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Branch-like NiO-based p-n heterostructures with enhanced gas sensing properties

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Metal oxides represent a vast class of materials of interest for various scientific communities, ranging from physics to chemistry, from material science to engineering. The majority of metal oxides are in principle sensitive to gases. However, in order to be performing materials for the fabrication of chemical sensors, they need to fulfill specific requirements such as sensitivity, selectivity, stability, fast response and recovery time. In the field of chemical sensing, metal oxides have been investigated in different forms, starting from thick to thin films. In recent years, nanostructured metal oxides, and in particular one-dimensional (1D) nanowires, have attracted a wide attention, especially in the field of conductometric sensing devices. These devices are among the most performing, smal size, easy readout and cheapest devices that can be integrated, for example, into portable detection systems. In order to increase the sensor response and selectivity, various strategies have been employed, such as the modulation of the sensing temperature, [1] morphological changes, [2] catalyst doping/loading, [3] and catalytic filtering of interference gases [4]. Another effective strategy to enhance the sensor response and selectivity is to construct heterojunctions between two different oxides that enables the control of conductivity at p-p, p-n, and n-n interfaces, and synergistic catalytic effects between different materials.
The main idea behind this work is to bring together the properties of two different nanostructure materials into a single sensing platform by using a common, simple, low cost and high yield growth method. Herein, we report on the novel preparation and characterization of NiO/WO3 and NiO/ZnO branched 1D-1D nano-heterostructures, consisting of inner NiO nanowires [5] and outer WO3 and ZnO nanowires obtained through the same vapor-phase method. The surface morphology of the nanowires was investigated by using scanning electron microscopy (SEM) while, for structural characterization GI-XRD, the transmission electron microscopy (TEM), and Raman spectroscopy were performed. The structural characterizations shows the presence of a ternary nickel tungstate (NiWO4) phase in NiO/WO3 nanostructures, while for NiO/ZnO no new phase was detected and the lateral growth of ZnO on NiO resulted almost epitaxial. Finally, NiO nanowire and heterostructure based conductometric gas sensing devices have been fabricated and tested towards different gases spices such as (NO2, H2, CO, VOC's) and their sensing performances have been compared. Interestingly, both NiO/WO3 and NiO/ZnO heterostructure based sensing devices shows superior performance compared to NiO sensors.

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Summary

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