Supplementary data

Facile and fast preparation of tung oil-based bendable transparent electrode with mechanically strong and environmentally stable via infiltration of silver nanowires into oxygen-inhibited surface layers

Fei Song[a,b#], Xiuxiu Zou[d#], Liang Yuan[c], Ye Sha[a], Qi Zhao[b], Meng Zhang[a,b], Lihong Hu[b], Xinbao Zhu[a*], Puyou Jia[b*], Yonghong Zhou[a,b]*

[a]*Jiangsu Co-Innovation Center of Efficient Processing and Utilization of Forest, Resources, College of Chemical Engineering, Nanjing Forestry University, Nanjing 210037, China.*

[b]*Institute of Chemical Industry of Forest Products, Chinese Academy of Forestry (CAF); Key Lab. of Biomass Energy and Material, Jiangsu Province; Nanjing 210042, People's Republic of China.*

[c]*Biomass Molecular Engineering Center, Anhui Agricultural University, Hefei 230036, Anhui, People's Republic of China.*

[d] *College of Forestry, Jiangxi Agricultural University, East China Woody Fragrance and Flavor Engineering Research Center of National Forestry and Grassland Administration; Camphor Engineering Research Center of National Forestry and Grassland Administration/Jiangxi Province, Nanchang 330045, People's Republic of China.*

([#] These authors contributed equally to this work. [*]Corresponding author: Puyou Jia (jiapuyou@icifp.cn), Meng Zhang (zhangmeng82@163.com), Xinbao Zhu (zhuxinbao@njfu.com.cn).

Mechanical and reprocessing property test

We carried out tensile stress–strain experiments at a stretching rate of 10 mm/min[1] using a CMT4000 Universal Testing Machine (according to ISO 527-2:1993). Each named sample was tested at least three times. For the reprocessing property tests, the PAMET0, and PAMET1.25 were crushed it into powder with a crusher and then pressed in a hot-pressing machine. Then, the PAMET0, and PAMET1.25 were hot pressed at 200°C with a constant pressure of 0.2 MPa for 1 h and 0.5 h, respectively. The remolded samples were then tested following the same procedure to study the mechanical properties of reprocessing.

Optical-electrical performances testes

Optical transmission of AgNWs/PAMET1.25 was carried out by a UV spectrophotometer (UV-8000, Shanghai Yuanxi Instrument Co., Ltd.) at a wavelength range of 400-800 nm. Sheet resistance of AgNWs/PAMET1.25 was estimated by M-6 four-point probe resistance tester (Hefei Crystalgen Materials Co. Ltd., Anhui, China) with a probe radius of 40 μm and a tungsten probe gap of 2 mm, and measuring five times for each sample to obtain the average value. In addition, voltage-current characteristics was measured using an adjustable DC power supply (UTP1310, UNI-T Co., China).

Characterization.

Fourier-transform infrared spectroscopy (FT-IR) was carried out on a Nicolet iS10 IR spectrometer (Nicolet Co., USA) over a range of 4000–500 cm^{-1} and with 32 scans at a resolution of 4 cm^{-1}. ^{1}H NMR spectra were confirmed by a Bruker ARX 300 nuclear magnetic resonance spectrometer with $CDCl_3$ as the solvent and tetramethylsilane as the internal standard. Dynamic mechanical analysis (DMA) was performed on a DMA Q800 instrument (TA Instruments, US) equipped at a heating rate of 3 °C/min from -50 to 200 °C with 1 Hz oscillatory frequency. DMA was then used to confirm the cross-linked nature of all materials. The cross-link density (ν) was calculated from the rubbery modulus using eq 1[54]

$$\nu = \frac{E}{3RT} \quad (1)$$

Where E is the storage modulus in the rubbery plateau region (T_g + 40 °C), R is the gas constant (8.314 J mol^{-1} K^{-1}), and T is the absolute temperature (in K).

