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GO/2D WS_2 Based Humidity Sensor †

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Abstract: In this work, 2D WS_2 nanosheets prepared by the exfoliation of WS_2 with Li-intercalation was combined with GO produced by the Hummer method for humidity sensing applications. The GO and WS_2 solutions were mixed with an equal concentration and coated on conductometric transducers. Sensing measurements towards humidity (0–80% RH) at room temperature revealed that the humidity response of hybrid was substantially higher by a factor of 3–9 depending on the RH value compared with those of GO and WS_2. Moreover, no cross sensitivity to common gaseous compounds was observed. Therefore, the GO/2D WS_2 composite is a highly promising humidity sensor.

Keywords: two-dimensional WS_2; graphene oxide; humidity sensor

1. Introduction

Two-dimensional (2D) nanostructures of transition metal dicalchogenide (TMD) such as tungsten disulfide (WS_2) and moblybdenum disulfide (MoS_2) nanosheets have earned considerable interest in humidity-sensing applications due its large specific surface area, rapid charge transport and 2D-quantum effects [1–3]. In particular, WS_2, a n-type semiconductor with a band gap of 1.3–1.4 eV has been widely used in the fields of sensors, solar cells, photocatalysts, energy storage, filed effect transistors and biosensors due to its unique semiconducting and 2D properties [4,5]. Similarly, 2D graphene oxide (GO) nanosheets are known to be promising for humidity sensing at room temperature [6–8]. However, there has been no report of their combination for humidity sensing.

In this work, the advantageous properties of two 2D materials are combined by forming WS_2/GO heterostructures, presenting a new humidity sensor based on WS_2-GO composite. GO/2D WS_2 nanohybrid are prepared by the exfoliation of graphite and WS_2 powders and is systematically studied for humidity sensing at room temperature. Its performance is compared with those of GO and 2D WS_2.

2. Materials and Methods

2.1. Synthesis of SnS_2 Nanostructures

2D WS_2 sheets were prepared by exfoliation of WS_2 following the protocol described previously [5]. A suspension of 3 g of WS_2 bulk powder in 20 mL of 1.7 M tert-butyl-lithium in pentane was prepared and then stirred for 72 h at 25 °C in argon atmosphere. The Li-intercalated material was separated by filtration in argon atmosphere and the intercalated compound was washed several times with hexane. Next, the separated TMDs with intercalated Li was placed in water (100 mL) and repeatedly centrifuged. The obtained material was then dried in vacuum oven at 50 °C for 48 h. GO solution was prepared by the standard Hummer method. The as-prepared material was characterized by Transmission and scanning electron microscopy (TEM and SEM).

2.2. Sensors Preparation and Characterization

The transducers were made of alumina planar substrates (3 mm × 3 mm) equipped with 2 pairs of conductometric transducers. The GO and 2D WS_2 solutions were mixed with the ratio of 1:1 (2.5:2.5 mg/mL) and then deposited on conductometric transducers with interdigitaed electrodes. Morphological analysis was carried out by SEM. The sensors were then introduced in a stainless-steel test chamber for the sensing tests. Gas and humidity sensing tests have been carried out by the flow through method in a thermostatic sealed chamber with controlled temperature and humidity with the setup reported earlier [9]. Dry air certified bottles have been used as gas source and certified mass flow controllers to reproduce desired gaseous composition inside the test chamber. The sensors were tested toward humidity with RH values in the range of 0–80% at room temperature. Nitrogen dioxide, hydrogen, ammonia, acetone and ethanol were also tested as possible interfering species at room temperature.

3. Results and Discussion

3.1. Characterization Results

A detailed characterization result of the 2D-WS_2 nanostructure using TEM has been reported previously [2]. It was shown that nanosheet structures contain highly ordered crystal domains of WS_2. On an edge, layer fringes analysis revealed that the number of WS_2 atomic layers is 3–4 and the distance between adjacent layers is also close to 0.6 nm. In contrast, GO was highly disorder and mostly monolayer with lattice spacing of around 0.3 nm.

