Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A. This journal is © The Royal Society of Chemistry 2022

Electronic Supplementary Information

Highly sensitive, weatherability strain and temperature sensors

based on AgNPs@CNTs composite polyvinyl hydrogel

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Supplementary Figures S1 to S17

Supplementary Tables S1

Supplementary Captions for Movies S1 to S4

References for SI reference citations

Other supplementary materials for this manuscript include the following:

Supplementary Movies S1 to S4



Figure S1. Schematic illustration of the preparation of AgNPs@CNTs powder.



Figure S2. Particle size statistics of AgNPs on the surface of AgNPs@CNTs. (a) Distribution of the particle size of AgNPs@CNTs surface AgNPs; (b) Average size statistics of AgNPs@CNTs surface AgNPs.



Figure S3. (a) XPS survey spectra of AgNPs@CNTs; (b) XPS high-resolution C1s spectrum of AgNPs@CNTs; (c) XPS profiles for Ag 3d spectrum of AgNPs@CNTs.



Figure S4. Comparison of the conductivity of PBGC hydrogel, PBGAc hydrogel, PBGU hydrogel and PBGA hydrogel.



Figure S5. Dispersion of four different CNTs after 72 hours. (a)1 h;(b)12 h;(c)24 h;(d)72 h, of which (i-iv) are CNTs, Ac CNTs, UV CNTs, AgNPs@CNTs respectively.



Figure S6. (a) Zeta potential test plots of four different CNTs; (b) Hydrophilic angle test plots of four different CNTs.



Figure S7. Infrared thermograms of PBGA hydrogels stretched at different temperatures below zero.



Figure S8. Variation in bulb brightness of PBGA hydrogels at sub-zero temperatures with different amounts of tensile deformation. (a) 0 %;(b) 40 %;(c) 60 %.



Figure S9. Amorphous hydrogels with extra high CNTs content.



Figure S10. Compression cycle curves of PBGA hydrogel with different shape variables.



Figure S11. Tensile electromechanical properties of PBGA hydrogel sensors at room temperature. (a) Relative resistance variation (50 % - 250 %) of PBGA hydrogels over multiple large deformation cycles; (b) Comparison of the change in relative resistance of PBGA hydrogels at large deformations (25 %-100 %);(c) Response time and recovery time of PBGA hydrogel sensors at 10 % strain; (d) Relative resistance change at 20 % tensile strain, repeatedly loaded-unloaded 2000 times.



Figure S12. (a) Relative resistance variation for cyclic loading-unloading at different tensile rates (from 25 to 500 mm/s) with a strain of 40 %; (b) Comparison of the details of the relative resistance variation of PBGA hydrogel under different deformation variables. (25%-100%).



Figure S13. Twisting properties of PBGA hydrogel. (a) Relative resistance change of PBGA hydrogel at different angles (0°, 90°, 180°, 270° and 360°) by twisting; (b) Linear curves of relative resistance change of PBGA hydrogels at different angles of twisting.



Figure S14. The relative rate of change of resistance for each of the four repetition cycles.



Figure S15. Relative rate of change of resistance at different cooling rates.



Figure S16. Variation of resistance with temperature for PBGA hydrogel sensors in the temperature range of -10 °C to 40 °C.



Figure S17. (a) PBGA hydrogel bionic sensor has good linearity of resistance change with hydraulic pressure change;(b) Detailed graph of the response time of the PBGA hydrogel bionic sensor to changes in water pressure.



Figure S18. (a) PBGA hydrogels are remolded by heating, injection and freeze-thaw cycles; (b) Comparison of the relative rate of change in resistance of PBGA hydrogels with those after refreezing and thawing for the same deformation variables (10%, 20% and 30%); (c) Weight change of PBGA hydrogels placed for 30 days (temperature of 25°C and humidity of 40 %);(d) Comparison of the electrical properties of PBGA hydrogel placed for 0, 7 and 15 days respectively.



Figure S19. (a) Comparison of weight percentages of PBGA hydrogels, PBA hydrogels and re-swollen PBGA hydrogels placed after 7 days; (b) Percentage change in volume of PBGA hydrogels placed for 30 days.



Figure S20. Antibacterial properties of PBGA hydrogel sensors. Antibacterial effect of four different hydrogels against (a) Pseudomonas aeruginosa and (c) Staphylococcus aureus; (i) PBGA hydrogel; (ii) PBGAc hydrogel; (iii) PGU hydrogel; (iv) PBG hydrogel. (b) and (d) are comparisons of the circles of inhibition of Pseudomonas aeruginosa and Staphylococcus aureus with different hydrogel.

References	Materials	TCR	Sensing ranges
		(%/°C)	(°C)
[1]	Reduced graphene	0.9	30-80
	oxide		
[2]	PVA/Gly/CB/CNT	0.935	20-80
	organohydrogel		
[3]	Graphene hydrogel	2.04	26-101
[4]	BP/LEG on SEBS	0.1736	25-50
[5]	MXene-AgNW-	0.2	24-54
	PEDOT:PSS-TeNW		
	nanocomposite		
[6]	TPU@IL	0.3-1.4	-40-100
[7]	Graphene/Alginate	1.5	20-45
[8]	CNT/InGaZnO	0.68	22.4-40
[9]	Polypyrrole/Ag NWs	0.086	17-50
[10]	Ag nanocrystal/PDMS	0.185	30-50
[11]	PANI NFs/PAA/Fe ³⁺	1.64	40-110
This work	Ag NPs/CNTs	2.99	-20-40

 Table 1. Summary of thermosensation capacities of temperature sensors

Movie captions:

Movie S1. PBGA hydrogels can be stretched extensively even after knotting at room temperature.

Movie S2. The PBGA hydrogel was connected to a circuit containing a small light bulb, which was lit when the wire was switched on. As the hydrogel was stretched, the brightness of the bulb changes. When the hydrogel was stretched, the bulb was dimmed, and vice versa.

Movie S3. PBGA hydrogel was subjected to tensile testing after knotting and tensile testing under twisting at near -20 °C.

Movie S4. We attached PBGA hydrogel to the surface of the human body for monitoring human behaviour. We used the keithley 2450 for outputting electrical

signals. The hydrogel synchronously outputs sensitive signal peaks with the bending

movements of the human finger and wrist.

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