The stress relaxation curves in "stress relaxation" mode with a constant strain of 5% using DMA Q800 instrument. Thermogravimetric analysis (TGA) was performed using a NETZSCH TG 209F1 (Netzsch Instrument Corp., Germany) at a heating rate of 20 °C/min from 35 to 800 °C under N_2 atmosphere. SU8100 scanning electron microscopy (SEM, FEI, USA) was used to observe the surface morphology of AgNWs/PAMET1.25 at 15.0 kV. Shimadzu SPM-9600 atomic force microscope (AFM) was used to determine the surface morphology and roughness of each sample. All measurements were performed in tapping mode under atmospheric conditions, and the AFM height and phase images were collected simultaneously.

Calculations of PAMET0 for activation energy (Ea)[2]

Equation obtained from Arrhenius law: y = 15.58447x –25.5302 (R^2 = 0.97799)

Which corresponds to: ln(τ) = 15.58447 × 1000/T –25.5302

Identifying this to the experimental equation: Ea/R = 15.58447 × 1000

Ea = 15.58447 × 1000 × 8.314 = 129.56 kJ mol^{-1}

Calculations of PAMET1.25 for activation energy (Ea)[2]

Equation obtained from Arrhenius law: y = 13.00793x –20.95941 (R^2 = 0.998949)

Which corresponds to: ln(τ) = 13.00793 × 1000/T –20.95941

Identifying this to the experimental equation: Ea/R = 13.00793 × 1000

Ea = 13.00793 × 1000 × 8.314 = 108.15 kJ mol^{-1}

Linear correlation equation of voltage-current

PAMET0： y = 0.3002x – 2.41994 (R^2 = 0.99154)

PAMET1.25： y = 0.08946x – 0.26507 (R^2 = 0.998949)

Linear correlation equation of voltage-current for ultrasonication treatment

0 h： y = 0.3002x + 2.41994 (R^2 = 0.99154)

0.5 h：$y = 0.21915x + 1.12462$ ($R^2 = 0.99855$)

2.5 h：$y=0.18415x + 0.37805$ ($R^2 = 0.99951$)

6.5 h：$y = 0.20113x + 1.04977$ ($R^2 = 0.992754$)

14.5 h：$y=0.26252x + 1.59931$($R^2=0.99879$)

26.5 h：$y=0.26252x + 1.59931$($R^2=0.99879$)

Linear correlation equation of voltage-current for repeated adhesion tests

0 times：$y=0.26252x + 1.59931$($R^2=0.99637$)

500 times：$y=0.29388x + 1.40408$($R^2=0.98776$)

1000 times：$y=0.31144x + 1.27981$($R^2=0.99489$)

Linear correlation equation of surface temperature-U^2

$y=0.33937x + 43.68087$($R^2=0.99802$)

