Heteroepitaxy and characterization of GaN with low dislocation on periodically grooved sapphire substrate

M.Yano[1], T.Detchprohm[3], R.Nakamura[1], S.Sano[1], H.Amano[2,3] and I.Akasaki[2,3]

[1] Department of Electrical & Electronic Engineering, Meijo University,

[2] Department of Materials Science and Engineering, Meijo University,

[3] High-Tech Research Center, Meijo University

1-501 Shiogamaguchi, Tempaku-ku, Nagoya 468-8502, Japan

TEL: +81-52-832-1151 ext. 5064, FAX: +81-52-832-1244, e-mail: c3992020@meijo-u.ac.jp

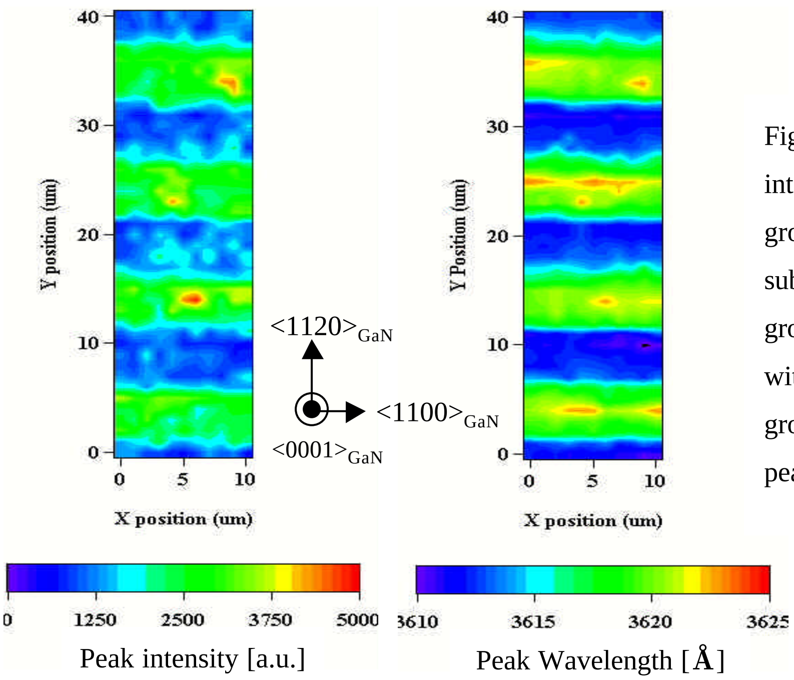
Lateral epitaxial overgrowth is an effective technique to produce GaN and related materials with a low dislocation density [1], and this technique is promising for fabrication of high performance optoelectronic devices and microwave devices. Recently reducing threading dislocations has shown to reduce the reverse leakage current by ~3 orders of magnitude in GaN p-n junction [2]. However, this technique requires GaN seed single crystal and, hence at least 2 steps of epitaxial growth with specific patterning processes are necessary. Moreover, careful treatments in patterning processes are needed to minimize contamination and damages to single crystal GaN seed, and it takes a lot of time and cost to produce such high quality GaN.

In this work we report on the growth and properties of GaN single crystal grown on periodically grooved substrate. This is a new technique to produce low dislocation density area using lateral overgrowth. In this technique, a substrate is fabricated into a groove pattern and thoroughly cleaned up prior to an epitaxial growth.

Surface of sapphire substrates was patterned in periodic grooves oriented in $\langle 11\bar{2}0 \rangle_{GaN}$ or $\langle 1\bar{1}00 \rangle_{GaN}$ direction by photolithography and reactive ion etching technique. Etching depths were 50 ~ 400nm and the groove widths were 3~5μm. A single period width was fixed at 10 μm. Then, GaN single crystal layers with AlN buffer layer was grown at 1000~1100℃ by metal organic vapor phase epitaxy. All samples were grown with flat and smooth surface.

Low dislocation density area was observed for GaN on the periodically grooved sapphire by cross-sectional transmission electron microscopy. Figure 1 shows plane-view peak intensity and peak wavelength mapping images of the GaN on periodically grooved sapphire measured by micro-PL at room temperature. We observed periodic change for both peak intensity and peak wavelength. The GaN grown in the groove area showed higher peak intensity than that of GaN grown in the terrace area by at least a factor of 2. Comparing with peak wavelength of GaN in terrace area, peak wavelength shifted to longer values for GaN in the groove area. These results imply that compressive stress has decreased in the groove area. Figure 2 shows peak energy shift between the terrace area and groove area for GaN grown on $\langle 11\bar{2}0 \rangle_{GaN}$ and $\langle 1\bar{1}00 \rangle_{GaN}$ oriented periodically grooved substrates as a function of trench depth. As trench depth increases, red shift become more significant.

We have obtained low dislocation density GaN by using periodically grooved substrate without GaN seed nor dielectric mask. Using this method, we will be simply able to produce low dislocation density GaN and related materials. More details on growth mechanism will be discussed.



(a) (b)

Figure 1 micro-PL mapping images for peak intensity (a) and peak wavelength (b) of GaN grown on periodically grooved sapphire (0001) substrate with groove depth of 200nm. Periodic grooves are aligned in $\langle 1\bar{1}00\rangle_{GaN.}$ Comparing with GaN grown in terrace area, GaN grown in groove area shows higher peak intensity with peak wavelength shifting to longer wavelength

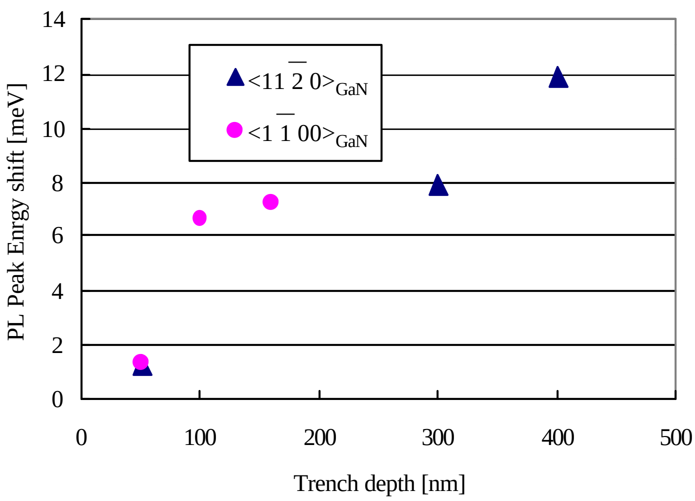


Figure 2 PL peak energy difference between GaN in terrace area and that in groove area, as a function of terrace depth.

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