Sensors & Actuators: B. Chemical 329 (2021) 129138

Contents lists available at ScienceDirect

Sensors and Actuators: B. Chemical

journal homepage: www.elsevier.com/locate/snb

Insight into mechanism of temperature-dependent limit of NO_2 detection using monolayer MoS_2

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ARTICLE INFO

Keywords:
Monolayer MoS_2
Gas sensor
Thermal treatment
In-situ Raman spectroscopy
Defect generation
Detection limit

ABSTRACT

Recently, many literatures report on the excellent performance of MoS_2-based NO_2 sensing, however, lacking the study on its thermal stability. Here, the insight mechanism in NO_2 sensor reactivity of monolayer MoS_2 at different temperatures from 25 to 200 °C was investigated. The relative effect of the morphological properties of the sensor and gas sensor reactivity at different temperatures was observed using in situ Raman mapping, optical microscope, and scanning electron microscope to demonstrate the mechanism of temperature-dependent limit of NO_2 detection in ppb. By increasing the temperature from 25 to 100 °C, the response of the sensor significantly improves (4.8 % vs. 54.4 %) at 200 ppb, and its limit of NO_2 detection strongly decreases (48.0 vs. 6.9 ppb). Interestingly, the sensor performance from 100 to 150 °C is likely equivalent to a limit of detection (LoD) that varies from 8.1 to 6.9 ppb, and the LoD slightly increases to 15.0 ppb at 200 °C. The line damages were found in monolayer MoS_2 basal plane by heating the sample up to 200 °C, that affect to the recovery of the NO_2 sensor. This study reveals an effective approach that may be useful in developing a gas sensor with a high response and limit of NO_2 detection in the ppb scale.

1. Introduction

The development of industrial processes, vehicles, and power plants is necessary in the era of modern industry; however, this leads to the increase in toxic gas emissions [1]. NO_2 is a typical toxic gas that strongly affects human respiratory systems and the environment [2]. Monitoring the air quality index is important for air pollution control. Therefore, the fabrication of NO_2 sensors with a low limit of detection, high selectivity, and fast response/recovery time is essential. In recent years, NO_2 sensors based on two-dimensional (2D) materials have been studied owing to their high surface to volume ratio, which results in their highly sensitive electrical response to their surface atmosphere [3–8]. Among various 2D materials, graphene has exhibited excellent gas sensing performance with a high response [9–11]. However, the excellent sensing properties of graphene for many types of gases renders it a low-selectivity sensing material [12]. Monolayer MoS_2 has been considered as a promising alternative to graphene and conventional metal-oxide sensing materials because of its high selectivity for NO_2 and soft-heated operation [13–16]. The key factor in improving NO_2 sensing response is the enhancement of the number of generated surface free electrons on the MoS_2 basal plane, which react with the NO_2 gas. In recent years, studies on the photo-induced gas sensing performance of MoS_2 at room temperature have been widely published [13,17–19]. However, the developed MoS_2 devices require light emitting diodes or

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https://doi.org/10.1016/j.snb.2020.129138
Received 22 June 2020; Received in revised form 24 October 2020; Accepted 27 October 2020
Available online 31 October 2020