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AlInN resistive ammonia gas sensors

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ABSTRACT

We report the growth of AlInN epitaxial layer and the fabrication of AlInN resistive NH_3 gas sensor. It was found that surface morphology of the AlInN was rough with quantum dot like nano-islands. It was also found that the conductance of these AlInN nano-islands increased as NH_3 gas was introduced into the test chamber. At 350 °C, it was found that measured incremental currents were around 105, 127, 147 and 157 μA when concentration of the injected NH_3 gas was 500, 1000, 2000 and 4000 ppm, respectively.

1. Introduction

Ammonia (NH_3) is a colorless gas with a special odor. It is commonly used in various industrial sectors [1]. Although NH_3 is extensively used in our daily life, people may develop a burning sensation in eyes, nose and throat when exposed to NH_3. Inhalation of NH_3 vapor could also cause acute poisoning to people. Hence, detecting and measuring NH_3 vapor concentration in the environment is necessary. The most commonly used method to detect gaseous NH_3 was either by potentiometric electrodes [2] or by infrared devices [3]. However, these devices are expensive and bulky. It is also possible to detect NH_3 vapor concentration by semiconducting metal oxide materials [4–9]. It has been shown that near surface conductivity of these materials changes upon exposure to certain gas molecules. Furthermore, it was found that such resistance change is related to various defects such as oxygen vacancy, metal vacancy or others [10,11].

Recently, it was found that III-nitride epitaxial layer can also be used to detect gaseous butane, propane, ethyl alcohol and carbon monoxide [12]. Although III-nitride-based materials are extensively used as light emitting diodes [13,14], ultraviolet photodetectors [15] and high power electronics [16], only few reports on III-nitride-based sensor for volatile organic compounds can be found in the literature [12]. Compared with metal oxide sensors, we should be able to integrate III-nitride-based gas sensors with III-nitride-based photodetectors and electronic devices on the same chip. Other than the binary GaN, ternary AlInN has attracted much attention in recent years. Compared with AlGaN and InGaN, AlInN is much less known due to the difficulty in growing high quality crystal [17]. It has been shown that AlInN can be grown lattice matched to GaN with an indium content of ∼17–18%. However, it is still difficult to grow high quality AlInN due to severe phase separation caused by the large disparity in cation sizes as well as by differences in thermal properties of the binary constituents [18]. It has also been reported that epitaxial AlInN layers are defective in general with a significant amount of aluminum vacancy, indium vacancy or nitrogen vacancy. Similar to metal oxide sensors, these defects should be able to enhance the reaction of gas molecular on sample surface and thus enhance the responsivity of AlInN-based gas sensors. In this study, we report the growth of AlInN. Sensing properties of the fabricated AlInN resistive NH_3 gas sensors will also be discussed.

2. Experimental

Samples used in this study were grown on a *c*-plane (0 0 0 1) sapphire (Al_2O_3) substrate by metalorganic chemical vapor deposition. Details of the growth can be found elsewhere [19]. Prior to the growth, we annealed the sapphire substrates at 1060 °C in H_2 ambient to remove surface contamination. We then deposited a 30-nm-thick low-temperature GaN nucleation layer at 530 °C, a 2-μm-thick n-type unintentionally doped GaN ($n = 3 \times 10^{16}\ cm^{-3}$) buffer layer at 1020 °C, and a 500-nm-thick n-type unintention-

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