Supporting Information

A Multifunctional Skin-like Sensor Based on a 3D printed Thermoresponsive Hydrogel

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This material includes

Rheological analyses of the 3D printing process.

Theoretical prediction of the capacitance changes upon increasing the temperature.

Fig. S1	A photo of the PDMA hydrogel and PDMA/NaCl/SDS hydrogel.
Fig. S2	The compression stress-strain curves of the PDMA-C18 hydrogel.
Fig. S3	Frequency and temperature dependencies of the G' and G" of the PDMA-C18
	hydrogel.
Fig. S4	Turbidity result of the PDMA-C18 hydrogel.
Fig. S5	DSC curves of PDMA-C18 hydrogels with different molar ratios of DMA and
	C18.
Fig. S6	Temperature-dependent IR spectra of the PDMA-C18 hydrogel.
Fig. S7	Frequency dependencies of the G' and G" of the grid-structured hydrogel.
Fig. S8	Comparison of the temperature sensitivity of the grid-structured hydrogel and
	the bulk hydrogel.
Fig. S9	Comparison of the pressure sensitivity of this work with previously reported
	sensors.
Fig. S10	Gentle finger touching response of the grid-structured hydrogel sensor.
References	S1-S18
N • 61	

Movie S1. The 3D printing process of the hydrogel.

Rheological analyses of the 3D printing process.

To analyze the rheological behaviors of the hydrogel when extruded at 45 °C for 3D printing, we performed viscometry measurements to depict the stress and viscosity as a function of shear rates (Fig. 1a). In the high-strain rate region (1-500 s⁻¹), a power-law fluid model is applied to describe the shear stress as a function of shear rates, $\tau = K \cdot \dot{\gamma}^n$, in which *n* is the exponent and *K* is the consistency index. By performing a power-law fluid flowing through a cylindrical tube of radius *r*, the Rabinowitsch–Mooney equation,^[S1]

$$\dot{\gamma} = \frac{(\frac{3n+1}{4n})\frac{4Q}{\pi r^3}}{\pi r^3}$$

where Q is the volumetric flow rate, is utilized to predict the shear rate $\dot{\gamma}$, which is about 297 s⁻¹ at 45 °C. Thus the corresponding viscosity of the hydrogel is about 1.5 Pa s (Fig. 1a). Immediately after extrusion, the viscosity increases to >> 365 Pa s, assuming a shear rate of far below 1 s⁻¹.

Theoretical prediction of the capacitance changes upon increasing the temperature.

In a parallel-plate configuration, the capacitance changes depend on the effective capacitive area changes based on the relationship of the deformation and capacitance, which can be described by a simplified mathematical model. Since the length (*L*) of the printed fiber is much larger than its diameter, the capacitive area changes mainly depend on the diameter changes in contact with the dielectric layer. Ideally, the cross section of the printed hydrogel fibre is an ellipse, whose major axis is 2a and minor axis is 2b. As shown in Fig. 3a, an orthogonal coordinate was established to describe the contacting diameter ($2|x_c|$),

$$\frac{x_c^2}{a^2} + \frac{y_c^2}{b^2} = 1$$

in which $y_c = \lambda b_{,}$

and thereby the contacting diameter can be expressed as $2|x_c| = 2\sqrt{1-\lambda^2} \cdot a$.

During the phase transition process, λ might be little different but it only has negligible influence on the value of $2|x_c|$. Approximately, the changes of the contacting diameter linearly depend on the major axis changes.

Therefore, the capacitance $C = \frac{\varepsilon S}{4\pi kd} = \frac{2\varepsilon L}{4\pi kd} \cdot |x_c| = \frac{2\varepsilon L\sqrt{1-\lambda^2}}{4\pi kd} \cdot a$ is also linearly related with the observed diameter (major axis) changes, as shown in Fig. 3.



Fig. S1 A photo of the PDMA hydrogel (left) and PDMA/NaCl/SDS hydrogel (right).



Fig. S2 The compression stress-strain curves of the PDMA-C18 hydrogel in the strain ranges

of (a) 0-54% and (b) 0-5%.



Fig. S3 (a) Frequency and (b) temperature dependencies of the G' and G" of the PDMA-C18 (1:1) hydrogel.



Fig. S4 Turbidity result of the PDMA-C18 (1:1) hydrogel.



Fig. S5 DSC heating and cooling curves of PDMA-C18 hydrogels with different molar ratios of DMA and C18.



Fig. S6 Temperature-dependent IR spectra of the PDMA-C18 (1:1) hydrogel in the regions of (a) 3800-800 cm⁻¹, (b) 1775-1525 cm⁻¹ and the corresponding second derivative curves of the C=O stretching band of C18.



Fig. S7 Frequency dependencies of the G' and G" of the grid-structured hydrogel.



Fig. S8 Comparison of the temperature sensitivity of the grid-structured hydrogel and the bulk hydrogel.



Fig. S9 Comparison of the pressure sensitivity (in the range of 0-1 kPa) of the grid-structured hydrogel sensor with previously reported capacitive sensors.^[S2-S18]



Fig. S10 (a) A photo of the grid-structured hydrogel sensor that was attached to a prosthetic finger and (b) corresponding gentle finger touching response.

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