# A Hierarchical Tuning Strategy for Continuously Adjustable Phase-Transition Ionic Conductors toward Multimodal Sensing

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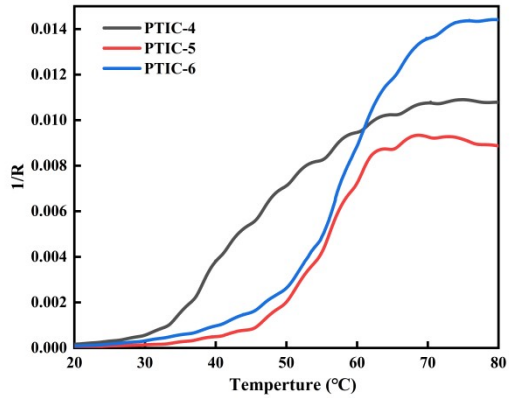


Figure S1 Temperature dependence of the reciprocal of resistance (1/R) for PTIC-4, PTIC-5, and PTIC-6.

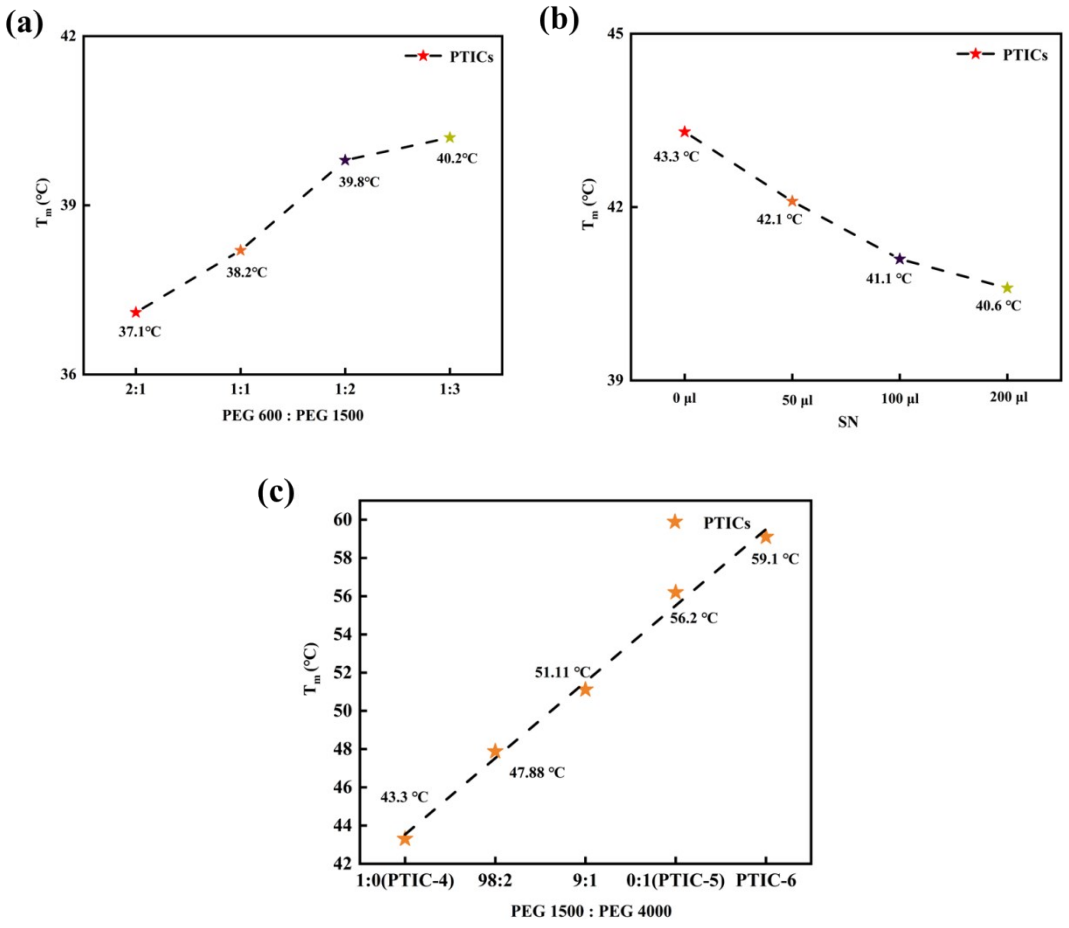


Figure S2. $T_m$ tuning of PTICs via different strategies. (a) $T_m$ of PTIC-4 with varying mass ratios of PEG 600 to PEG 1500. (b) $T_m$ of PTIC-4 with different volumes of the plasticizer SN. (c) $T_m$ of PTICs based on PEG 1500 blended with PEG 4000 at mass ratios of 100:0 (PTIC-4), 98:2, 90:10, and 0:100 (PTIC-5), compared with PTIC-6.

