Investigation of photoelectric properties of a photosensitive device based on ZnO/rGO composite with different optical filters

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Abstract

In this paper, a ZnO-based photosensitive device was fabricated and the nanocomposite was characterized by transmission electron microscopy and energy dispersive X-ray spectroscopy. The effect of optical filter on the photoelectric response of ZnO/rGO photosensitive device was studied. The photocurrents of the device were recorded under different filter conditions. The photocurrents of the device at different distances were also recorded. The relevant experimental phenomena have been discussed. The photosensitive device may have potential application prospects in zinc oxide based photosensors.

Keywords

Semiconductor, ZnO, Device, Sensor.

1. Introduction

Zine Oxide (ZnO) is an excellent wide bandgap(3.37 eV) semiconductor material and has a large exciton binding energy (60 meV). It is commonly considered as a promising optoelectronic material with potential application in photodetectors, light-emitting diodes and solar cells [1-7].However, the direct bandgap of ZnO leads to problems, including high recombination rates and reduced efficiency [8-9]. Due to the high recombination of photogenerated electron and hole pairs in the pure ZnO semiconductor, its practical application is greatly hindered. In recent years, many researchers have effectively optimized the properties of single zinc oxide nanomaterial by doping ion or combining with other electron materials [10-13]. Graphene, a unique two-dimensional structure consisting of sp^2 bonded carbon atoms in a hexagonal lattice, has attracted extensive interest during the past decade or so due to its superior physical properties including high charge carrier mobility, optical transparency, mechanical strength, flexibility, chemical stability, etc[14-17]. Graphene can be viewed as a large-area usable atomic thin film and is compatible with traditional thin film-based microelectronics, as established microfabrication processes can be easily applied to fabricate graphene-based electronic, photonic and optoelectronic devices and circuits.

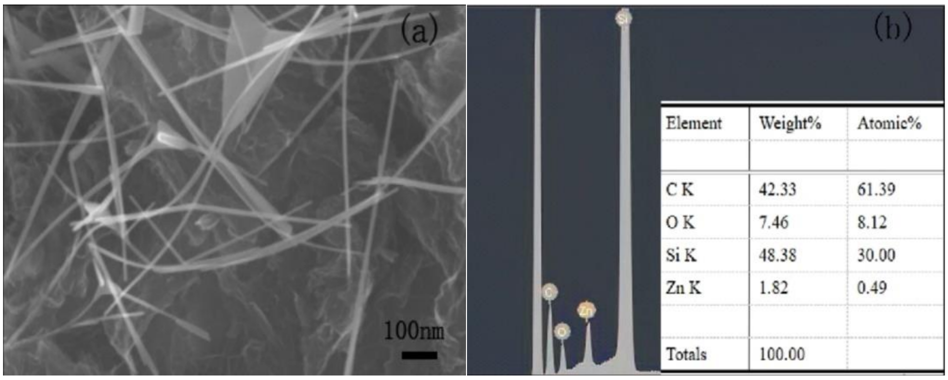
When ZnO is in contact with graphene, the work function of graphene is lower than the ZnO conduction band. Thus, the excited electrons in the ZnO conduction band move to graphene, inhibiting the carrier recombination in the ZnO semiconductor. Graphene's large surface area and high carrier mobility both contribute to its high efficiency, while graphene's transparency ensures that photons can reach ZnO and utilize as many photons as possible. Embedding ZnO on graphene can also prevent the aggregation of the two materials, thereby maintaining their high surface volume ratio and excellent efficiency. The ZnO/graphene heterostructure nanohybrids combine the physical properties of graphene and ZnO, providing a unique platform for exploring various applications such as photodetectors, gas sensors, and stress sensors.

