APPLICATION NOTE

OPTIMISATION OF InGaN EPILAYERS GROWN BY PA-MBE IN COMPACT 21

Introduction

The development of Light Emitting Diodes (LEDs) and laser diodes (LD) has focussed a great deal of research on nitrides. The bandgap of InGaN alloy covers a wide spectral range, from near IR to UV, making it ideal for numerous optoelectronic applications. For instance, the active region of GaN-based LED and LDs consists of InGaN multi quantum well.
Riber is pleased to report here the studies of Professor S.V. Ivanov and his team at the Ioffe Institute in Saint-Petersburg, Russia. First part of research activity concentrated on finding the optimum growth conditions of InGaN epitaxial layers. Growth kinetics studies of InGaN revealed that indium incorporation strongly depends on the substrate temperature and on the choice of the substrate and buffer. Then, studies were carried out on phase separation (PS) of $In_xGa_{1-x}N$ epilayers, demonstrating on one hand the boundary conditions between no PS and complete PS and on the other hand delivering the best parameters to obtain highest optical quality InGaN layer.
Growths were carried out in Riber Compact 21 MBE system, equipped with standard Riber ABN effusion cells and a plasma source HD-25 Oxford Appl. Research. X-ray diffraction, photoluminescence, scanning and transmission electron microscopy analysis equipment were employed to characterize the structures of the InGaN films.

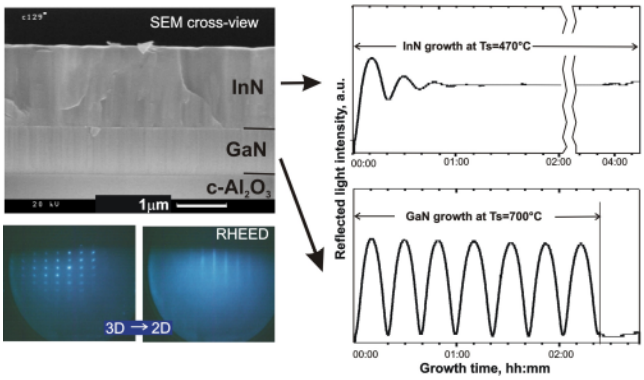

Fig 1: Growth parameter calibration, monitored by SEM, RHEED and optical interference

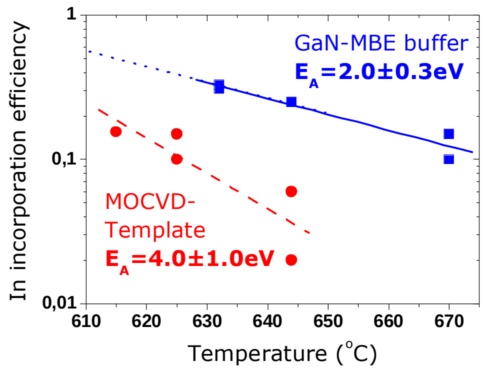

Fig 2: In incorporation efficiency as a function of growth temperature and substrate choice

Experimental

We present below a summary of all the growth parameters. More experimental details can be found in references [1-2].

The group-III (Ga, In) and activated nitrogen (N*) fluxes were calibrated by using *in-situ* optical interference measurements of growth rates of binary GaN and InN compounds grown under different stoichiometric conditions controlled by RHEED (Fig. 1). The c-sapphire substrates covered by either 1-μm-thick GaN buffer layer grown by PA MBE or 3-μm-thick MOVPE-GaN were used.
Different growth temperatures (T_S=580-670°C), III/N* and In/Ga flux ratios were employed. Special attention was paid to the choice of the plasma source parameters [1]. Relatively high values of N_2, flow of 5 sccm corresponding to a pressure in the growth chamber of 3.10^{-5} Torr was fixed during all processes. The RF-power variation within the 110-180 W range resulted in a linear dependence of the activated nitrogen flux yielding the maximum III-N growth rates of 0.22-0.72 $\mu m \cdot h^{-1}$, respectively.

Growth of $In_xGa_{1-x}N$ layers with x up to 0.6

Indium incorporation efficiency

The study of the growth kinetics of InGaN revealed that In-incorporation efficiency (α_{In}) defined as the ratio of incorporated to incident fluxes is strongly dependent on T_S and less dependent on the III/N ratio [2].
Fig. 2 shows drastic reduction of α_{In} (down to 0.1) with rising the T_S from 580°C up to 670°C. An additional significant suppression of In incorporation in the InGaN layers grown on GaN MOCVD templates as compared to those grown on MBE GaN-buffers has been revealed.

608 29 P 42 - © 07 January 2008 by RIBER – This document is property of RIBER

Phase separation (PS) study

Study of phase separation (PS) in the $In_xGa_{1-x}N$ epilayers and related inhomogeneous spatial distribution of indium as a function of the In content (x=0.1-0.6) and the film thickness (up to 300 nm) has been performed [3]. It has been found that PS phenomena are not observed in thin (~80 nm) strained InGaN layers with x≤0.10, as it is shown in Fig.3.

The epilayers with higher InN content (x~0.3) exhibit wider PL spectra and x-ray diffraction (XRD) curves with several maxima as the elastic strain releases, that can be attributed to kinetically limited PS. The completed PS is observed in the 200-nm-thick InGaN layers with x>0.5. These samples demonstrate a series of XRD and PL peaks of middle InGaN compositions as well as peaks usually observed in binary InN MBE films (Fig. 4).

