DOI 10.5162/IMCS2012/6.3.1

Metal Oxide Sensor for Petroleum Industry Applications

Ahsan-Ul-Haq Qurashi
King Fahd University of Petroleum& Minerals Center of Excellence in Nanotechnology
Chemistry Department
Dhahran, 31261Saudi Arabia
e-mail: ahsanulhaq@kfupm.edu.sa

Introduction

The primary stimulus on semiconductor gas sensors was given by Heiland [1], Bielanski et al. [2], and Seiyama et al. [3] and the important step was taken when Taguchi developed semiconductor sensors based on metal oxides as an industrial product (Taguchi-type sensors) [4]. Metal oxide based gas sensors attained tremendous interests since the first discovery in 1962 by Seiyama et al. [4] and Taguchi [5]. In semiconductor based gas sensors, atoms and molecules interacting with semiconductor surfaces influence surface properties of semiconductors, such as conductivity and surface potential [6-12]. Depending upon the nature of gases (oxidising or reducing) and type of materials (p-type or n-type semiconductor) electrical resistance either decrease or increase and recorded accordingly.

One of the most significant components of sensor is the sensing material. Thus the choice of appropriate materials is extremely important for the development of good sensors in terms of sensitivity, selectivity, reversibility, sustainability, dynamic range, and etc. Nanostructured materials present paramount advantages to facilitate integration and miniaturization of the devices. Controlling the size, shape, and structure of inorganic nanomaterials to search for new properties has become one of the major objectives of nanoscale science and technology, because of their structure, size, and shape-dependent characteristics and novel electronic, magnetic, optical, chemical, catalytic, and mechanical properties that cannot be obtained in their bulk counterparts. Crystalline mesoporous nanostructured metal oxides with narrow pore size distributions and controllable morphologies have attracted huge interests in a wide range of applications such as gas sensing, optics or catalysis. Various interesting techniques have been used for the fabrication of mesoporous metal oxide nanostructures which include nanocasting, anodization, templating, metal templating, etc

The high surface area and thermal stability of the metal oxide materials instantly created interests in using these materials for efficient sensors. More recently, mesoporous and mesostructured materials have been recognized as promising candidates for the next-generation of optoelectronic miniatured devices. These characteristic features of metal oxide nanostructures potentially make them ideal candidates for efficient gas sensors.

Metal oxide nanostructures

A complex synthesis of In_2O_3 (SnO_2, and TiO_2) nanostructures with well-defined shapes are of special interest to understand basic size-dependent scaling laws and may be useful in a wide range of application fields, including photonics, nanoelectronics, information storage gas sensors, chemical and biosensors and catalysis. In this work we report controlled growth of In_2O_3 nanostructures by simple chemical vapor deposition and thermal evaporation methods. The fabrication of large-scale In_2O_3 nanowires, nanopencils, nanoneedles, nanocolumns, nanosyringes, hierarchical structures, nanopushpins, nanopyramids, octahedrons, nanorods, nanotrees, patterned nanowires etc. were realized. These larger families of In_2O_3 nanostructures were attained at very low temperature (~ 250-800°C). Structural analysis reveals that these In_2O_3 nanostructures are body centered cubic (bcc), with single crystal structure. TEM analysis showed that all different types of In_2O_3 nanostructures are single crystalline in nature. Raman and PL spectrum also showed that these wide varieties of In_2O_3

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nanostructures have promising optical properties. It is noteworthy to mention that we are the first to develop large varieties of In_2O_3 nanostructures in grams quantity by reducing the overall growth temperature up to 250°C by a novel modified thermal evaporation and vapor transport techniques. For the first time horizontal and vertical nanopatterning of 1D In_2O_3 nanostructures is accomplished. On the basis of experimental parameters a possible growth mechanism for the formation of In_2O_3 nanostructures was proposed. The complex In_2O_3 nanostructures with high crystal quality provided new building blocks in future architecture functional nanodevices. These In_2O_3 nanostructures also have potential applications in ultrasensitive gas sensors, chemical and biosensor devices, where well defined easily accessible crystal surface is required. Hydrogen sensor response was measured for different types of In_2O_3 nanostructures and showed promising response and recovery time. Figure 1 shows FESEM image of indium oxide nanostructures grown for different temperatures. Figure 2 shows XRD spectrum of In2O3 nanowires. Furthermore the fabrication of sensor devices based on In_2O_3 nanostructures is under the investigation.

Petroleum industry

Metal oxides are promising materials for gas sensors for petroleum industry due to several reasons. These oxide materials are highly stable and can respond in harsh atmosphere. Air quality monitoring is difficult in harsh environmental conditions. Petroleum industry is keenly looking for highly stable sensing materials with long term stability to monitor ambient air, composition of effluents and the gases coming from the combustion. The chemical moieties are mainly SO_2, H_2S, CO_2, CO and VOC. Especially detection of H_2S and SO_2 based sensors are paramount to petroleum industry.

The current material and technology in use put limitation in term of maintenance, reliability and sensitivity. Petroleum industry is looking more sensitive options in terms of detecting low quantity (ppm) and reliability (accuracy). The current options being used by petroleum industry some time fails to differentiate between some materials of close chemistry for instance H_2S and other sulphur gases at ppm level.

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