DEVELOPMENT OF HUMIDITY SENSING MATERIAL USING ZnO DOPED DERIVED CHARCOAL FROM THE WASTE PVC

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INTRODUCTION

Humidity sensors are one of the most commonly used sensing devices in various fields, such as industrial and medical, etc. [1]. Therefore, the development of novel low-cost sensing materials is important to satisfy the growing sensor market. The main aim of this study is to develop low-cost sensor material from waste polymer materials and compare the sensing characteristics like resistance, hysteresis, recovery and response times, and stability with respect to relative humidity. PVC has a good tendency to form conductive charcoal via removing bonded Cl molecules.

MATERIALS AND METHOD

Conductive carbon was prepared by pyrolyzation of PVC at 600°C, and ZnO was doped under hydrothermal treatment at 140 °C. Then the sensor was prepared by depositing ZnO doped pyrolyzed carbon composite on the gold-coated resistive type electrode [2]. The prepared composite was characterized using scanning electron microscopy (SEM), X-ray diffraction spectroscopy (XRD), Thermal gravimetric analysis (TGA), and RAMAN spectroscopy. Also, humidity sensing performance was investigated.

RESULTS AND DISCUSSION

Structural and morphological investigation

The fabricated sensor was further characterized using FTIR and Raman spectroscopy. The FTIR spectra and Raman spectrum of the sensing material are shown in Fig.1 below. Fig.1(a) shows FTIR on raw PVC waste and Fig.1(b) shows ZnO doped PVC waste. Fig.1(d) shows the RAMAN spectra representing the carbonized waste PVC sample with zinc oxide and Fig.1(c) depicts natural graphite. The PVC sample shows a broad 2D peak and a lower 2D to G ratio. The preparation process has successfully developed a graphite-like structure due to the thermal process.

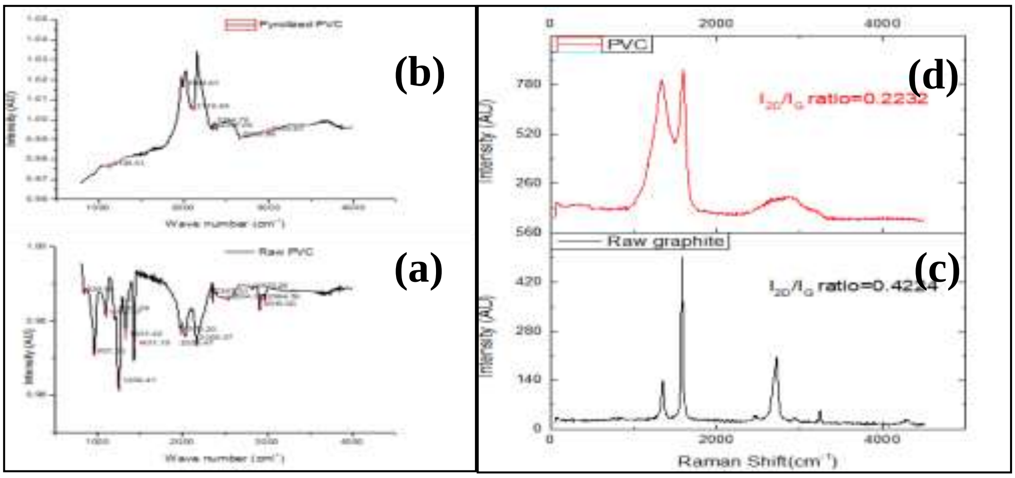

Fig. 1

Fig. 1. (a) FTIR spectra of raw PVC sample, (b) spectra of carbonized PVC sample with Zinc Hydroxide (c) Raman spectra of natural graphite, (d) Raman spectra of carbonized PVC sample with Zinc Hydroxide.

