Supporting Information

Ultra-wide sensing range film strain sensor based on brunch-shaped carbon nanofibers and carbon black synergistic conductive network for human motion and human-machine interface

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KEYWORDS: film strain sensor, branch-shaped PAN-based carbon nanofiber, wide sensing range, ultra-low detection, human-machine interface, human motion detection.

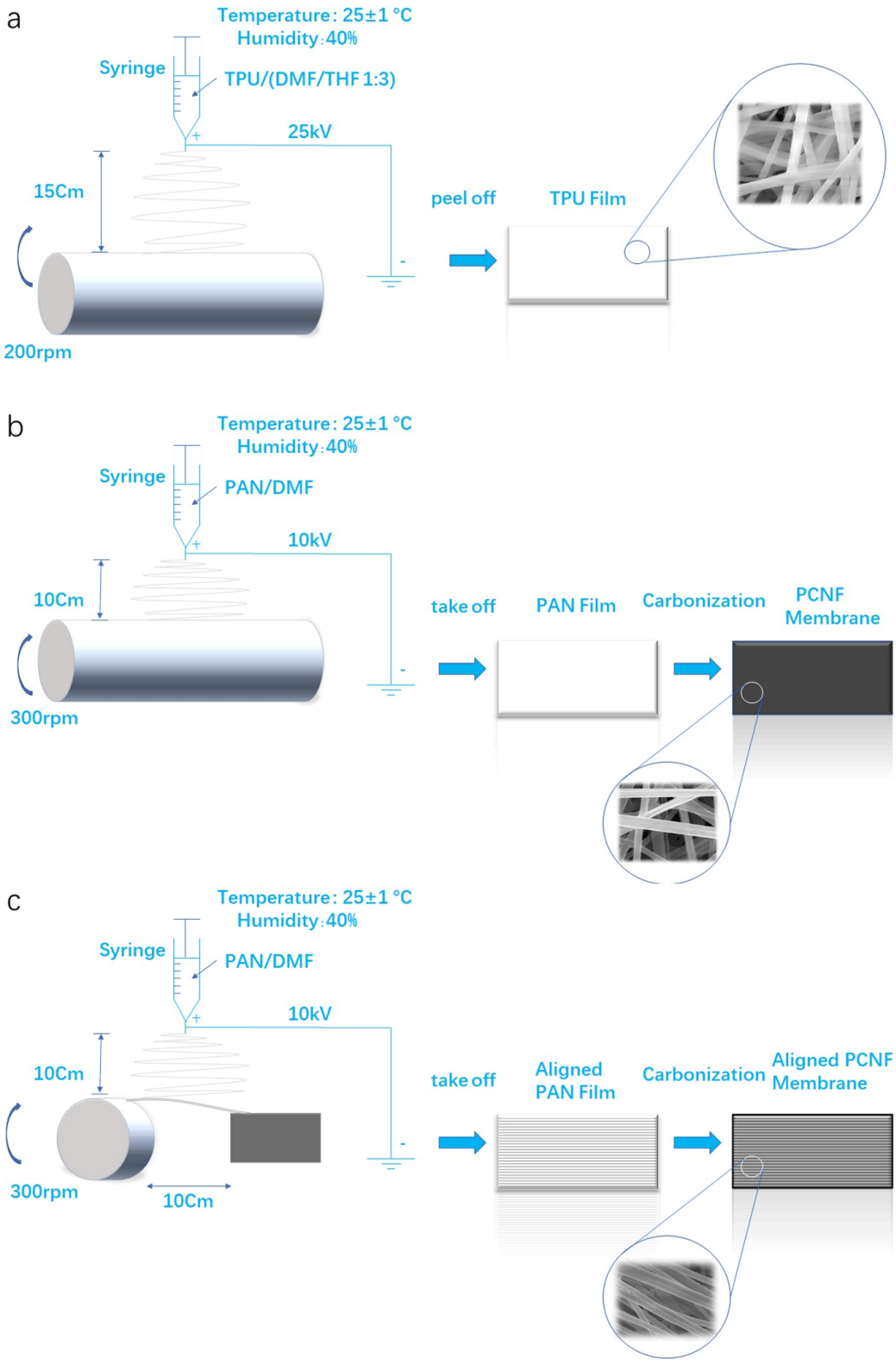

Figure S1 The fabrication of TPU membrane in (a) mormal PAN-based carbon nanofiber membrane(b) and aligned PCNF membrane(c), respectively.