3.2. Sensing Results

Figure 1 reports the conductance of 2D WS_2, GO and hybrid GO/2D WS_2 in response to a sequence of humidity pulses with RH ranging from 0% to 80%. It is seen that the conductance values of all sensors increase rapidly upon exposure to humidity, indicating charge transfer from H_2O molecules to sensor surface. In addition, the 2D WS_2 based sensor exhibits relatively high baseline conductance but low humidity response compared with the GO one. After combining them into the hybrid film, the baseline conductance decreases greatly by more than two orders of magnitude while the humidity response is substantially higher than that of GO by a factor of 3–9 depending on the RH value. Moreover, no cross sensitivity to other tested gaseous compounds was observed at room temperature. Therefore, the combination of GO and 2D WS_2 is an effective mean to enhance the humidity response of 2D nanostructure and the GO/2D WS_2 hybrid structure is promising for highly sensitive and selective humidity measurement.

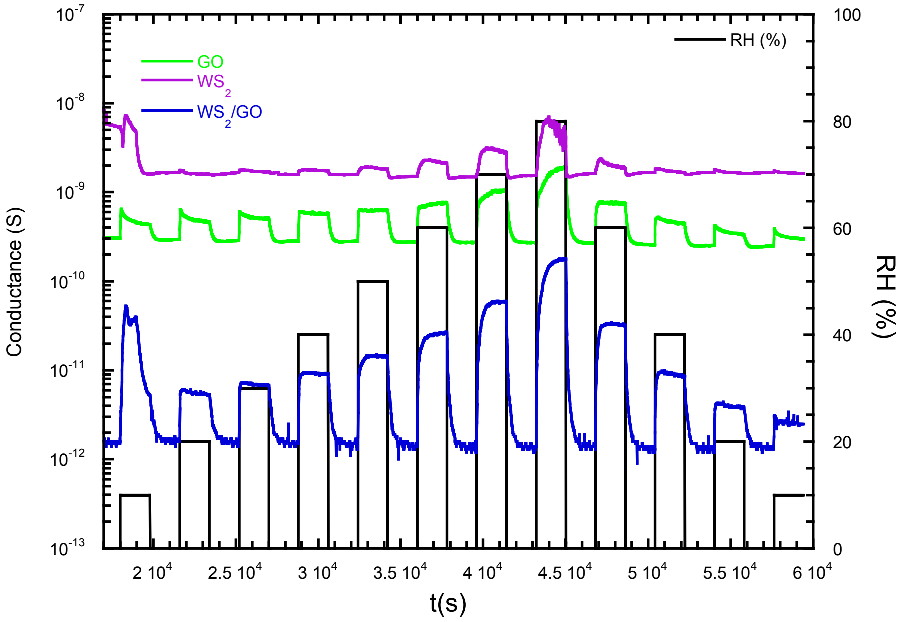

Figure 1. Conductance variations of GO, 2D WS_2 and GO/2D WS_2 sensors subjected to various pulses of humidity with RH values ranging from 0% to 80% at room temperature.

4. Conclusions

In conclusion, nanocomposite containing 2D WS_2 nanosheets prepared by the exfoliation of WS_2 with Li-intercalation and GO produced by the Hummer method have been studied for humidity sensing applications. The GO and WS_2 solutions were mixed with an equal concentration and coated on conductometric transducers. Sensing measurements towards humidity (0–80% RH) at room temperature revealed that the humidity response of hybrid was substantially higher by a factor of 3–9 depending on the RH value compared with those of GO and WS_2. Moreover, the composite sensor display no cross sensitivity to common gaseous compounds including nitrogen dioxide, hydrogen, ammonia, acetone and ethanol. Therefore, the GO/2D WS_2 composite is highly promising for humidity sensing applications.

Author Contributions: Elisabetta Comini and Gorgio Sberveglieri performed gas-sensing measurements, Anurat Wisitsora-at and Wojtek Wlodarski offered concepts and wrote the manuscript. Zdenek Sofer, Carmen C. Mayorga Martinez and Martin Pumera prepared the sensor materials.

Conflicts of Interest: The authors declare no conflict of interest.

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