Growth and characterization of GaN epilayer on sapphire substrate by ammonia gas source MBE

Satoshi Kurai[1)], Shuichi Kubo[1)], Tomokazu Okazaki[1)], Tsunemasa Taguchi[1)],
Matt Rosamond[2)], Jim Van Hove[2)] and Peter Chow[2)]

1) Faculty of Engineering, Yamaguchi University
2-16-1 Tokiwadai, Ube, Yamaguchi 755-8611, Japan
tel : +81-836-85-9407 fax : +81-836-85-9401

2) SVT Associates, Inc.
7620 Executive Drive, Eden Prairie, MN 55344, USA
tel : +1-952-934-2100 fax : +1-952-934-2737

kurai@po.cc.yamaguchi-u.ac.jp

Metalorganic chemical vapor deposition (MOCVD) has widely been used for the fabrication of GaN-based optoelectronic devices. On the other hand, it is recognized that molecular beam epitaxy (MBE) is the best growth method to realize completely controlled-layered-structure and high-quality devices. Nitrogen plasma source is one of active nitrogen species to grow the group III nitride by MBE. However, the nitrogen plasma source is too active to migrate Ga atom freely on the growing surface, and this may result in the poor surface morphology in plasma-assisted MBE. Thermally decomposed ammonia is also used as the active species in MBE nitride growth. Two dimensional growth mode of GaN epilayer grown by ammonia gas source MBE with GaN buffer layer was reported, and in addition, strong and sharp excitonic emission was dominant in those samples.[1] These are merits of using ammonia gas as nitrogen source. The growth of high-quality GaN using ammonia as nitrogen source, and their structural, optical and electrical properties will be reported in this conference.

GaN growth was performed by ammonia gas source MBE system (SVT Associates, Inc BLT-N35). 8N-grade Ga, 6N-grade Al and 5N-grade ammonia gas were used as source materials. The sapphire (0001) as the substrate was etched in a H_3PO_4-H_2SO_4 solution before loading into the growth chamber. Nitridation and deposition of high-temperature AlN buffer layer were carried out at 850°C. The thickness of AlN buffer layer was about 200 Å. Undoped GaN epilayer was then grown at 800 °C. The growth rate of GaN epilayer was estimated to be about 1µm/min. Ammonia was cracked on the growing surface through all processes. Reflection high-energy electron diffraction (RHEED), atomic force microscopy (AFM), photoluminescence (PL), X-ray diffraction and Hall measurements were then carried out for the ammonia gas source MBE-grown GaN epilayer.

The streaky (1 x 1) RHEED pattern appearing after cool down indicates that the GaN epilayer grown by MBE using ammonia as nitrogen source had a Ga polarity. The surface AFM image measured for an area of 1 x 1 μm^2 was shown in Fig.1. The root mean square (RMS) roughness of the GaN epilayer was about 5 Å and step-like morphology was clearly observed. Many small pits, which corresponds to threading dislocations with screw component[2] were also observed and the density is estimated to be 10^9 cm^{-2}. Photoluminescence (PL) and photoreflectance (PR) spectra measured at 4.2 K with a He-Cd laser as an excitation source were shown in Fig. 2. Strong and narrow emission line observed at 3.4804 eV was attributed to radiative recombination of neutral donor-bound excitons (I_2). Free-exciton (X_A) line also appeared in PL and PR spectra. Temperature-dependent PL spectra ranged from 14 K to 280 K were shown in Fig. 3. Thermal depopulation effect between bound-exciton and free-exciton was clearly observed against the temperature increasing. Excitonic emission can be observed up to 280 K. High-resolution x-ray rocking curves were measured by multi-axis X-ray diffractometer with four-crystal monochromator. The FWHM of symmetric (002) and asymmetric (102) diffraction were 316 arcsec and 529 arcsec, respectively. They are slightly higher value than those of conventional MOCVD-grown GaN epilayers. With the pit density on AFM image and etch pit by H_3PO_4-H_2SO_4 etching (EPD=4 $\times 10^9$ cm^{-2}), GaN epilayer grown by MBE using ammonia as nitrogen source will contain larger amount of threading dislocations than conventional MOCVD-grown GaN. Van der Pauw Hall measurement was performed at room temperature. The carrier density and electron mobility were estimated to be 4 $\times 10^{17}$ cm^{-3} and 425 cm^2/Vs, respectively. Further improvement of the luminescence and electrical properties in the GaN epilayer grown by MBE using ammonia as nitrogen source will be obtained by reducing threading dislocation.