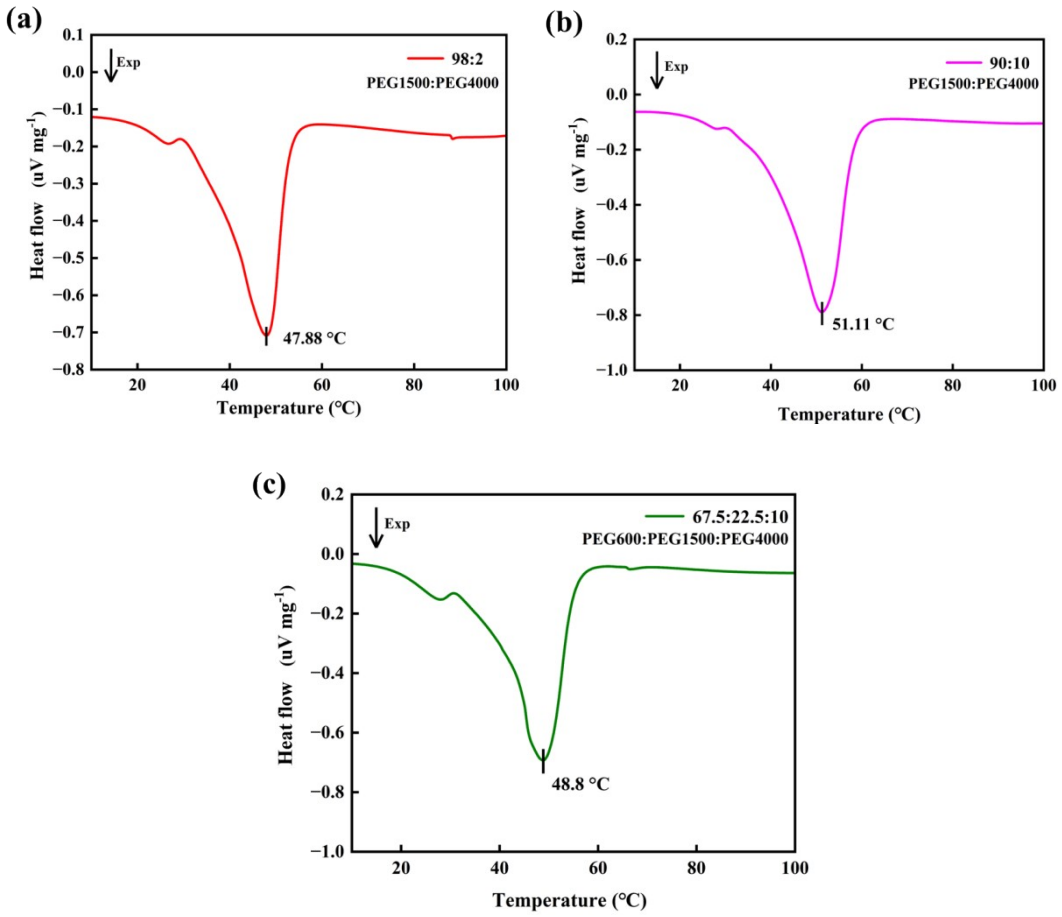


Figure S3 DSC curves comparing PTICs based on PEG 1500/PEG 4000 blends (mass ratios: 98:2 and 90:10) and a ternary PEG blend (PEG600:PEG1500:PEG4000=22.5:67.5:10), measured at 10 °C $min^{-1}$.

