ACS Applied Materials & Interfaces
2017
Volume 9, Issue 27, pag. 23107-23118

Single and Networked ZnO–CNT Hybrid Tetrapods for Selective Room-Temperature High-Performance Ammonia Sensors

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https://doi.org/10.1021/acsami.7b03702

Abstract

Highly porous hybrid materials with unique high-performance properties have attracted great interest from the scientific community, especially in the field of gas-sensing applications. In this work, tetrapodal-ZnO (ZnO-T) networks were functionalized with carbon nanotubes (CNTs) to form a highly efficient hybrid sensing material (ZnO-T–CNT) for ultrasensitive, selective, and rapid detection of ammonia (NH3) vapor at room temperature. By functionalizing the ZnO-T networks with 2.0 wt % of CNTs by a simple dripping procedure, an increase of 1 order of magnitude in response (from about 37 to 330) was obtained. Additionally, the response and recovery times were improved (by decreasing them from 58 and 61 s to 18 and 35 s, respectively). The calculated lowest detection limit of 200 ppb shows the excellent potential of the ZnO-T–CNT networks as NH3 vapor sensors. Room temperature operation of such networked ZnO–CNT hybrid tetrapods shows an excellent long-time stability of the fabricated sensors. Additionally, the gas-sensing mechanism was identified and elaborated based on the high porosity of the used three-dimensional networks and the excellent conductivity of the CNTs. On top of that, several single hybrid microtetrapod-based devices were fabricated (from samples with 2.0 wt % CNTs) with the help of the local metal deposition function of a focused ion beam/scanning electron microscopy instrument. The single microdevices are based on tetrapods with arms having a diameter of around 0.35 μm and show excellent NH3 sensing performance with a gas response (Igas/Iair) of 6.4. Thus, the fabricated functional networked ZnO–CNT hybrid tetrapods will allow to detect ammonia and to quantify its concentration in automotive, environmental monitoring, chemical industry, and medical diagnostics