DOI 10.5162/IMCS2018/GS7.2

Carbon-Encapsulated Co_3O_4 Nanofibers for Room Temperature Selective NH_3 sensors

Qiuxia Feng, Xiaogan Li, Jing Wang
School of Electronic Science and Technology, Institute for Sensing Technologies, Key Laboratory of Liaoning for Integrated Circuits Technology, Dalian University of Technology, Dalian 116024, China
Corresponding author's e-mail address: lixg@dlut.edu.cn (X. Li); wangjing@dlut.edu.cn (J. Wang)

Abstract :

Carbon-encapsulated Co_3O_4 nanofiber composites with rGO were successfully fabricated by using the electrospinning technology. The morphology and resistance of Carbon-encapsulated Co_3O_4 samples can be controlled by preparing condition. The as-electrospun carbon-Co_3O_4 nanofiber composites based chemo resistive sensor all showed good sensitivity to different concentrations of ammonia. Besides this, the sensor exhibited good selectivity to several potential interferents such as methanol, ethanol, formaldehyde, acetone, benzene, and methylbenzene. Water did play an important role in the sensing process. We discussed the sensing mechanism based on DFT-based first principle calculations.

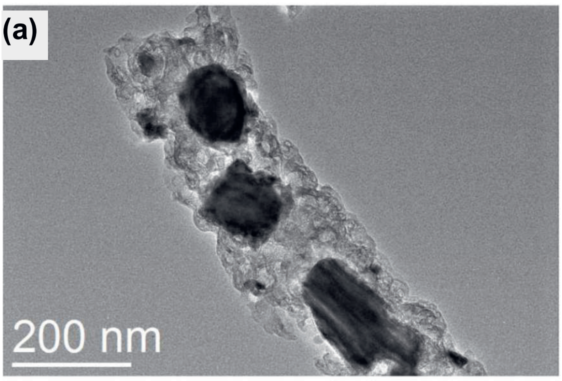
Key words: Electrospinning, Carbon encapsulated Co_3O_4 Nanofibers, Room-Temperature Ammonia Sensors, DFT Calculations

Introduction

The rGO with noble metals/metal oxide/organic ligands nanocomposites have been found to effectively improve ammonia gas sensing properties because of their potentials to combine the desirable properties of different nanoscale building blocks to improve mechanical, chemical and electronic properties [1]. As mean while, the first principles were more and more widely used in studying the atomic and electronic structure informations of materials[2]. I. Maity et al. studied the selectivity tuning of graphene oxide based gas sensor devices, where the role of oxygen functional groups were investigated for hysisorption of NO_2, NH_3, CO, and H_2O using first principle calculation. Besides, reduced graphene oxide (rGO) encapsulated Co_3O_4 composite nanofibers had shown excellent sensing properties in our previous work[3]. It is necessary to further study the preparing condition that affected the morphology and resistance, and discuss the sensing mechanism based on experimental results and DFT-based first principle calculations.

Results and conclusions

The morphology and resistance of carbon-encapsulated Co_3O_4 samples were affected by the existence of a small amount of O_2 during the thermal treatment. The morphology of carbon-encapsulated Co_3O_4 samples of A0 and A1 was shown as the SEM images in Fig. 1. A small amount of O_2 was added in the thermal treatment for sample A1 which had resistence of several hundreds of thousand Ohm. For A0 which had resistence of only several Ohm, we did not add O_2 for purpose. The sensors of A1 showed good sensitivity to ammonia (see Fig. 2.) while the sensors of A0 did not. Such desirable response features may be attributable to the unique interaction of ammonia with the porous structure with the polarized C-Co^{3+} covalent centers.



DOI 10.5162/IMCS2018/GS7.2

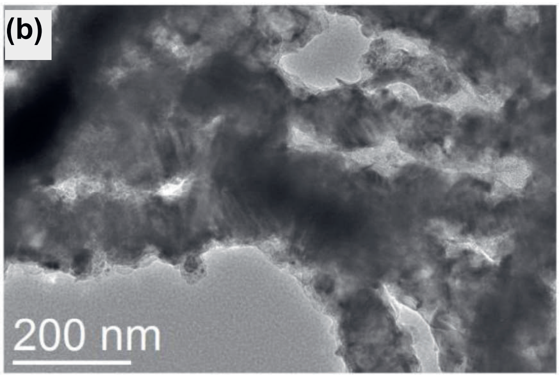


Fig. 1. Images of carbon-encapsulated Co_3O_4 samples: (a) no O_2 was added for purpose (b) a small amount of O_2 was added during the thermal treatment.

