checksimilarityartikeljournal 2

by Iwan Susanto

Submission date: 17-Apr-2022 03:20PM (UTC+0700)
Submission ID: 1812439201
File name: Artikel_2019_2_Jurnal_Phys_Iwan.pdf (526.34K)
Word count: 2322
Character count: 12117

Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Morphology and surface stability of GaN thin film grown on the short growth time by Plasma Assisted Molecular Beam Epitaxy

To cite this article: Iwan Susanto *et al* 2019 *J. Phys.: Conf. Ser.* **1364** 012067

View the article online for updates and enhancements.

This content was downloaded from IP address 140.213.136.64 on 05/02/2020 at 07:44

Morphology and surface stability of GaN thin film grown on the short growth time by Plasma Assisted Molecular Beam Epitaxy

Iwan Susanto[1,2], Chi-Yu Tsai[1], Tia Rahmiati[2], Fachruddin[2], Ing-Song Yu[1]

[1]Department of Materials Science and Engineering, National Dong Hwa University, Hualien 97401, Taiwan
[2]Department of Mechanical Engineering, State Polytechnic of Jakarta, Depok 16424, Indonesia

*iwan.susanto@mesin.pnj.ac.id

Abstract. Gallium nitride (GaN) has successfully grown at the short time on the sapphire substrate by plasma-assisted molecular beam epitaxy (PAMBE). The great regular spotty pattern associated with the high crystalline structure has generated perfectly on the GaN thin films monitored by RHEED. The hexagonal structure with the smooth surface condition has been obtained expressly through the surface morphology of GaN films. Moreover, the stability of surface composition was obviously achieved on the GaN thin film evidenced by the high percentage of GaN bonding created on the surface of films. Good quality on the surface morphology followed by the reliable stability of surface composition might even be reached through each the high crystalline and smooth surface of the substrate.

Keywords: gallium nitride; thin films; sapphire substrate; semiconductor; molecular beam epitaxy

1. Introduction

Gallium nitride is one amongst the semiconductor material that has been widely used for a few applications within the optoelectronics and electronic devices [1], [2]. Therefore, it absolutely was being developed to support for future technology through both electronic and optoelectronic components like high electrons mobility transistor [3], lead-emitting diode [4], solar cells [5], and sensor [6]. However, the performance and long live application will be restricted by the defect attended on the structure and morphology of GaN thin film[7]–[9]. Some reports are devoted to reduce the defects by molecular beam epitaxy (MBE) method[10]–[13]. Unfortunately, the investigating of morphology and surface stability of the GaN thin film at the short growth time has not been demonstrated. The high defect quantity could be generated on the surface closed to the interface between subtract and thin film. It might be created due to lattice mismatch resulted from both of materials [11]. As be known for lattice mismatch between the GaN with both c-plan and a-plan sapphire substrate is 13.9% and 2%, respectively [14]. It was confirmed that the defects were initiated from there site and they creep till the surface of GaN thin films [7], [8]. So, the purpose of this study was to observe the morphology and surface stability of GaN thin film grown on the short growth time using PAMBE method.

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

2. Methodology

The GaN thin films were grown on the sapphire substrate using the PA-MBE system. The growth temperature of GaN thin film was given at 600 °C during 20 minutes in the growth chamber. While, the thermal cleaning is carried out at the same temperature for 40 minutes to clean up the substrate from the contaminant. Meanwhile, pre-nitridation has done on the surface of the substrate for 10 minutes to create the bonding connection between substrate and nitrogen atoms. During the above process, the *in-situ* characterization is performed by reflection high energy electron diffraction (RHEED) operating at 20 kV. Meanwhile, the *ex-situ* characterizations are carried out on the GaN thin film after the growth process. The surface morphology and surface roughness are observed by a JEOL field emission scanning electron microscopy (FESEM) with accelerating voltage 15 kV and atomic force microscopy (AFM) by Nano Surf C3000, successively. Whereas the surface chemical composition and character properties are examined by VGS Thermo K-Alpha X-ray photoelectron spectroscopy (XPS).