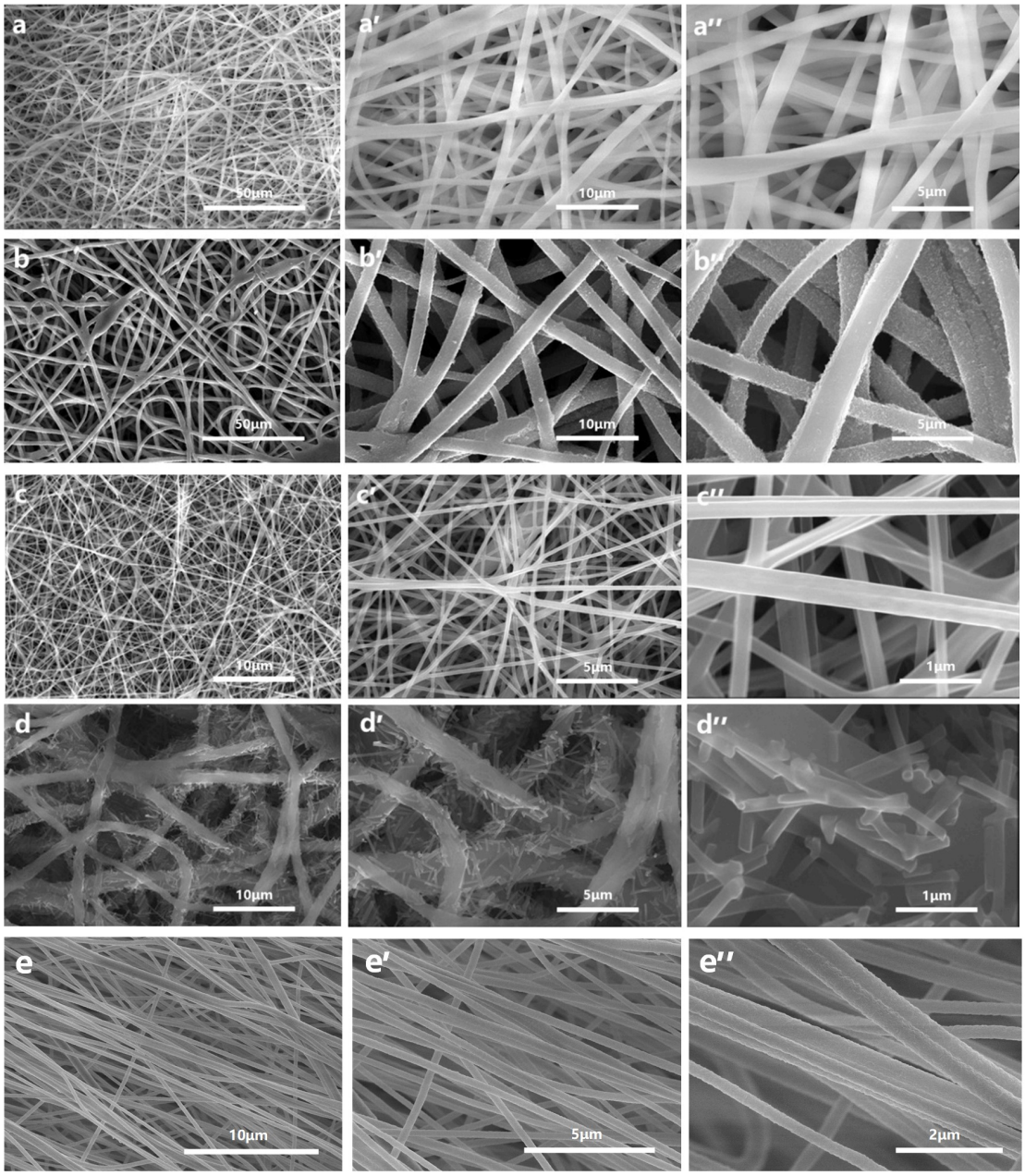

Figure S2 The morphology of TPU, TPU-CB, carbonized bPCNF membrane, surface of TPU-bPCNF and aligned rPCNF membrane The smooth TPU surface and evenly distributed TPU fibers with diameters 1-2 um can be seen clearly in **Figure S2**a. **Figure S2**b exhibits that massive carbon black particles were firmly anchored on the surface of TPU nanofiber by ultrasonication. PAN (Polyacrylonitrile) was used by electrospinning and followed carbonizing. **Figure S2**c presents the surface of

