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Characteristics of p-type InGaN grown by metalorganic chemical vapor depostion

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1. Introduction

III-nitrides and their alloys have received much attention due to their application to blue-light emitting sources and high-power electronic devices. Although the material quality of the nitrides was much improved, there are still material-related problems to be solved. One of them is low electrical conductivity of p-type GaN layer. The self-compensation of Mg atoms in GaN films results in a low carrier concentration [1]. This effect increases contact resistivity, which makes p-type GaN layers not suitable to effectively use as a contact layer. Recently several researchers studied p-type InGaN as the contact layer instead of p-GaN. It is expected that p-type InGaN can be used as the contact layer in devices with low resistivity, because the bandgap is narrower than that of GaN [2], giving rise to decreased acceptor activation energy.

InGaN has mainly been used as the active layer for light emission. In order to grow InGaN with high In mole fraction, the growth temperature should be below 850°C due to the high volatility of the In atoms. The InGaN layers usually show n-type conductivity due to low decomposition efficiency of ammonia (NH_3) at low temperature.

In this paper, we performed the electrical and optical characterizations for Mg-doped p-type InGaN layers with different In composition grown by metalorganic chemical vapor deposition (MOCVD).

2. Experimental procedure

InGaN layer were grown on sapphire substrates by a vertical low pressure MOVCD system. During the growth procedure trimethylgallium (TMGa), trimethlylindium (TMIn), biscyclopentadienyl magnesium (Cp_2Mg) and ammonia (NH_3) were used as precursors for Ga, In, Mg, and N, respectively. Prior to the growth, sapphire substrates were thermally cleaned at 1100°C in a hydrogen ambient to remove any surface contamination. A 30nm-thick low-temperature (540°C) GaN nucleation layer was deposited, followed by high-temperature (1040°C) undoped GaN layer. Then, Mg-doped p-InGaN layers were grown at a fixed temperature of 780°C in a nitrogen ambient. Two p-$In_xGa_{1-x}N$ samples (sample A and B) were grown with the same Cp_2Mg flow rate but different TMIn flow rate. With the fixed growth temperature and TMGa flow rate, the In mole fraction (x) was controlled by changing TMIn flow rate. The growth rate and thickness of the p-InGaN layers were 1Å/s and 250nm, respectively. Before Mg activation at 700 °C, 200nm thick SiO_2 was coated by plasma assisted chemical vapor deposition on the p-InGaN films in order to prevent surface degradation during the annealing process.

Double-crystal X-ray diffraction (DCXRD), Hall effect measurement and photoluminescence (PL) were carried out after the growth.

3. Results and discussion

Figure 1 shows XRD θ-2θ scan for the two p-InGaN/GaN samples. The In mole fraction was measured by using Vegard's law, yielding x=0.1 for sample A and x=0.05 for sample B.

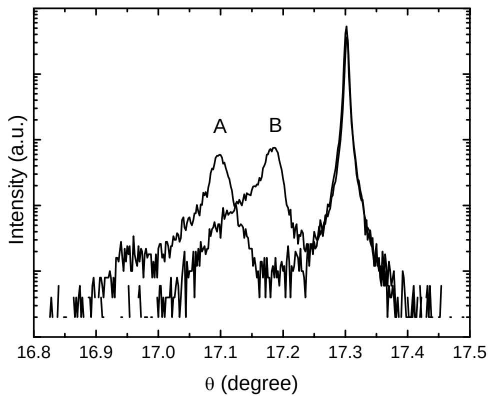

Fig. 1 XRD θ-2θ scan for the two p-InGaN/GaN samples.

Table 1 lists the room-temperature resistivity, mobility, and hole concentration collected from Hall effect measurement. High hole concentration of 1.2×10^{18} cm^{-3} was obtained for sample A (x=0.1), where mobility and resistivity were 4.9 Ωcm and 1.1 cm^2/Vs, respectively. The increased hole concentration for sample A is attributed to the decreased activation energy of Mg-acceptor and to the increased Mg-acceptor concentration in InGaN layers with increasing In mole fraction.

Table 1 Electrical properties of Mg-doped InGaN films obtained by room-temperature Hall effect measurement

ID	x	ρ (Ωcm)	μ (cm^2/Vs)	P (cm^{-3})
A	0.1	1.1	4.9	1.2×10^{18}
B	0.05	1.8	7.8	4.5×10^{17}

Figure 2 shows room-temperature PL spectra for the p-type InGaN layers. They exhibit the intense luminescence at around 500–550nm, which is attributable to donor-acceptor pair (DAP) recombination. The peak position is shifted to longer wavelength with increasing In composition. In addition, the PL intensity is increased with increasing hole concentration, analogous to DAP recombination for p-GaN.

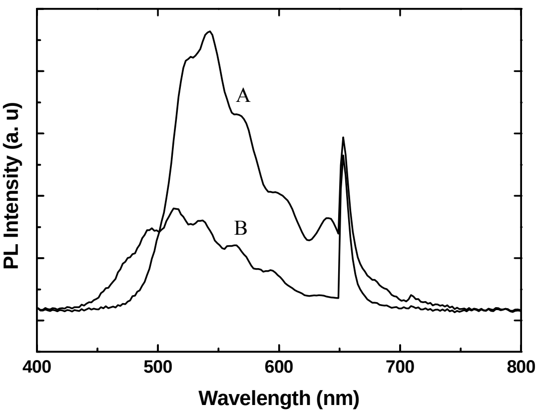

Fig. 2 RT-PL spectra of the p-$In_xGa_{1-x}N$ sample A (x=0.1) and B (x=0.05).

4. Conclusions

Two p-type InGaN epitaxial layers were prepared by MOCVD and their optical and electrical characterizations were carried out. Hole concentration was increased with increasing In composition (x), attributable to the decreased activation energy of Mg-acceptor in InGaN with higher x. High hole concentration of 1.2×10^{18} cm^{-3} was obtained for sample with x=0.1. Besides, the PL intensity of DAP transition was increased with increasing hole concentration, analogous to DAP recombination for p-GaN. These p-InGaN layers are expected to lower contact resistance, resulting in improved performance of optoelectronic devices.

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