Supplementary Information (SI) for Journal of Materials Chemistry C.
This journal is © The Royal Society of Chemistry 2026

# Gradient-Structured Ionic Bimodal Sensor with Giant Piezoionic and thermal-resistive effect for Crosstalk-Free Pressure-Temperature Perception

Huanyu Liu*[a], Yongqi Kuang[a], Qizhao Liang[a], HongYan Chen[a], Wen Li[a], Peng Wu[a], JingXu[a] and Yunhui Wu*[abc]

a. School of Mechanical Engineering, College of Materials Science and Engineering, Dongguan University of Technology, Dongguan 523808, PR China

b. Guangdong Provincial Engineering Technology Research Center of Key Materials for High Performance Copper Clad Laminates, Dongguan 523808, PR China

c. Subcenter of Dongguan University of Technology of National Engineering Research Center of Electronic Circuits Base Materials, Dongguan 523808, PR China

**Corresponding authors**

**Huanyu Liu, E-mail: liuhuanyu@dgut.edu.cn**

**Yunhui Wu, E-mail: wuyh@dgut.edu.cn**

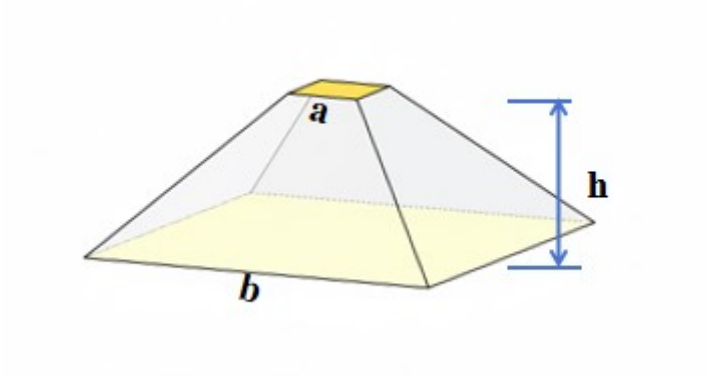


**Figure S1.**The scheme diagram of gradient structure with a trapeziform shape (a=1, b=$\sqrt{5}$, h=2)

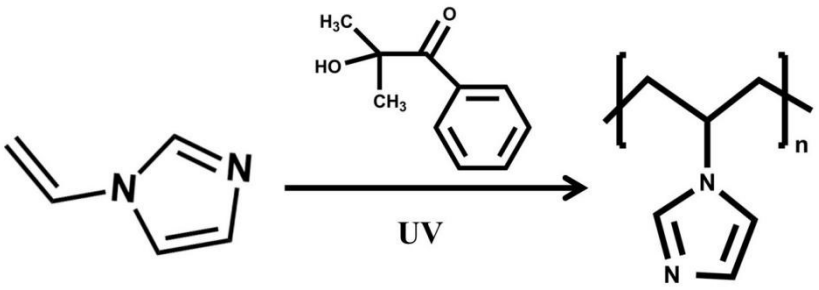


**Figure S2.** Reaction mechanism of PVM through a one-step photopolymerization.

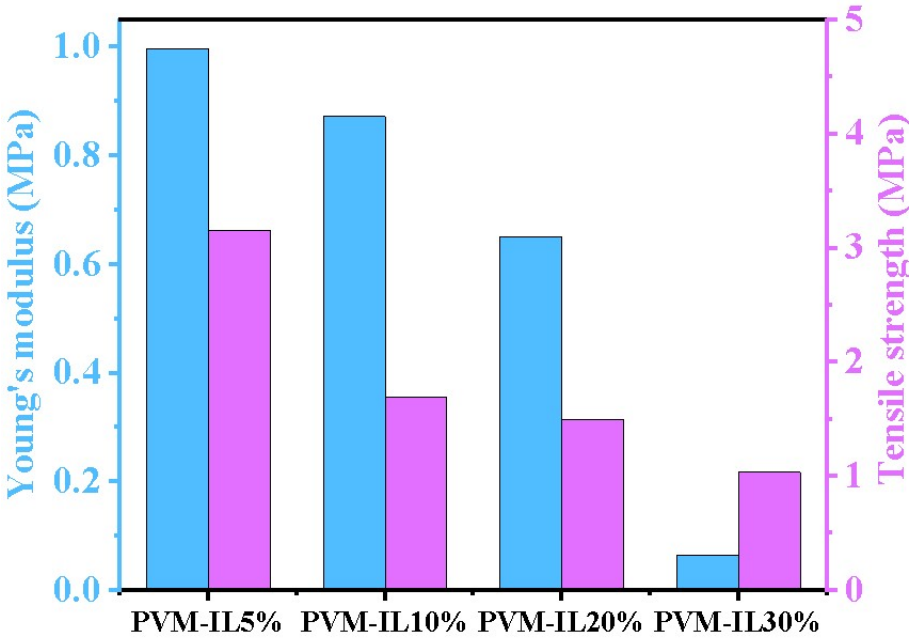


**Figure S3.** Mechanical performances of PVM+IL.

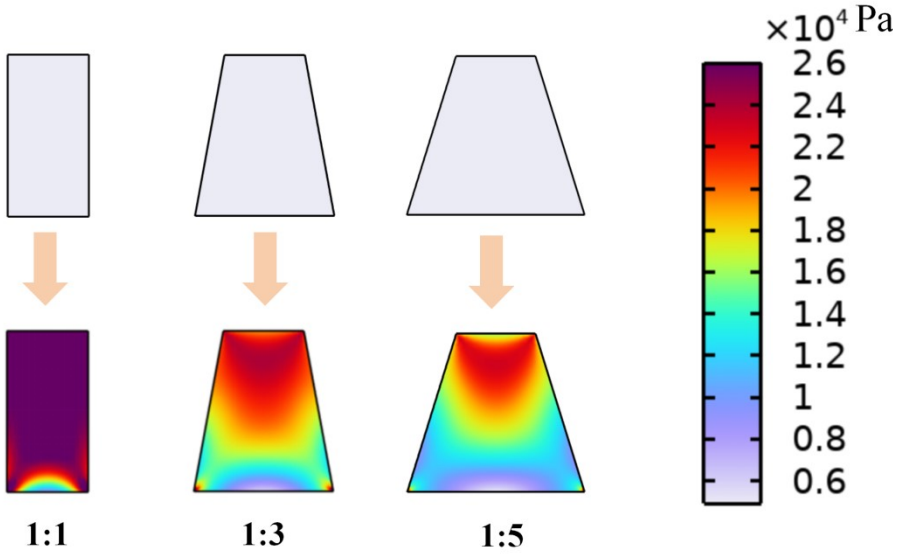


**Figure S4**. Stress Contour Plot of pressure gradient along the height for the structure with various area ratio obtained from COMSOL software.

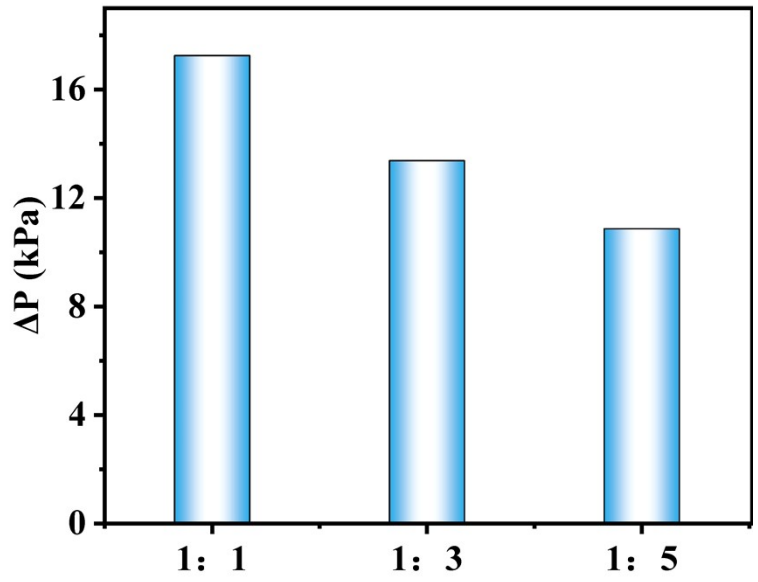


**Figure S5**. Pressure difference along the thickness for the structure with various area ratio obtained from COMSOL software.