carbonized PAN. After carbonization, mean diameters was in the range of 120-220 nm. The surface of as-designed film strain sensor was also visualized by SEM and presented in **Figure S2**d. It can be clearly seen that abundant PCNFs were firmly anchored on the TPU fiber after ultrasonication process. The rod-shaped PCNF with diameters range of 120-200 nm can be clearly discovered from the aligned PCNF membrane. The parallel PCNF was attributed by tensile force caused by the split electric field.

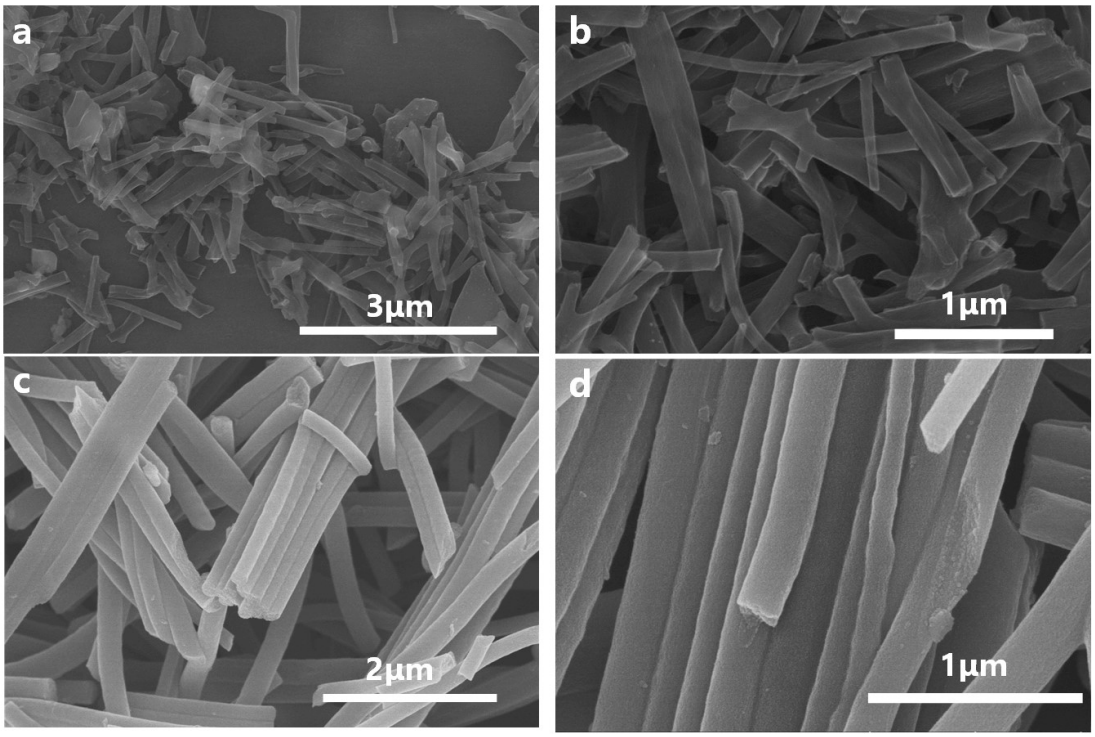

Figure S3 the geometry of branch-shaped PCNF (a) 3um and (b) 1um and rod-shaped PCNF (c) 2um and (d) 1um magnification.

