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Hydrogen gas sensor based on highly ordered polyaniline nanofibers☆

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ABSTRACT

Presented is the structural and gas sensing properties of polyaniline nanofibers deposited on 36° lithium tantalate ($LiTaO_3$) surface acoustic wave (SAW) transducers. The polyaniline nanofibers were synthesized using electropolymerization and subsequently dedoping technique. Field emission scanning electron microscopy (FE-SEM) revealed that the diameter of the polyaniline nanofibers is in the range of 40–50 nm. The SAW sensors with different thicknesses of thin film made of polyaniline nanofibers were then exposed to different concentrations of hydrogen (H_2) gas at room temperature.

1. Introduction

Hydrogen, which is a colourless and odourless gas, has attracted a great deal of attention due to the fact that it can be used as a clean energy source when coupled with fuel cell technology. It is highly flammable and burns in air at concentrations as low as 4%. Furthermore, this gas needs only low ignition energy to deflagrate [1]. H_2 sensors employing metals and metal oxides as sensitive layers [2–6] have been widely studied. Recently, H_2 gas sensing based on conducting polymers has garnered great interests in the scientific community, despite the fact that they were discovered in mid 70s [7]. They are also important for applications in aerospace, refineries and biomedical systems [8,9].

Conducting polymers such as polyaniline have been widely investigated for gas sensing applications. Polyaniline has received increasing interest due to its room temperature operation, low fabrication cost, ease of deposition and rich chemistry for structural modification [10,11]. It is also a unique conjugated polymer since its conductivity can be tailored to a specific application through an acid–base doping process. When the polymer is doped with acid, an electrically conductive polyaniline is formed which is known as emeraldine salt. At this state, the imine nitrogen is protonated on the polymer backbone and charge carriers are induced. Studies have shown that polyaniline has three main oxidation states, which can be seen by noting the colour changes ranging from transparent leucoemeraldine, and yellow/green emeraldine to blue/black pernigraniline [12,13].

Conductivity of polyaniline depends on its ability to transport charge carriers along the polymer backbone and for the carriers to hop between the polymer chains. This principle enables polyaniline to be used as a sensitive layer for gas sensing. Doped polyaniline or emeraldine salt has been actively studied and reported for the use as a sensing layer. Xie et al. [14] investigated the sensing performance of Langmuir–Blodgett deposited ultra-thin film polyaniline based conductometric sensors towards NO_2. Polyaniline nanofibers in bulk quantity have also been successfully developed via chemical synthesis [15]. By drop-casting polyaniline nanofibers onto conductometric transducers, Huang et al. [16] formed sensitive films of polyaniline for which they investigated the sensitivity when exposed to HCl vapour. The performance towards HCl vapour was found unaffected by the thin film thickness of drop-casted polyaniline. At the same time, they have shown that dedoped polyaniline nanofibers based conductometric sensors are much less responsive than their doped counterparts [16]. However, Sadek et al. [17] work on dedoped polyaniline based gas sensors recently has proven that previous statement was not completely right for many gas targets. Dynamic responses of the measured sensors revealed that dedoped polyaniline based sensors have shorter response towards H_2 gas and good repeatability compared to doped polyaniline based sensors.

The synthesis of polyaniline via electropolymerization techniques [19,20] is quite common. This method allows the control of the deposited polymer thickness [18]. However, the use of interdigitated transducers (IDTs) as working electrodes when forming an electropolymerized polyaniline film can be a tricky task as the gap between electrodes needs to be covered to establish a continuous film. Recently, Kalantar-zadeh et al. [21] have successfully deposited

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