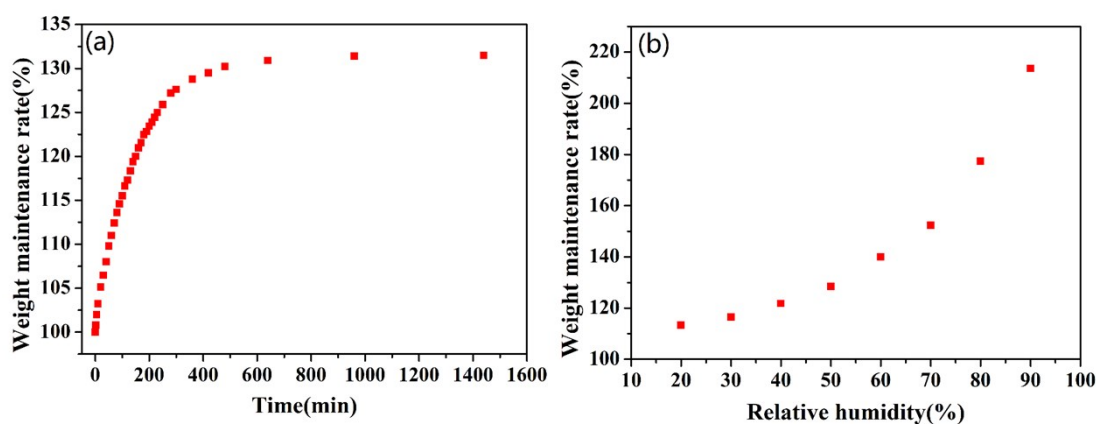
**Fig. S2** (a) Tensile stress–strain tests of the ionogel with various PEGDA concentration. (b) Conductivities of the ionogel with various PEGDA concentration.

Fig. S2 (a) shows the tensile stress–strain curves of ionogel prepared at different PEGDA concentrations and a fixed ionic liquid concentration of 70 wt%, while Fig. S2 (b) shows their conductivities. With the increase of PEGDA concentrations from 0.01 to 0.1 mol%, due to the increase of chemical crosslinking, the ionogels increased their tensile stress from 0.004 MPa to 0.085 MPa, but decreased fracture strains from 2550% to 360%, while the conductivity slightly decreased. Hence, the content of PEGDA was determined to be 0.025 mol% to ensure the obtained ionogel has a high stretchability and a suitable modulus.



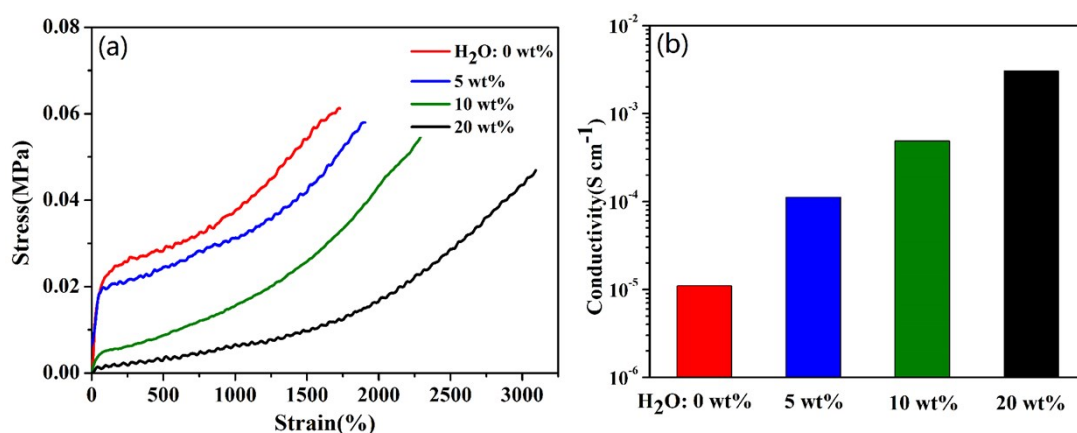
**Fig. S3** (a) Tensile stress–strain tests of the ionogel with various [EMIM]Cl concentration. (b) Conductivities of the ionogel with various [EMIM]Cl concentration.

Increasing the content of [EMIM]Cl when the PEGDA content was fixed at 0.025 mol%, the tensile stress decreased from 0.88 MPa to 0.005 MPa (Fig. S3 (a)), but the stretchability increased from 1200% strain to 2700% strain and the conductivity sharply increased from  $2.2 \times 10^{-7}$  S cm<sup>-1</sup> to  $4.4 \times 10^{-5}$  S cm<sup>-1</sup> (Fig. S3 (b)). So, considering the balance between electrical and mechanical properties, the content of the [EMIM]Cl was determined to be 70 wt%.