3. Result and Discussion

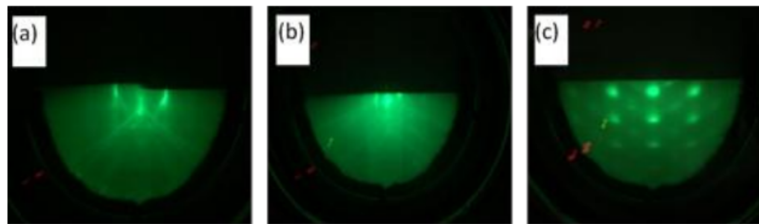

Figure 1. RHEED pattern images from (a) Substrate after thermal cleaning, (b) Substrate after nitridation and (c) GaN thin films grown on the substrate

Figure 1 display the RHEED pattern images for both substrate and GaN film. RHEED can be used for monitoring the character each surface condition and growth steps sample during epitxial GaN thin film inside the growth chamber. The streak closed to spot pattern with strong intensity shown on the Figure 1(a) correspond to crystalline structure which was formed on the surface of the substrate. The crystalline structure on the surface of substrate could facilitate perfectly the epitaxial growth for both atom gallium and nitrogen to construct the GaN thin films. While the spot pattern with higher intensity was also demonstrated by RHEED pattern shown in Figure 1(b). It indicates that the crystalline structure has consistently created after nitridation process. Its process was carried out to generate the bonding mechanism between nitrogen atoms and the surface of substrate. As was known that the pre-nitridation process might facilitate the nitrogen atom to initiate for establishing the nucleation site since nitrogen has both higher energy migration (1 eV) and higher adsorption (4.6 eV) compared to Ga [15]. Figure 1(c) shows the spot pattern image on the surface condition after the growth of GaN thin films. The spot pattern with great intensity show the crystalline structure formed on the GaN thin film. The pattern also indicate for which 3-dimension stage has been built on the surface of GaN thin film. The 3-dimension stage of GaN thin film could be constructed due to N-rich condition during epitaxial growth [16], [17]. Additionally, the great regular spotty pattern was also indicated a single crystal wurtzite GaN formed on the film [18].

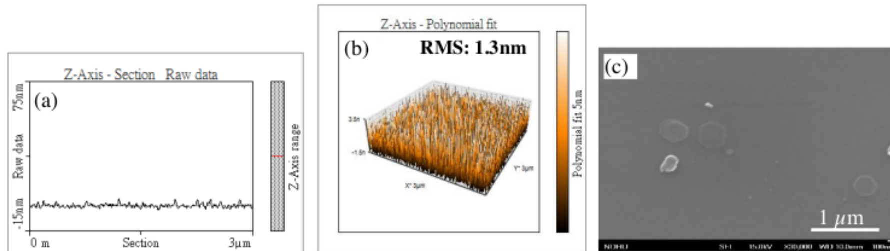

Figure 2. Surface GaN thin films (a) Line scan and (b) 3-dimension surface using AFM, (c) Morphology by FE-SEM

Figure 2 show the surface morphology of GaN thin films demonstrated by AFM and FE-SEM image. The line scan observed throughout 3 μm shown on Figure 2(a) exhibit both the valley and peak value is obtained at -2.8 and 3.8 nm, serially. Meanwhile, the 3-dimesion image with scan area 3 μm x 3 μm displayed on the Figure 2(b) demonstrate the peak and valley created in the range 3.5 nm and -1.5 nm, respectively. Whereas the root mean square (RMS) value scanned in the area has been achieved at 1.3 nm. Based on those values, the smooth surface has been constructed obviously on the surface of GaN thin film. In addition, Figure 2(c) display the FE-SEM image from the surface morphology of GaN thin film. The hexagonal shape with 300 to 400 nm in size corresponded to structure the GaN film has been created on the thin films. While, the bright particle with irregular shape related to GaN cluster also appear on the surface of film. The cluster might be created during the growth epitaxial at the low temperature. As be well-known that the low growth temperature could facilitate for creating the gallium metallic (Ga-Ga) on the surface of films [19].

