Effect of nitrogen plasma treatment on Mg-doped GaN and blue LED

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Thermal annealing has been used to produce p-type conductivity in Mg-doped GaN grown by MOCVD by dissociating hydrogen atoms from the Mg-H complexes, resulting in a hole density in the low 10^{17} cm^{-3} range. However, some evidences[1-3] have showed that the major problem which limits the hole concentration is, not only the hydrogen passivation, but also the self-compensation caused by a nitrogen vacancy.[3] Self-compensation in MOCVD-grown Mg-doped GaN could not be controlled only by post growth treatments and is an issue which remains to be solved. In this work, we investigated the effect of nitrogen plasma treatment (NPT) on the electrical properties of Mg-doped GaN and InGaN/GaN MQW blue LEDs grown by MOCVD.

The electrical characteristics of the NPT p-GaN samples treated at different temperatures with different RF plasma power are shown in Table 1. The NPT sample which had been treated at 380 ^{o}C showed a drastic increase in the sheet hole concentration (by 5 times) and a reduction in the sheet resistance (by 1/3 times), compared with the sample subjected only to a conventional RTA. Figure 1 shows representative PL spectra of the RTA and the NPT sample. For the RTA sample, the PL bands located at 2.95 eV and 2.7 eV are dominant while for the NPT sample a new band at 3.27 eV is newly developed as the PL peaks at 2.95 eV and 2.7 eV. dimish in their intensities. The probability changes of 3.27 eV (Mg^0,e) [4] and the 2.95 eV DAP transitions seem to be due to the annihilation of the deep donors near the surface after the NPT. We therefore conclude that the NPT effectively reduces the degree of self-compensation near the surface region of a Mg-doped GaN, leading to a high conductivity p-type in the GaN film. Fig. 2 shows the typical current-voltage (I–V) characteristics for the NPT and the RTA samples which have as-deposited Pt contact pads. Nonlinear curves are seen for the samples treated by RTA annealing process followed by HCl or BOE treatment. However, the HCl treated NPT sample showed a linear I–V ohmic behavior. The I-V characteristics of the InGaN MQW (5 periods) blue LEDs treated by a conventional RTA and a NPT process is shown in fig. 3. The current flow of the NPT LED in the high voltage region (I > 1 mA) is higher than that of the RTA LED. This result shows that the enhancement of electrical properties in the NPT LED compared with the RTA LED is mainly attributed to the reactivation of Mg acceptor in the Mg-doped GaN by NPT.[5]

References

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Sample	T (°C)	P (W)	p_s (cm^{-2})	ρ_s (Ω/square)	μ (cm^2/Vs)
RTA only	.	.	2×10^{13}	2×10^{4}	9
NPT A	250	30	6×10^{13}	1×10^{4}	10
NPT B	300	30	7×10^{13}	1×10^{4}	8
NPT C	350	30	9×10^{13}	9×10^{3}	8
NPT D	380	30	1×10^{14}	7×10^{3}	6

Table 1. Sheet hole concentration (p_s), sheet resistance (ρ_s) and Hall mobility (μ) of plasma treated p-type GaN films. The NPT was performed with different RF power (P) levels and temperatures (T) under a fixed nitrogen flow rate (500 sccm), chamber pressure (1 torr), and treatment time (9 min).

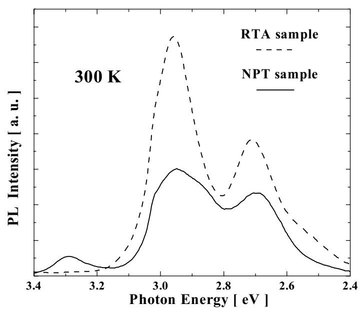

Fig. 1. Room temperature PL spectra for p-type GaN samples treated with the NPT and the RTA. The NPT was carried out under an RF power of 30 W at 380 °C for 9 min.

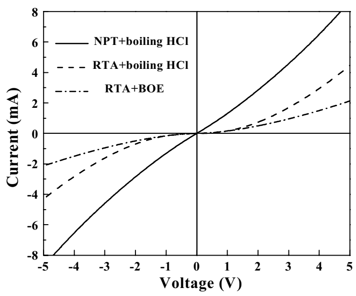

Fig. 2. Current-voltage (I-V) characteristics of Pt contact to p-type GaN with the NPT and the RTA treatment. The NPT was carried out under an RF power of 30 W at 380 °C for 9 min.

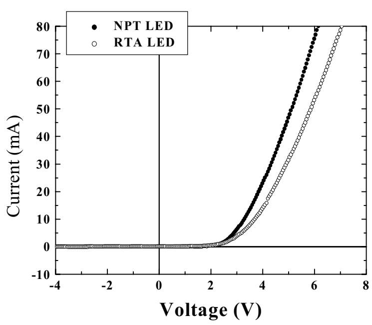

Fig. 3. Current-voltage (I-V) characteristics of the InGaN MQW (5 periods) LEDs using a RTA and a NPT process.