Extended Abstracts of the 2011 International Conference on Solid State Devices and Materials, Nagoya, 2011, pp228-229

Deep UV Light Emitting Diodes on AlN Templates Grown by Commercialized MOCVD (<1200°C)

Masahito Kurouchi, Misaichi Takeuchi and Yoshinobu Aoyagi

R-GIRO, Ritumeikan Univ.
1-1-1 Noji-Higashi, Kusatsu, Shiga, 525-8577, Japan
Phone: +81-77-561-3769 E-mail: kurouchi@fc.ritsumei.ac.jp

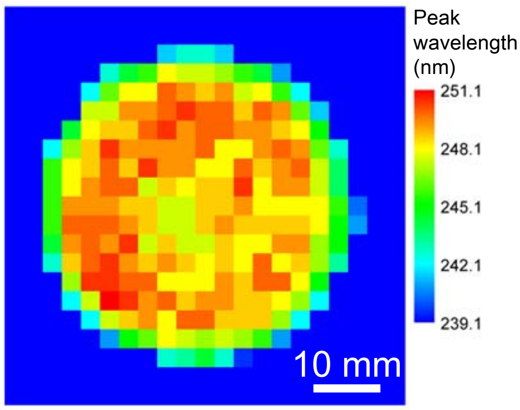
1. Introduction

Deep UV light emitting diodes (DUV-LEDs) based on AlGaN semiconductors have attracted much attention for compact systems of water purification, sterilization and ozone detection. Since these LED structures are grown on AlN templates in order to avoid crack formation in AlGaN, high-quality AlN templates are important. Growth of high-quality AlN templates generally requires high temperatures (>1300°C), whereas it is difficult to heat substrates at such high temperatures by commercialized metalorganic chemical vapor deposition (MOCVD) systems, wherein temperature limitations are around 1200°C. In addition, temperature ununiformity on wafers during the growth increases at high temperatures. In present work, we report the growth of high quality AlN templates in the range from 1080°C to 1150°C by new-concept MOCVD technique consisting of annealing after the growth of initial 200 nm-thick AlN [1] and succeeding AlN growth by flow modulation[2-3]. Highly uniform AlGaN layers, which were measured by photoluminescence (PL), were grown on these AlN templates. DUV-LEDs grown on these AlN templates were operated at ~265 nm

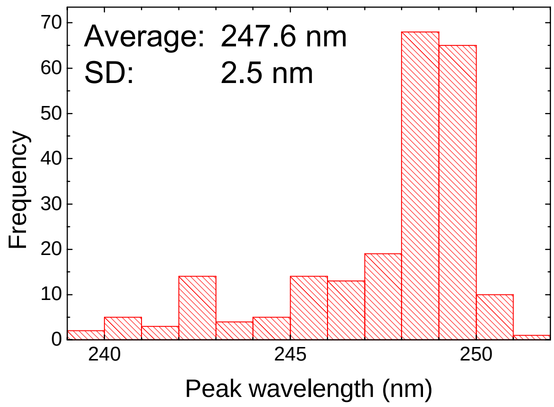
2. Experimental and results

MOCVD growth was performed in a commercialized reactor "AIXTRON AIX200/4RF-S" with an in-situ monitoring system "Laytec EpiCurve R-TT". Initial 200 nm-thick AlN layers were deposited on 2-inch c-plane sapphire substrates with including a mixture of N- and Al-polar grains, and then the epi-wafers were annealed for 30 minutes [1] to decompose the N-polar grains. Subsequently, 2.3 µm-thick AlN layers were overgrown by flow-modulation (FM) method [2-3]. These growth processes were done in the range from 1080°C to 1150°C. The full widths at half maximum (FWHMs) of x-ray rocking curves of the AlN templates were around 220 arcsec for (002) and 450 arcsec for (102).

In order to characterize the uniformity of the epilayers, a 0.88 µm-thick n-$Al_{0.61}Ga_{0.39}N$ layer grown at 1110°C on our AlN template. Optical uniformity was measured by a PL mapping system with an ArF excimer laser (λ=193 nm) for excitation. Figure 1 shows the distribution of the peak wavelengths of the near-band-edge (NBE) emission from n-$Al_{0.61}Ga_{0.39}N$. The deviation of the peak wavelengths was 247.6 ± 2.5 nm. Figure 2 shows the distribution of the peak intensities of the NBE emission. The deviation of the peak intensities was 475 ± 67 counts. This result indicates that the crystalline quality of n-$Al_{0.61}Ga_{0.39}N$ grown on our AlN template was fairly uniform. It is expected that the deviation of the crystalline quality of the AlN template was similar to that of the n-$Al_{0.61}Ga_{0.39}N$ layer.