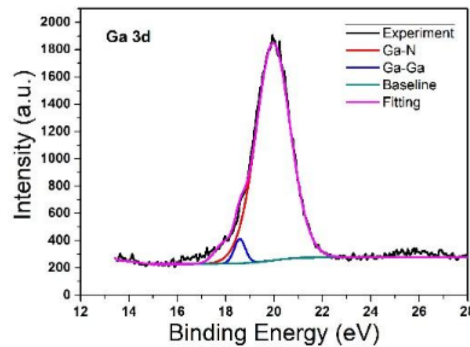

Figure 3. Deconvoluted of Ga 3d for GaN thin film by XPS

Figure 3 display the deconvoluted of Ga-3d for chemical surface composition of GaN thin film which carried out by XPS technique. The XPS spectra was divided into two region namely Ga-N and Ga-Ga bonding [20], [21]. According to XPS fitting using Advantage software in the area orbital of Ga-3d, the main peak positions of Ga-N bonding located at 19.96 eV, whereas the Ga-Ga bonding related to Ga metallic located at 18.58 eV. The percentage of Ga-N bonding was achieved up to 94.6%, while the Ga-Ga bonding was only 18.5 %. The higher percentage of Ga-N bonding might indicate the more stable the surface composition of GaN thin films. Thus, the ratio value of $R_{Ga\text{-}Ga/Ga\text{-}N}$ is 0.03 which

indicate the strong stability for surface composition. The lower ratio value shows the higher both purity and stability the surface composition constructed on the GaN thin films.

4. Conclusion

The GaN thin film was successfully grown on the sapphire substrate by plasma assisted molecular beam epitaxy in the short time of growth. The spotty pattern with strong intensity associated to high crystalline structure generated on the surface of GaN thin film, was demonstrated trough *in-situ* monitoring of RHEED. The smooth surface condition with 1.3 nm of RMS value has been constructed on the surface of GaN thin film, whereas the hexagonal shape related to GaN structure has also created on it. High percentage of Ga-N bonding corresponded to stability of surface composition has been generated on the GaN thin film.

References

[1] D. Zhu, D. J. Wallis, and C. J. Humphreys, "Prospects of III-nitride optoelectronics grown on Si," *Reports Prog. Phys.*, vol. 76, no. 10, 2013.
[2] B. S. J. Pearton and F. Ren, "GaN_electronics," no. 21, pp. 1571–1580, 2010.
[3] T. Hashizume, K. Nishiguchi, S. Kaneki, J. Kuzmik, and Z. Yatabe, "State of the art on gate insulation and surface passivation for GaN-based power HEMTs," *Mater. Sci. Semicond. Process.*, vol. 78, no. September 2017, pp. 85–95, 2018.
[4] J. T. Oh *et al.*, "High-performance GaN-based light emitting diodes grown on 8-inch Si substrate by using a combined low-temperature and high-temperature-grown AlN buffer layer," *J. Alloys Compd.*, vol. 732, pp. 630–636, 2018.
[5] S. R. Kodigala, "Surface studies and photoluminescence of GaN epitaxial layers grown by MOCVD technique for applications of solar cells and light emitting devices," *J. Alloys Compd.*, vol. 674, pp. 435–446, 2016.
[6] A. K. Pantazis, G. Konstantinidis, and E. Gizeli, "Characterization of a GaN lamb-wave sensor for liquid-based mass sensing applications," *IEEE Sens. J.*, vol. 14, no. 3, pp. 908–911, 2014.
[7] S. Krishna *et al.*, "Correlation of growth temperature with stress, defect states and electronic structure in an epitaxial GaN film grown on c-sapphire via plasma MBE," *Phys. Chem. Chem. Phys.*, vol. 18, no. 11, pp. 8005–8014, 2016.
[8] N. Aggarwal *et al.*, "Extenuation of Stress and Defects in GaN Films Grown on a Metal–Organic Chemical Vapor Deposition-GaN/c-Sapphire Substrate by Plasma-Assisted Molecular Beam Epitaxy," *Cryst. Growth Des.*, vol. 15, no. 5, pp. 2144–2150, 2015.
[9] B. G. Park *et al.*, "Comparison of stress states in GaN films grown on different substrates: Langasite, sapphire and silicon," *J. Cryst. Growth*, vol. 425, pp. 149–153, 2015.
[10] J. J. M. Law, E. T. Yu, G. Koblmüller, F. Wu, and J. S. Speck, "molecular beam epitaxy Low defect-mediated reverse-bias leakage in „ 0001 … GaN via high-temperature molecular beam epitaxy," vol. 102111, no. 0001, 2010.
[11] C. D. Lee *et al.*, "Role of Ga flux in dislocation reduction in GaN films grown on SiC(0001)," *Appl. Phys. Lett.*, vol. 79, no. 21, pp. 3428–3430, 2001.
[12] I. Susanto, K. Y. Kan, and I. S. Yu, "Temperature effects for GaN films grown on 4H-SiC substrate with 4° miscutting orientation by plasma-assisted molecular beam epitaxy," *J. Alloys Compd.*, vol. 723, pp. 21–29, 2017.
[13] G. Koblmüller, F. Reurings, F. Tuomisto, and J. S. Speck, "Influence of Ga/N ratio on morphology, vacancies, and electrical transport in GaN grown by molecular beam epitaxy at high temperature," *Appl. Phys. Lett.*, vol. 97, no. 19, pp. 22–25, 2010.
[14] L. Liu and J. H. Edgar, "Substrates for gallium nitride epitaxy.pdf," *Mater. Sci. Eng. R Reports*, vol. 37, pp. 61–127, 2002.
[15] Y. Alaskar *et al.*, "Towards van der Waals Epitaxial Growth of GaAs on Si using a Graphene Buffer Layer," *Adv. Funct. Mater.*, vol. 24, no. 42, pp. 6629–6638, 2014.