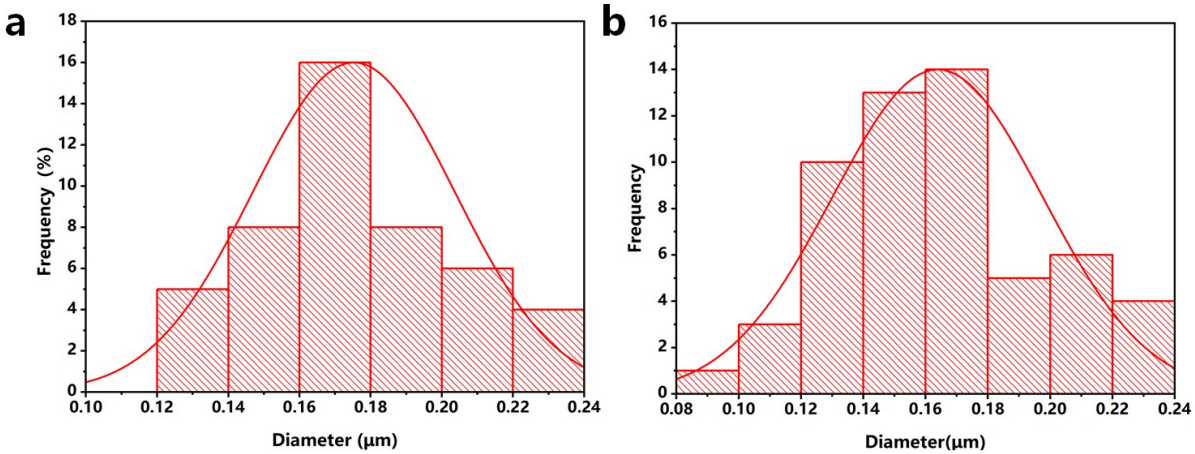

Figure.S4 The diameter statistic of b-PCNF (a) and r-PCNF (b).

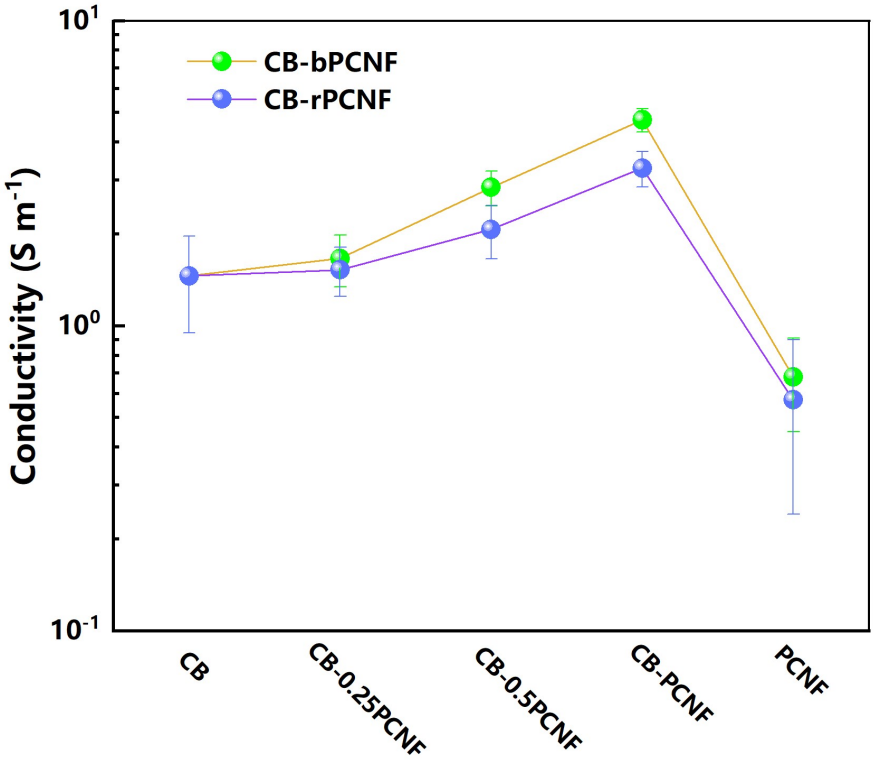

Figure.S5 The relative mass fraction of r/b-PCNF as a function of conductivity.

