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Thin Film InN Resistive Gas Sensor Device for The Diagnosis of Liver Dysfunction

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Abstract

Sub-ppm detection of exhaled breath ammonia is relevant for the diagnosis of liver malfunction. In order to detect such low range concentration, we have demonstrated a thin film InN resistive gas sensor device for the sub-ppm ammonia gas sensing. The thin film InN epilayer is grown by the RF-MOMBE technique. The lower detection limit of the InN gas sensor is 0.2 ppm for the ammonia gas. The percentage change in current variation ratio (ΔI/Io) is measured for the 1 ppm and 0.8 ppm ammonia is 0.3 % and 0.1 % respectively. Therefore, InN gas sensor is highly sensitive for the exhaled breath ammonia gas at 200 °C. The InN gas sensor can be utilized for the detection of the liver dysfunction.

1. Introduction

Liver cirrhosis is a chronic liver disease. According to the survey in the year 2010, approximately 1 million of death occurred because of liver failure which is approximately 2% of all death worldwide in that particular year [1]. Early detection may prevent the development of sever conditions such as liver cirrhosis, so it is required to detect and monitor the liver condition regularly. Currently, people are using invasive methods, such as blood test, blood biopsy for the detection of liver disease. To avoid the unnecessary pain to the patients, researchers are trying to utilize volatile organic compounds (VOCs) present in the breath for monitoring the liver disease. Ammonia is an important biomarker present in breath related to the liver and renal disease [2]. The concentration ranges of ammonia (< 0.275 ppm) for healthy patient and ammonia (> 0.745 ppm) in case of liver cirrhosis [3, 4]. Low concentration trace of the gas can be detected by various other approaches such as metal oxide based sensors, conducting polymer-based ammonia sensor, optical sensor. But these methods may lack either in selectivity, sensitivity or fast response [5]. In comparison to these InN shows high electron accumulation near the surface, long-term chemical stability, bio-compatibility and high sensitivity [6-8] which make it a promising material for ultra-thin resistive type gas sensor application [9, 10]. Apart from this InN have the narrow band gap (0.6−0.7 eV), high mobility (> 1000 $cm^2/V\cdot s$), and excellent electron transport characteristics over a wide range of temperature.

In this work, we have demonstrated the RF-MOMBE technique to grow (~ 40 nm) thin film InN epilayer on sapphire substrate. The InN resistive gas sensor device can sense sub ppm trace of ammonia gas and the lower detection limit is 0.2 ppm for ammonia. Hence thin film InN gas sensor device can be utilized as a breath sensor for the detection for liver malfunction.

2. Results and Discussion

The schematic of the device structure in Fig. 1. Comprised of (~ 40 nm) thin film of InN grown on AlN buffer layer at the top of the sapphire substrate. RF-MOMBE epitaxial technique is used to grow the thin film of InN. The RF-MOMBE system combines the characteristics of both MBE and MOCVD is suitable for mass production of InN. The AlN layer deposited by nitridation processes is used as a buffer layer to minimize the lattice mismatch between the InN and the sapphire substrate. The pair of electrodes of (Au/Al/Ti) is deposited on InN layer for measuring the change in current on the exposure of the gas. The thickness of the electrode is (50nm/ 50nm/200nm). The thin film of Pt is deposited on InN epilayer acts as a catalyst to enhance the reaction rate of the exhaled breath ammonia gas.

The performance of the device mostly depends on the InN thin film. The InN film is very sensitive for the ammonia gas. The sensing mechanism is schematically represented in Fig .2.

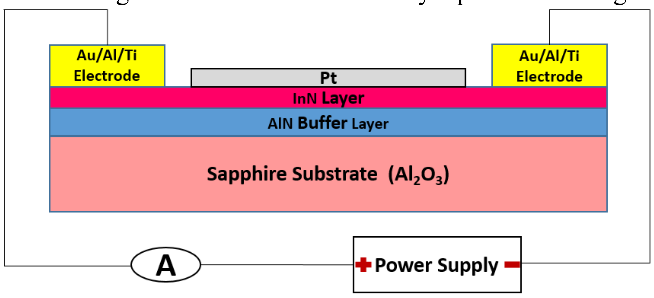

Fig. 1. Schematic structure of the device consists of (~40nm) InN thin film coated with Pt, grown on AlN buffer layer on Sapphire Substrate

