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Functionalized individual ZnO microwire for natural gas detection

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ABSTRACT

A single ZnO microwire detector for the monitoring of natural gas species is described. Single-crystal ZnO microwires were synthesized using a carbothermal reduction vapor phase transport method. It was characterized by XRD, EDX, SEM, Raman and photoluminescence techniques. The sensor structure was fabricated by in situ lift-out method using focused ion beam (FIB) system. The prototype is then functionalized with palladium and used as sensing element. The main advantage of the FIB procedure is a quick verification/testing of concept and is compatible with micro/nanoelectronic devices. A response of 5% was obtained for a single ZnO microwire sensor at 2000 ppm natural gas in the air at room temperature. At 400 °C the response increases to 40%. Selectivity to different gasses was investigated and higher response was detected for natural gas.

1. Introduction

Natural gas (NG) is an important feedstock for potential residential fuel cell systems because the infrastructure to supply natural gas is already established and the technology for producing hydrogen from natural gas [1] is available. The majority of current natural gas sensors are based on the catalytic mechanism of operation. The obvious drawback of these types of sensors is that they can be easily poisoned by halogens and halogen derivatives. The oxide semiconductor (SnO_2, ZnO, etc.)-based natural gas sensors showed excellent response and recover characteristics and can potentially overcome obstacles, such as sensitivity and selectivity [2–6]. Among various materials, ZnO is one of the most promising multifunctional materials for NG sensors due to its advantageous features, such as high sensitivity under ambient conditions, low-cost and simplicity in synthesis. Few data on ZnO as sensing material for natural gas were reported previously. Wang et al. [7] reported on thermal desorption spectroscopy TDS and adsorption probability measurements of iso-butane on the Zn-terminated surface of ZnO. Mazingue et al. [8] reported on optogeometric properties of ZnO sensitive thin films involved in butane gas sensing and on the butane sensing using ZnO-nanostructured coatings prepared by pulsed laser deposition [9]. Lupan et al. [10] investigated gas response of an individual ZnO tetrapod-based sensor to CH_4 gas at 100 ppm concentration. Lee et al. [11] studied the ZnO nanorod-coated quartz crystals as self-cleaning thiol sensors for natural gas fuel cells and their results highlight the potential of ZnO nanorod-grown quartz crystal microbalance as self-cleaning sensors capable of long-term operation under harsh conditions. Kim et al. [12] demonstrated possibility to develop on oxide films propane/butane gas sensor with low power consumption (as low as 100 mW) for the application to portable gas detection devices. However, no reports on the natural gas using individual Pd-functionalized ZnO microwire were found in the literature.

ZnO nanorods/nanowires have been grown by a variety of methods such as pulsed laser deposition [13], vapor phase transport process [14], chemical vapor deposition method [15].

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