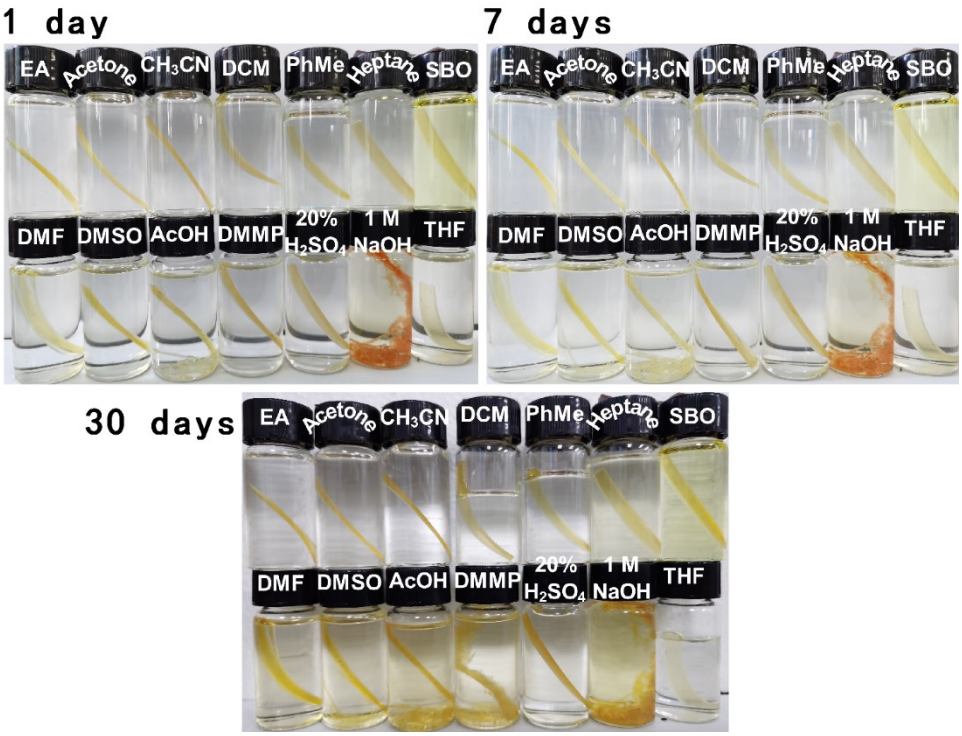

Fig. S1 The dissolution experiments for PAMETs in ethanol (EA), acetone, CH3CN, dichloromethane (DCM), toluene (PhMe), heptane, soybean oil (SBO), dimethylformamide (DMF), dimethyl sulfoxide (DMSO), acetic acid (AcOH), dimethyl methanephosphonate (DMMP), 20% H_2SO4 solution, 1 M NaOH solution and tetrahydrofuran (THF).

