Electronic Supplementary Information

Safer cable based on advanced materials with self-healing technique: Can be directly powered off and restored easily at any time

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Methods

Preparation of difunctionalized PEGs (DF-PEG)

3.26 g Polyethylene glycol (Mw=2000), 0.98 g 4-formylbenzoic, and 0.05 g dimethylamino pyridine (DMAP) were dissolved in 100 ml of Tetrahydrofuran (THF) under nitrogen protection. 1.68 g dicyclohexyl carbodiimide (DCC) was added at 20℃ and stirring continued for 18 h. After filtering, the white solid was obtained, and then the product was dissolved in THF and precipitated by ether three times. The final product was treated by vacuum drying for 12 h.

Preparation of polypyrrole-Chitosan hybrid solution

Different amounts of chitosan (CS) (3%, 4%, 5%, 6%, 7% and 8%) solutions were obtained by dissolving CS powder (Mw=600,000) in 2% aqueous acetic acid solution. Then different amounts of pyrrole (Py) monomer (12.5, 25, 50 and 75 μL) were added in 20 g of chitosan solution, while ferric chloride hexahydrate ($FeCl_3 \cdot 6H_2O$) was added as oxidizing agent. The in situ polymerization reaction was stirring continued in ice bath for 12 h. Finally, the polypyrrole-chitosan (PPy-CS) hybrid solution was obtained.

Preparation of self-healing conductive hydrogel

0.5 g of DF-PEG was dissolved in 2 mL of water solution, and then 0.7 g PPy-CS hybrid solution was added in the above DF-PEG solution, and mixed by the vortex oscillator for 10 s. The self-healing conductive hydrogel (SHCH) was obtained.

Characterization of self-healing conductive hydrogel

Proton nuclear magnetic resonance spectroscopy (^{1}H-NMR) experiments were performed by using a Bruker Avance 300 MHz spectrometers (Bruker, Germany). Fourier transform infrared (FT-IR) spectra were recorded using a Cary 5000 Fourier transform infrared spectrophotometer (VARIAN, USA). The morphology of dried hydrogel was characterized using scanning electron microscopy (SEM, JEOL JSM-6300, Japan).

The gelation times were recorded via the vial tilting method. Until no flow could be observed for 1 min after the vial being inverted, the solutions were regarded as being in the gel state.

At the same time, the storage modulus (G') and loss modulus (G'') were recorded to prove the self-healing property. The rheological experiments was performed using a Rheometer with a parallel plate (plate diameter = 25 mm, gap = 0.5 mm) in oscillatory mode at 37℃ with a frequency of 1 Hz and a strain of 1% at 37℃. Firstly, the DF-PEG solution was first added to the bottom plate. Then the PPy-CS hybrid solution was added with mild mixing. Next, the upper plate was lowered down to a measurement gap distance of 1 mm, and moderate silicon oil was carefully applied around the hydrogel to prevent dehydration.

For the self-healing test, the hydrogel was cut into two pieces, and at different time intervals, photographs were taken to record the appearance of the united hydrogel with an Olympus E-620 camera (Olympus Ltd, Japan).

The conductivity of the hydrogel was calculated by the results from the measurement of sheet resistance (Rs) and thickness (t) defined by the following equation: σ ¼ 1 Rst (1) The sheet resistance was measured using a four-point probe with a linear probe head (1.0 gap mm, JANDEL HM21, UK).

Video S1. Safer cable based on advanced materials with self-healing technique: Can be directly powered off and restored easily at any time.