**Fig. S4** (a) Weight change of the ionogel with time at 25 °C with 50%RH. (b) Weight change of the ionogel with humidity at 25 °C

Since [EMIM] Cl and AA are both hydrophilic materials, the obtained ionogel could absorb moisture in air. As shown in Fig. S4 (a), at 25 °C with 50%RH, the ionogel absorbed moisture in air, and finally reached absorption equilibrium. Figure S4 (b) shows that the equilibrium water absorption of the ionogel is related to the air humidity. This result indicates that the ionogels prepared with hydrophilic raw materials are not stable in air.

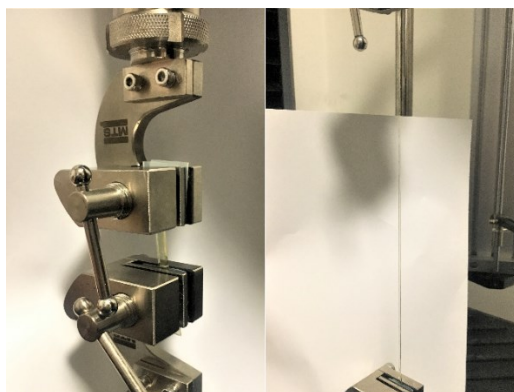


**Fig. S5** (a) Tensile stress–strain tests of the ionogel with various water concentration.

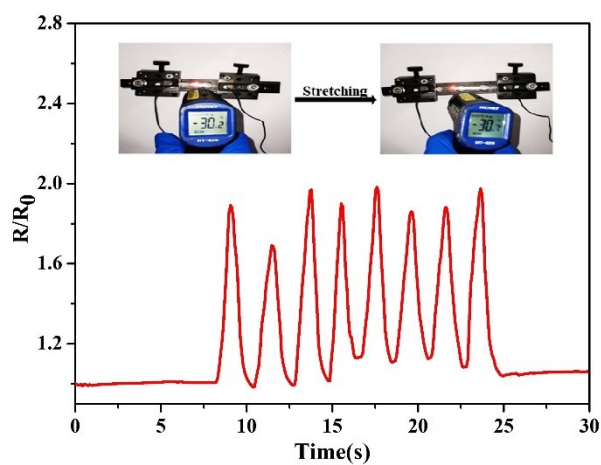
(b) Conductivities of the ionogel with various water concentration.

The effect of water on the performance of ionogel was investigated. When the PEGDA content was fixed at 0.025 mol% and the [EMIM]Cl content was fixed at 70 wt%, the addition of water to the ionogel resulted conductivities dramatically increasing from  $1.1 \times 10^{-5} \text{ S cm}^{-1}$  to  $3.1 \times 10^{-3} \text{ S cm}^{-1}$  (Fig. S5 (b)), while the stretchability also increased (Fig. S5 (a)). This phenomenon may be attributed to that the addition of water destroys the crystallization of the ionic liquid and reduces the viscosity, which promotes the free-ion separation and improves ion mobility. But, the increase in water content decreases the mechanical strength of the ionogel. Therefore, it was finally decided to

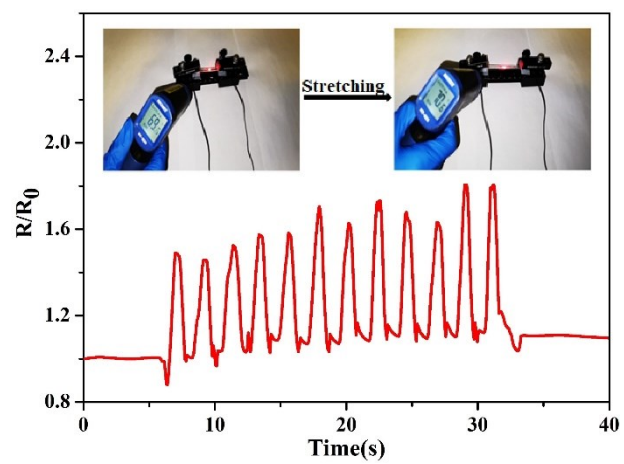
add 10 wt% water to obtain an ionogel with high stretchability and high conductivity and use it as an e-skin. The results in Fig. S4 and S5 indicate that PAA ionogel can absorb moisture in the air and cause the conductivity change, so PAA ionogel can be applied as a humidity sensor.



**Fig. S6** Digital photograph of the tensile stress–strain test of the ionogel.



**Fig. S7** Resistance change ( $R/R_0$ ) of the ionogel at  $-30\text{ }^\circ\text{C}$ .



**Fig. S8** Resistance change ( $R/R_0$ ) of the ionogel at 70 °C