Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting Information

Highly flexible and stretchable MWCNT/HEPCP nanocomposites integrated near-IR, temperature and stress sensitivity for electronic skin

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Characterization of MWCNT/HEPCP nanocomposite films

Fourier transform infrared spectroscope (FTIR):

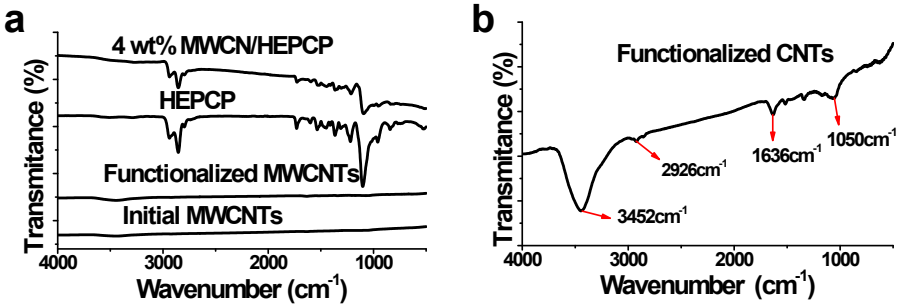

Fig. S1 The FTIR spectroscope of initial MWCNTs, functionalized MWCNTs, HEPCP, 4 wt% MWCNT/HEPCP nanocomposite.

Functionalized MWCNTs (Fig. S1b): There is no infrared absorption peak between 1700 cm^{-1} and 3000 cm^{-1}.

HEPCP: 2860 (ν CH_2) cm^{-1}, 1732 (ν C=O) cm^{-1}, 1533 and 1452 (ν C=C aromatic) cm^{-1}, 1366 (ν_{as} CH_2) cm^{-1}, 1218 (ν_{as} C-N aromatic) cm^{-1}, 1100 (ν_s CH_2) cm^{-1}, 956 (ν_{as} C-O-C) cm^{-1}.

MWCNT/HEPCP nanocomposites: 2860 (ν CH_2) cm^{-1}, 1732 (ν C=O) cm^{-1}, 1530 and 1448 (ν C=C aromatic) cm^{-1}, 1366 (ν_{as} CH_2) cm^{-1}, 1213 (ν_{as} C-N aromatic) cm^{-1}, 1093 (ν_s CH_2) cm^{-1}, 952 (ν_{as} C-O-C) cm^{-1}.

UV-Vis-NIR spectroscope:

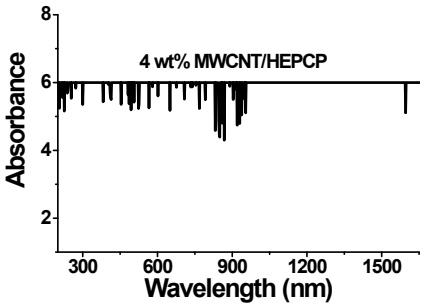

Fig. S2 The UV-vis-NIR spectroscope of 4 wt% MWCNT/HEPCP nanocomposite film (Thickness, 0.4 mm).

Sensitivity to IR illumination, temperature, and tensile strain

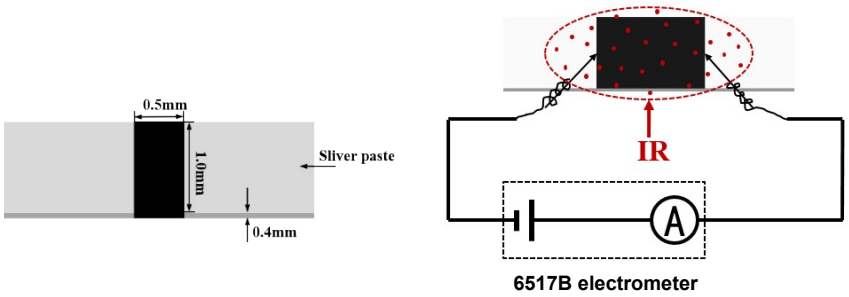

Fig. S3 The schematic diagram of the IR response test experiments (sample size: 1.0 mm × 0.5 mm × 0.4 mm).