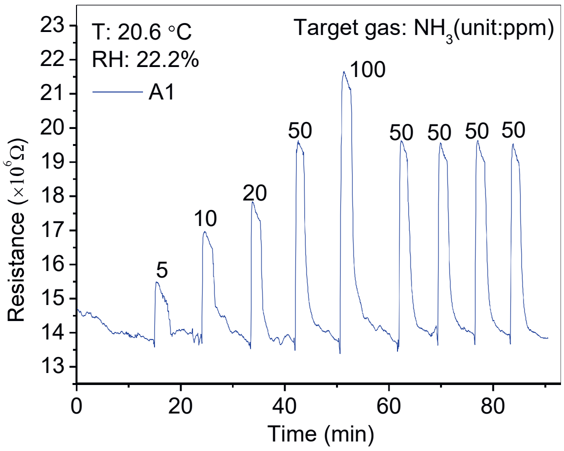
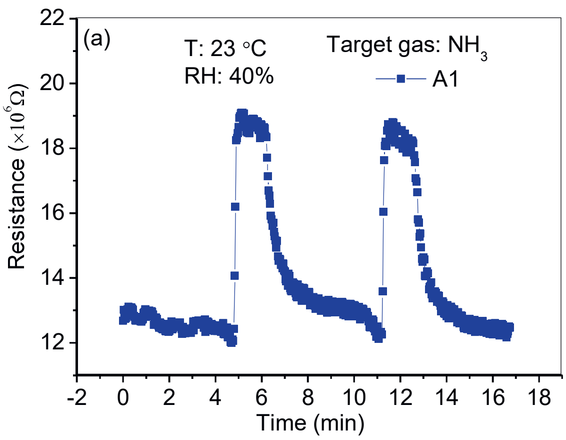


Fig. 2. The response to NH_3 of 5-100 ppm and the repeatability of response to NH_3 of 50 ppm for A1.

Water did play an important role in the sensing process which was shown in the results of sensing test (see Fig. 3).



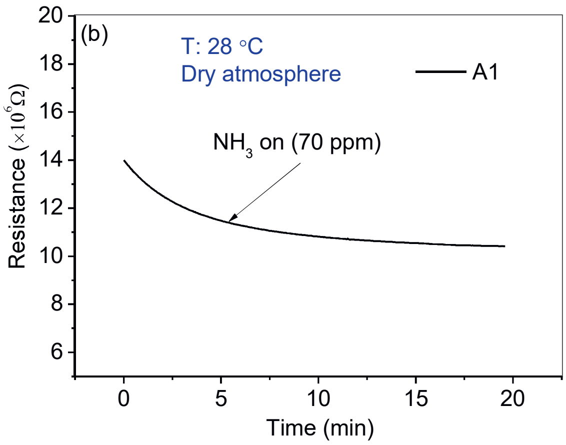


Fig. 3. The response to NH_3 of 70 ppm for (a) in moist air with 40% RH and (b) in dry atmosphere.

Among various volatile organic compounds, the carbon-encapsulated Co_3O_4 nanofibers showed excellent selectivity for ammonia to several possible interferences as shown in Fig. 4.

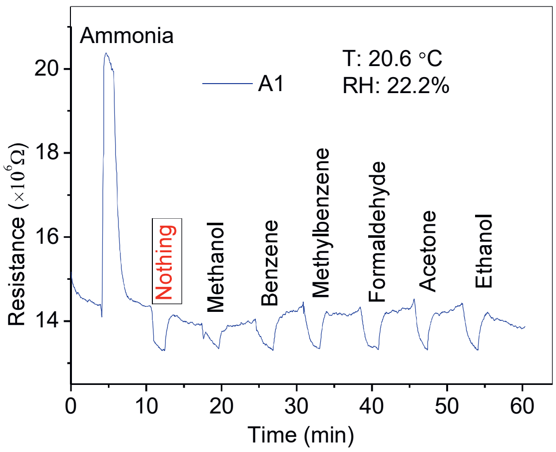


Fig. 4. Selectivity of the response of carbon-encapsulated Co_3O_4 composite nanofibers.

Finally, we also discussed the sensing mechanism based on DFT-based first principle calculations.

References

[1] Q. Feng, X. Li, J. Wang, Percolation Effect of Reduced Graphene Oxide (rGO) on Ammonia Sensing of rGO-SnO_2 Composite Based Sensor, *Sensors and Actuators B: Chemical* 243 1115-1126 (2017); doi: 10.1016/j.snb.2016.12.075.
[2] X. Xie, Y. Li, Z.-Q. Liu, M. Haruta, W. Shen, Low-Temperature Oxidation of CO Catalysed by Co_3O_4 Nanorods, *Nature* 458 746-749 (2009); doi: 10.1038/nature07877.
[3] Q. Feng, X. Li, J. Wang, A.M. Gaskov, Reduced Graphene Oxide (rGO) Encapsulated Co_3O_4 Composite Nanofibers for Highly Selective Ammonia Sensors, *Sensors and Actuators B: Chemical* 222 864-870 (2016); doi: 10.1016/j.snb.2015.09.021.