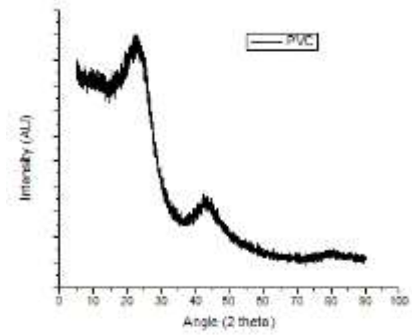

Fig.2

Figure 2 shows the XRD spectra representing the carbonized waste PVC sample

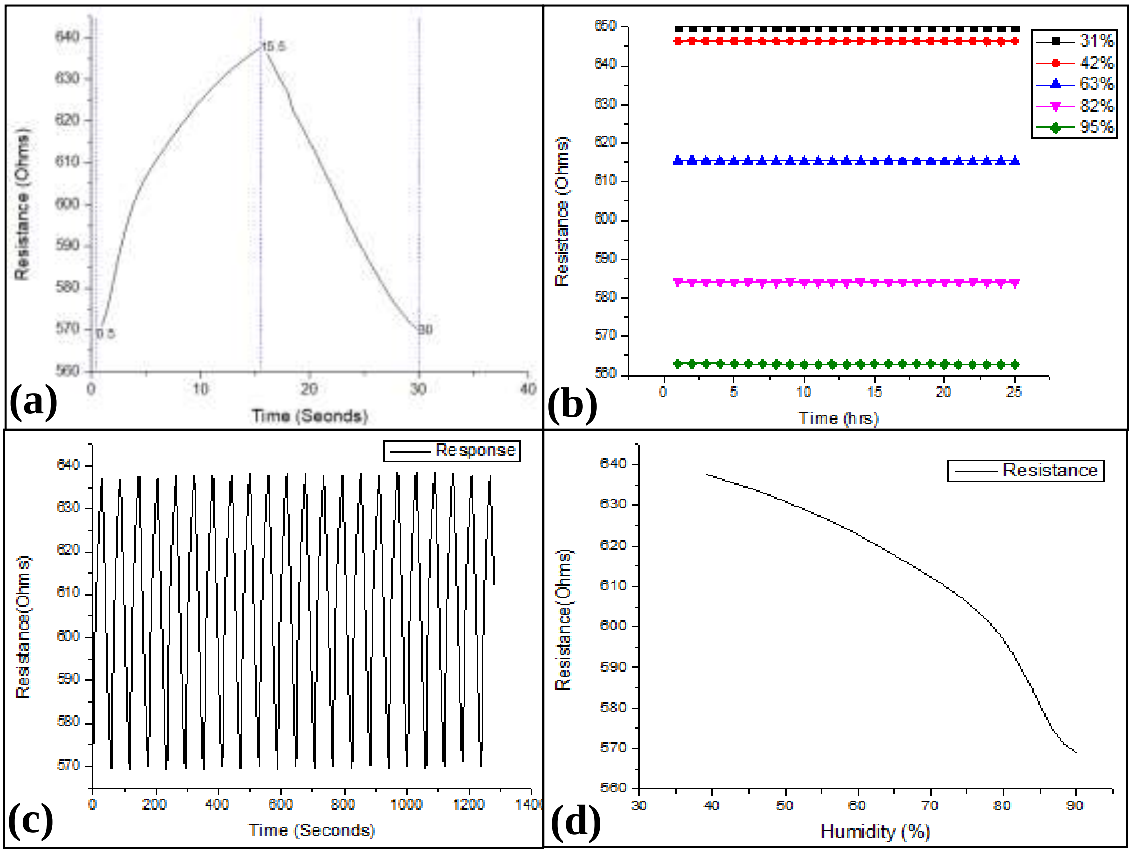

Fig.3

Fig.3(a) Response time and recovery vs relative humidity changed from 40 %RH to 94 % RH.

Fig. 3(b) Stability of sensor during a 24-hour time period, Fig. 3(c) Repeatability for sensing material through 24 hours. Fig. 3(d) Linear relationship between RH and resistance of the sensing material.

Sensing performance

The prepared sensor was tested for basic sensing properties, which are, relative response and recovery, repeatability, linearity, sensitivity, and stability at different humidity levels.

The sensor was exposed to the humidity levels for several consecutive cycles to assess the repeatability of the sensing material. Fig.3(c) shows good repeatability for sensing materials over 24 hours. The humidity levels used for testing stability were 31%, 42%, 63%, 82%, and 95% RH at room temperature. During 24 hours, the response values didn’t change significantly, which is shown in Fig.3(b). Because the relative humidity changed from 94 %RH to 40 %RH, in Fig. 3(a) the sensor showed a response time of 15 s and recovery of 14.5 s while the relative humidity changed from 40 %RH to 94 % RH.

Using equation 1 given below [3], the response of the PVC charcoal /ZnO humidity sensor was calculated and the value obtained was 10.48%.

$$\text{Response} = (R_{40\%}-R_{94\%})/R_{94\%} * 100\ \% \qquad (1)$$

$$\text{Response} = (635.3\ \text{Ohms} - 575.4\ \text{Ohms})/\ 575.4\ \text{Ohms} * 100\ \%$$

$$\text{Response} = 10.48\ \%$$

Fig. 3(d) shows the linear relationship between relative humidity and resistance of the sensing material. The sensor showed a good linear relationship between relative humidity and the resistance of the sensor.

CONCLUSION

The charcoal prepared using waste PVC and ZnO can be used effectively for preparing low-cost high-performance humidity sensors. The recovery time and response time are very low at room temperature. The study shows that waste PVC can be used for advanced electronic applications by converting to conductive carbon in controlled environments. Nanocomposite has the potential in humidity sensors as an effective way of utilizing nitrile butadiene rubber (NBR) waste as a value-added product.

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