Application of SnO_2 nanoparticle as sulfide gas sensor using UV/VIS/NIR spectrophotometer

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Abstract. Sulfide gas monitoring is required to protect organisms from its toxicity. Nanoparticles of metal oxides have characteristics that applicable as sensors for controlling environmental pollution like sulfide gas. Thin film of SnO_2 as one part of the sulfide gas sensor was synthesized with the chemical liquid deposition method, and characterized by UV/VIS/NIR-Spectrophotometer before and after gas application, also using FTIR, SEM and XRD. Characterization studies showed nanoparticle sizes from the diameters range of 38-71 nm. Application of SnO_2 thin film to sulfide gas detected by UV/VIS/NIR Spectrophotometer with diffuse reflectance showed chemical reaction by the shifting of maximum % R peak at wavelength of 1428 cm. The benefit of measurement of sulfide gas using this SnO_2 nano thin film is that it could be done at the room temperature.

Keywords: metal oxide, SnO_2, sulfide gas sensor, UV/VIS/NIR-Spectrophotometer

1. Introduction

Carbon disulfide, CS_2 is one of gas that produced by many activities in viscose rayon production process, petroleum or natural gas drilling and refining, also pulp production, which is using Kraft method [1]. The toxicity level of this gas can harm organisms. At low concentration it can affect the nervous system, while at high level can cause death. The monitoring of CS_2 concentration becomes very important nowadays, and nanoparticle of metal oxide as one type of material applied as sensors can control this environmental pollution. The research of nanoparticle synthesis for improving the sensor system of CS_2 become increases [2]. The previous research results showed that SnO_2 nanoparticle can be applied as sensor of gas used the electrically method by conductance to change the sample upon exposure of the gas. In this research, it also showed that SnO_2 gave chemical reaction when it applied to adsorb CS_2 detected by UV/VIS/NIR Spectrophotometer. The benefit of measurement of sulfide gas using SnO_2 nano thin film is that it could be done at the room temperature and low cost production.

2. Materials and methods

Thin film of SnO_2 can be produced by deposition of this metal oxide on the glass substrate. Soda lime float glass with 1-1.2 mm of thickness (Yancheng Huida Medical Instruments Co.) was used in this experiment. The substrate was cleaned by rinsing with acetone at 40°C for 15 minutes, then rinsed with ethanol at room temperature, and finally washed with distilled water and dried. $SnCl_2.2H_2O$ and NaOH were used as the precursors, and the deposition was done by spraying. The annealing temperatures were varied from 200ºC - 500ºC. Thin film of SnO_2 as the sulfide gas sensor was synthesized by a simple method of chemical liquid deposition, and characterized using UV/VIS/NIR-Spectrophotometer

(Shimadzu UV3101PC) at λ = 200-2400 nm, FTIR Spectrophotometer, Optic and Scanning Electron Microscope, and also XRD with Cu[(Kα)] with $\lambda\alpha_1$ = 1.54060 nm and $\lambda\alpha_2$ = 1.54439 nm. The application of thin film to sulfide gas was tested using 20 ppm of CS_2 cylinder gas standard with flow of 0.2 L/min.

3. Results and discussion

Infrared spectrum of SnO_2 nano thin film showed specific peaks for annealing temperature variation from 200ºC to 500ºC (figure 1). It was analyzed by FTIR in the range from 400 to 4500 cm^{-1}. The bands between 400-800 cm^{-1} were correlated to metal oxide bond (SnO_2). Bands around 800-1700 are due to the oxygen stretching and bending frequency. Infrared spectrum of SnO_2 nano thin film showed specific peaks at 3425 cm^{-1}, 1625 cm^{-1}, and 615 cm^{-1} for annealing temperature 500ºC. It can be seen from the spectrum that the highest annealing temperature showed results as most clear spectrum. Functional group –OH seems to be wider at the lower annealing temperature, showed at band around 3400 cm^{-1}.