Acknowledgments

This work was financially supported by the MITI/NEDO/JRCM "Light for the 21st Century" national project. We acknowledge Mr. Tadashi Takahashi at UNIVERSAL SYSTEMS Co., Ltd. for the financial support.

References
[1] N.Grandjean et al. : J.Appl.Phys. **83** (1998) 1379.
[2] S. Keller et al. : Jpn.J.Appl.Phys. **37** (1998) L431.

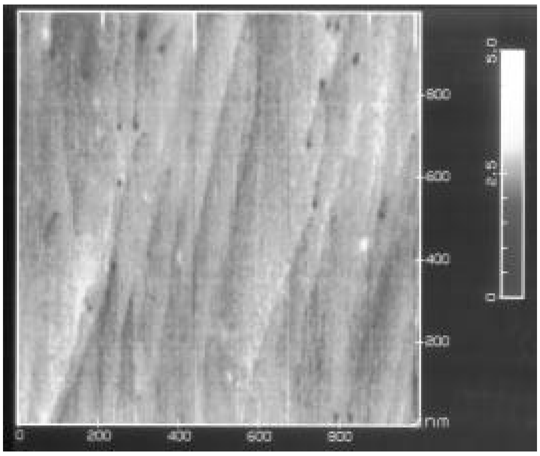

Fig. 1. AFM image of GaN epilayer grown by MBE using ammonia as nitrogen source.

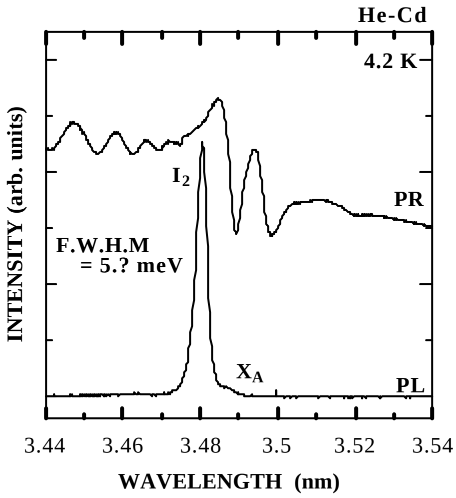

Fig. 2. Photoluminescence and photo-reflectance spectra taken from GaN epilayer grown by MBE using ammonia as nitrogen source.

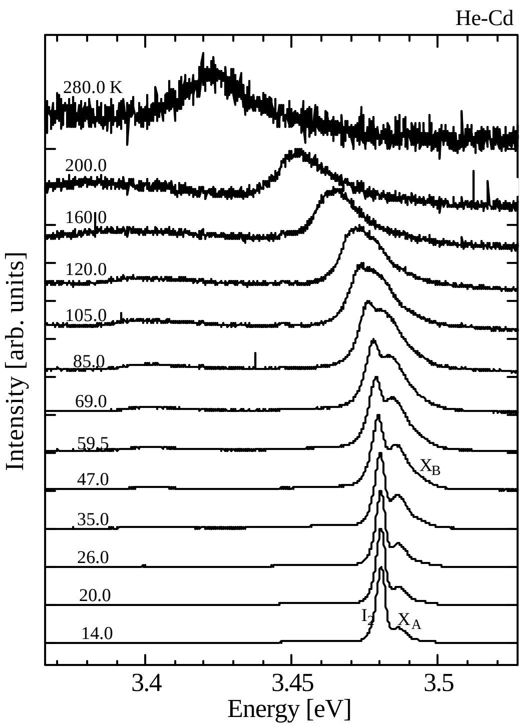

Fig. 3. Temperature dependence of PL spectra taken from GaN epilayer grown by MBE using ammonia as nitrogen source ranged from 14 K to 280 K.