Bulk Growth of GaN by HVPE

H.Ashraf*[1], R.Kudrawiec[2], J. Misiewicz[2], P.R.Hageman[1]

[1]Applied Material Science, Institute for Molecules and Materials, Radboud University Nijmegen, Toernooiveld 1, 6525 ED Nijmegen, The Netherlands

[2] Institute of Physics, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland.

Corresponding author E-mail: h.ashraf@science.ru.nl +31-24 -3653432.

Keywords: GaN, HVPE, Dislocation density, Thermal stress.

Abstract

Bulk like GaN material (~3mm) was grown on the free standing (FS) GaN layers by hydride vapor phase epitaxial (HVPE). FS-GaN layers were obtained as a result of high thermal stress built up between sapphire substrate and the GaN layer during the cooling down step, which resulted in spontaneous lift off of the GaN layers. Bulk like GaN grown on FS-GaN exhibited good structural and optical quality and the dislocation density was in range of 10^5-10^6 cm^{-2}.

INTRODUCTION

Bulk GaN substrates are still a big issue despite the recent fast progress of this technology. Hydride vapor phase epitaxy (HVPE) has proven to be an effective technique to manufacture free standing (FS) GaN substrates. The approach used by employing HVPE, is to grow thick GaN layers and successively remove the substrate by the void assisted method, laser lift off, or facet controlled epitaxial overgrowth [1-3]. However, getting crack-free large size FS-GaN using laser lift-off technique is not easy because of fracturing of GaN during the laser irradiation. On the other hand FS-GaN of high quality has been realized successfully by the void assisted method and by facet controlled epitaxial overgrowth. However, these methods require complicated processing of substrate prior to growth process and are time consuming.

In this presentation we report our results on bulk like GaN material grown on FS-GaN substrates which were obtained as a result of spontaneous lift off. The spontaneous lift off and the properties of heteroepitaxial and FS-GaN and bulk like GaN material are discussed and presented.

EXPERIMENTAL

In this study, crack-free layers of thickness between 200-350µm were grown initially directly on the sapphire substrate by an optimized process [4]. All the layers were grown in a horizontal HVPE reactor. The description of the reactor is given elsewhere [4]. Afterwards, these layers were used for overgrowth. However, due to high built up of stress between sapphire substrate and the GaN layer, FS-GaN was obtained in considerably big pieces, i.e. (20x15)mm. The lift off process was completely spontaneous and involved no prior processing of the substrate or special step during the deposition process. The thickness of FS-GaN layers was between 400 to 650µm. These thick FS layers were used to grow bulk like GaN by HVPE as well (~3mm thick).

In order to understand the spontaneous lift off phenomena, and to study the properties of heteroepitaxial, FS-GaN and bulk like GaN, samples were characterized and studied by different techniques. Differential interference contrast optical microscopy (DIC-OM) and scanning electron microscopy (SEM) was employed to study the morphology, etch pit density and the cross-sections of the samples. Optical quality was determined by the contactless electro-reflectance (CER)- and photoluminescence (PL) spectroscopy. The structural quality was checked by recording the symmetrical (002) and anti-symmetrical (105) rocking curves (RC) by high resolution X-ray diffraction (HR-XRD) and the stress in the layer was probed by the micro Raman (µ-Raman) spectroscopy.

RESULTS AND DISCUSSION

To find the origin of spontaneous lift off, cross-sectional SEM, CER- and PL spectroscopy were performed on as-grown heteroepitaxial layers (300µm). The results revealed that the lift off is from the GaN instead of from the sapphire substrate.

These non processed Ga-face FS-GaN layers were employed for the growth of bulk like GaN of thickness ranging between 1mm to 3mm by HVPE. The morphology of this bulk like GaN is dominated by the polygonal shaped pits. Recently *Lucznik et al* [5] has reported in similar work, the presence of such pits in bulk like GaN and that these pits always recur themselves in successive growth process even if they were first polished away. In our case we also overgrow on some polished samples and indeed these pits re-appeared in the grown material.

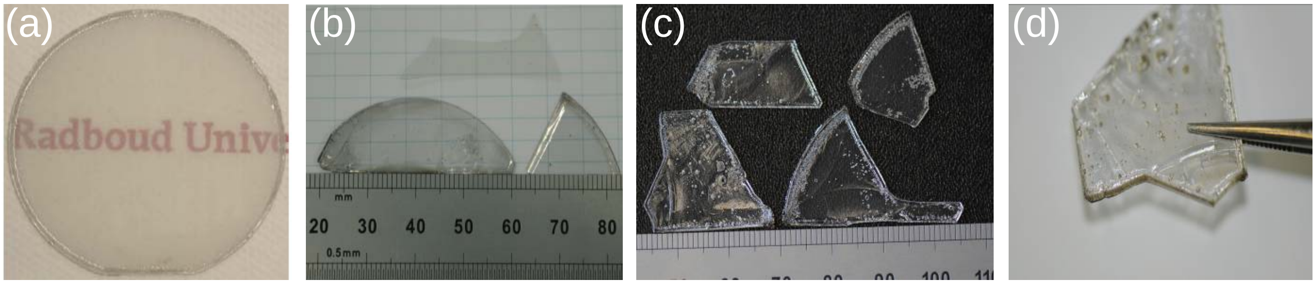

Fig.1. GaN grown by HVPE: a) 300µm thick hetero-epitaxial layer grown on sapphire in single process, b) 400µm-650µm thick FS-GaN obtained as a result of spontaneous lift off, c) 1mm-3mm thick bulk GaN grown on FS-GaN, d) Image of 1.5mm thick bulk GaN crystal. Pit like defects are visible in the image.

In order to count the defect density, the samples were etched in a eutectic solution of NaOH and KOH [6]. The defect density in these layers was on average of the order of 10^6 cm^{-2} and in some cases even $10^5 cm^{-2}$. The structural properties were studied by recording symmetric (002) and non-symmetric (105) scans employing HR-XRD. Non polished samples showed very wide and non symmetric peaks; however the full width half maximum (FWHM) values decreased when the same samples were measured after polishing.

ACKNOWLEDGEMENTS

The research work was funded by the Dutch technology Foundation (STW) under project number NAF6937.

References

[1] M.K. Kelly, R.P. Vaudo, V.M. Phanse, J. Gorgens, O. Ambacher, M. Stutzmann, Jpn.J.Appl. Phys., 38, (1999) L217.

[2] Y.Oshima, T.Eri, M. Shibata, H. Sunakawa, K. Kobayashi, T. Ichihashi, A.Usui, Jpn.J.Appl.Phys., Part 2 42,(2003) L1.

[3] S. Bohyama, H.Miyake, K. Hiramatsu, Y. Tsuchida, T.Maeda, Jpn.J. Appl. Phys., 44 (2005) L24.

[4] H. Ashraf, J.L. Weyher, G.W.G. van Dreumel, A. Gzregorzych, P.R. Hageman, J. Cryst. Growth 310, 3957 (2008).

[5] B.Lucznik, B.Pastuszka, J.L. Weyher, G. Kamler, I. Grzegory, S. Porowski, Phys. Status. Solidi C, 1-4(2009)/ DOI 10.1002/pssc.200880794, presented at International workshop on Nitride Semiconductors (IWN) 2008, Montreux, Switzerland.

[6] J.L. Weyher, S. Lazar, L. Macht, Z. Liliental-Weber, R.J. Molnar, S. Muller, V.G.M. Silvel, G. Nowak, I. Grzegory.