Novel Flexible Belt-shaped Coaxial Microcables with Tunable Multicolor Luminescence, Electrical Conduction and Magnetism

Hong Shao, Qianli Ma, Xiangting Dong*, Wensheng Yu, Ming Yang, Ying Yang, Jinxian Wang, Guixia Liu

Supplementary Information

Structure of specially designed coaxial spinneret

We designed a specially designed coaxial spinneret in this study. The inner stainless-steel needle was connected to the inner plastic syringe just like the traditional one. The outer stainless-steel needle was replaced by a plastic nozzle, and connected to the outer plastic syringe. The tip of the inner stainless-steel needle was shortened 2 cm from the tip of the outer plastic nozzle. This structure of the specially designed coaxial spinneret has the advantage of making sure that the highly viscous spinning solution for fabricating microcables flows easily, and the tapering shape of the plastic nozzle does not make the tip of the specially designed coaxial spinneret too thick relative to the Taylor cone. The sharper tip has another advantage in that it increases the charge density of the Taylor cone (point discharge phenomenon) so that the applied voltage does not need to be very high. Besides, the surface tension between the spinning solution and plastic nozzle is not strong enough to make the spinning solution spread up the plastic nozzle, so the electric-field force has not to overcome this surface tension, which further decreases the required voltage. As illustrated in the following Figure S1, two kinds of spinning solution have formed a coaxial structure. This illustrates how the structure of the final products reflects the structure of the spinning solutions in the lower part of the spinner and the Taylor cone.



Figure S1 Photograph (left) and schematic diagram (right) of the specially designed coaxial spinneret.

Infrared spectra analysis

Figure S2 shows the FTIR spectra of PMMA, PANI/PMMA, camphor sulfonic acid (CSA) doped PANI/PMMA, CSA doped PANI/PMMA/Fe₃O₄. The FTIR spectrum in Figure S2a is characterized by two intense peaks relative to stretching carbonyl group vibration (C=O) at 1730 cm⁻¹ and stretching ester group vibration (C-O) at 1149 cm⁻¹. In the range of 3000-2854 cm⁻¹, the (C-H) groups exhibit stretching modes, whereas in the range of 1485-1387 cm⁻¹, the (C-H) groups exhibit deformation mode. The weak peak at 1060 cm⁻¹ is due to the (OCH₃) rocking mode. The broad peak ranging from 1260 to 1000 cm⁻¹ is attributed to the stretching vibration of the (C-O) ester bond. The peaks at 989 and 966 cm⁻¹ correspond respectively to (O-CH₃) symmetric stretching and CH₃ rocking, which is the typical mode of PMMA¹. The FTIR spectrum of PANI/PMMA is presented in Figure S2b. The peaks at 1593 and 1500 cm⁻¹ correspond to the stretching of N=quinoid ring=N ring and stretching of N-benzene ring-N ring respectively. The peak at 1308 cm⁻¹ is assigned to the C-N stretching band. The absorption band at 1240 cm⁻¹ corresponds to the protonated groups C-N⁺ vibrations. The peaks at 1167, 1146, 1115 and 832 cm⁻¹ are assigned to the C-H bending band. The absorption band at 711 cm⁻¹ is assigned to the bending vibrations of C-C on benzene ring and quinoid ring². The most prominent changes of the spectrum of CSA doped PANI/PMMA are the red shift

of peaks at 1593 and 1500 cm⁻¹ to 1568 and 1489 cm⁻¹ (Figure S2c) and the increase in absorption at 1239 cm⁻¹ corresponding to the bipolaron structure². This absorption is very weak in PANI. The spectrum of CSA doped PANI/PMMA exhibits all characteristic peaks observed in PANI/PMMA (Figure S2c), thus confirming the ability of CSA to protonate the PANI. The FTIR spectrum of CSA doped PANI/PMMA/Fe₃O₄ is shown in Figure S2d. The band at 580 cm⁻¹ corresponded to the vibration of the Fe-O bonds in the crystalline lattice of $Fe_3O_4^5$. During preparation of Fe_3O_4 nanoparticles by the chemical co-precipitation, their surfaces were readily covered with hydroxyl groups in an aqueous environment^{3, 4}. Thus, the characteristic bands of hydroxyl groups, 1630 and 3405 cm⁻¹, appeared in the FTIR spectrum. The bands at 2852 and 2922 cm⁻¹ were attributed to the asymmetric CH₂ stretch and the symmetric CH₂ stretch in oleic acid, respectively⁵. The FTIR spectra of PANI bases are similar to that of pure PMMA. The reason is that CSA, Fe₃O₄ and PANI are doped in PMMA matrix. Moreover, it is observed that there has a broad band centered at 3430 cm⁻¹ (vO-H) which is attributed to coordinated waters among. The above results indicate that CSA doped PANI has been synthesized, and Fe₃O₄ nanoparticles have been successfully added into the core.



Figure S2 FTIR spectra of PMMA (a), PANI/PMMA (b), CSA doped PANI/PMMA (c) and CSA doped PANI/PMMA/ Fe_3O_4 (d).

References

- 1. M. O. Bensaid, L. Ghalouci, S. Hiadsi, F. Lakhdari, N. Benharrats and G. Vergoten, Vib. Spectro., 2014, 74, 20.
- 2. M. Trchová, J. Stejskal and J. Prokeš, Synth. Met., 1999, 101, 840.
- R. M. Cornell and U. Schwertmann, Chapter 16. Soils in *The Iron Oxides*, Wiley-VCH Verlag GmbH & Co. KGaA, 2004, ch16, 433.
- 4. X. Q. Liu, Z. Y. Ma, J. M. Xing and H. Z. Liu, J. Magn. Magn. Mater., 2004, 270, 1.
- 5. K. Yang, H. B. Peng, Y. H. Wen and N. Li, Appl. Surf. Sci., 2010, 256, 3093.