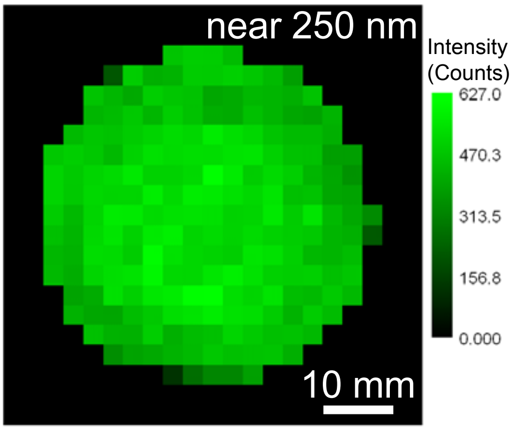


(a) Wafer map of peak wavelengths

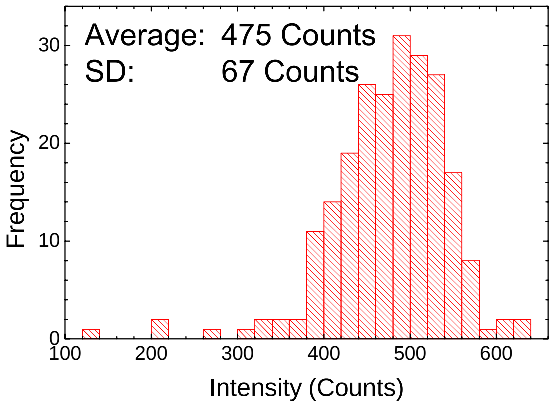


(b) Frequency distribution of peak wavelengths

Fig. 1 Distribution of peak wavelengths of near-band-edge (NBE) emission from n-$Al_{0.61}Ga_{0.39}N$ measured by photoluminescence.



(a) Wafer map of peak intensities



(b) Frequency distribution of peak intensities

Fig. 2 Distribution of emission intensities of NBE emission from n-$Al_{0.61}Ga_{0.39}N$ measured by photoluminescence.

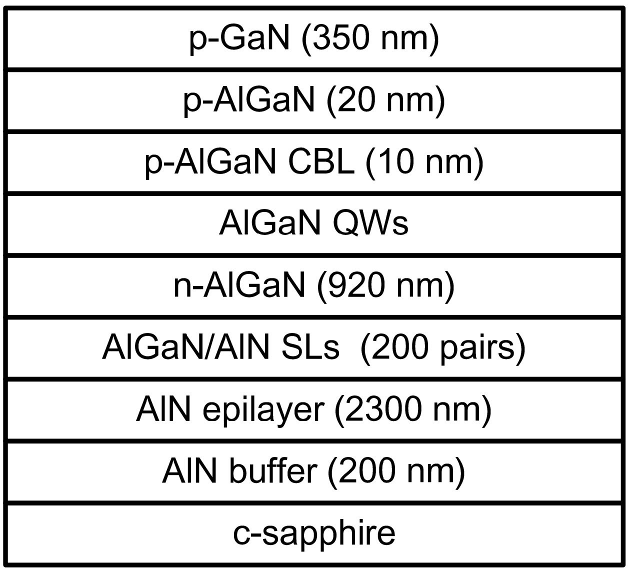


Fig. 3 Schematic diagram of LED structure grown on AlN template grown by new-concept MOCVD.

Heterostructures for DUV LEDs grown on our AlN templates are shown in Fig. 3. The active layers consisted of 3 multiple AlGaN quantum wells (QWs), and high-Al content p-type AlGaN carrier blocking layers (CBL) were inserted prior to p-type AlGaN layers and p-type GaN contacting layers. LED devices were fabricated as the following processes. After organic cleaning, finger-shaped mesa areas (size: ~500 μm × ~500 μm) were formed by a reactive ion etching (RIE) with the mixture gas of Cl_2 and Ar in order to access the n-AlGaN layers. n- and p-electrode materials were Ti/Al/Ti/Au and Ni/Au, respectively. Au pads contaceted on the n- and p-electrodes.

Electroluminescence properties of the bare LEDs were examined in pulse operation without any cooling system. The peak wavelength of emission was ~265 nm and the output power over 1 mW was obtained. This strong emission is attributed to our high-quality AlN templates.

3. Conclusions

High-quality AlN templates were successfully grown on 2-inch c-plane sapphires by using a new-concept MOCVD technique in the temperature range from 1080°C to 1150°C, which consists of annealing the mixed polarity AlN initial layers and the overgrowth by flow modulation MOCVD. The n-$Al_{0.61}Ga_{0.39}N$ layer grown on the AlN template showed fairly uniform optical properties. DUV LEDs (λ~265 nm) formed on these AlN templates performed emission over 1 mW. We believe that these results will lead to the future success of the DUV LEDs in the commercial field using the conventional MOCVD systems.

References

[1] M. Kurouchi, M. Takeuchi and Y. Aoyagi., IWN2010 (2010) AP1.37.
[2] M. Takeuchi, H. Shimizu, R. Kajitani, K. Kawasaki, T. Kinoshita, K. Takada, H. Murakami, Y. Kumagai, A. Koukitu, T. Koyama, S.F. Chichibu, Y. Aoyagi, J. Cryst. Growth **305** (2007) 360.
[3] M. Takeuchi, S. Ooishi, T. Ohtsuka, T. Maegawa, T. Koyama, S. F. Chichibu and Y. Aoyagi, APEX **1** (2008) 021102.