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Recovery of Reacted MoS_2-based Gas Sensor Using UV-LED Illumination

*Yunsung Kang, Kyeongseob Hwang, Eunhwan Jo and Jongbaeg Kim**
School of Mechanical Engineering, Yonsei University,
50 Yonsei-ro, Seodaemun-gu, Seoul 120-749, Republic of Korea
kimjb@yonsei.ac.kr

Abstract:

This paper reports a unique method to recover MoS_2-based gas sensor to its initial unreacted resistance value using UV-LED illumination after the exposure to NO_2 of 3~10 ppm. The recovery mechanism involving photo-generated electron-hole pairs in MoS_2 was proposed and experimentally verified, while the identical sensor without UV could not recover the original resistance. The recovery of resistance under UV-LED illumination after the exposure to different concentrations of NO_2 was also demonstrated. Our approach to recover the reacted MoS_2 using UV-LED is highly advantageous for the MoS_2-based room temperature gas sensor to be reusable unlike many existing works on 2D nanomaterials-based room temperature gas sensors that may not recover the initial state after the exposure to target gas.

Key words: Molybdenum disulfide (MoS_2), Nitrogen dioxide (NO_2) sensor, UV-LED illumination, Recovery, Room temperature gas sensor

Introduction

Nanomaterials which can be applied to room temperature gas sensing have attracted much interest to simplify the fabrication process and sensor design. Recently, two-dimensional (2D) transition metal dichalcogenides (TMDCs) have been studied for room temperature gas sensor [1]. Of many 2D TMDCs, molybdenum disulfide (MoS_2) has received significant attention as chemical sensing material due to high surface-to-volume ratio and its unique electrical property such as a varying band gap as the number of layers changes [2]. MoS_2 is also known to be functional to detect harmful gases at room temperature, however, it requires elevated temperature (~200°C) to recover the original resistance after the exposure to target gas [3]. In this work, we propose a novel method to recover the original resistance of MoS_2-based gas sensor at room temperature using ultraviolet light-emitting diode (UV-LED) illumination that could induce the desorption of gas molecules absorbed onto the MoS_2 surface after NO_2 exposure.

Results and Discussion

Fig.1 depicts the optical microscope image of fabricated sensor. The fabrication process is as follows. Firstly, commercially available (6 Carbon Technology) MoS_2, which was synthesized by chemical vapor deposition (CVD) on SiO_2 substrate, is prepared. After that, the metal (Cr/Au) electrodes with 15 μm gap are deposited and patterned through a shadow mask by evaporation. The Raman spectra of CVD-grown MoS_2 on SiO_2 substrate are presented in Fig. 2. The difference in Raman shift between E_{2g} and A_{1g} peaks is used to determine the number of MoS_2 layers. In our sample used, we could estimate that the number of MoS_2 layers on the SiO_2 substrate is

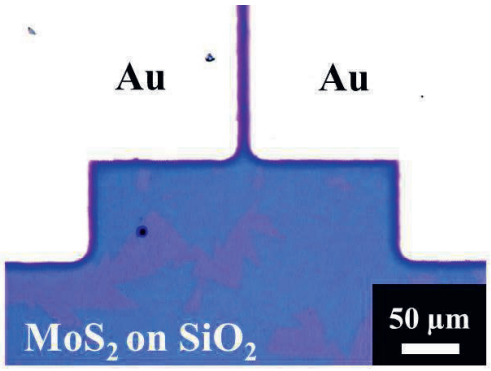

Fig. 1. The optical microscope image of fabricated sensor. Cr/Au electrodes with 15 μm gap are deposited and patterned on the CVD-grown MoS_2 through shadow mask by evaporation.

