Optoelectronic structures with InAlN layers grown by MOVPE

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Abstract. The results of the some practical applications of InAlN layers in a device hetrostructures grown by MOVPE is presented. It is shown that use of InAlN allows not only create high-quality DBRs and HEMT structures, but also effectively modify properties of InAlN/GaN/InGaN light-emitting devices.

Keywords: Nitrides, MOVPE, DBR, HEMT.
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INTRODUCTION

In spite of the great progress in epitaxy of III-N compounds, most of devices developed during last 20 years were composed of GaN, AlGaN and InGaN layers, which are well technologically developed and investigated. Third ternary alloy in a GaN-AlN-InN system – an InAlN looks very promising but extremely complicated in point of view of synthesis. Use of InAlN in GaN-based optoelectronic structures gives additional degree of freedom, because InAlN depending on composition may be lattice-matched to GaN, tensile or compressively strained. This alloy can be useful for creation of different structures, including HEMT, RC LED and other optoelectronic devices.

EXPERIMENT

Epitaxial structures were grown on (0001) sapphire substrates using two MOVPE systems: standard AIX2000HT with Planetary Reactor and laboratory scale system with horizontal-flow inductively heated single-wafer reactor (strongly re-designed Epiquip VP-50RP). Details of growth can be found in [1].

InAlN/GaN DBRs

Growth of InAlN is a complicated task itself, as growth conditions is a compromise of typical regimes for InGaN and AlGaN growth. Details of InAlN growth optimisation can be found in [1], below presented some results of InAlN device application. Fine adjustment of growth parameters allows to growth thick enough $In_{0.18}Al_{0.82}N$ layers lattice matched to GaN without phase separation and makes possible formation of high-quality DBRs with reflectivity exceeding 99%; Si doping of such structures results in conductive DBR making possible their use as n-type emitters in a RC LEDs with top metallic mirror.

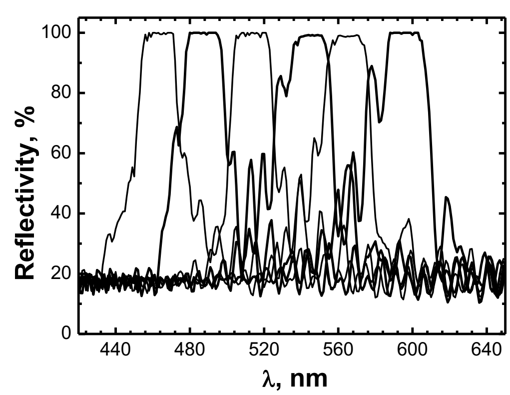

FIGURE 1. Optical reflectance spectra of InAlN/GaN 57-pair DBRs with different stop-band positions.

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InAlN/AlN/GaN HEMTs

Use of InAlN in a 2D electron gas structures shifts the limits for carrier concentration that arise from lattice mismatch in AlGaN/GaN system [3]. For example, concentration can be easily increased from $1.1*10^{13}$ cm^{-2} for $GaN/AlN/Al_{0.3}Ga_{0.7}N$ to $3.1*10^{13}$ cm^{-2} for lattice-matched structure $GaN/AlN/In_{0.18}Al_{0.82}N$. Moreover, use of InAlN allows compensating spontaneous polarization by piezoelectric field from *compressively* strained InAlN. Unfortunately, increase in In composition results in increased alloy scattering and decrease in mobility in spite of decreasing carrier concentration (Table 1).

TABLE 1. Parameters of GaN/AlN/InAlN HEMTs at RT.

In Content	n, cm^{-2} $*10^{13}$	μ, cm^2/Vs
18-19	3.1	667
19-20	2.9	555
20-21	2.8	580
21-22	2.7	520

InAlN/InGaN/GaN LEDs

Some specific results were obtained for GaN/InAlN/GaN/InGaN optical structures, were thin (1-18 nm) InAlN layer was grown in regimes close to phase separation. It was observed that growth of GaN/InAlN structure can results in formation of quantum dots with very high density (>$2*10^{11}$ cm^{-2} by AFM data). High-resolution transmission electron microscopy (HRTEM) studies of 3 nm-thick InGaN quantum well grown over such bi-layer shows that InGaN grow predominantely over such tenth-nm islands (fig 2) in a strain-control mode.

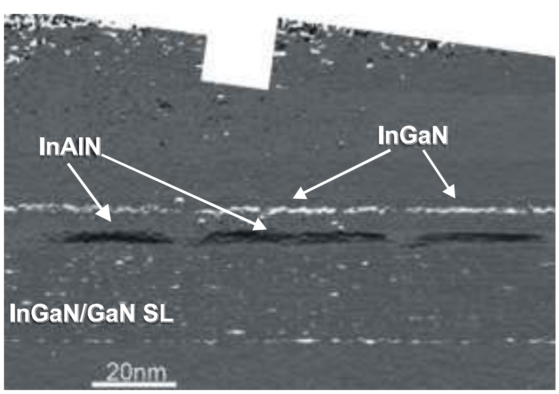

FIGURE 2. HRTEM image of InGaN QW grown on InAlN/GaN bi-layer structure.

What is more interesting, these structures exhibit narrow luminescence in a blue spectral region in comparison with 3 nm-thick InGaN QW grown just on GaN layer (see fig.3), indicating strong suppression of phase separation of InGaN inside these 20-30 nm islands. Such structures, combining carrier localization on rather big islands preventing them from nonradiative recombination with “uniform QW”-like spectrum, can be very interesting for applications were narrow gain spectra is necessery, e.g. lasers or electrooptical modulators.

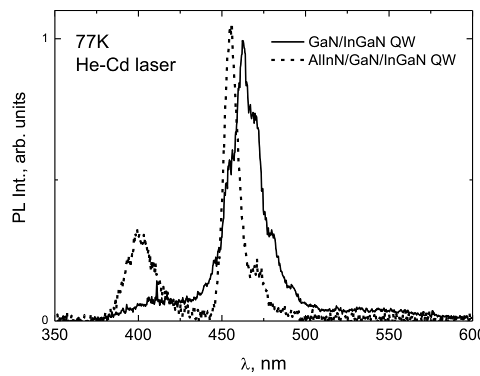

FIGURE 3. PL spectra of InGaN QW grown on GaN or on InAlN/GaN bi-layer structure.

ACKNOWLEDGMENTS

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