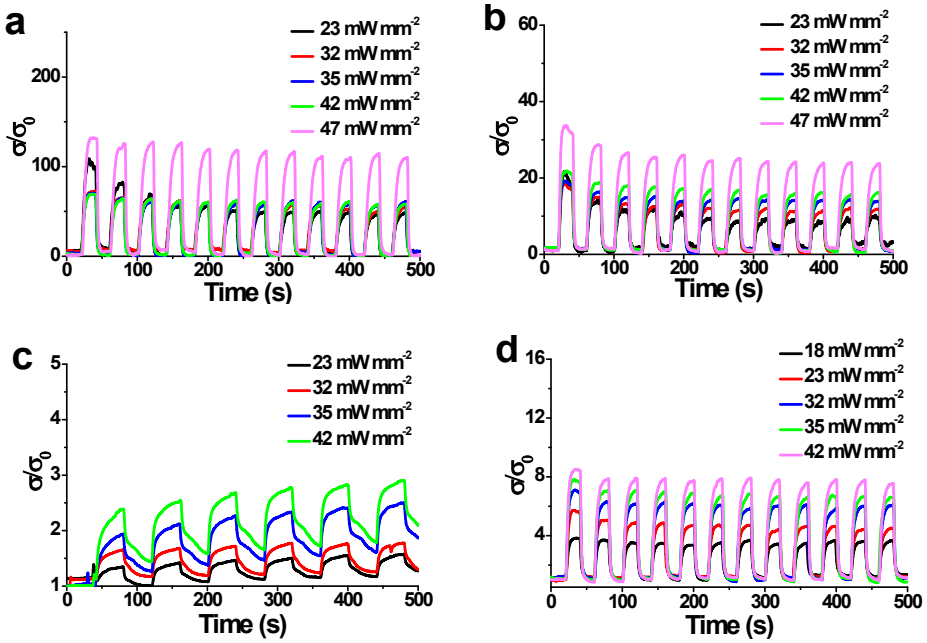

Fig. S4 The IR-regulated on/off electrical conductivity ratio of the MWNT/HEPCP nanocomposite films at different IR power density (IR power density: 18, 23, 32, 35, 42 and 47 mW mm^{-2}): (a) 3 wt% MWCNT/HEPCP nanocomposite; (b) 5 wt% MWCNT/HEPCP nanocomposite; (c) 7 wt% MWCNT/HEPCP nanocomposite; (d) 8 wt% MWCNT/HEPCP nanocomposite.

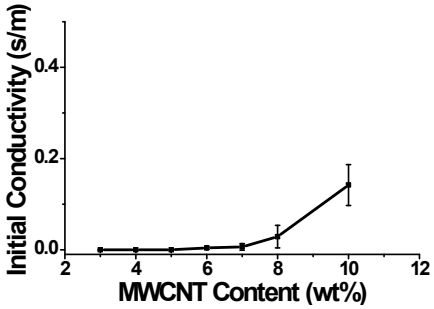

Fig. S5 Initial electrical conductivity of MWCNT/HEPCP nanocomposite films (3 wt%–10 wt%; sample size: 1.0 mm × 0.5 mm × 0.4 mm) measured at room temperature before IR, temperature and tensile strain response test.

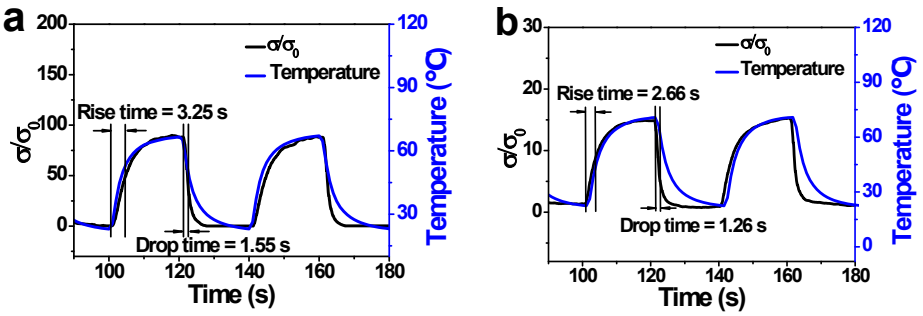

Fig. S6 The response time of IR and temperature profiles for (a) the 3 wt% and (b) 5 wt% MWCNT/HEPCP nanocomposites at an IR power density of 35 mW mm^{-2}.