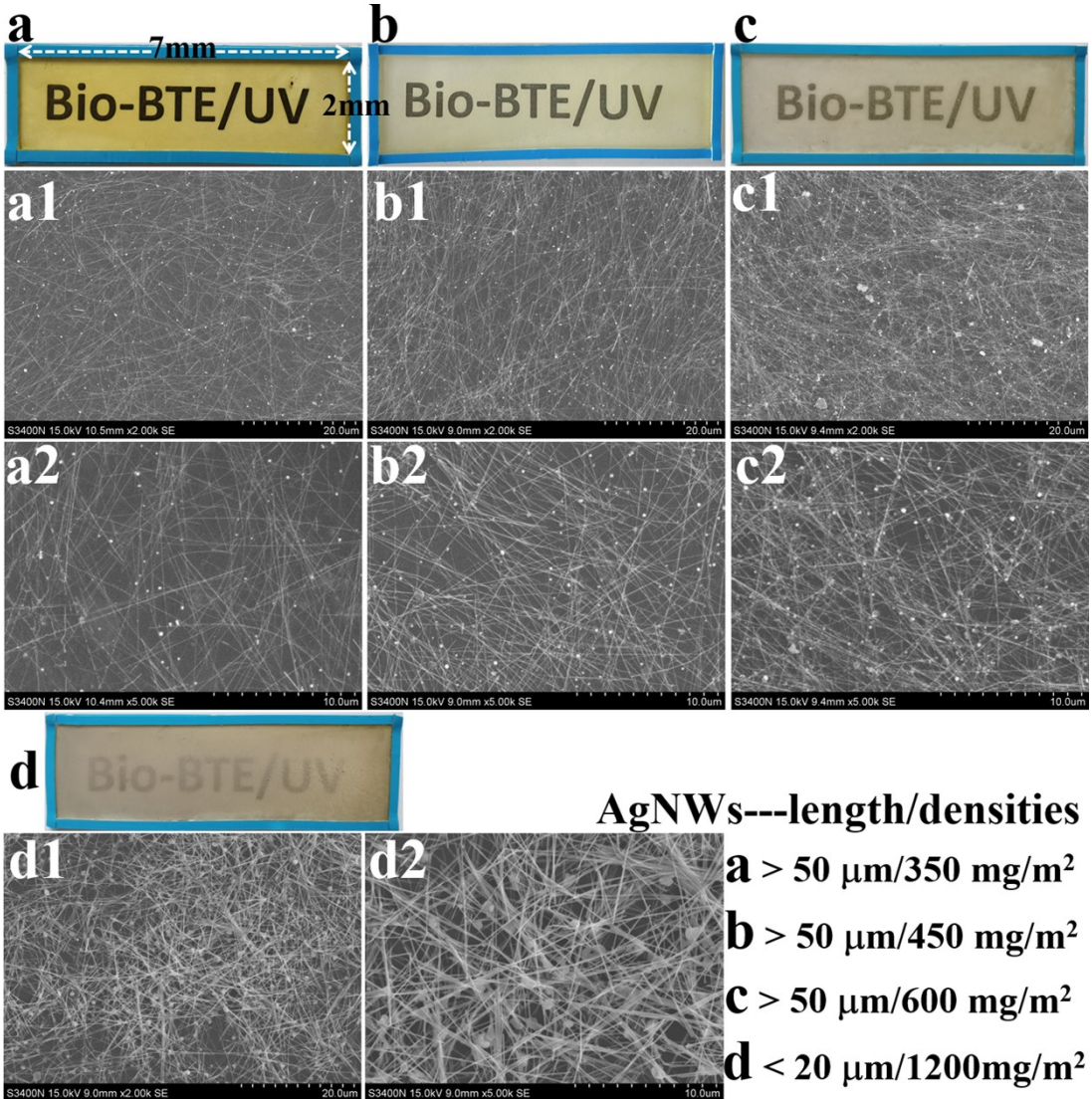

Fig. S2 Photographs and SEM images of the fabricated AgNWs/PAMET1.25 with different AgNWs area densities.

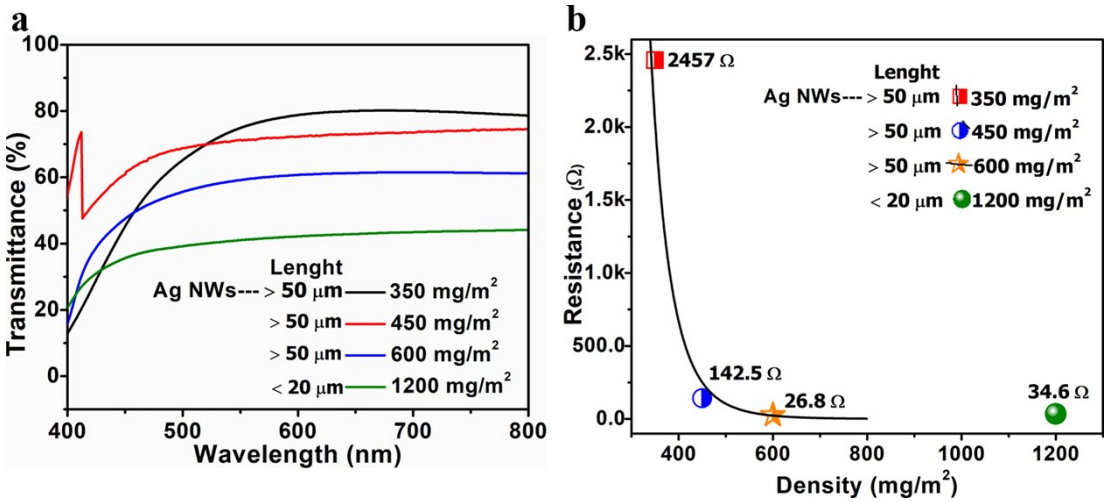

Fig. S3 Transmittance spectra (a) and Resistance (b) of AgNWs/PAMET1.25 with different AgNWs area densities.

