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Highly sensitive and selective hydrogen single-nanowire nanosensor

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Metal oxides such as ZnO have been used as hydrogen sensors for a number of years. Through doping, the gas response of zinc oxide to hydrogen has been improved. Cadmium-doped ZnO nanowires (NWs) with high aspect ratio have been grown by electrodeposition. Single doped ZnO NWs have been isolated and contacted to form a nanodevice. Such nanosystem demonstrates an enhanced gas response and selectivity for the detection of hydrogen at room temperature compared to previously reported H_2 nanosensors based on pure single-ZnO NWs or multiple NWs. A dependence of the gas response of a single Cd–ZnO nanowire on the NW diameter and Cd content was observed. It is shown that cadmium-doping in single-crystal zinc oxide NWs can be used to optimize their response to gases without the requirement of external heaters. The sensing mechanisms responsible for such improved response to hydrogen are discussed.

1. Introduction

Hydrogen sensors are widely used in combustion systems of automobiles to monitor pollution, certain types of bacterial infections, as well as in the petroleum, chemical, or semiconductor industries [1,2]. The potential applications of semiconductor nanocrystals and quantum dots for chemical sensing have been pointed out [3], and tremendous progress has been made in recent years in the synthesis and assembly of such materials [4–6]. In addition, new physical and chemical properties can be obtained upon nanocrystal doping [5,7–12], enabling new applications in the fields of nano-electronics and nano-optoelectronics [3,4,12,13]. Previous reports discussed different aspects of doping for nanocrystals [4,5,7–12]. In the case of ZnO, direct chemical methods for the synthesis of doped nanowires (NWs) such as thermal evaporation, chemical vapor deposition, or solid-state synthetic techniques were found to require annealing temperatures above 500 °C [12–15]. Aqueous solution routes including electrochemical deposition constitute alternative methods for low temperature doping [11,16–25] of nanowires and nanorods, with the added advantages of its simplicity, fast implementation, and low cost. In addition, the electrochemical method allows the control of the dopant concentration, the orientation and density of the nanorods formed by adjusting deposition potentials, current densities, temperature, and/or salt concentrations [19–25]. Cadmium is an excellent dopant for ZnO, because Zn and Cd belong to the same group in the Periodic Table, and they both occupy the same type of lattice sites in wurtzite structures [22,25]. Thus, the stable wurtzite ZnO structure is expected to be preserved upon Cd-doping at low concentrations [22,24,25].

One-dimensional nanostructures show great potential for nanodevice applications [26–31] based on their large surface to volume ratio and controlled flow of confined charge carriers. For example, Cd-doped ZnO NWs have been used in light-emitting devices, thin-film transistors, and sensing nanodevices [22,24,26]. Many nano-ZnO-based H_2 sensors have been demonstrated [28–31]. For example, hydrogen-selective sensing in nano-zinc oxide based

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