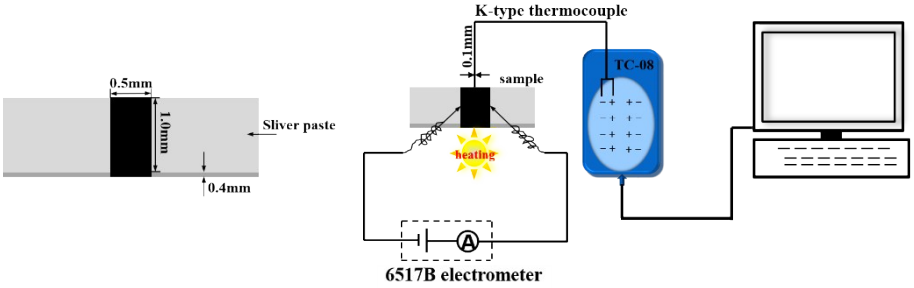

Fig. S7 The sample size and experimental schematic of the temperature response test (sample size: 1.0 mm × 0.5 mm × 0.4 mm).

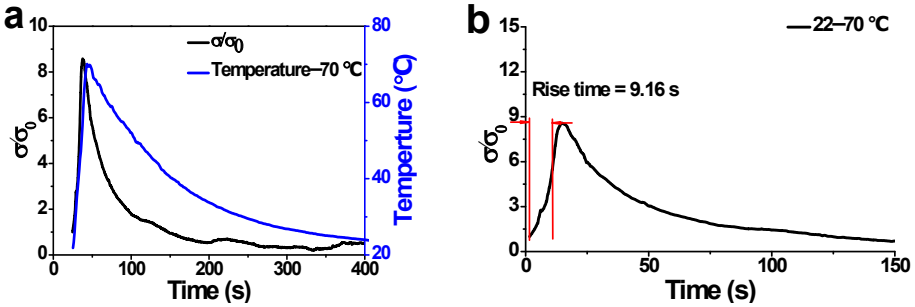

Fig. S8 (a) The temperature dependence electrical conductivity ratio (σ/σ_0) and temperature profile correspond to the heating process from room temperature to 70 °C in 20 s, then cooling to the room temperature at room temperature. (b) The response time (the time taken for the conductivity rise to 63.2% of the total magnitude of conductivity change during heating.) of temperature dependence electrical conductivity ratio (σ/σ_0) of 4 wt% MWCNT/HEPCP during the heating process from room temperature to 70 °C in 20 s.

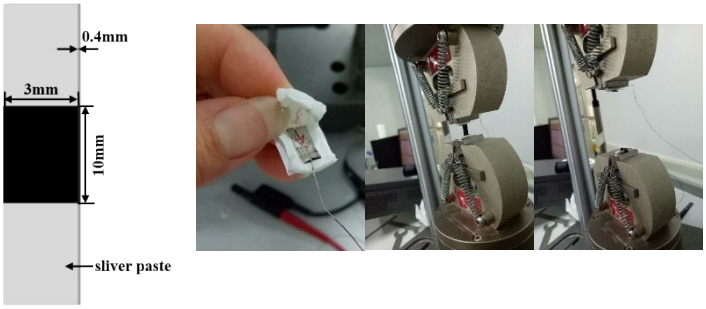

Fig. S9 The sample size and experiment device diagram of the tensile stress response test (sample size: 10 mm × 3 mm × 0.4 mm).