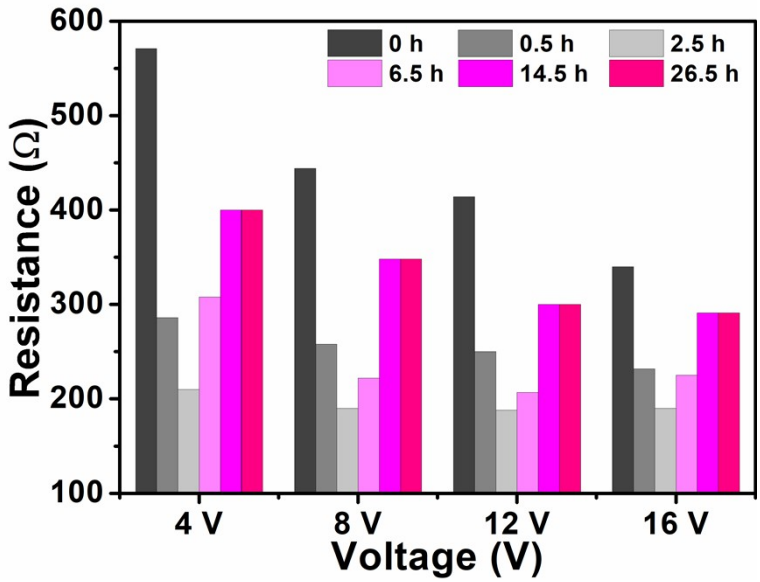

Fig. S4 Resistance of AgNWs/PAMET1.25 after ultrasonic vibration tests measured.

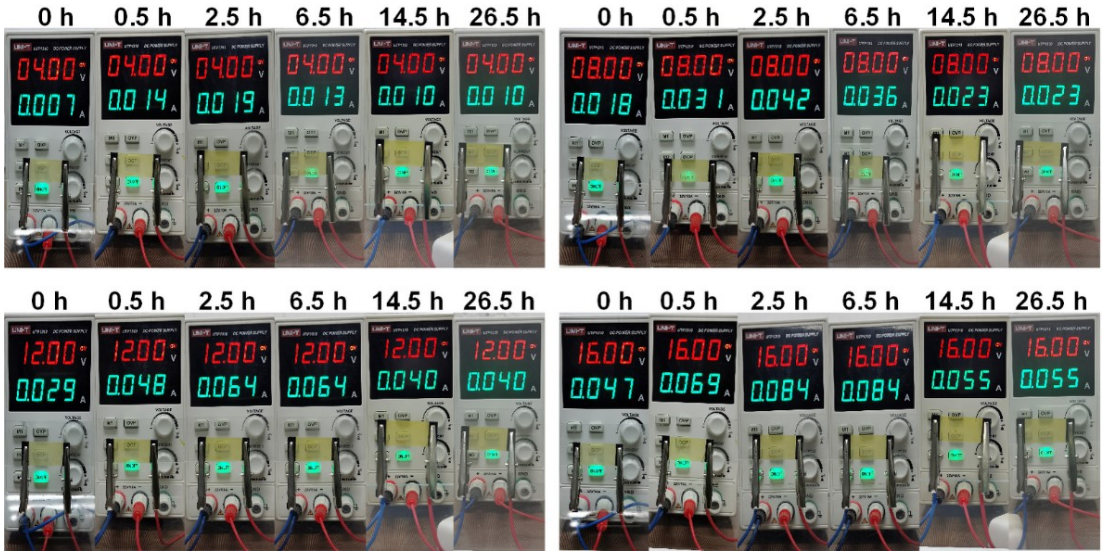

Fig. S5 Optical images of AgNWs/PAMET1.25 after ultrasonic vibration tests measured.