Optical measurement of SnO_2 nanoparticle was carried out with UV/VIS-spectrophotometer, and analysis result showed that the increasing of annealing temperature can decrease the transmittance or increase the absorbance (figure 2). The results were the average spectrum from ten times measurements, and done at the room temperature with the glass substrate slide as the standard.

XRD pattern of SnO_2 variance 500ºC were calculated based on Bragg law,

$$n\lambda = 2d \sin\theta \tag{1}$$

where λ is X-ray wavelength, d is the distance between lattice planes, θ is the angle of incidence with lattice plane, and n is integer [3, 4]. The observed peaks of XRD pattern in the figure 3 are indexed assuming SnO_2 phase, giving peaks position, with Miller indices (110), (101), (200), (211), (220), (310) and (301) planes. Characterization studied by SEM showed nanoparticle sizes from the range 38-71 nm of diameters (figure 4).

The application of SnO_2 thin film for CS_2 gas sensor tested using UV/VIS/NIR-spectrophotometer showed a shifting of %Reflectance peak from wavelength 1274 cm^{-1} with 45.21 % of reflectance to wavelength 1428 cm^{-1} with 79.21%. This response was used as a starting point for detecting gas quantitatively at wavelength 1428 cm^{-1} (figure 5). The research will be continued with statistical approach of quantitative analysis by making standard curve and determination of detection limit.

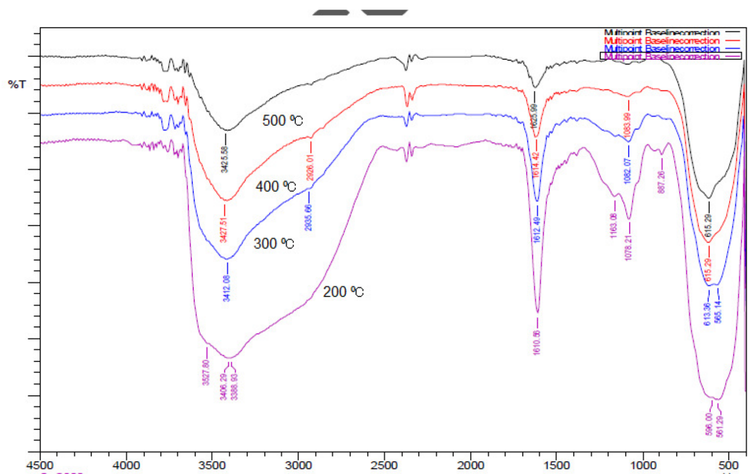

Figure 1. Infrared spectrum of SnO_2 nano thin film at various annealing temperatures of 200ºC, 300ºC, 400ºC, and 500ºC.

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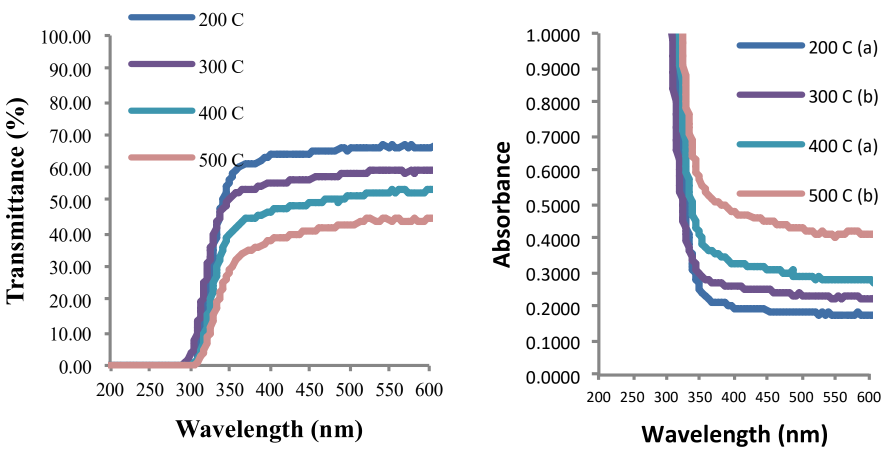


(a) (b)

Figure 2. UV/VIS (a) transmittance and (b) absorbance spectrum of SnO_2 nano thin film.