[16] S. S. Kushvaha, M. S. Kumar, A. K. Shukla, B. S. Yadav, and D. K. Singh, "RSC Advances Structural , optical and electronic properties of homoepitaxial GaN nanowalls grown on GaN template by laser molecular beam epitaxy," *RSC Adv.*, vol. 5, pp. 87818–87830, 2015.

[17] I. Susanto, T. H. Tsou, Z. P. Yang, C. Y. Lee, H. Li, and I. S. Yu, "Effects of N/Ga flux ratio on GaN films grown on 4H-SiC substrate with 4° miscutting orientation by plasma-assisted molecular beam epitaxy," *J. Alloys Compd.*, vol. 710, pp. 800–808, 2017.

[18] P. Kumar, J. Kuyyalil, and S. M. Shivaprasad, "Ga induced superstructures as templates for lattice matched hetroepitaxial growth of GaN on Si(111) substrate," *Appl. Phys. Lett.*, vol. 97, no. 22, pp. 28–31, 2010.

[19] J. K. Tsai *et al.*, "Effect of N to Ga flux ratio on the GaN surface morphologies grown at high temperature by plasma-assisted molecular-beam epitaxy," *J. Appl. Phys.*, vol. 95, no. 2, pp. 460–465, 2004.

[20] S. S. Kushvaha *et al.*, "Structural, optical and electronic properties of homoepitaxial GaN nanowalls grown on GaN template by laser molecular beam epitaxy," *RSC Adv.*, vol. 5, pp. 87818–87830, 2015.

[21] M. Mishra, T. C. S. Krishna, N. Aggarwal, M. Kaur, S. Singh, and G. Gupta, "(Pit assisted oxygen chemisorption on GaN surfaces," *Phys. Chem. Chem. Phys.*, vol. 17, no. 23, pp. 15201–15208, 2015.

checksimilarityartikeljournal 2

ORIGINALITY REPORT

12%	10%	8%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

#	Source	%
1	umpir.ump.edu.my Internet Source	3%
2	core.ac.uk Internet Source	2%
3	Iwan Susanto, Chi-Yu Tsai, Yen-Teng Ho, Ping-Yu Tsai, Ing-Song Yu. "Temperature Effect of van der Waals Epitaxial GaN Films on Pulse-Laser-Deposited 2D MoS2 Layer", Nanomaterials, 2021 Publication	1%
4	apps.dtic.mil Internet Source	1%
5	Fong Kwong, Li Li, Sue Ann, Zainuriah Hass. "Chapter 4 Gallium Nitride: An Overview of Structural Defects", IntechOpen, 2011 Publication	1%
6	confit.atlas.jp Internet Source	1%
7	repository.unair.ac.id Internet Source	1%

#	Source	Match
8	eprints.nottingham.ac.uk Internet Source	1 %
9	repository.bilkent.edu.tr Internet Source	<1 %
10	scholar.afit.edu Internet Source	<1 %
11	Man Young Sung, Woong-Je Sung, Yong-Il Lee, Chun-Il Park, Woo-Boem Choi, Sangsig Kim. "Effect of Excimer Laser Annealing on Optical Properties of GaN Films Deposited by R.F. Magnetron Sputtering", MRS Proceedings, 2011 Publication	<1 %
12	Loitsch, Bernhard, Fabian Schuster, Martin Stutzmann, and Gregor Koblmüller. "Reduced threading dislocation densities in high-T/N-rich grown InN films by plasma-assisted molecular beam epitaxy", Applied Physics Letters, 2013. Publication	<1 %

Exclude quotes On
Exclude bibliography On
Exclude matches Off