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Supplementary Materials

Conductive Thermoplastic Polyurethane Nanocomposite Foams Derived from Cellulose/MWCNTs Aerogel Framework: Simultaneous Enhancement of Piezoresistance, Strength, and Endurance

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1. Density test

For the prepared cylindrical aerogel sample, the diameter d and the height h were measured respectively, then the mass m of the sample was measured using an electronic analytical balance, while the density ρ was calculated by the formula 1.

$$\rho = \frac{4\mathrm{m}}{\pi \mathrm{d}^2 \mathrm{h}} \quad (1)$$

2. Compression performance test

The C_5T_{10}/TPU foam was cut into a cube-shaped sample with a width and height of about 5 mm. The cycle compression test was performed at a 3 mm/min speed using a high-low temperature double-column tester (Instron 5996) with the maximum compression set of 10%, 30%, and 50%, respectively. Meanwhile, the stress-strain curve was recorded, and the energy loss coefficient at different strains was calculated. During compression testing (compare Figure 6), the dissipated energy ΔU was determined by the area enclosed by the loading and the unloading curves. The total energy U and the elastic energy were calculated as the areas underneath the loading and unloading curves. Then, the loss coefficient Ψ was calculated using equation 2 [1,2].

$$\Psi = \Delta U / U \tag{2}$$

3. Piezoresistive performance test

The copper wire was adhered to the upper and lower ends of the cylindrical composite foam material with a conductive adhesive and was connected to an insulation resistance tester (TH2683) to form a real-time resistance test system. The insulation resistance tester was connected to the computer end, and the computer software recorded the resistance measurement value. After stabilizing the resistance value, the foaming material was subjected to a compression test using a high and low-temperature double-column test machine. The impact of different compression strains (0%, 10%, 30%, 50%), compression rates (1.0 mm/min, 2.0 mm/min, 3.0 mm/min), number of cycles (1, 5, 100 times), etc., was investigated. The relationship between the change of the resistance value of the material and the compressive strain was analyzed. Besides, the properties of materials such as force sensing limits, sensitivity, and sensing range were explored.

A strain gauge factor (GF) was introduced to express the sensitivity of the electrical sensing performance by the material. The calculation formula was presented in Equation 3 [3,4].

$$GF = \left(\left(R_0 - R \right) / R_0 \right) / \varepsilon \tag{3}$$

Where R represents the resistance value of the conductive TPU/cellulose/MWCNTs foam composite under compressive strain ε, and R_0 represents the initial state resistance value.

The IU performance of the TPU/cellulose/MWCNTs foaming composite was measured. The copper wire adhered to the upper and lower ends of the cylindrical composite foam material and connected to the electrochemical workstation. The electrochemical workstation experimental mode was set to multipotential timing current method, the voltage range of -1 V to +1 V and the scan rate of 0.1 V/s, as well as the ohmic performance at 0%, 10%, 30%, and 50% of the deformation variables, were measured, respectively.

4. **The dimension of aerogels and composite materials**

Table S1. The dimension of aerogels

MWCNTs weight percentage (wt%)	0	1	3	5	8	10
height/cm	0.7	2	1.2	2.2	2.2	1.6
diameter/cm	2.4	1	2	0.8	1	2

Table S2. The dimension of composite materials

MWCNTs weight percentage (wt%)	0	1	3	5	8	10
length/cm	0.7	0.7	0.8	1.8	1.8	0.7
width/cm	1	1.2	1.4	0.7	0.8	1.3
height/cm	1.6	0.9	1.2	0.8	0.7	1

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