Table S1 Detail information of Figure S5

Type	Conductivity (S m^{-1})	Difference Value	Standard Deviation
CB	1.4575	/	0.51
CB-0.25rPCNF	1.5271	0.0696	0.28
CB-0.25bPCNF	1.6614		0.32
CB-0.5rPCNF	2.069	0.774	0.41
CB-0.5bPCNF	2.843		0.37
CB-rPCNF	3.2862	1.4488	0.44
CB-bPCNF	4.735		0.41
rPCNF	0.5714	0.1088	0.3
bPCNF	0.6802		0.23

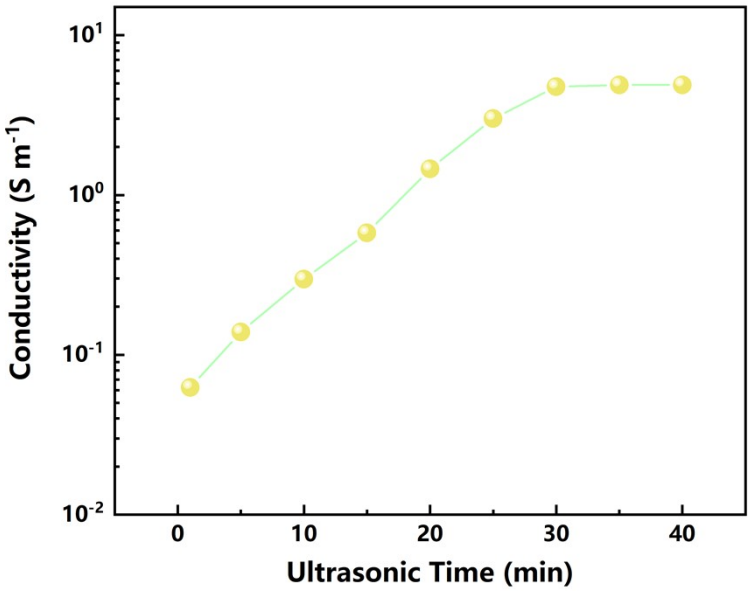

Figure S6 The conductivity as the function of ultrasonic time for the TPU-CB/bPCNF (mass fraction ratio of CB 2mg/ml-bPCNF 2mg/ml, test length 1cm)

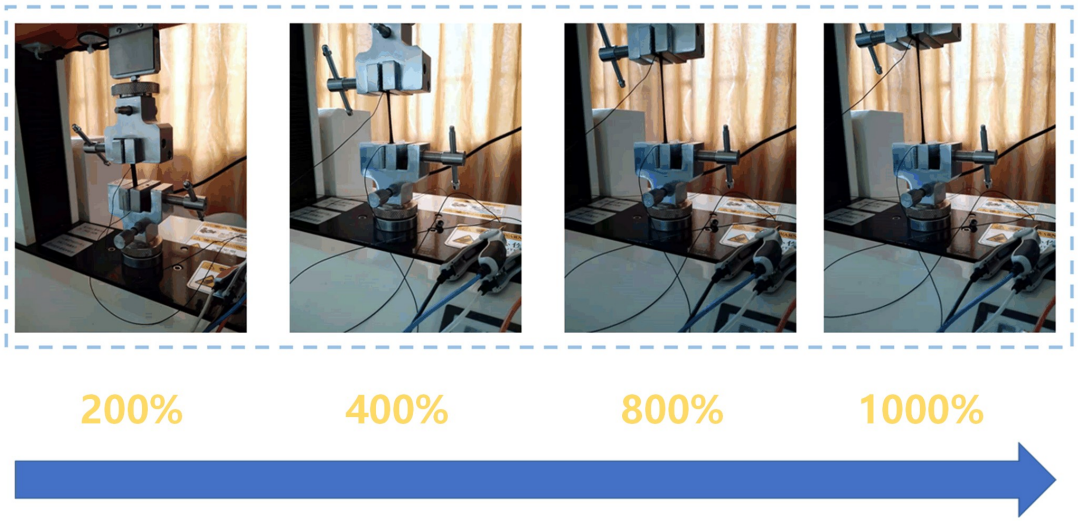

Figure S7 The digital image of TPU-CB/bPCNF stretching process.