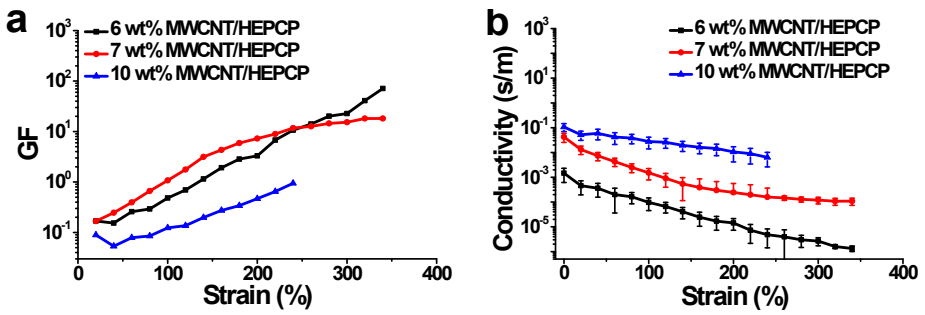

Fig. S10 (a) Gauge factor of the 6, 7 and 10 wt% MWCNT/HEPCP nanocomposite films as a function of tensile strain; (b) Electrical conductivity of 6, 7 and 10 wt% MWCNT/HEPCP nanocomposite films as a function of tensile strain.

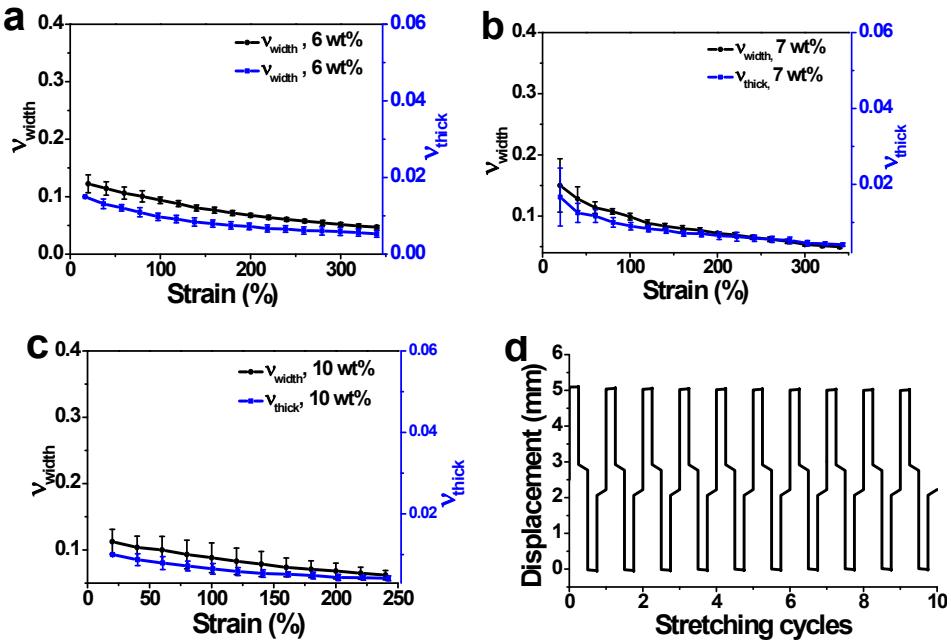

Fig. S11 Poisson's ratio of width and thickness of (a) 6 wt%, (b) 7 wt% and (c) 10 wt% MWCNT/HEPCP nanocomposite films as a function of tensile strain; (d) The displacement of 6 wt% MWCNT/HEPCP nanocomposite film in the recurrent stretching cycles, strain ε = 50%.

