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VOC Sensing Properties of Hybrid Nanostructures

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Abstract

In this study, polymer/TiO_2 nanoheterostructures were fabricated to investigate their gas sensing properties. TiO_2 nanorods were fabricated by hydrothermal method. Then polystyrene polymer was coated on TiO_2 nanorods by spin coating method. The morphologies and structure of the samples were characterized by X-ray diffraction (XRD), scanning electron microscope (SEM). Electrical and VOC sensing properties of hybrid nanostructure device were investigated. The hybrid nanostructure shows highest sensor response for ethanol (EtOH) at 100 ^{o}C.

Key words: TiO_2 nanorods, polymer, heterostructure, VOC, gas sensor.

Introduction

The gas sensors are the subject of an intensive research because of their applications in the industry (such as petro chemistry, mining, cosmetic, automobile, and food industry), healthcare, agriculture, environmental protection, military, and security [1, 2]. The several materials such as the metals and metal oxides are widely used as the sensing layer which can be successfully produced as thin films, nanowires [3], nanotubes [4], in order to improve the properties of the sensor. Also, organic materials such as phthalocyanines [5] and polymers can be coated in order to develop sensor parameters.

In this work, polymer/TiO_2 nanoheterostructures were fabricated to investigate their gas sensing properties.

Experimental

TiO_2 nanorods were hydrothermally fabricated onto fluorine-doped tin oxide (FTO) substrate. 1 ml Titanium (IV) n – butoxide was used as a Ti precursor and mixed by HCl: deionized water with equal volume. The hydrothermal reaction was performed in teflon lined stainless steel autoclave at 150 °C for 18 h. Fig. 1a shows schematic illustration about teflon and stainless steel autoclave which used for growth nanorods on FTO by hydrothermal method. SEM image of TiO_2 nanorods is given by Fig. 1b.

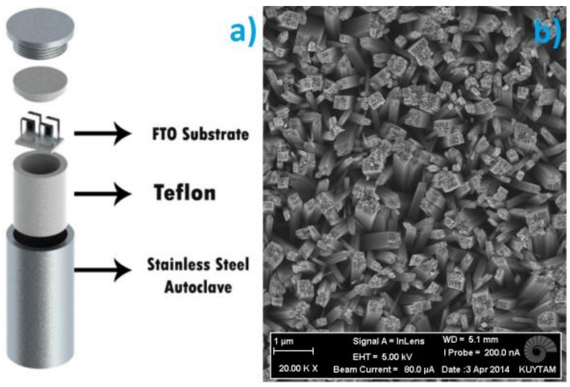

Fig. 1. a) A schematic illustration about hydrothermal method, b) SEM image of TiO_2 nanorods.

P(S-*co*-CMS-C_{60}) (P3) was prepared as follows: A mixture of P(S-*co*-CMS-N3) (P2), C_{60} and chlorobenzene was placed in a round bottom flask and degassed by bubbling argon for 10 min. The homogeneous reaction mixture was stirred at 60 ^{o}C under argon for 2d. The solution was heated 130 ^{o}C and allowed to continue overnight again. The resulting mixture was evaporated to dryness and then THF was added the residue. The mixture was stirred at room temperature. Unreacted C_{60} and other insoluble matters were filtered off. The clean filtrate was evaporated and dried in vacuum desiccator to obtain brown product. Then synthesized polystyrene polymer was coated on TiO_2 nanorods by spin coating method.

Results and Discussion

TiO_2 nanorods were fabricated by hydrothermal method as seen in Fig. 1b. The length and diameter of the fabricated TiO_2 nanorods were about 1μm and 100 nm respectively. According to the XRD results, the peaks represent the reflections from rutile TiO_2 crystallites, and FTO substrate as seen in Fig. 2.

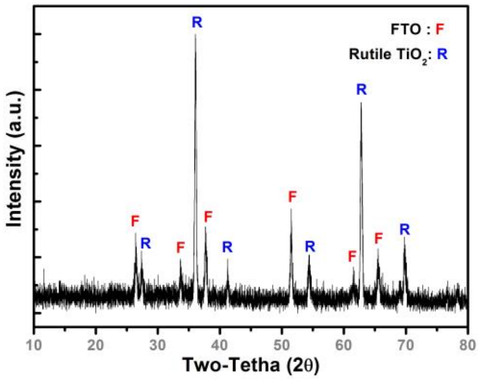

Fig. 2. XRD of TiO_2 nanorods.

Polystyrene polymer was coated on TiO_2 nanorods by spin coating method as a thin film.

For gas sensing measurement, gold contacts were coated on hybrid nanostructures. Fig. 3a shows schematically illustration of polymer/TiO_2 nanorods hybrid nanostrucutres. The DC electrical properties of hybrid device were investigated under dry air flow depending on temperature. The I-V characteristics of hybrid device have a hysteresis at all temperatures and the hysteresis increased with increasing temperature as seen in Fig. 3b.

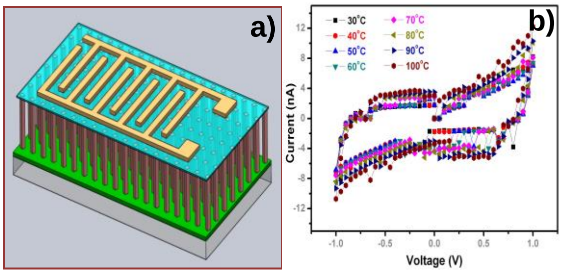

Fig. 3. a) A schematic illustration about hybrid device, b) IV characteristics of hybrid device.

VOC sensing properties of hybrid nanostructure device were investigated at 100 ^oC and the sensor response of the device is given in Fig 4. VOCs were sent to test cell for 10 min, and then the cell recovered by dry air for 20 min. The hybrid nanostructure shows highest sensor response for ethanol (EtOH).

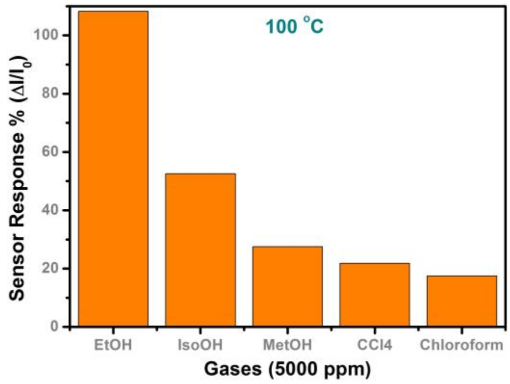

Fig. 4. VOC sensing properties of hybrid device at 100 ^oC.

It is well known that mostly carbon atom is accessible to the gas because they are the surface atoms and gas sensing for P3 may depend on the surface interaction between the gas and π electrons in C_{60}s. While the copolymer chain provides solubility, C_{60} moieties ensure the sensing [6].

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