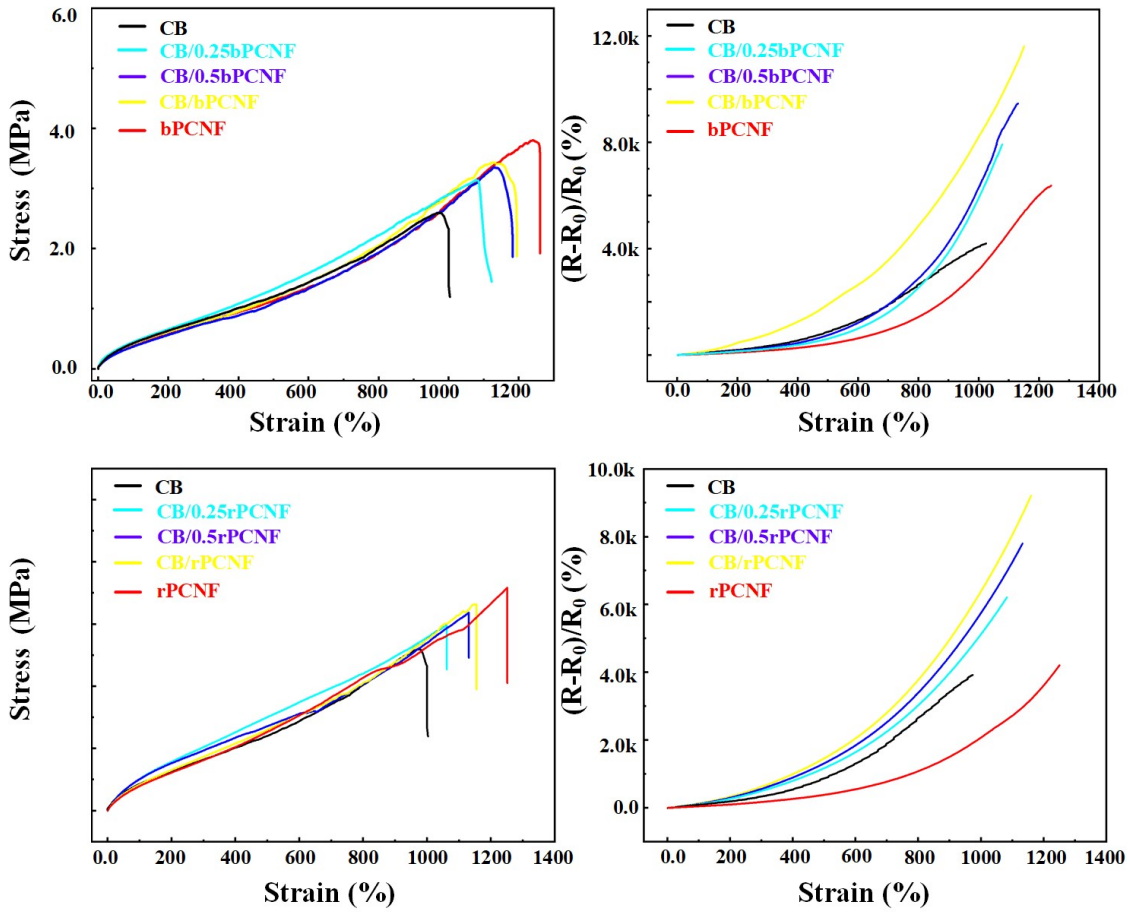

Figure S8 The comparison of elongation vs tensile stress and sensing performance of nine samples.

