

Efficient Structural, Compositional and Morphological Modifications of TiO₂-based Hierarchical Multicomponent Materials for Chemical Sensing

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Abstract:

We have synthesized pure, mixed and multicomponent structures by coupling different cost-effective techniques. Prepared TiO₂-based hierarchically assembled nanostructures have been thoroughly characterized by scanning electron microscope, X-ray diffraction, Raman spectroscopy and X-ray photoelectron spectroscopy. The sensing properties of materials have been studied towards explosive and toxic gaseous compounds. Investigations have shown the material crystalline structure, the variation of mixture concentration in the material and the modification of carbon-based layers have crucial effect on the response and the selectivity of materials. The obtained results demonstrate that the prepared multicomponent structures can be applied in the area of chemical sensors for the environmental monitoring and medical diagnoses.

Key words: TiO₂, hierarchically assembled, nanotubes, multicomponent structures, chemical sensor.

Introduction

Among the transition metal oxides TiO₂ with its unique physical and chemical properties is a very attractive material for the manufacturing of functional devices. TiO₂ is one of the most studied materials of last years for the fabrication of gas sensors to provide security and environmental monitoring [1]. Moreover, recently TiO₂ have been studied for the application in breath analysis and clinical diagnostics [2]. Especially, one-dimensional TiO₂ nanotube arrays with their large surface to volume ratio and superior electron transport properties have been used for the fabrication of chemical sensors. The studies have shown that the TiO₂ nanostructures with the porous shape have good response towards volatile organic compounds and explosive gases. Then, the researchers carried out intensive studies to develop efficient strategies to improve the sensing performance of porous TiO₂ nanostructures.

Carbon has attracted and great interest for the application in functional devices due to the discovery of its allotropes (fullerenes, graphene and carbon nanotubes). Carbon-based nanomaterials with their high strength, excellent resistance to corrosion, exceptional electrical and thermal conduction, and stability are used in a wide range of fields, including sensors, energy harvesting, energy storage and medicine. However, despite numerous advances researchers faced challenges regarding the synthesis, stability and reproducibility of carbon-based materials at the relatively high operating temperatures. Thus, to be able to develop new applications of these materials further improvements of their properties are in need.

Herein, we report efficient strategies for the preparation and the enhancement of sensing properties of well aligned TiO₂ nanotube arrays.

Experimental

We have fabricated pure, mixed and multicomponent structures based on TiO₂

nanotubes and modified graphene-based materials.

The structures were prepared by combination of sputtering, chemical and electrochemical oxidation approaches. We studied the obtained materials by means of scanning electron microscope (SEM) equipped with field emission gun, X-Ray diffraction (XRD), Raman spectroscopy and X-ray photoelectron spectroscopy. The gas sensing performance of the samples was studied towards different gases, such as acetone ethanol, hydrogen, carbon monoxide, ammonia and nitrogen dioxide.

Results

Fig. 1 reports the morphologies of the obtained TiO_2 nanotubes and multicomponent structures. XRD measurement of the TiO_2 tubular arrays is reported in Fig. 2. Fig. 3 reports the isothermal dynamic response of the obtained pure (S1), mixed (S2) and multicomponent (S3) samples towards different concentrations of carbon monoxide (30, 60 and 120 ppm) and hydrogen (120, 240 and 480 ppm) at 300 °C.

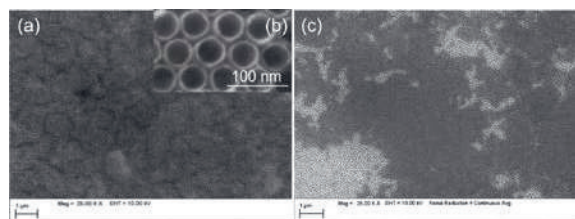


Fig. 1. (a) and (b) SEM images of the TiO_2 nanotubes with the different magnifications. (c) SEM micrographs of the prepared multicomponent structures.

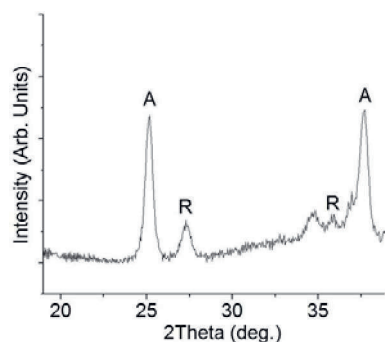


Fig. 2. XRD pattern of the TiO_2 nanotubular structures.

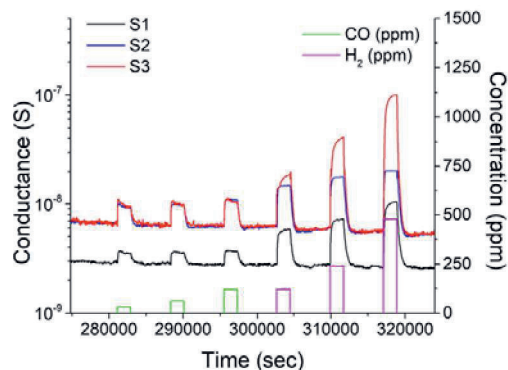


Fig. 3. Dynamic response of the prepared samples towards different concentrations of carbon monoxide and hydrogen.

Conclusion

Pure, mixed and multicomponent structures based on TiO_2 nanotubes and modified graphene-based layers were prepared through the sputtering, chemical and electrochemical oxidation techniques. We studied the effect of each material on the sensing properties of the samples. In the presence of reducing gases, the obtained materials showed highly sensitive, reversible and reproducible responses. The response and the selectivity of structures are improving depending on the modification of their composition and operating temperature. Meanwhile, we developed a cost-effective and easy synthesis method for the fabrication of high performance and small size chemical gas sensors.

Acknowledgements

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