In this work, the photosensitive structure of ZnO/rGO nanocomposite was prepared by chemical vapor deposition combined with microfabrication. The photoelectric response of the device with low bias voltage under white light source was studied. Optical filters have been applied in the photoelectric detection system. The current values of different optical filters were recorded under white light irradiation. The influence of optical filters on the light response of the photosensitive device has been discussed. At the same time, the variation of the optical response of the device as the distance between the light source and the device changes has also been analyzed.

2. Experimental

The ZnO nanomaterial was prepared by chemical vapor deposition, and the reduced graphene oxide sample was synthesized by Hummers method previously reported [18,19]. The carbon fiber was dispersed in a strong acid solution, and then processed in an ultrasonic container. The resulting suspension can be mixed with ZnO nanomaterial, and the mixed suspension was dropped on the chip electrode. The sensitive structure was formed and fabricated. The morphology of the sample was observed by scanning electron microscopy(SEM). Agilent 4156C was used to test and study the current-voltage characteristics of the device. Different filters were placed between the visible light source and the photosensitive device. The initial distance between them was 15cm and the I-V curves under different filter conditions were recorded. At the same time, the Agilent tester also recorded the I-V curves of the device as the distance changed under the condition that two layers of colorless filter were placed between the light source and the device.

3. Results and discussion



Element	Weight%	Atomic%
C K	42.33	61.39
O K	7.46	8.12
Si K	48.38	30.00
Zn K	1.82	0.49
Totals	100.00	

Fig. 1. (a) SEM image of ZnO/rGO nanocomposite (b) EDX pattern of ZnO/rGO nanocomposite

Fig. 1(a) shows the SEM image of the prepared nanocomposite. After mixing ZnO nanomaterial with reduced graphene oxide sheet, it can be seen that the nanocomposite has a good combination of graphene sheets and ZnO nanowires. Fig. 1(b) shows the energy dispersive X-ray spectra of ZnO/rGO nanocomposite. This clearly indicates that the presence of Zn and C atoms comes from ZnO and rGO, respectively. The EDX analysis also proves that no metal contamination has occurred in the device during the preparation process.

Fig. 2(a) shows the I-V curves of the device based on the ZnO/rGO nanocomposite structure at 1V. It can be seen from the curves that the photocurrent values of the device are obviously different under different filter conditions. Compared with the dark light condition, the current value of the device increases significantly when the white light source is turned on. Under the condition of colorless filter, the current value is 9.6 uA. The current value of blue filter is greater than that of purple filter, and the current value is the largest when no filter is placed. Fig. 2(b) shows the responsiveness values of the device under different conditions. This result shows that the light response value of blue filter is greater than that of purple filter, and the light response value of colorless filter is greater than that of blue or purple filter. There is a possible physical mechanism to explain the above phenomenon, colorless filters are more conducive to a wider wavelength range of light transmission than blue or purple filters, resulting in colorless filters have a greater light response than blue or purple filters. The white light source emits a beam of blue light through a blue filter, and the composition of white light contains violet light and ultraviolet light with narrow wavelengths, resulting in a smaller light response. The light response of no filter is larger than that of colorless filter because the presence of colorless filter weakens the light intensity of white light, thus affecting the responsiveness of the device. Therefore, the filter conditions can affect the performance parameters of the device, and this result may have potential significance for the application of photosensors.