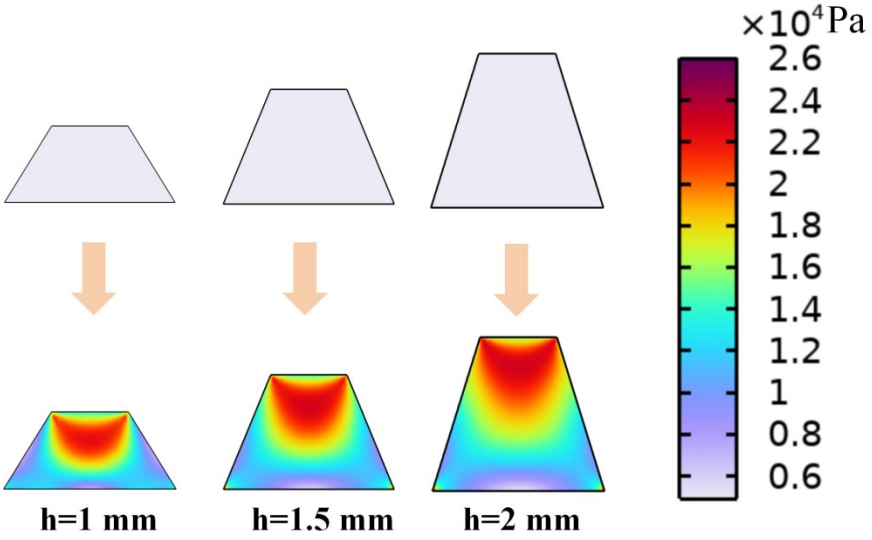


**Figure S6**. Stress Contour Plot of pressure gradient along the height for the structure with various heights (h) obtained from COMSOL software.

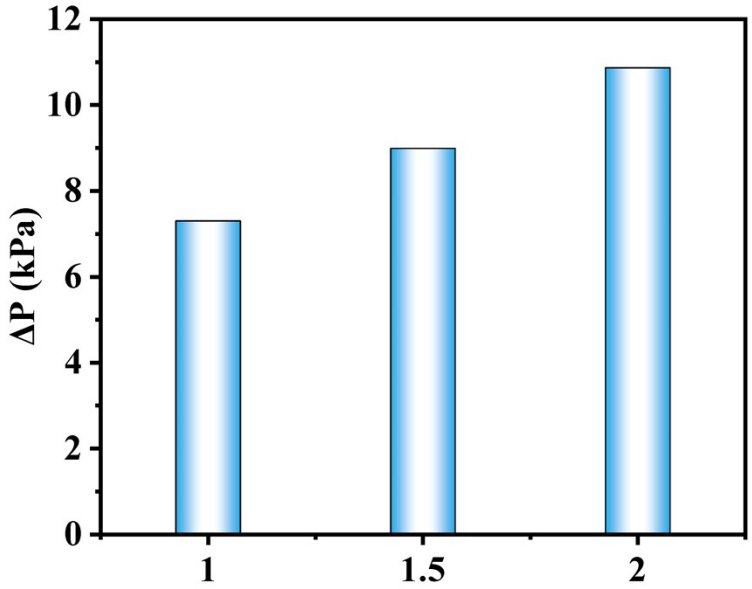


**Figure S7**. Pressure difference along the thickness for the structure with various various heights obtained from COMSOL software.

