



Contents lists available at ScienceDirect

Superlattices and Microstructures

journal homepage: www.elsevier.com/locate/superlatticesInfluence of hydrogen impurity on the resistivity of low temperature grown p-Al_xGa_{1-x}N layer (0.08 ≤ x ≤ 0.104)

Feng Liang^{a, b}, Ying Yang^{a, *}, Degang Zhao^{a, c, **}, Desheng Jiang^a,
Zongshun Liu^a, Jianjun Zhu^a, Ping Chen^a, Wei Liu^a, Shuangtao Liu^a,
Yao Xing^a, Liquan Zhang^d, Wenjie Wang^e, Mo Li^e, Yuantao Zhang^f,
Guotong Du^f

^a State Key Laboratory on Integrated Optoelectronics, Institute of Semiconductors, Chinese Academy of Science, Beijing 100083, China^b College of Materials Science and Opto-Electronic Technology, University of Chinese Academy of Sciences, Beijing 100049, China^c School of Electronic, Electrical and Communication Engineering, University of Chinese Academy of Sciences, Beijing 100049, China^d Suzhou Institute of Nano-Tech and Nano-Bionics, Chinese Academy of Sciences, Suzhou 215123, China^e Microsystem & Terahertz Research Center, Chinese Academy of Engineering Physics, Chengdu 610200, China^f State Key Laboratory on Integrated Optoelectronics, College of Electronic Science and Engineering, Jilin University, Changchun 130023, China

ARTICLE INFO

Article history:

Received 7 November 2017

Received in revised form 1 December 2017

Accepted 1 December 2017

Available online xxx

Keywords:

p-AlGa_N

Resistivity

Hydrogen impurity

ABSTRACT

Low temperature grown p-AlGa_N layer with a small resistivity is crucial to improve the performance of the GaN-based laser diodes (LDs). In this study, growth temperature of the p-Al_xGa_{1-x}N (0.08 ≤ x ≤ 0.104) layers are controlled to be relatively low, and the influence of hydrogen impurity on the resistivity is investigated in detail. According to the dependence of hole concentration and resistivity on hydrogen impurity concentration, it is found that when Mg doping concentration is unchanged, reducing hydrogen impurity concentration in p-Al_xGa_{1-x}N (0.08 ≤ x ≤ 0.104) layers could reduce the resistivity effectively, which is attributed to weaken the compensation or passivation effect of hydrogen impurities on Mg acceptors. A p-Al_{0.09}Ga_{0.91}N layer with a low resistivity of 4.6 Ω cm has been achieved.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Recently, GaN-based laser diodes (LDs) are attracting unprecedented attention due to their tremendous application prospect in mini projector, laser display and solid state lighting [1–6]. For the GaN-based LDs, a p-Al_xGa_{1-x}N layer with low aluminum content, e.g. 8%–10%, is often used as the cladding layer (CL) and has great influence on the performance of GaN-based LDs [7–10]. Nevertheless, the performance of the GaN-based LDs would be poor, since the p-type AlGa_N CL is conventionally grown at the optimal temperature of higher than 1000 °C and results in a thermal degradation of InGa_N/Ga_N quantum wells [11–14]. Thus, the growth and the annealing temperatures of p-Al_xGa_{1-x}N cladding layer are preferentially to

* Corresponding author.

** Corresponding author. State Key Laboratory on Integrated Optoelectronics, Institute of Semiconductors, Chinese Academy of Science, Beijing 100083, China.

E-mail addresses: yangjing333@semi.ac.cn (Y. Yang), dgzhao@red.semi.ac.cn (D. Zhao).<https://doi.org/10.1016/j.spmi.2017.12.002>

0749-6036/© 2017 Elsevier Ltd. All rights reserved.

be relatively lower to weaken the thermal degradation of InGaN/GaN quantum wells. However, a p-Al_xGa_{1-x}N layer grown under lower temperatures often shows a high resistivity which is bad for the GaN-based LDs. Especially, for the Mg-doped GaN material, the hydrogen impurity often passivated the Mg acceptor by forming a neutral Mg–H complex due to the H-containing MOCVD growth environment, thus the resistivity of Mg-doped GaN is often relatively high [15,16]. In addition, as far as we know now, for the resistivity low temperature grown p-Al_xGa_{1-x}N layers, only one study reported that the resistivity is about 2.1 Ω cm where the Al content is only 7% and the growth temperature is 964 °C [8]. Therefore, in order to obtain a p-Al_xGa_{1-x}N layer with a lower resistivity when growth and annealing temperature is relatively low, the role of hydrogen in p-AlGaN layer should be investigated deeply.