Growth condition optimization

The most intense photoluminescence (PL) at room temperature for a peak wavelength within 470-800 nm range was observed in InGaN layers grown under nitrogen-rich conditions and relatively high T_s=600-670°C, limited by In incorporation efficiency [4]. The rough (columnar) layer morphology obtained under these conditions has been revealed to enhance drastically the PL intensity.

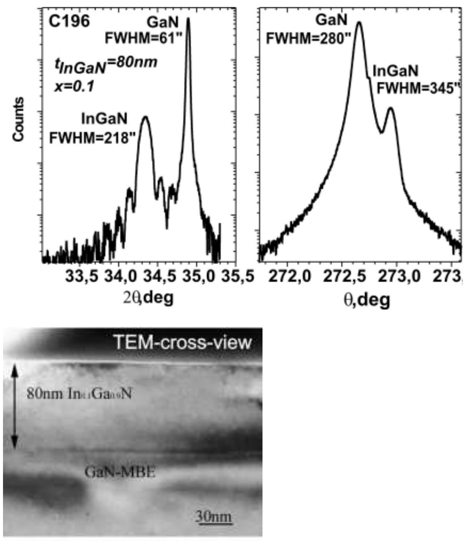

Fig3:X-Ray diffraction patterns of strained InGaN layer grown on a MOCVD-GaN template and its TEM image.

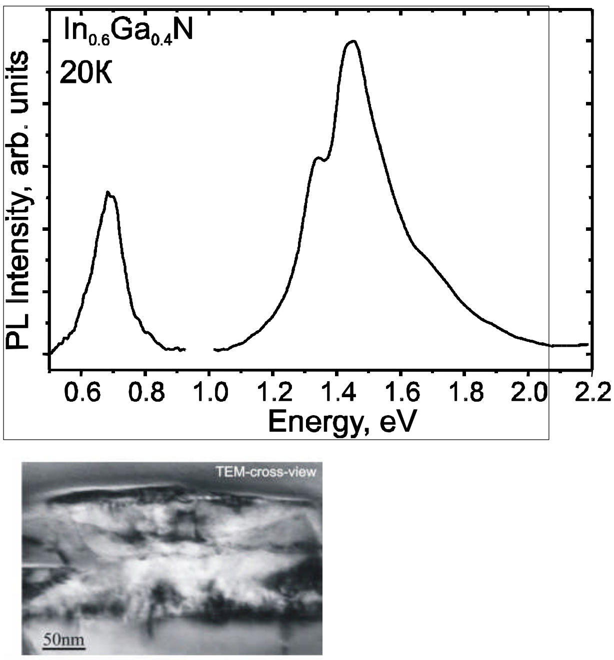

Fig 4: Complete photoluminescence spectra at different laser excitation wavelengths and TEM image of $In_{0.6}Ga_{0.4}N$ layer undergone complete phase separation.

About the Ioffe Physico Technical Institute

(http://www.ioffe.ru/)

The Ioffe Physico-Technical Institute of the Russian Academy of Sciences is one of largest Russian institutions for research in physics and technology, and employs a staff of 1,100 researchers. It was founded in 1918 in St Petersburg and run for several decades by Abram F. Ioffe. The Institute was directed for a long time by Prof. Zhores I. Alferov, winner of the 2000 Nobel Prize in physics, who has been encouraging the development of modern semiconductor technologies in the Ioffe Institute, particularly in MBE. First MBE setup – RIBER 1000 – has been purchased by Prof. Alferov in 1979 for the development of AlGaAs.

About Riber

(www.riber.com)

RIBER is a leading supplier of MBE processing equipments and related services. The company offers a wide range of tools, from R&D systems for most compounds to volume production platforms, and provides a global service network with 495 operational systems worldwide (at the end of 2007). RIBER plays a key role in the development of MBE technology via several Process Technology Centers (PTC) providing customer solutions from epitaxial growth through device processing.

References:

[1] V.N. Jmerik, A.M. Mizerov, T.V. Shubina, S.B. Listoshin, and S.V. Ivanov, *Controlling Active Nitrogen Flux in Plasma-Assisted Molecular Beam Epitaxy of Group III Nitrides*, Technical Physics Letters **33** (2007) 333–336.

[2] S.V. Ivanov, V.N. Jmerik, T.V. Shubina, S.B. Listoshin, A.M. Mizerov, A.A. Sitnikova, M.H. Kim, M. Koike, B.-J. Kim, P. S. Kop'ev, *InGaN-based epilayers and quantum wells with intense room temperature photoluminescence in the 500–650nm range***,** J. Crystal Growth 301–302 (2007) 465–468.

[3] V.N. Jmerik, T.V. Shubina, M. A. Yagovkina, A.A. Sitnikova, S.V. Ivanov, M.-H. Kim, M. Koike, B.-J. Kim, *Phase separation in InGaN epilayers grown by plasma-assisted MBE,* **,** Abstracts of ISGN-I, Linkpping, Sweden, WeP-27 (2006).

[4] V.N. Jmerik, A.M. Mizerov, T.V. Shubina, M.A. Yagovkina, V.B. Listoshin, A.A. Sitnikova, S.V. Ivanov, M.-H. Kim, M. Koike, B.-J. Kim, *Plasma-assisted MBE of InGaN epilayers with atomically smooth and nanocolumnar morphology, grown on MOVPE GaN/Al_2O_3-templates* J. Crystal Growth 301-302 (2007) 469-472

608 29 P 42 - © 07 January 2008 by RIBER – This document is property of RIBER