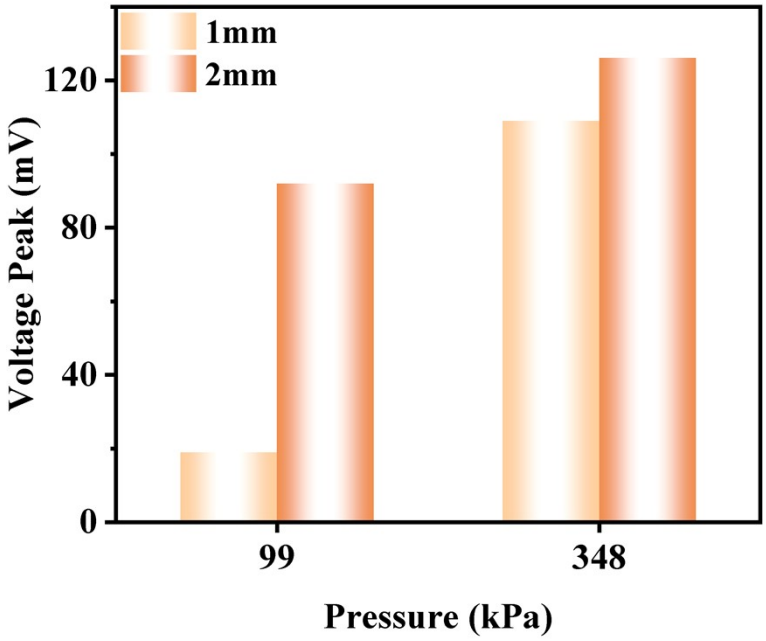


**Figure S8**. The comparison of piezoionic response in gradient-structure ionogels with various height.

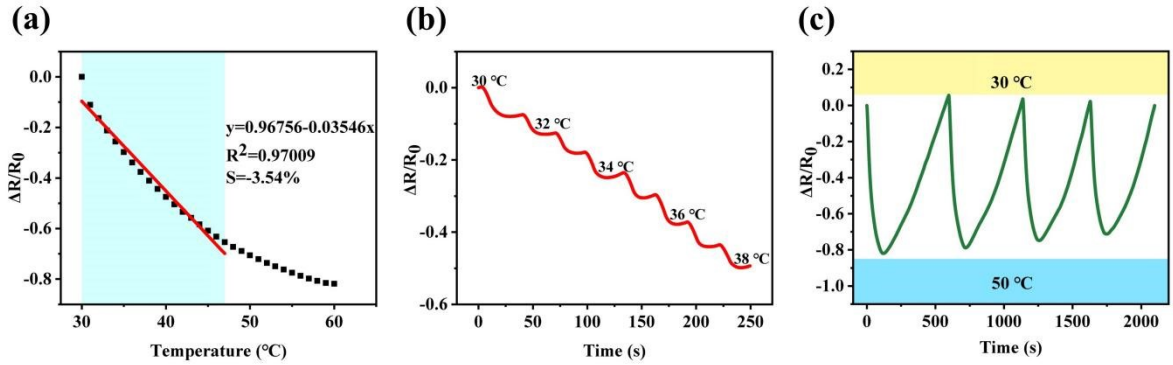


**Figure S9.** Temperature sensing performances of the bimodal sensor. (a) $\Delta R/R_0$ in the range of 30-60 °C. (b) $\Delta R/R_0$ with increments of 1 °C from 30 to 38 °C. (c) Cyclic test of temperature conducted between 30 and 50 °C.