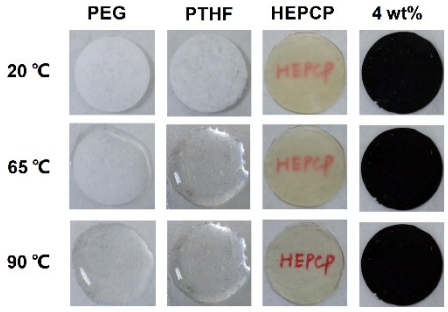

Fig. S12 Comparison of the macroscopic morphology of the pure PEG (6 kDa), pure PTHF (2.9 kDa), HEPCP and 4 wt% MWCNT/HEPCP nanocomposite at different temperatures.

Mechanism underlying the IR, temperature, and tensile stress response of the nanocomposites

Differential Scanning Calorimetry (DSC):

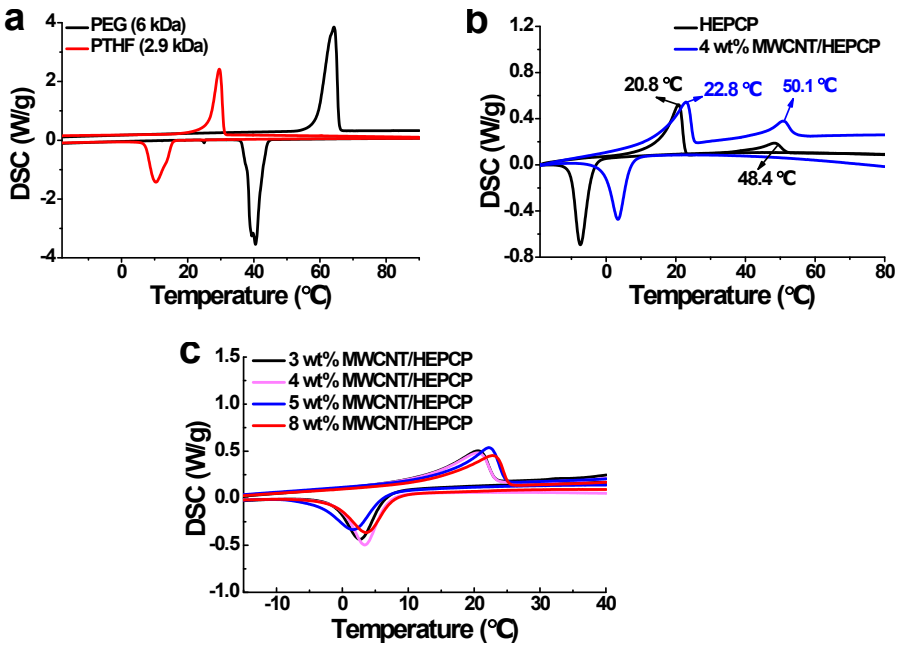

Fig. S13 The DSC curve of PEG (6 kDa), PTHF (2.9 kDa), HEPCP and MWCNT/HEPCP nanocomposites (heating and cooling rate: 5 ^{o}C min^{-1}): (a) The DSC curve of PEG (6 kDa), PTHF (2.9 kDa); (c) The DSC curve of HEPCP and 4 wt% MWCNT/HEPCP nanocomposite; (b) The DSC curve of 3 wt%, 4 wt%, 5 wt% and 8 wt% MWCNT/HEPCP nanocomposites.

Table S1 Phase transition behavior of PEG (6 kDa), PTHF (2.9 kDa), HEPCP and MWCNT/HEPCP nanocomposites.

Sample	ΔH [J g^{-1}]		T_m [^{o}C]	T_c [^{o}C]
	Heatin	Cooling	Heating	Cooling
PEG [6 kDa]	173.88	167.34	64.21	40.50
PTHF [2.9 kDa]	95.06	88.08	39.38	10.45
HEPCP	37.65	36.43	20.77	-7.42
3 wt%	30.50	31.81	22.75	2.75
4 wt%	37.69	33.73	22.75	3.42
5 wt%	31.53	34.28	22.25	1.77
7 wt%	45.09	36.56	24.33	5.24
8 wt%	32.98	31.75	22.75	3.58

(Where ΔH is the enthalpy of the phase transition; T_m is the melting peak temperature; T_c is the recrystallization peak temperature.)