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Selectivity and Sensitivity NO_2 Gas Sensors using PbS CQD Ink prepared via Phase-Transfer Exchange

*Baohui Zhang, Jingyao Liu, Zhixiang Hu, Shuqin Yang, Zhuang Chen, Huan Liu**
School of Optical and Electronic Information, Huazhong University of Science and Technology, 1037 Luoyu Road, Wuhan, Hubei, 430074, P. R. China
Corresponding author's e-mail address: huan@mail.hust.edu.cn

Abstract:

Colloidal quantum dots (CQDs) are promising building blocks for low cost and high performance gas sensors due to their low temperature solution processability and extremely small size. PbS CQDs showed a good sensitivity and selectivity for gas sensing, however the complexity of the multiple-step CQD-layer-deposition process still influence device consistency. Herein, gas sensors prepared with CQD-ink using a phase transfer exchange (PTE) method are reported. Devices are fabricated by a simple single-step spin coating using CQD ink instead of past layer by layer deposition via solid state ligand exchange. Gas sensors via PTE method shows a good performance with a towards NO_2 detection. The PTE device shows a better performance with a 8.2 response towards 10 ppm NO_2 with a response and recovery time 3 s and 127 s respectively.

Key words: Gas Sensor; Lead Sulfide; Colloidal Quantum Dot; Ligand Exchange; Nitrogen oxide.

Instruction

Highly sensitive gas sensors for detecting tiny amounts of toxic and hazardous gases play a vital role in our daily life for public safety, industrial processes, medical diagnosis, and continuous monitoring of environmental pollution. To date, worldwide effort has been made to develop reliable gas sensors with high sensitivity and selectivity, and rapid progress has been achieved driven by the emerging nanoscience and nanotechnology. Colloidal quantum dots (CQDs) have expressed great potential in gas sensing by its large surface area and low temperature solution processing controllable suface.

Recent researches in CQD materials engineering have led to CQD inks that offers advantages over solid state exchange devices such as simple single-step spin coating deposition, less surface trap introduced, valid ligand exchanged completely with oleate ligand and smoother energy landscape in each of the conduction and valence bands. OA capped CQDs in octane undergo a phase transfer to a polar solvent containing halide precursors and salts such as metal iodide and ammonium acetate. The dots are then concentrated into an ink for film deposition.

Experimental details

PbS CQDs were synthesized under Schlenk-line conditions according to the literature procedure. For the phase transfer ligand exchange process, PbS CQDs in octane (3 mL, 20 mg/mL) was stirred vigorously with NH_4Br in methanol (3 mL, 20 mg/mL) for 30 min. Upon stirring, the PbS CQDs were transferred from the octane (nonpolar) phase to the methanol (polar) phase. After removal of the octane phase, the methanol phase was washed three times to remove the remaining. The polar phase was centrifuged at 5000 rpm for 5 min to separate the exchanged PbS CQDs. The PbS CQDs were dried in vacuum for 1 h to yield CQD powder. The dried PbS CQDs were suspended in butylamine/formamide mixture to prepare concentrated PbS CQD ink.

NH_4Br-treated LBL devices was fabricated as literature procedure. PTE devices was spin coated onto the alumina substrate without any other treatment.

Results

Response curves under a series concentrate NO_2 (1 ppm, 3 ppm, 5 ppm, 10 ppm, 30 ppm and 50 ppm) were shown in Fig 1. The PTE device shows a better performance with a 8.2 response at 10 ppm NO_2 than LBL device with

5.4 response. It has a response and recovery time 3 s and 127 s respectively, faster than which 10 s and 159 s of LBL device.

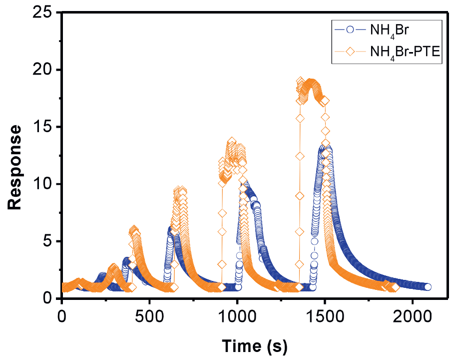

Fig. 1. Response curves of NH_4Br-treated PbS CQD and NH_4Br PTE PbS CQD ink under NO_2 concentrates of 1 ppm, 3 ppm, 5ppm, 10 ppm, 30ppm and 50ppm.

Conclusions

In conclusion ,we made a CQD-ink by using the PTE method. The CQD-ink enabled devices fabrication by single-step coating. The PTE device shows better performance with a 8.2 response at 10 ppm NO2. The response show that the PTE method improved surface ligand exchange compared with traditional solid state exchange devices. It intrduced a fast and easier process in gas sensing device fabrication.

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