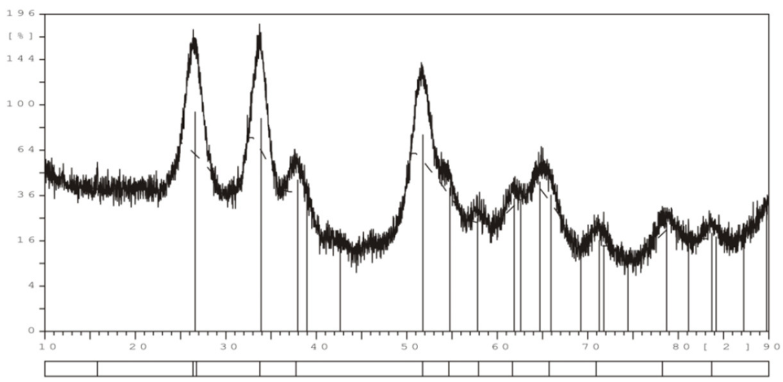
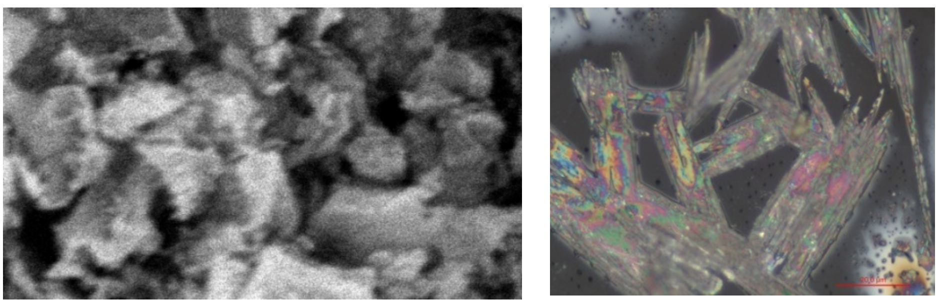


Figure 3. XRD spectrum of SnO_2 nano thin film.



(a) (b)

Figure 4. (a) SEM and (b) optical microscope morphology of SnO_2 nano thin film.

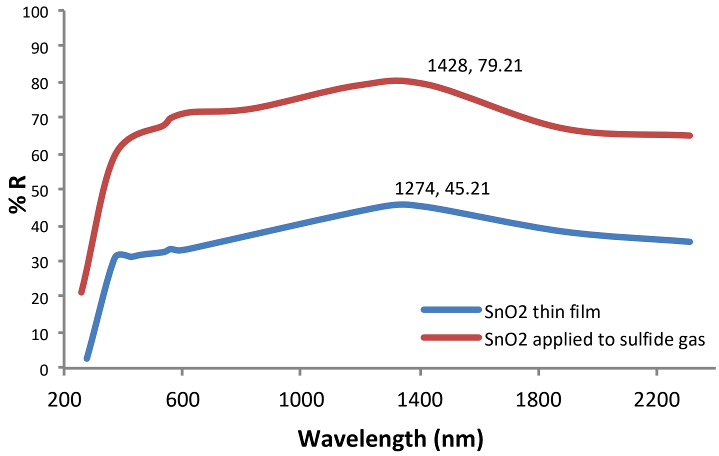


Figure 5. Application of SnO_2 to sense 20 ppm of CS_2 gas standard.

4. Conclusions

SnO_2 nanoparticle can be produced by a simple chemical liquid deposition, and at annealing temperature of 500 ºC it can be achieved particle sizes diameter in the range of 38-71 nm. Application of SnO_2 thin film to sulfide gas detected by UV/VIS/NIR Spectrophotometer with diffuse reflectance showed a specific chemical reaction by the shifting of maximum % R peak from wavelength of 1274 to 1428 nm.

Acknowledgements

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