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PdO/PdO2 functionalized ZnO:Pd films for lower operating temperature H2 gas sensing

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Abstract

Noble metals and their oxide nano-clusters are considered to be the most promising candidates for fabricating advanced H2 gas sensors. Through this work, we propose a novel strategy to grow and modulate the density of PdO/PdO2 nanoparticles uniformly on nanostructured Pd-doped ZnO (ZnO:Pd) films by a one-step solution approach followed by thermal annealing at 650 °C, and thus to detect ppm-level H2 gas in a selective manner. The gas sensing properties of such hybridized materials showed that the PdO-functionalized ZnO samples offer significantly improved H2 gas sensing properties in an operating temperature range of 25–200 °C. The deposition of ZnO:Pd films via a simple synthesis from chemical solutions (SCS) approach with an aqueous bath (at relatively low temperatures, <95 °C) is reported. Furthermore, the functionalization of palladium oxide nanoclusters by a simple but highly effective approach on ZnO:Pd film surfaces was performed and is reported here for the first time. The morphological, structural, vibrational, optical, chemical, and electronic properties were studied in detail and the mixed phases of palladium oxide nanoclusters on the ZnO surface were found. Sensor studies of the ZnO:Pd samples (in the range of 25–350 °C operating temperature) showed good selectivity to H2 gas, especially in the range of higher temperatures (>150 °C, up to 350 °C); however, the PdO/PdO2 mixed phases of the nanocluster-modified surface ZnO:Pd films showed a much better selectivity to H2 gas, even at a lower operating temperature, in the range of 25–150 °C. For such PdO-functionalized ZnO:Pd films, even at room temperature, a gas response of ~12.7

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to 1000 ppm of H2 gas was obtained, without response to any other reducing gases or tested vapors. The large recovery time of the samples at room temperatures (>500 s) can be drastically reduced by applying higher bias voltages. Furthermore, we propose and discuss the gas sensing mechanism for these structures in detail. Our study demonstrates that surface functionalization with PdO/PdO2 mixed phase nanoclusters–nanoparticles (NPs) is much more effective than only the Pd doping of nanostructured ZnO films for selective sensing applications. This approach will pave a new way for the controlled functionalization of PdO/PdO2 nanoclusters on ZnO:Pd surfaces to the exact detection of highly explosive H2 gas under various atmospheres by using solid state gas sensors.