Sensors and Actuators B 141 (2009) 511–517

Contents lists available at ScienceDirect

Sensors and Actuators B: Chemical

journal homepage: www.elsevier.com/locate/snb

A single ZnO tetrapod-based sensor

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ARTICLE INFO

Article history:
Received 30 March 2009
Received in revised form 1 June 2009
Accepted 3 July 2009
Available online 15 July 2009

PACS:
78.30.Fs
78.55.Et
81.05.Dz
81.10.Dn

Keywords:
Fabrication
ZnO nanorod
ZnO tetrapod
UV sensor
Gas sensor
Zinc oxide

ABSTRACT

Transferable ZnO tetrapods were grown by an aqueous solution method. An individual ZnO tetrapod-based sensor was fabricated by in situ lift-out technique and its ultraviolet (UV) and gas sensing properties were investigated. This single tetrapod-based device responds to the UV light rapidly and showed a recovery time of about 23 s. The sensitivity of a single ZnO tetrapod sensor to oxygen concentration was also investigated. We found that when UV illumination is switched off, the oxygen chemisorption process will dominate and assists photoconductivity relaxation. Thus relaxation dynamics is strongly affected by the ambient O_2 partial pressure as described.

We also studied the response of ZnO tetrapod-based sensor in various gas environments, such as 100 ppm H_2, CO, *i*-butane, CH_4, CO_2, and SO_2 at room temperature. It is noted that ZnO tetrapod sensor is much more sensitive to H_2, *i*-butane and CO. It is demonstrated that a ZnO tetrapod exposed to both UV light and hydrogen can provide a unique integrated multiterminal architecture for novel electronic device configurations.

1. Introduction

At present, there exists emerging interest in the applications of wide-bandgap semiconductor nanomaterials. Devices based on nanoarchitectures such as nanowires, nanotubes and nanorods have attracted vast and persistent attention for a variety of applications, including detecting ultraviolet (UV) radiation, gas sensing, and detecting chemical and biological molecules [1–10]. Detection of UV radiation is important in a number of applications like flame sensing, missile plume detection, space-to-space communication, astronomy and biological research [5,9–12]. Among different wide-bandgap materials used in UV detectors, zinc oxide has a high exciton binding energy of 60 meV [13], a room temperature direct bandgap of $\Delta E_g = 3.37$ eV, and is transparent in the visible region [14]. ZnO is chemically more stable and capable of operation at much higher temperatures than Ge or Si [15]. ZnO also has an ability to operate in harsh environments and is radiation resilient [16–18]. It possesses a combination of attractive and unique optical, piezoelectrical, sensing and magnetic properties [14,19,20]. It has been demonstrated that ZnO nanorods and nanowires exhibit many unique properties associated with their shape anisotropy and high thermal and chemical stability [14,21]. Thus, the main driving force of extensive studies on micro- and nano-ZnO is the potential of new or better photonic and electronic devices that could have a huge commercial impact [22].

Several reports [5,9,11,12,23] have demonstrated that single ZnO nanorod/nanowire UV radiation and gas sensing devices have the advantages of cost-efficiency, miniaturization and low-power consumption. Due to the high aspect ratio of nanorod/nanowire, the active volume that contributes to the dark current is much smaller than that of a conventional detector. It has been suggested that, the detection sensitivity may be improved to a single photon or a single-molecular detection level [24] if the active volume can be further reduced.

Recently, it has been demonstrated that ZnO readily self-assembles into a diversity of nanocrystalline structures [19], branched nanorods [8,25], nanorod crosses [10], tetrapods [26],

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doi:10.1016/j.snb.2009.07.011