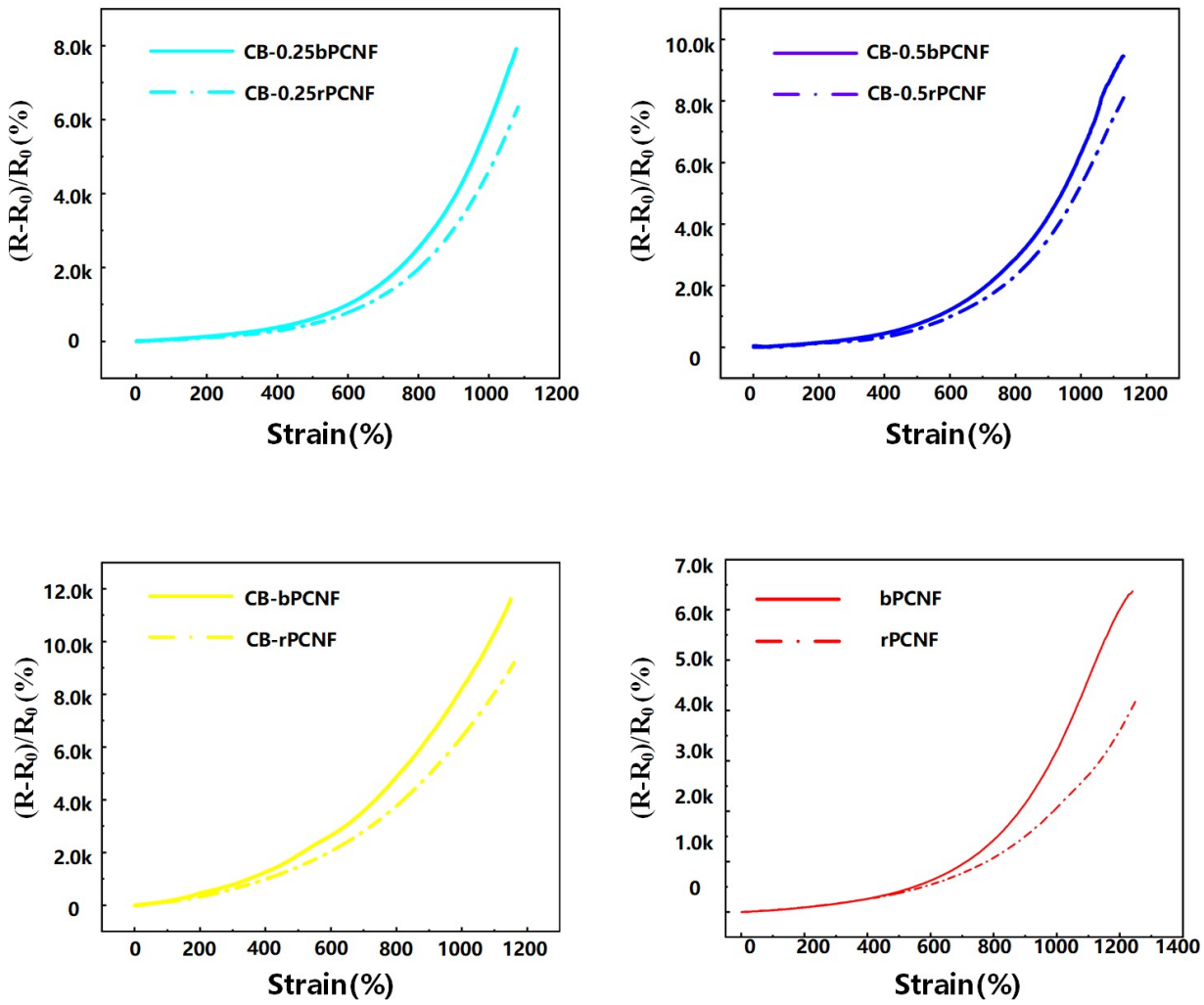

Figure S9 Detail comparison of sensing performance of nine samples.