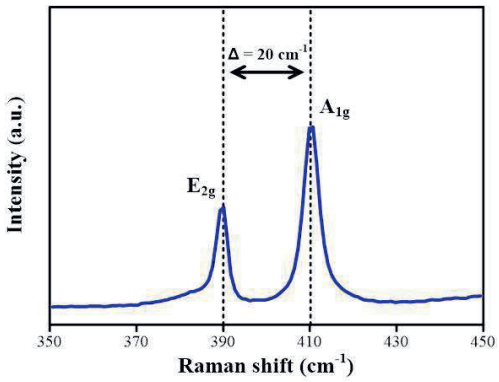

Fig. 2. Raman spectra of MoS_2 on SiO_2 substrate. The Raman shift, Δ represents the difference between E_{2g} and A_{1g} peaks, which determines the number of MoS_2 layers. It was estimated that bilayered MoS_2 pieces were used in our sensor.

two. Fig.3 shows the response of MoS_2 at the exposure to 10 ppm NO_2 and the effect of UV-LED illumination to the recovery of the sensor after NO_2 exposure. The changed resistance of MoS_2 right after the NO_2 supply was turned off didn't recover in the absence of UV light. With the aid of UV-LED illumination, however, elevated resistance in MoS_2 decreased to its original value before the exposure to NO_2. This would be originated from the role of photo-generated electron-hole pairs in MoS_2. The photo-generated holes could react with $NO_{2\ (ads)}^-$ remaining on the surface of MoS_2 after NO_2 exposure. This reaction induces the desorption of gas molecules from the surface of MoS_2 by converting the $NO_{2\ (ads)}^-$ to $NO_{2\ (gas)}$ state. The remaining photo-generated electrons could also contribute to the reduction of resistance in MoS_2. The inset in Fig. 3 shows the optical image of the experimental setup and the operating power consumption of 275 nm UV-LED was 31.38 mW. Fig. 4 provides the response of MoS_2 to NO_2 at the concentrations from 9 down to 3 ppm with- and without the recovery process assisted by UV-LED illumination. Unlike the insignificant change in recovery of sensing signal after exposure to different concentrations of NO_2 (Fig. 4a), the recovery of resistance in MoS_2 was confirmed with the aid of UV-LED illumination (Fig. 4b). This is a highly advantageous aspect of our approach in that the sensor can discriminate the different concentrations of the target gas.

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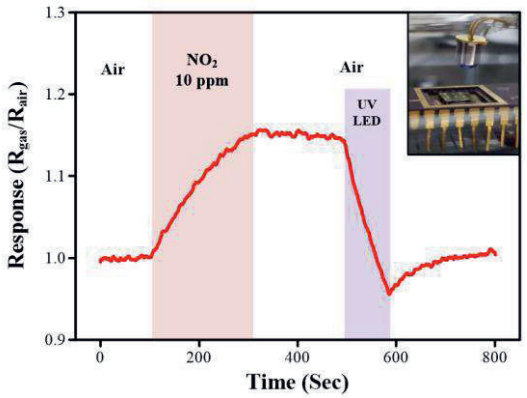

Fig. 3. The response of MoS_2 at the exposure to 10 ppm NO_2 and the effect of UV-LED illumination to the recovery of the sensor after NO_2 exposure. The inset shows the optical image of the experimental setup.

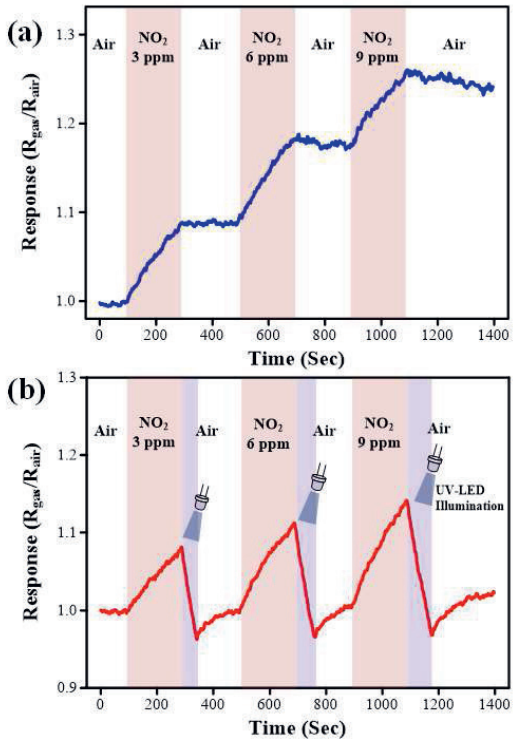

Fig. 4. The response of MoS_2 to NO_2 at the concentrations from 9 down to 3 ppm (a) without- and (b) with the recovery process assisted by UV-LED illumination.

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