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Synthesis and Enhanced Gas Sensing Properties of MoS_2 Nanoflakes

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Abstract

Morphology and structure control is an efficient way to improve the sensing performance of sensing materials. In this work, MoS_2 nanoflakes were synthesized via a facile hydrothermal route without any template. The sensing measurements reveal that the MoS_2 nanoflakes not only exhibit high response to NO_2 but also reduce the working consumption. The improved sensing properties are mainly attributed to the few layer nanoflakes structure and high specific surface area, which provides more active edge and sufficient room for reactions.

Key words: MoS_2, nanoflakes, NO_2, gas sensing, room temperature

Introduction

MoS_2, a p-type semiconductor, received increasing attention because its promising layered structure which facilitates the intercalation of molecules and ions between layers, and exhibits potential application in gas sensor devices[1]. Although some team began to study the sensing property of MoS_2 in recent years, the high operating temperature and relative low sensitivity are still the major limitation for achieving widespread applications[2]. One method to improve the properties of gas sensors is controlling the dimension and morphology of nanomaterials to enlarge the surface to volume ratio[3]. In this work, we report a facile way to produce MoS_2 nanoflakes which show high sensing performance for NO_2 detection at room temperature.

Experimental

MoS_2 nanoflakes were synthesized via a simple hydrothermal method by using $Na_2MoO_4{\cdot}2H_2O$ and L-cysteine as reactant, the pH of the solution was modulated by oxalate acid. The hydrothermal process maintained for 48 h under 200℃. The different molar ratio of Mo and S make the different morphology of production, and the Mo/S was controlled by the molar ratio of $Na_2MoO_4{\cdot}2H_2O$ and L-cysteine The samples were named 1-MoS_2 and 3-MoS_2 for Mo/S=1 and 3, respectively.

The samples were pasted on interdigitated Au electrodes previously patterned on SiO_2 for further gas sensing test. The sensing properties were detected by a homemade sensing test system.

Results and discussion

Microstructure

Figure 1 shows that the morphologies and structures of 1-MoS_2 and 3-MoS_2 samples. The morphology of these two MoS_2 samples changed from nanospheres to nanoflakes as the Mo/S ratio changed from 1 to 3. The lattice fringes in two samples with a constant spacing of 0.610 nm ascribed to the (002) plane of MoS_2, which illustrate that the Mo/S ratio only change the morphology of MoS_2.

Gas sensing property

Figure 2a present the sensing response of these two samples to 300 ppm NO_2 at different temperatures. The result indicated that the 3-MoS_2 exhibited the excellent sensing property (189.52%) at room temperature, while the sensitivity of 1-MoS_2 reached maximum(25.8%) at 150℃. The dynamic response of 3-MoS_2 under different concentration from 10-400 ppm of NO_2 at room temperature was revealed in Figure 2b, which illustrate that this sensor exhibited excellent response and recovery characteristic to different concentration of NO_2.

MoS_2 nanoflakes shows its p-type semiconductor character in this case, NO_2 molecules capture electrons from MoS_2 conductance band, which thicken the hole accumulation layer and decrease the resistance

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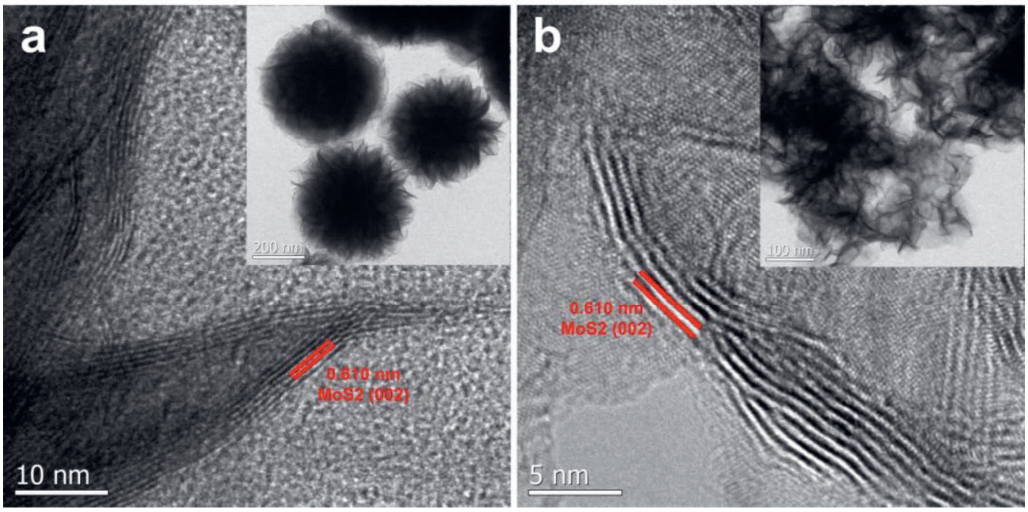

Figure 1: The morphology and structure of (a)1-MoS_2 nanospheres and (b) 3-MoS_2

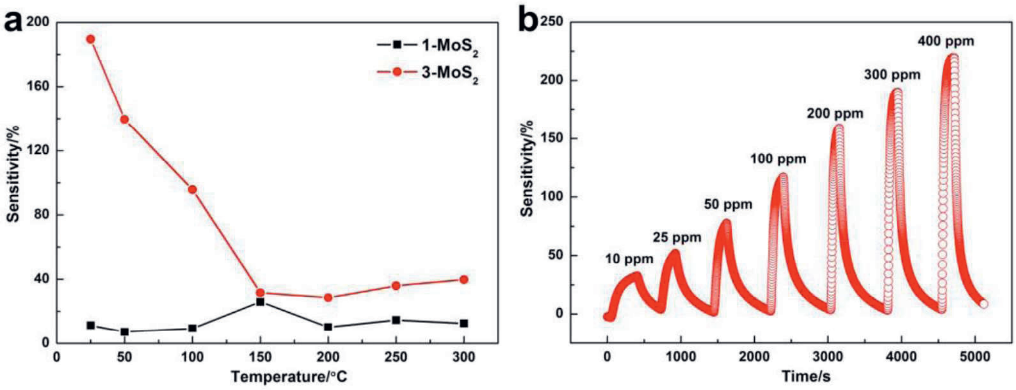

Figure 2: (a) The responses of 1-MoS_2 and 3-MoS_2 working at different temperature to 300 ppm NO_2. (b) Dynamic response of 3-MoS_2 nanosheets at room temperature.

of the sensors[4]. A proposed chemical interaction mechanism is given by Eq.(1).

$$MoS_2+NO_2(gas) = MoS_2+NO_2^-(ads)+h^+ \qquad (1)$$

The enhancement in gas sensing properties on 3-MoS_2 nanoflakes were attributed to the high surface area. Comparing with the 1-MoS_2 nanoflakes, 3-MoS_2 nanoflakes were looser, the sheets are thinner which exposed increased active edge of MoS_2 and provide more room for chemical reaction with gas.

Conclusions

In summary, changing the molar ratio of Na_2MoO_4 and L-cysteine is a efficient way to control the morphology of MoS_2 nanostructures, from nanospheres to nanoflakes. The sensor based on the 3-MoS_2 nanoflakes increasing the sensitivity(189.52%) as well as reducing the working temperature comparing with 1-MoS_2 nanospheres. The enhancement of sensing properties are ascribed to the thinner flakes and large specific surface area whcih increased active edge and reaction rooms of 3-MoS_2 nanoflakes.

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