

1 **Preparation of a Low-Temperature, Thermally Insulating,**
2 **and Flexible Sensing Hydrogel Using Hemp-Derived High-**
3 **Charge Nanocellulose**

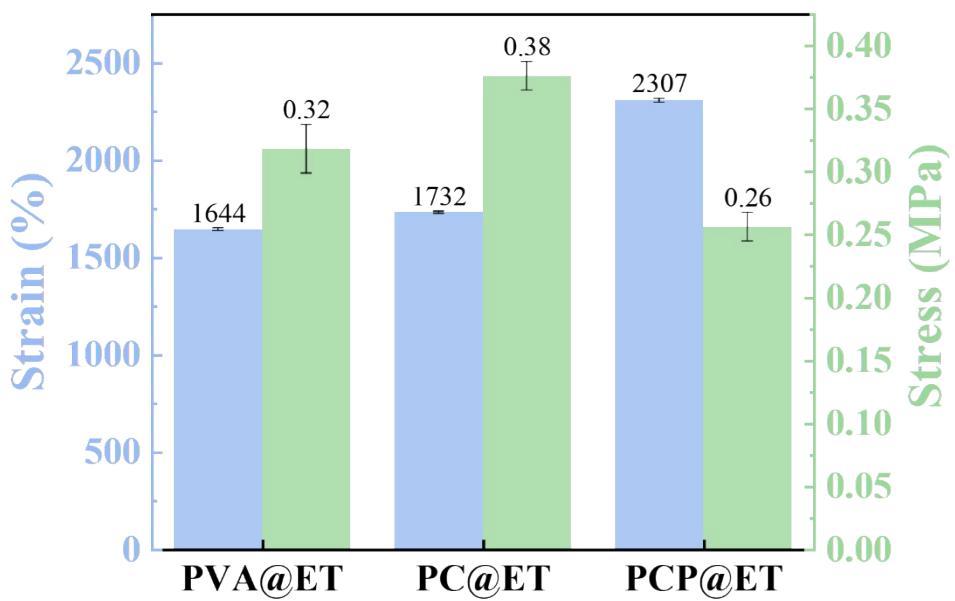
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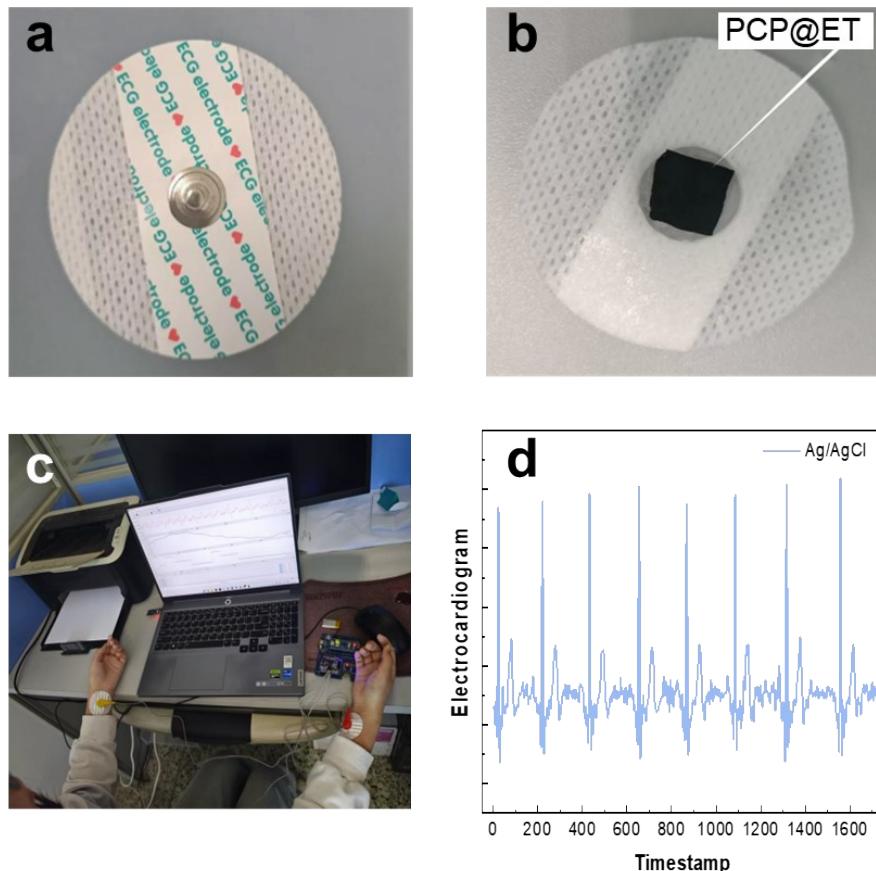
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11 Figure S1 The average values and error values of stress-strain curves for PVA@ET,
 12 PC@ET, and PCP@ET during 5 stretching processes