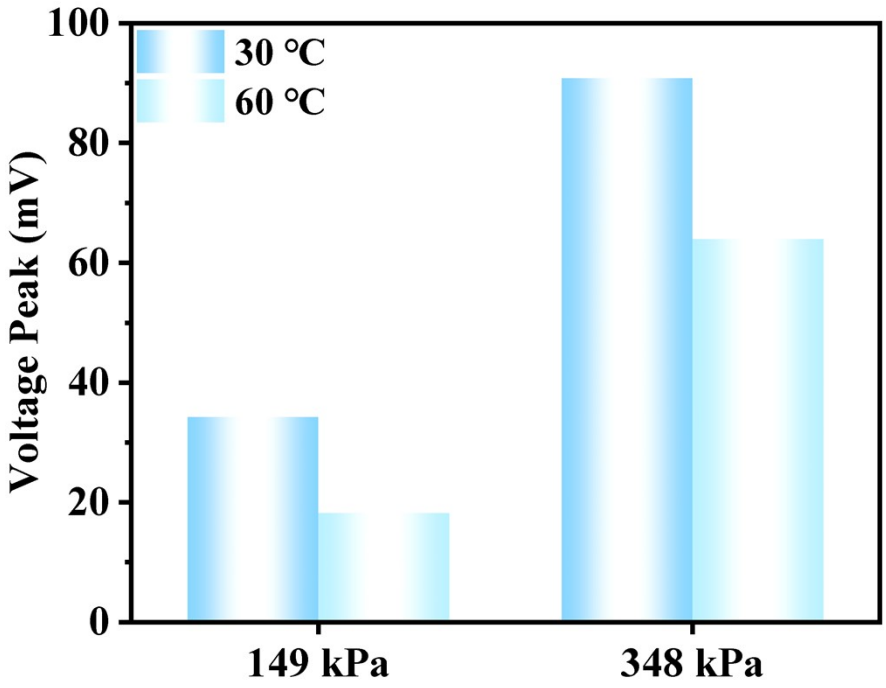


**Figure S10**. The comparison of voltage peak for the bimodal sensor at the temperature of 30 ℃ and 60 ℃

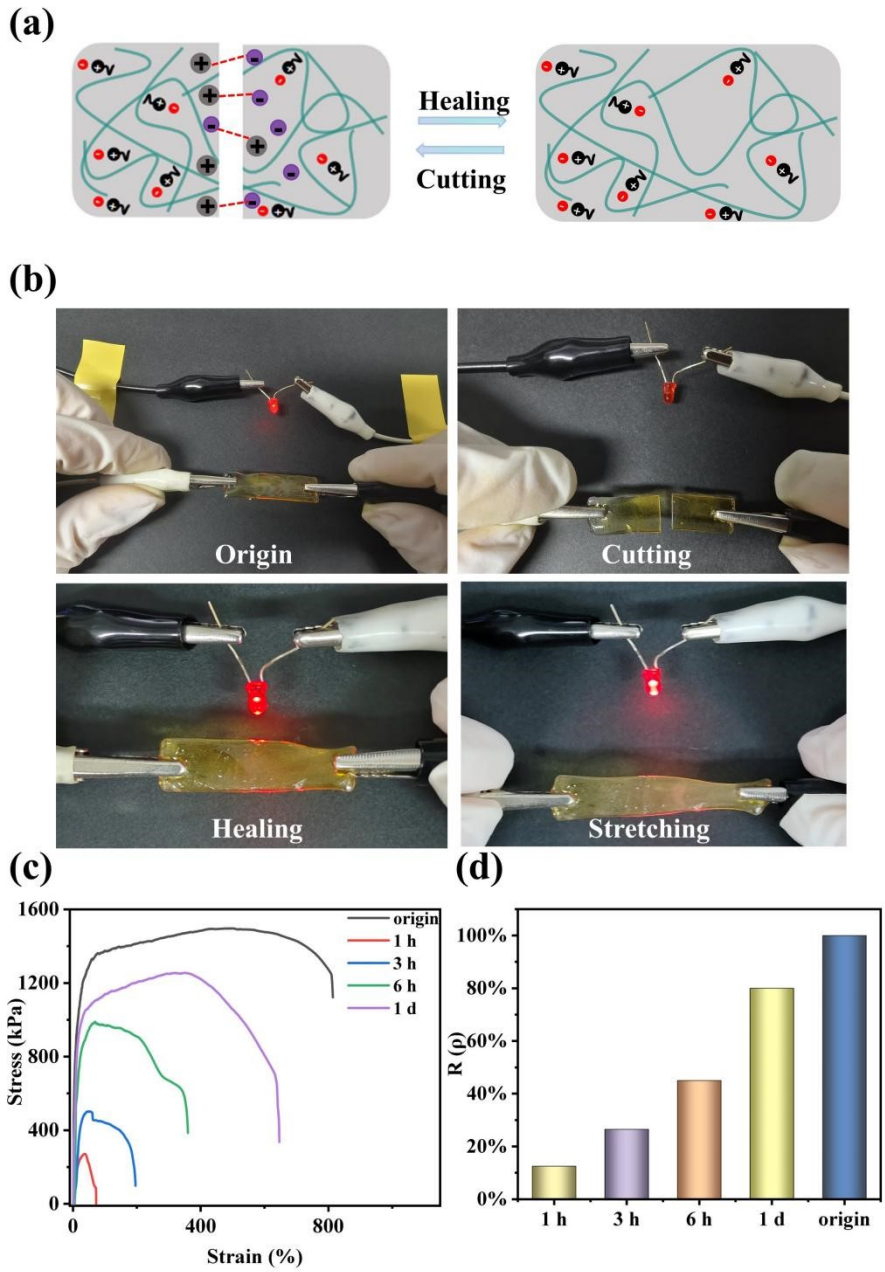


**Figure S11**. (a) Self-healing mechanism of PVIM+IL samples. (b) Images of PVIM+IL before and after self-healing at ambient temperature (25℃ ). (c)Tensile stress–strain curves of the PVIM+IL at various healing times. (d) Self-healing efficiency of PVIM+IL for various healing time.

