

Light-Activated WS_2 -Decorated rGO as NO_2 for environmental gas sensing applications

J. De Santis¹, V. Paolucci¹, G. Di Iorio¹, L. Ottaviano^{2,3} and C. Cantalini¹

1. Dept. of Industrial and Information Engineering and Economics, Piazzale Pontieri, 1 – 67040 Monteluco di Roio – University of L'Aquila, Italy
2. Dept. of Physical and Chemical Sciences, University of L'Aquila, via Vetoio, 67100 L'Aquila, Italy
3. CNR-SPIN Uos L'Aquila, Via Vetoio 10, I-67100 L'Aquila, Italy

Introduction

The performances of a chemoresistive gas sensor made of WS_2 -decorated rGO are presented. In this paper, we report the exfoliation of WS_2 powders by a combined ball milling and sonication technique to produce mono to few-layer WS_2 . WS_2 flakes are mixed with rGO flakes to yield WS_2 -decorated rGO as chemoresistive NO_2 thin films deposited on large-area Si_3N_4 substrates.

The aim of this paper is firstly to demonstrate the reliability of the decoration process leading to the deposition of thin films of well dispersed WS_2 flakes over large-size, interconnected rGO flakes, secondly, to demonstrate and discuss the influence of purple blue light ($\lambda = 430$ nm) to detect NO_2 gas in air in the operating temperature range of 25 °C to 50 °C, and lastly, to investigate the influence of water vapor on the NO_2 gas response.

Preparation of GO via a modified Hummers method

Dispersion of GO flakes in water

Exfoliation of WS_2 powder by ball milling assisted sonication

Dispersion of WS_2 flakes in ethanol

Mixing equal amounts of the GO/water and WS_2 /ethanol solutions and sonicated for 10 mins

Drop casting on Si_3N_4 substrates and annealing at 70°C for 30 mins to obtain rGO

Measurement of electrical resistance by volt-ampometric technique

Experimental section

High-resolution TEM. Yellow arrow highlights typical folded edges of GO layer, while the red circles show some WS_2 flakes vertically aligned.

XPS spectra of the WS_2 -decorated rGO showing (a) C1s core level spectrum of rGO flakes and (b) W 4f core level spectrum of WS_2 .

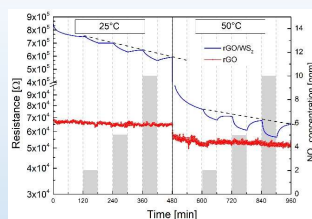
STEM on the previously analyzed flake confirms that it is actually made of WS_2 ((a) is sulfur and (b) is tungsten), and there are GO flakes above and below it, as demonstrated by the presence of both carbon (c) and oxygen (d) even in the area of the flake

Lateral size distribution of WS_2 flakes and corresponding Log Normal fit.

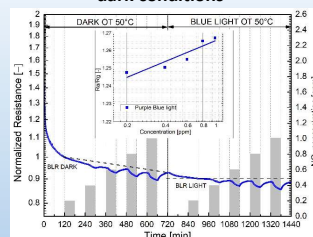
Results

ELECTRICAL RESPONSE

Comparison of the rGO electrical response decorated with WS_2 at 25 °C and 50 °C OT. It can be shown that by increasing the OT to 50 °C, the WS_2 decorated rGO exhibits faster response, better equilibrium conditions and reduced baseline drift.

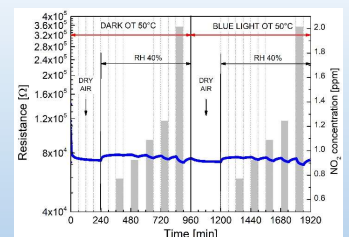


Comparison between the normalized dynamic responses to gases of the WS_2 - rGO sensor at 50°C OT in light and dark conditions

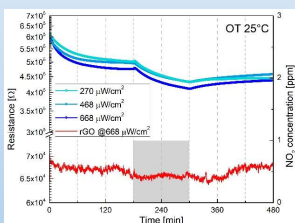


Reproducibility tests of the electrical response under pulse and cumulative NO_2 adsorption/desorption exposures exhibit no substantial irreversible adsorption/desorption phenomena, as well as a fairly good reproducibility of the electrical response.

The influence of 40% RH on the NO_2 response of WS_2 -decorated rGO under dark and PB light condition at 50°C OT

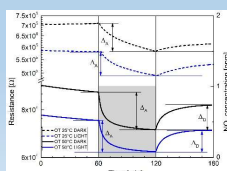


It is possible to demonstrate that humidity, regardless of the lighting conditions, does not appreciably interfere with the NO_2 gas adsorption mechanism, suggesting that NO_2 preferentially adsorbs on WS_2 , since it is energetically favored ads respect to water vapor.



Bare rGO exhibits neither significant changes of the electrical response at different power densities nor any gas response to 1 ppm NO_2 . WS_2 decorated rGO provides relative responses and recovery times that improve with increasing power density to 1 ppm NO_2 .

Equilibrium conditions are achieved under adsorption/desorption conditions when light irradiation is performed and when the OT is increased to 50 °C.



CONCLUSIONS

A thin film made of GO and few-layered WS_2 is produced and characterized and its performances as a room temperature gas sensor has been tested. The degree of reduction is controlled by a mild thermal annealing. The presence of WS_2 improves the sensitivity to NO_2 and humidity and also the presence of PB light enhances the response and baseline recovery.

Some References

- [1] M. Donarelli, S. Prezioso, F. Perrozzi, L. Giancaterini, C. Cantalini, et al Graphene oxide for gas detection under standard humidity conditions, 2D Mater. 2 (2015).
- [2] F. Perrozzi, S.M.M. Emamjomeh, V. Paolucci, et al, Thermal stability of WS_2 flakes and gas sensing properties of WS_2/WO_3 composite to H_2 , NH_3 and NO_2 , Sensors Actuators, B Chem. 243 (2017) 812–822.
- [3] X. Liu, T. Ma, N. Pinna, J. Zhang, Two-Dimensional Nanostructured Materials for Gas Sensing, Adv. Funct. Mater. 1702168 (2017) 1–30.
- [4] G. Lu, L.E. Ocola, J. Chen, Gas detection using low-temperature reduced graphene oxide sheets, Appl. Phys. Lett. 94 (2009) 083111.