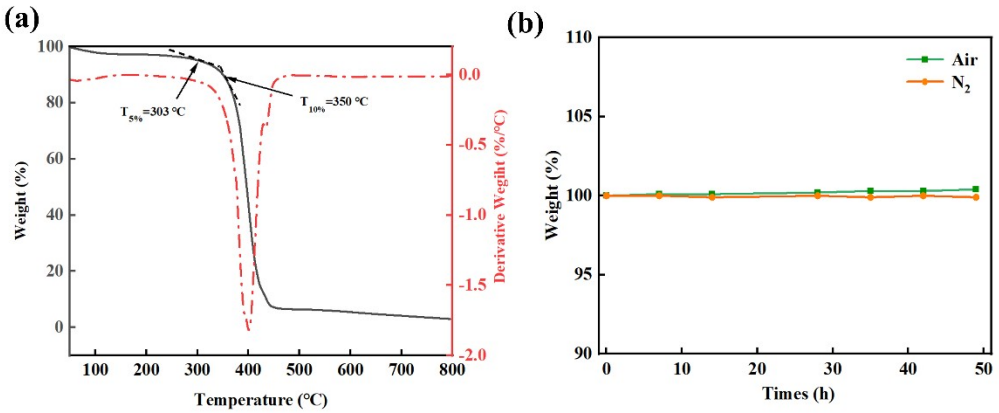


Figure S4 Stability test of PTIC-4 ionic conductor (a) TGA test; (b) Mass change over time in air and nitrogen

Table S1 Comparison of temperature coefficient of resistance among reported representative conductive elastomeric materials

| Conductive elastomer | Temperature range（℃） | *TCR*（%/℃） | Reference |
|---|---|---|---|
| PEG/P(AA-co-BA) | 30~40 | -7.64 | This work |
| PU/LiTFSI-3 | 25~60 | -2.38 | [1] |

| | | | |
|---|---|---|---|
| PIL-PDES | 20~40 | -5.93 | [2] |
| PMP DN ICH | 30~60 | -1.96 | [3] |
| PSTA50-LS30 PTIC | 36 | -8.5 | [4] |
| PAA–$Zr^{4+}$/Gly/IL gel | 0~50 | -1.891 | [5] |
| PS/PPy/CNTs hydrogel | 14.5~68.2 | -0.56 | [6] |
| PVA/PAS–PPy gel | 25~75 | -0.64 | [7] |
| Ionohydrogels ($Al_{2.8}IL_{25}$) | 0~45 | -0.035 | [8] |

# Reference


[1] Yan K, Chen H, Wang J, et al. Temperature- and pressure-sensitive ionic conductive elastomer for respiratory monitoring and human motion sensing [J]. Journal of Materials Chemistry C, 2024, 12(8): 2824-2835.

[2] Zhou C J, Song X, Xia W J, et al. Recyclable multifunctional ion conductive elastomers for strain/ temperature sensors and bioelectrodes [J]. Chemical Engineering Journal, 2024, 489: 151433.

[3] Zhao W C, Zhou H F, Li W K, et al. An Environment-Tolerant Ion-Conducting Double-Network Composite Hydrogel for High-Performance Flexible Electronic Devices [J]. Nano-Micro Letters, 2024, 16(1): 99-116.

[4] Zhou Y C, Yu C T, Zhang X, et al. Ultrasensitive Ionic Conductors with Tunable Resistance Switching Temperature Enabled by Phase Transformation of Polymer Cocrystals [J]. Advanced Materials, 2024, 36(15): 2309568 .

[5] Feng E K, Li X, Li X Q, et al. Toughened, self-healing and self-adhesive conductive gels with extraordinary temperature adaptability for dual-responsive sensors [J]. Journal of Materials Chemistry A, 2022, 10(48): 25527-38.

[6] Abodurexiti A, Maimaitiyiming X. Carbon Nanotubes-Based 3D Printing Ink for Multifunctional "Artificial Epidermis" with Long-Term Environmental Stability [J]. Macromolecular Chemistry and Physics, 2022, 223(11): 2100486.

[7] Wang S B, Zhang D, He X M, et al. Anti-Swelling Zwitterionic Hydrogels as Multi-Modal Underwater Sensors and All-in-One Supercapacitors [J]. Acs Applied Polymer Materials, 2022, 4(10): 7498-507.

[8] Zhang X R, Cui C, Chen S, et al. Adhesive Ionohydrogels Based on Ionic Liquid/Water Binary Solvents with Freezing Tolerance for Flexible Ionotronic Devices [J]. Chemistry of Materials, 2022, 34(3): 1065-77.