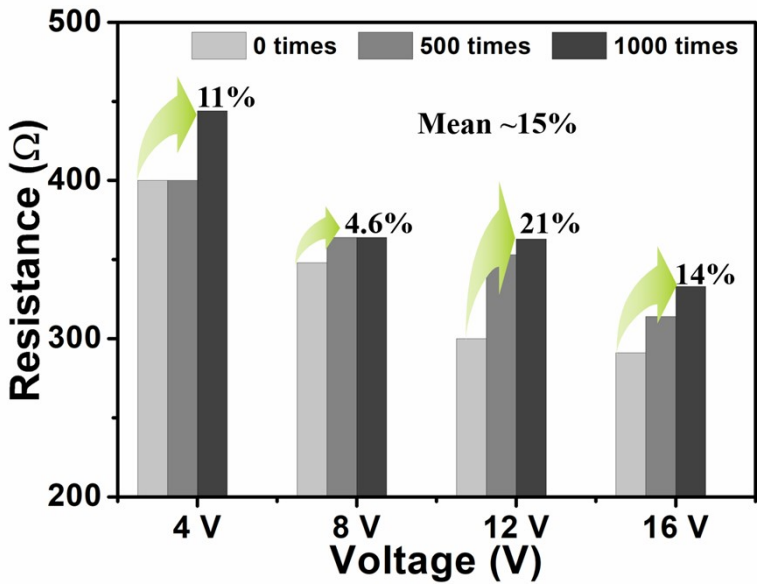

Fig. S6 Resistance of AgNWs/PAMET1.25 after adhesion tests measured.

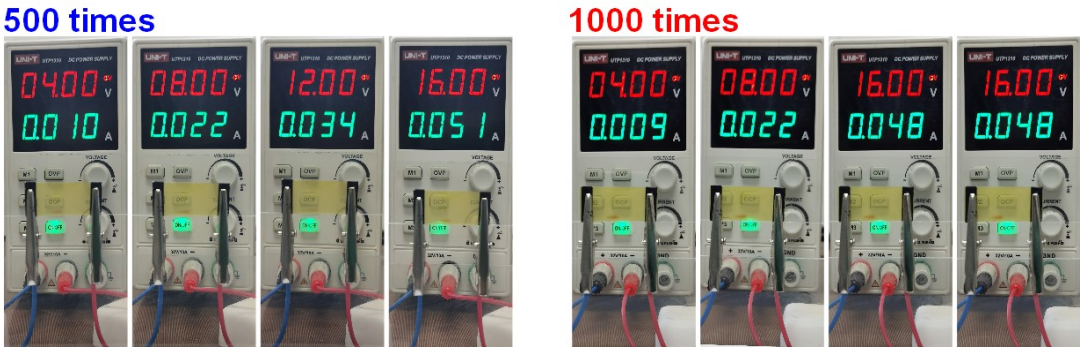

Fig. S7 Optical images of AgNWs/PAMET1.25 after adhesion tests measured.

