Flexible and Highly Sensitive Humidity Sensor Based on Sandwich-Like Ag/Fe₃O₄ Nanowires Composite for Multiple Dynamic Monitoring

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Preparation of the amidoxime PP nonwoven fabrics: Before graft polymerization, the PP nonwoven fabric was extracted with boiling acetone over 12 h to remove the impurities attached on the surface. Then it was placed in tubes containing a 20:80 vol% AN:DMF solution. The solution was degassed by bubbling with nitrogen for 20 min to remove the oxygen, and the tubes were then sealed and irradiated with a 60Co γ-ray source for 17 h at room temperature. The total absorbed dose was 20 kGy. The grafted PP nonwoven fabric (coded as PP-g-PAN) was washed using DMSO and ethanol to remove the residual monomer and homopolymer, and then dried in a vacuum oven at 60 °C to a constant weight. The degree of grafting (DG) was...
determined according to Equation (1):

$$DG(\%) = \left( \frac{W_1 - W_0}{W_0} \right) \times 100\%$$ (1)

where $W_0, W_1$ are the weights of PP nonwoven fabrics before and after grafting, respectively.

In this work, the DG of PP-g-PAN was 46.4%.

The PP-g-PAN fabric was reacted with hydroxylamine hydrochloride in a DMSO/H$_2$O (v/v = 1:1) solution with pH 7.0 at 80 °C for 4 h. The molar ratio of the cyano group to hydroxylamine hydrochloride was 1:8. Subsequently, the sample was removed from the solution and repeatedly washed with distilled water to remove any residual reagent, and then dried in a vacuum oven at 60 °C. The resultant material was designated as PP-g-PAO.

**Preparation of PP-g-PAO/Fe$_3$O$_4$ composite nonwoven fabrics:** In a three-necked flask, FeCl$_3$·6H$_2$O (10.8 g) and FeSO$_4$·7H$_2$O (6.7 g) were dissolved in deionized water (200 ml), and then the PP-g-PAO (0.5 g) was added with continuous stirring for 30 min at 65 °C under N$_2$ atmosphere. A diluted ammonia solution (3.8-4.2 wt%, 100 mL) was added dropwise into the flask over 60 min and kept at 65 °C for 3 h under continuous stirring. The obtained composite was ultrasonically cleaned for 40 min to remove Fe$_3$O$_4$ nanoparticles (NPs) adsorbed on the surface of the PP-g-PAO/Fe$_3$O$_4$ via Van der Waals forces. Finally, the sample was repeatedly washed with distilled water until the pH reached 7, and then dried in a vacuum oven at 60 °C. The resultant material was designated as PP-g-PAO/Fe$_3$O$_4$.

![Figure S2. EDS mappings of Ag, Fe, C, O and N on the Ag@PP-g-PAO/Fe$_3$O$_4$ fabrics corresponding to the SEM images: (a) the outer surface and (b) the inner surface of Ag@PP-g-PAO/Fe$_3$O$_4$ based sensor.](image-url)
Figure S3. EDS spectra of (a,b) PP-g-PAO/Fe₃O₄ and (c,d) Ag@Fe₃O₄-MS.

Figure S4. The influence of Ag@Fe₃O₄-MS to pure nitrogen, and pure oxygen.
**Figure S5.** Relative current intensity for Ag@Fe3O4-MS versus relative areas. (Relative area is defined as the ratio of sample area to minimum sample area.)

**Figure S6.** Current responses of the sensor sewn into a face mask when the wearer said the words “hi” and “hello”, showing the ability to distinguish different sounds.
Supporting Information

Figure S7. Detection of the rate and strength of adult respiration for 30 min. Inset on the left: enlarged view of the breathing frequency plot. Insets on the right: the working mechanism of the Ag@Fe3O4-MS sensor for detecting respiration.

Figure S8. Ag@Fe3O4-MS sensor responses to a water droplet placed on it.

Figure S9. (a) Ag@Fe3O4-MS sensor responses to a NaCl solution (or milk) droplet placed on it, and then five NaCl solution (or milk) droplets; NaCl solution is 1 g/L. (b) Dependence of relative current of Ag@Fe3O4-MS at RH = 95%, before and after the sensor was assessed in additional NaCl solution or milk; insert of corresponding photographs. Scale: 10 mm.
Supporting Information

References

[1] M. Zhang, M. Wang, M. Zhang, A. Maimaitiming, L. Pang, Y. Liang, J. Hu, G. Wu, FeO nanowire arrays on flexible polypropylene substrates for UV and magnetic sensing, ACS Appl. Nano Mater. 1(10) (2018) 5742-5752.