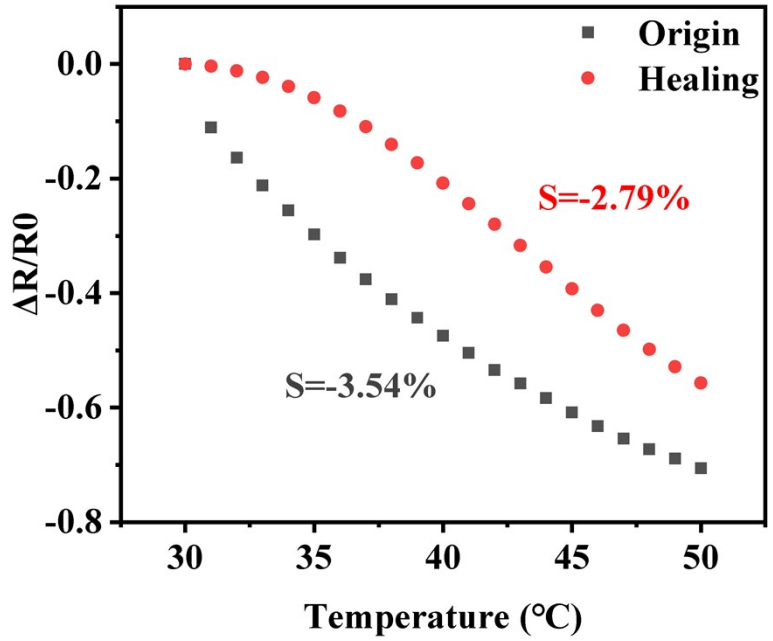


**Figure S12**. Temperature response of the bimodal sensor before and after self-healing.

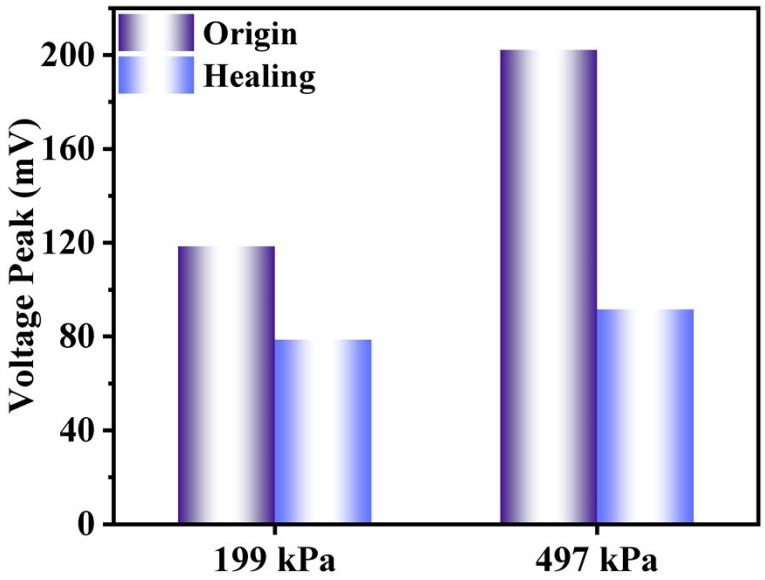


**Figure S13**. Voltage peak of the bimodal sensor before and after self-healing.

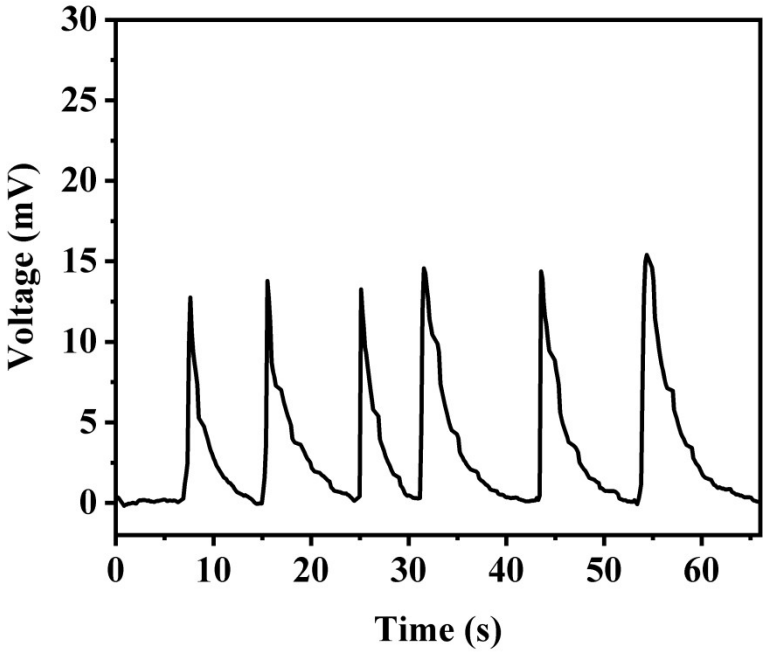


**Figure S14.**The voltage response of the bimodal sensor when monitoring repeat wrist bending.

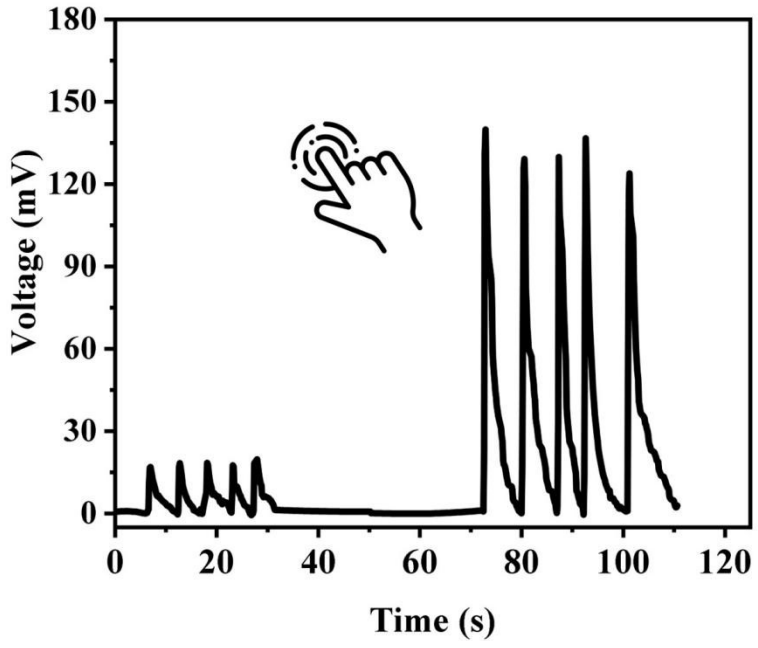


**Figure S15.** The voltage response of PIL senor when monitoring finger pressing.

Table S1. Comparison between the present work and reported bimodal ionic sensors.

| **Working mechanism** | **Detection Range** | **Fabrication Complexity** | **Decoupled** | **Partial self-powered** | **References** |
|---|---|---|---|---|---|
| Piezoresistive/ Thermal-resisitive | 80 kPa/ 70 ℃ | Two sensitive material | - | No | 1 |
| Piezoresistive/ Thermal-resisitive | 4 kPa/ 50 ℃ | Single material | - | No | 2 |
| Piezocapacitive/ Thermal-resisitive | 0-600 kPa/ 80 ℃ | Two sensitive material | Decoupled | No | 3 |
