Fabrication and Characterization Of Volatile Organic Compound Gas Sensor Based GaN Thin Film

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Abstract. Gas sensor using GaN film has been proposed on silicon substrate by sol gel spin coating technique with parameters growth temperature of 850°C, spinner rate of 1000 rpm, Ga2O3 molarity of 1.33 M and N sources derived from nitrogen gas at a flow rate of 100 sccm. From the results of testing the electrical properties of the gas environment type volatile organic compound, especially hydrogen gas turns electric resistance GaN semiconductor thin films declined sharply from 1.5 x 10^{-2} to 7 x 10^{-3} Ohm.cm. The GaN thin film not only exhibited good sensitivity to hydrogen gas but also showed good linearity in the characteristic of the sensitivity to hydrogen gas concentration.

1. Introduction
Historically, research and development of semiconductor alloy materials has been closely related to the development of optoelectronic devices and electronic devices. One device electronics is quite important is the gas sensor to monitor the gases that are harmful such as hydrogen (H2), Methane (CH4), carbon monoxide (CO), acetylene (C2H2), and nitrous oxide (NO2) at relatively high temperature. Semiconductor materials used for gas sensor applications are being studied extensively by researchers as a semiconductor alloy metal oxides such as SnO2 (Yamazoe et al., 1992, Morrison, 1982), but because this material has an energy band gap is not so wide, thermostability of the gas sensor made of SnO2 have less good quality. Gas sensor made of SnO2 are known to have poor sensitivity for many gas and has a response time that is long on the sensor signal (Gopel and Schierbaum, 1995). To increase the sensitivity of the gas sensor is required of semiconductor materials that have wide energy band gap and thermostable at high temperatures (Shur et al., 1999, Sardar et al., 2003, Kung et al., 1995, Srite et al., 1992, Akasaki et al., 1994, Fertita et al., 1994). GaN material is a material most appropriate alternative, because in addition to these materials have a wide energy band gap (3.4 eV) also has the energy band gap structure with direct transition (direct bandgap). Another advantage of this material is to have the chemical stability, mechanical, and thermal high, so that the stable used in extreme environmental conditions. Therefore in this study examined the potential of GaN material for gas sensor applications.

This research is directed to the study of the manufacture of gas sensors to produce devices gas sensor has high sensitivity for monitoring gases that are harmful such as hydrogen (H2), methane (CH4), carbon monoxide (CO), acetylene (C2H2), and nitric oxide (NO2) at relatively high temperatures. Thus the problem in this research are: "How sensitivity gas sensors are made of a semiconductor material GaN? " To answer this research has been carried out a study of growing GaN thin films with the techniques of sol gel spin coating by optimizing the parameters of growth like...
molarity gel, the rpm of the spinner, and the growth temperature thus found parameter of growth that is optimum to produce GaN thin films which have physical characteristics are good for gas sensor applications. Furthermore, the next stage will be made of a gas sensor GaN thin films to be tested the sensitivity of some kind of gas, in terms of the initial phase of test gas used is nitrogen gas and hydrogen gas.

2. Experimental
The gas sensor made of a GaN material that growth with sol gel spin coating technique with the parameters growth temperature of 850°C, the spinner rate of 1000 rpm, Ga₂O₃ molarity of 1.33 M and N sources derived from nitrogen gas 100 sccm. The structure of the gas sensor made in this study as shown in Figure 1.

![Figure 1. Structure of gas sensor](image1)

The undoped GaN thin films were grown by sol gel spin coating on a Silicon (111) substrate. For ohmic contact, Al electrodes was deposited on the front surface of the substrate. To investigate the sensitivity of sensor shown in Figure 2.

![Figure 2. Schematic diagram for gas sensor measurement](image2)

Where Rs is the resistance of GaN, Vc is the circuit voltage, VRL is the output voltage, and RL is the load resistance. The sensitivity was defined as \((R_{\text{gas}} - R_{\text{air}}) / R_{\text{air}} \times 100\%\) (Dae, 2003), where \(R_{\text{gas}}\) and \(R_{\text{air}}\) are the electrical resistance of GaN sample in gases to be detected and the in air, respectively.
3. Results and Discussions
To determine the potential for using GaN as gas sensor the resistance of GaN films was measured on hot plate $300^\circ$ C. Figure 3 shown profile of I-V characterization of GaN gas sensor in nitrogen and hydrogen gases.

![Figure 3. Current variation of GaN film as function of voltage](image)

As shown in Figure 3, the current increased with increasing voltage, which is general property of ohmic contact of semiconductor. The gas sensing properties of GaN based sensor was tested in chamber containing hydrogen and nitrogen gases. The sensitivities of the sensor, which correspond to the resistance variation of GaN when it was exposed to these gases, are shown in Figure 4.

![Figure 4. The sensitivity of GaN film as function of Gas flow rate at $300^\circ$ C](image)

As shown in Figure 4, GaN film have high selectivity to hydrogen gas compared to nitrogen gases. Environmental sensitivity gas sensors in the hydrogen gas is about 60% more sensitive than in a nitrogen gas environment around 50% for the test gas with a gas flow rate of 100 sccm.

4. Conclusion
From the results of the characterization of the sample gas sensor made of GaN semiconductors with spin coating techniques with the parameters of growth: growth temperature of $850^\circ$ C, the spinner rate of 1000 rpm, $\text{Ga}_2\text{O}_3$ molarity of 1.33 M and N sources derived from nitrogen gas 100 sccm, it shows the level of sensitivity which is good especially for the testing of nitrogen gas and hydrogen gas.
Environmental sensitivity gas sensors in the hydrogen gas is about 60% more sensitive than in a nitrogen gas environment around 50% for the test gas with a gas flow rate of 100 sccm. From the test results on samples of the gas sensor, it can be developed a prototype gas sensor for gas leak detection systems are very useful for the many security laboratory use or exploit gas.

5. References
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