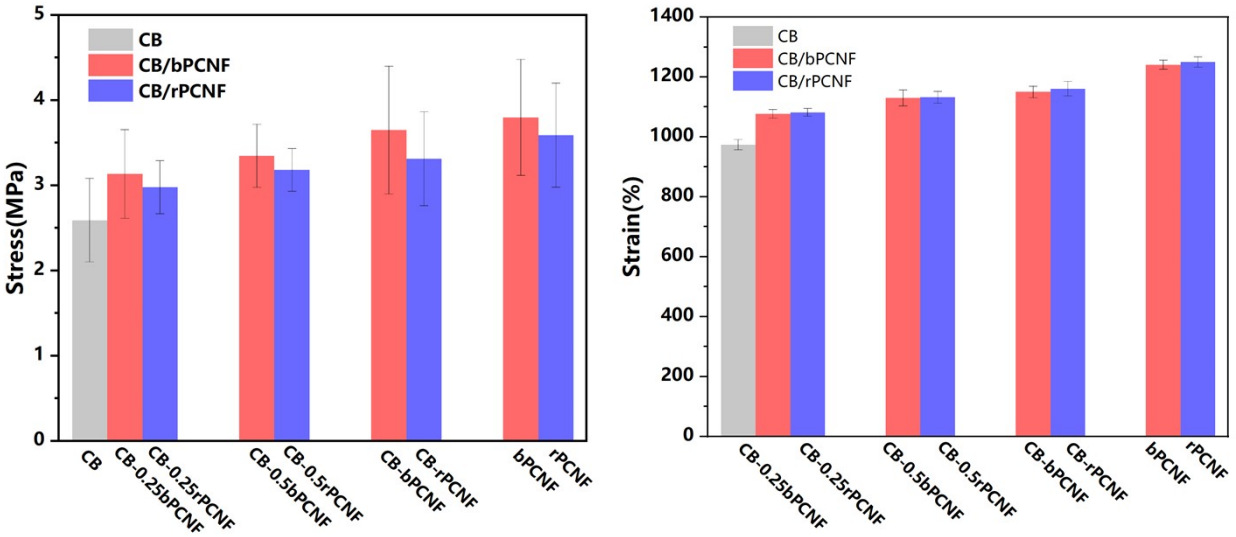

Figure S10 The comparison of maximum elongation and tensile stress of nine samples.

Table S2 Detail data for **Figure S10**

Type	Max Strain (%)	Standard Deviation	Max Stress (MPa)	Standard Deviation
CB	937.93	17.29	2.592	0.49
CB-0.25bPCNF	1077.36	14.32	3.135	0.52
CB-0.25rPCNF	1082	12.97	2.98	0.31
CB-0.5bPCNF	1130	26.37	3.348	0.37
CB-0.5rPCNF	1132	19.63	3.183	0.25
CB-bPCNF	1150	19.11	3.65	0.75
CB-rPCNF	1161	24.32	3.314	0.55
bPCNF	1241	15.35	3.8	0.68
rPCNF	1250	17.54	3.589	0.61

Table.S3 The comparison between sensing range of reported work and our work

Materials	Min Sensing range(%)	Max Sensing Range(%)	Gauge Factor	Ref.
Cotton fabric/Graphene	0.4%	75%	2.01-2.49	31
TPU/Ecoflex/Carbon Black	0.5%	225%	3186.4	16
PDMS/Carbon Nanotube/Graphene	0.5%	550%	45.6-186.5	17
TPU/MWCNT/Graphene/ Ag/SR	0.5%	650%	1.2-16.5	32
TPU/Carbon Nanotube	0.05%	600%	Not Given	33
TPU/MXene	0.05%	270%	1000	34
PDMS/Au/SWCNT	0.1%	100%	$3.4x10^6$	4
PU/CNF	Not Given	300%	72	27
PDMS/Aligned CNF	Not Given	Over 30%	180(parallel) 0.3 (vertical)	28
TPU-CNF(Graphene-reinforced)	0.1%	38%(parallel) 60% (vertical)	10.5 (parallel) <2 (vertical)	29
TPU-CB/PCNF	0.1%	1000%	18.92	This Work