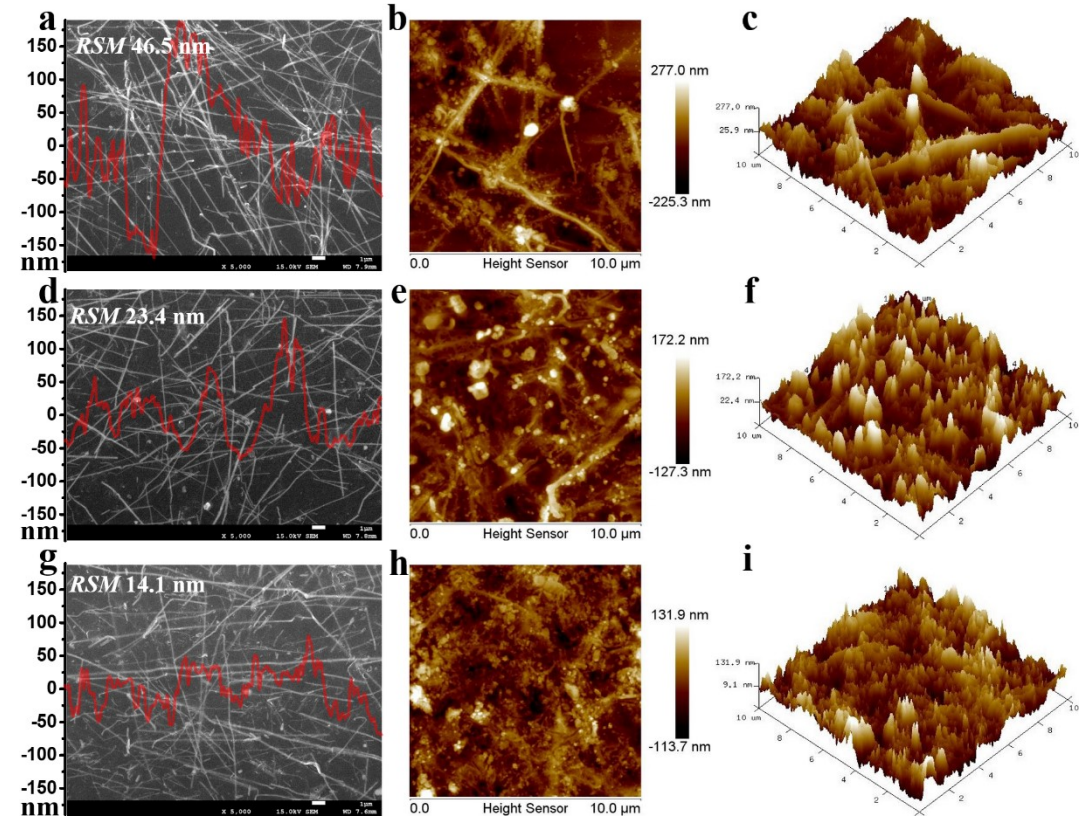

Fig. S8 SEM and AFM height images (a, g and g), AFM section profiles (b, e and h) and corresponding 3D (c, f and i) images of PAMET1.25-Ags after ultrasonication treatment (a, b and c), repeated adhesion tests (d, e and f) and wipe test (g, h and i).

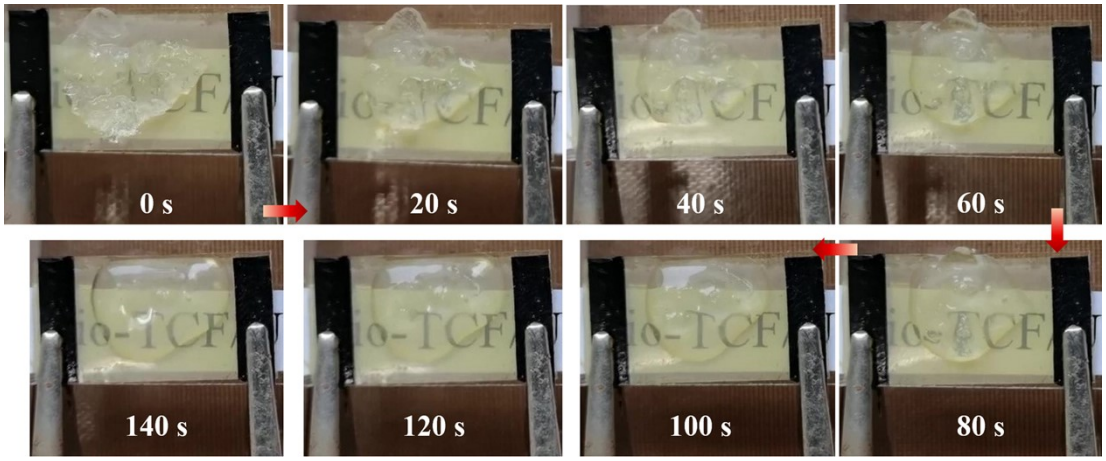

Fig. S9 Optical images of AgNWs/PAMET1.25 deicing under applied voltage of 4 V for 140 s.