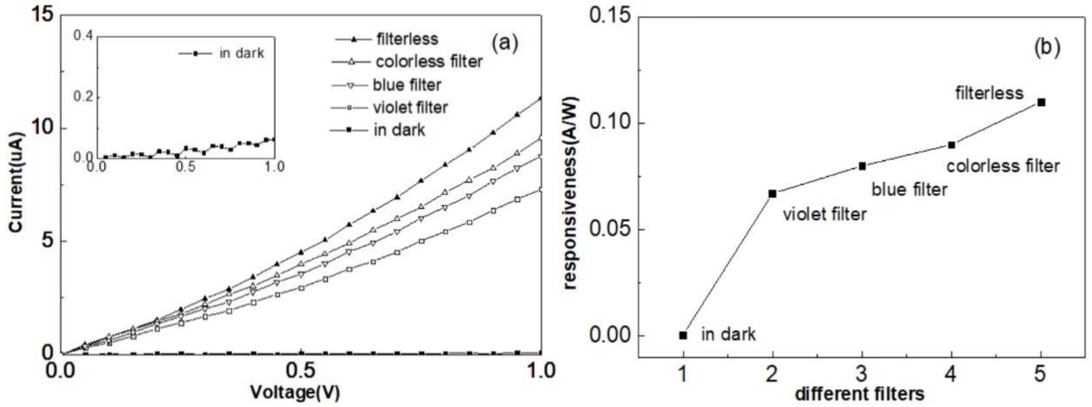


Fig. 2. (a) I-V characteristics of the device under different optical filter conditions. Higher inset: amplified I-V characteristic of the device in the dark. (b) Responsiveness of the device under different conditions.

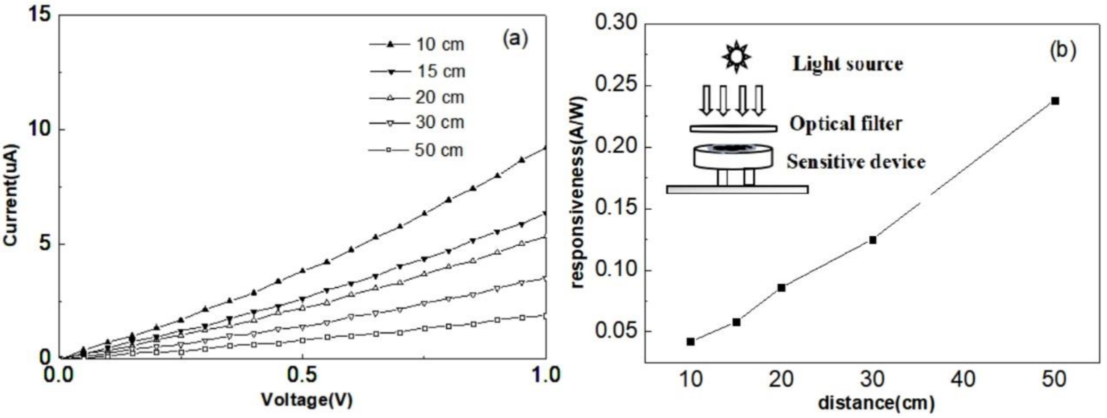


Fig. 3. (a) I-V characteristics at different distances between the light source and the device. (b) Responsiveness values of the device at different distances. Higher inset: schematic diagram for photosensitive detection set up.

Fig. 3(a) shows the I-V curves of the device at different distances between the light source and the device. It can be clearly seen that the current value of the device at 1V, the smaller the distance, the larger the current value of the device, this is because the smaller the distance, the greater the luminous flux on the unit area of the device, more electrons are transferred from the valence electrons to the conduction band of the ZnO semiconductor, the photocurrent value will be increased. Fig. 3(b) shows the responsiveness values of the device at different distances between the light source and the device. The results show that the responsiveness value of the device decreases with the decrease of the distance. At this time, although the photocurrent will increase with the decrease of the distance, the responsiveness value is also related to the light intensity irradiated on the device, and the smaller the distance, the greater the light intensity, so the responsiveness value decreases. The above result shows that the distance affects the sensitivity and responsiveness of the device, and is an important factor affecting the parameters of this kind of photosensor.

Conclusion

The effect of optical filter on the photoelectric response of ZnO/rGO photoconductive device has been discussed in this paper. The results show that the response value of blue filter is greater than that of purple filter, and that of colorless filter is greater than that of blue and purple filter. On the other hand, the current value of the device increases with the decrease of distance, but the responsiveness value decreases with the decrease of distance. These results may have a potential significance for the application of ZnO-based photosensors.

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