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Highly sensitive ethanol chemical sensor based on Ni-doped SnO_2 nanostructure materials

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ABSTRACT

Due to potential applications of semiconductor transition doped nanostructure materials and the important advantages of synthesis in cost-effective and environmental concerns, a significant effort has been consummated for improvement of Ni-doped SnO_2 nanomaterials using hydrothermal technique at room conditions. The structural and optical properties of the low-dimensional (average diameter, 52.4 nm) Ni-doped SnO_2 nanostructures were demonstrated using various conventional techniques such as UV/visible spectroscopy, FT-IR spectroscopy, X-ray powder diffraction (XRD), and Field-emission scanning electron microscopy (FE-SEM). The calcined doped material is an attractive semiconductor nanoparticle for accomplishment in chemical sensing by simple *I–V* technique, where toxic chemical (ethanol) is used as a target chemical. Thin-film of Ni-doped SnO_2 nanostructure materials with conducting coating agents on silver electrodes (AgE, surface area, 0.0216 cm^2) revealed higher sensitivity and repeatability. The calibration plot is linear (R, 0.8440) over the large dynamic range (1.0 nM–1.0 mM), where the sensitivity is approximately 2.3148 $\mu A\,cm^{-2}\,mM^{-1}$ with a detection limit of 0.6 nM, based on signal/noise ratio in short response time. Consequently on the basis of the sensitive communication among structures, morphologies, and properties, it is exemplified that the morphologies and the optical characteristics can be extended to a large scale in doping nanomaterials and proficient chemical sensors applications.

1. Introduction

The significance of safety for lives as well as ecological plants has been studied with great attention in semiconductor sensors for toxic chemical detection by reliable methods (Shaalan et al., 2011). Semiconductor nanostructure materials are very sensitive and efficient due to their smaller particle size and high active surface to volume ratio as contrasted to the conventional nanomaterials in micro- or nano-meter range. Nanostructure metal oxides have demonstrated an enormous deal of consideration owing to their outstanding properties occurring of huge active surface area, high stability, quantum confinement consequence, and high porosity as well as permeability (meso-porous nature), which are reliant on the shape and size of the nanocrystal (Umar et al., 2008). Metal oxide, especially tin oxide (SnO_2) is one of the most significant and well-known n-type nanomaterial semiconductors with large band gap (~3.6 eV) (Li et al., 2009). Owing to their distinctive electronic, physical, optical, chemical, and catalytic properties, it has been extensively employed in flat-panel displays, transparent conducting electrodes, solar cells, sensors, and rechargeable Li-ion batteries (Wang et al., 2010). The attention in tin oxide is revealed due to the naturally stoichiometric apparent conducting oxide containing high transparency in visible region and high reflectivity in infra-red region. Further, the electrical resistance of SnO_2 is small compared to other semiconductor nanomaterials (Batzill and Diebold, 2005). It is normally monitored that increasing the surface/bulk or surface to volume ratio by decreasing the particle size of SnO_2 aggregated nanoparticles is vital for attaining high sensitivity in sensors (Fang et al., 2008). One of the most significant routes to modify the features of the nanomaterials is the introduced of doped materials in the parent system. It has been revealed that several dopants (Cr, Co, Mn, Al, Mg, Cu, Fe) can escort to enhance the surface area of SnO_2 nanostructure. These dopants alleviated the surface and promote the decrease in size as well as change the shapes. To acquire the maximum benefit of the properties of metal ions doped SnO_2 nanomaterial, a number of techniques have been introduced for the efficient preparation of metal doped SnO_2 nano-materials. Few of them are mechanical alloying (Albuquerque et al., 2010), condensed vapor deposition (Huh et al., 1999), sol–gel method (Zhang and Gao, 2004), solvo-thermal method (Liu et al., 2008), spray pyrolysis (Pena et al., 2003), gel-combustion method (Fraigi et al., 1999), and physical vapor deposition (Davazoglou, 1997).

Here, it is prepared nickel-doped SnO_2 nanoparticles by hydrothermal technique. This method has several advantages such

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