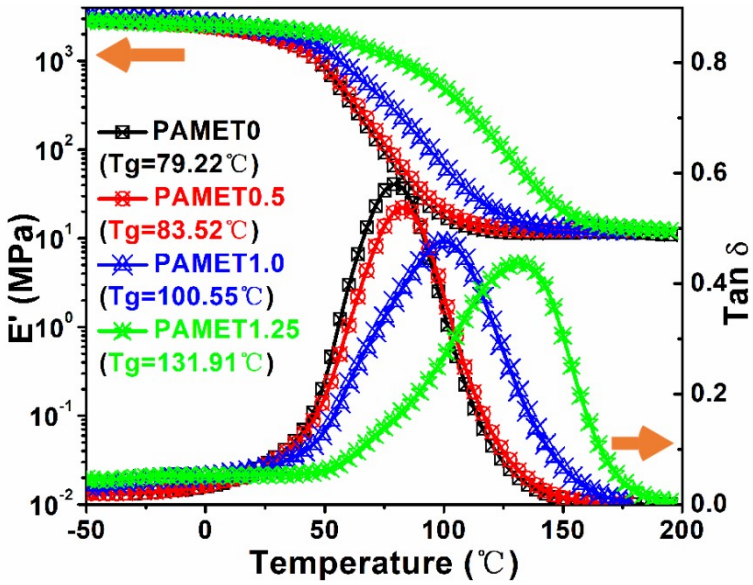

Fig. S10 Temperature sweep dynamic mechanical analysis result of PAMETs.

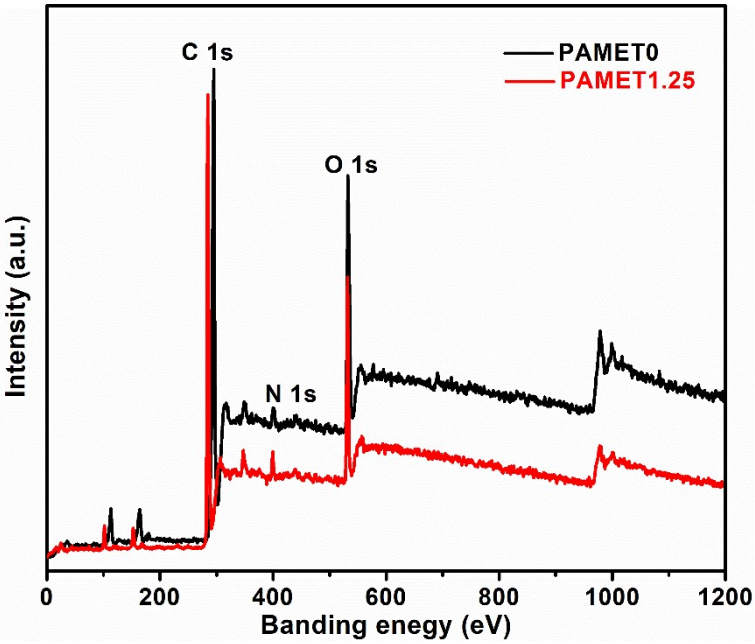

Fig. S11. XPS survey spectra of PAMET0 and PAMET1.25

Table S1. Comparison of the ΔR/R0 values after wiping, ultrasonicating and tests among the AgNWs/PAMET1.25 and other reported BETs.

Sample	Type	Time	$\Delta R/R_0$ (%)
This work	Wiping test	500	56
	Ultrasonicating test	26.5 h	-15
	Adhesion test	1000	5
AgNWs[*Ref.2*]	Adhesion test	4	3700
AgNWs/PEDOT[*Ref.2*]		100	880
AgNWs/PEDOT:PEG[*Ref.2*]		100	2.8
Ag/PET[*Ref.7*]	Wiping test	120	9
	Ultrasonicating test	0.03 h	6
	Adhesion test	80	2
Raygloss®/AgNWs[*Ref.15*]	Wiping test	100	20
	Adhesion test	60	4
Epoxy-embedded AgNWs[*Ref.20*]	Wiping test	1000	27
	Adhesion test	1000	3
Al/F-SnO_2[*Ref.23*]	Wiping test	30	1400
	Adhesion test	1000	8
AgNWs/PMMA[*Ref.29*]	Wiping test	30	61
	Ultrasonicating test	0.14 h	1
	Adhesion test	1	10900
AgNWs/PET[*Ref.36*]	Wiping test	10	51
	Wiping test	30	3

Supplementary Movie S1. The wipe test process.