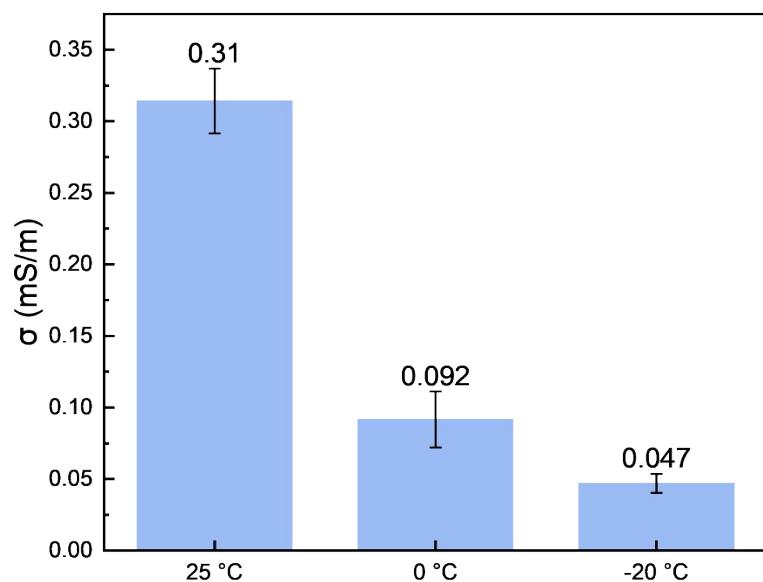


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14 Figure S2 (a) the circuit-connection side; (b) the skin-contact side; (c) the ECG testing

15 process with the subject remaining stationary; and (d) the ECG waveform obtained
16 using standard clinical Ag/AgCl electrodes under identical conditions.

17 Figure S2 illustrates the structure of the hydrogel electrode used in this study and
18 the electrocardiogram (ECG) testing setup. Figure S2a is the circuit-connection side of
19 the electrode, featuring connection terminals such as metal snaps or sockets, which
20 interface with the ECG lead wires to transmit and record cardiac electrical signals.
21 Figure S2b is the skin-contact side of the electrode, coated with conductive gel to reduce
22 skin impedance, enhance electrical conductivity, and ensure stable adhesion to the skin
23 for accurate bio-signal acquisition. Figure S2c is Static ECG testing scenario:
24 experiments were conducted in a quiet, temperature-controlled (25 °C) room.
25 Electrodes were attached to the skin following a standard lead configuration, ensuring
26 firm, bubble-free contact while the subject remained at rest. Figure S2d is ECG
27 waveform obtained under identical conditions using standard clinical Ag/AgCl
28 electrodes, provided as a reference for comparison.



30 Figure S3 Conductivity (σ) of the PCP@ET hydrogel at 25, 0, and $-20\text{ }^{\circ}\text{C}$.

31 The conductivity (σ) of PCP@ET was evaluated across a temperature range from
32 $25\text{ }^{\circ}\text{C}$ to $-20\text{ }^{\circ}\text{C}$. Samples were equilibrated in a temperature-controlled chamber for
33 24 h at each target temperature (25, 0, and $-20\text{ }^{\circ}\text{C}$). The electrical resistance was
34 measured five times per condition using a digital multimeter, and the average value was
35 used to calculate conductivity. The resulting conductivities were 0.31 mS/m at $25\text{ }^{\circ}\text{C}$,
36 0.0921 mS/m at $0\text{ }^{\circ}\text{C}$, and 0.0471 mS/m at $-20\text{ }^{\circ}\text{C}$.