| Capacitive / Capacitive | 133.5 kPa/ 75 ℃ | Single material | Machine-learning decoupled | No | 4 |
| Piezoresistive/ Thermoelectric | 120 kPa/ -(not provided) | Two sensitive material | Decoupled | No | 5 |
| Piezocapacitive/ Thermal-resisitive | 300 kPa/ 50 ℃ | Two sensitive material | Decoupled | No | 6 |
| Piezoionic/ thermal-resisitive | 497 kPa/ 60 ℃ | Single material | Decoupled | Yes | This work |

## References


1. Z. Wang, L. Zhang, J. Liu and C. Li, *Nanoscale*, 2019, 11, 14242–14249.
2. S. Feng, Q. Li, S. Wang, B. Wang and T. Zhang, *ACS Appl. Mater. Interfaces,* 2019, 11.
3. L. Fan, X. Yang and H. Sun, *J. Mater. Chem. C*, 2023, 11, 10163–10177.
4. W. Yang, L. Lv, H. Feng, Y. Xu, H. Shao, Y. Ye, Y. Xiao, J. Wang and H. Chen, Chen, *Chem. Eng. J*., 2026, 172561.
5. Y. Yin, Y. Wang and H. Li, *Chen, Chem. Eng. J.*, 2022, 430, P434.
6. Y. Liu, C. He, J. Fang, J. Zhou, K. Shang, X. Pu, L. Qian and T. Yang, *Mater. Today Phys.*, 2024, 41, 10.