In this study, the influence of hydrogen impurity on low temperature grown p-Al_xGa_{1-x}N (0.08 ≤ x ≤ 0.104) layers has been investigated in detail through X-Ray diffraction (XRD), secondary ion mass spectroscopy (SIMS), Hall measurements and room temperature (RT) photoluminescence (PL) spectra. It is found that reducing the hydrogen impurity in p-Al_xGa_{1-x}N layers would decrease the resistivity of low temperature grown p-AlGaN layer.

2. Experiments

The schematic structure of p-Al_xGa_{1-x}N samples is shown in Fig. 1. All p-Al_xGa_{1-x}N samples were grown on c-plane sapphire substrates by MOCVD in an Aixtron 6 × 2 inch reactor, which is equipped with the close coupled showerhead (CCS). Trimethylaluminum (TMAl), trimethylgallium (TMGa), ammonia (NH₃), and bis(cyclopentadienyl) magnesium (Cp₂Mg) were used as the organometallic precursors for Al, Ga, N, and Mg, respectively. First, a thin unintentionally-doped GaN nucleation layer (LT u-GaN) and a 2 μm-thick unintentionally-doped GaN (u-GaN) was successively grown on the sapphire substrates. Next, about 1 μm-thick Mg-doped p-Al_xGa_{1-x}N layer was grown at 900 °C and 400 mbar. A thin and heavily Mg-doped GaN (p⁺⁺-GaN) layer was grown above to ensure a good ohmic contact during Hall measurement, and the thickness of this p⁺⁺-GaN capping layer is around 25 nm. Finally, X-Ray diffraction (XRD), rapid thermal annealing, Hall measurements, room temperature (RT) photoluminescence (PL) spectra and secondary ion mass spectroscopy (SIMS) were taken. (002) ω-2θ rocking curves and the asymmetrical (105) reciprocal space map (RSM) were obtained by XRD with Cu Kα1 radiation (Rigaku SmartLab 3 KW), and the working current and voltage of XRD is 30 mA and 40 kV. For the Hall measurement, the resistivity of the p-Al_xGa_{1-x}N sample is measured through Van De Pauw method. The p-Al_xGa_{1-x}N samples were first cut into square with size 1 cm × 1 cm, and then the metal indium is used to form ohmic contact with p-Al_xGa_{1-x}N samples. The depth profiles of the impurities in p-Al_xGa_{1-x}N layers were measured by SIMS (ATOMIKA SIMS 4500) with Cs⁺ ions as the primary source, and the raster size is 80 μm × 80 μm and the collected area (in diameter) is 30 μm.

Flow rate ratio between TMAl and TMGa is varied to obtain p-Al_xGa_{1-x}N layers with different aluminum content, i.e. 8.0%–10.4%, and the corresponding p-Al_xGa_{1-x}N samples are named as A, B, C, D and E, respectively. More detailed growth conditions are listed in Table 1. In addition, the growth rate is calculated according to the *In situ* optical reflectance curves.

3. Results and discussion

XRD rocking curves at (002) reflection and reciprocal space map (RSM) of the 5 samples were measured to check the aluminum content and strain relaxation of p-AlGaN layer, respectively. In Fig. 2(a), there are two diffraction peaks in the high resolution (002) ω-2θ XRD rocking curves, and the diffraction peaks located in the low and high value of 2θ are originated from GaN and AlGaN materials, respectively. According to the values of 2θ, for samples A-E, the aluminum content of p-AlGaN layers can be obtained, i.e. 8.0%, 8.6%, 9.0%, 9.6% and 10.4%, respectively. It indicates that the aluminum content of p-AlGaN

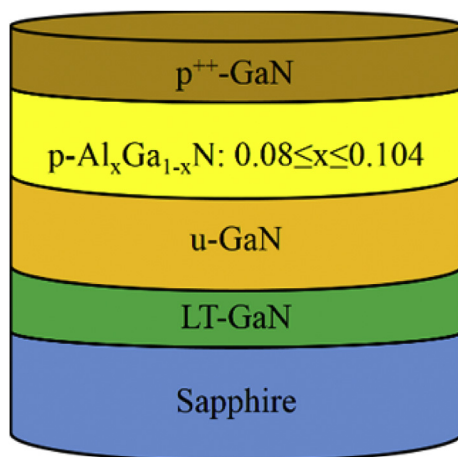


Fig. 1. A schematic illustration of p-Al_xGa_{1-x}N samples.

Download English Version:

<https://daneshyari.com/en/article/7939499>

Download Persian Version:

<https://daneshyari.com/article/7939499>

[Daneshyari.com](https://daneshyari.com)