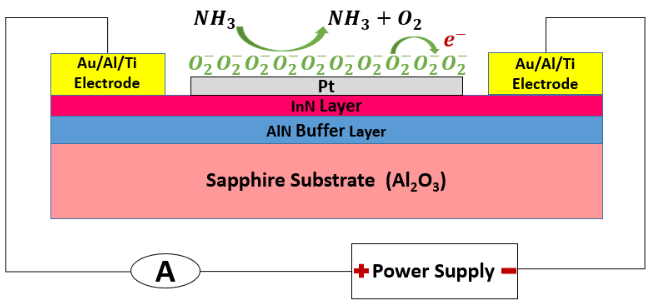

Fig. 2. Schematic representation of device mechanism in air background

It is found universally that a huge electron accumulation occurs at the surface of the InN[11, 12]. When the InN film interacts with air at higher temperatures (>100°C), oxygen started to adsorbed on the InN surface in both molecular (O^{2-}) as well as atomic (O^{-}) form. The physically adsorbed oxygen acts as an ion acceptor which leads to charge transfer from the sensing film to the adsorbed oxygen. Which results in decreasing the conductivity. When the ammonia is exposed on the sensing film it takes out the physically adsorbed oxygen from the surface of the InN, leave behind an electron which increases the conductivity of the film by reverse charge transfer[13]. When sub ppm ammonia gas is exposed on the sensor in air background at 200°C temperature, the current response increases with the increasing concentration. The current response for 0.2 ppm, 0.5 ppm, 0.8ppm, 1ppm and 5 ppm is shown in Fig .3. The percentage change in current variation (ΔI/Io) response on the InN gas sensor for the different concentration such as 0.8ppm, 1 ppm is 0.3% and 0.1% respectively in Fig. 4.

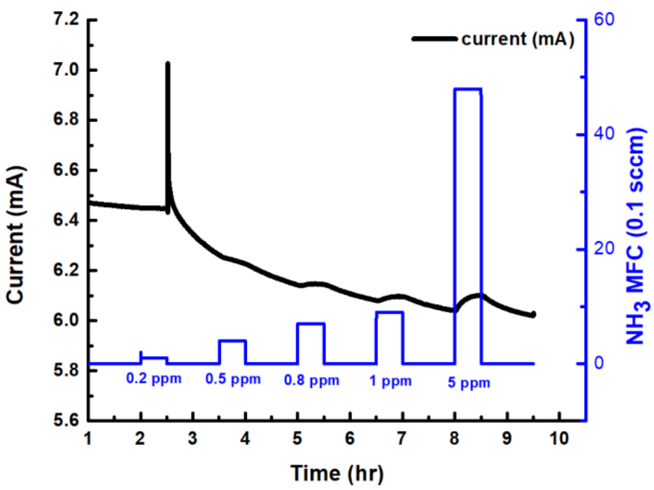

Fig. 3. The current response of the sensor for different concentration of NH3 gas in air background at 200°C temperature.

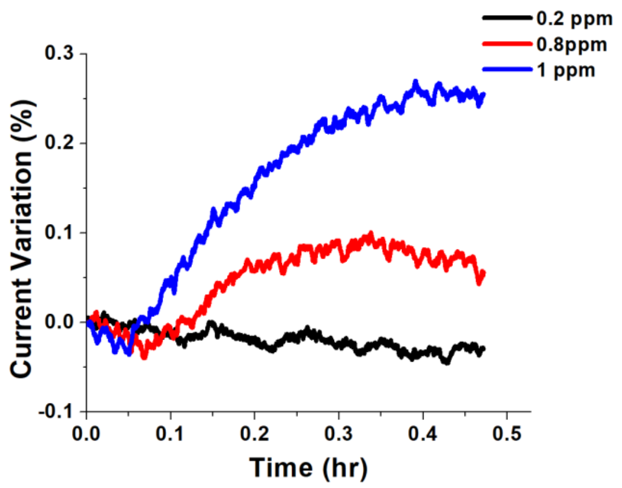

Fig. 4. Current variation (ΔI/Io) with respect to different concentration of the NH3 gas in air background

3. Conclusions

A thin film InN (~40 nm) resistive gas sensor device has been fabricated using RF-MOMBE technique. The fabricated sensor is used for sub ppm range of ammonia gas sensing. The sensor is exposed to the different concentration of ammonia gas and it shows the different response for different concentrations. The limit of detection (LOD) is observed 0.2 ppm for ammonia gas. Hence the fabricated sensor can be utilized in breath sensing for diagnosis of liver dysfunction.

Acknowledgements

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