Meta-stable Blue Emission of Mg-Doped GaN by Mg_3N_2 Diffusion

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計劃名稱：氮化鎵族光電材料與元件之研發（I）
子計劃三：鋁銦鎵氮化物微結構及光電特性分析
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Abstract

Mg was incorporated into un-doped GaN by diffusion method under 900 限 and 1000 限 for 3 hours. 325.5 nm He-Cd Laser was applied on both samples to perform PL measurement. There exhibited decaying blue emission and D-A pair emission at different temperatures. The decay curves were second-order with very long time-constants. No obvious free exciton decay and yellow luminescence decay were observed. A Trapping –level mechanism was proposed to explain the emission spectrum.

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Summary

1 Introduction

GaN and related III-V nitride semiconductors have attracted considerable attention because of its potential for use in optoelectronics in UV-band and high-temperature electronic devices [1].One of the important issues in fabricating LED is to accomplish high quality *p*-type GaN. In general, the *p*-type GaN is obtained by Cp_2Mg incorporated in the process of metalorganic chemical vapor deposition (MOCVD). The formation of Mg-H complexes during MOCVD growth has usually been suggested to be responsible for the high resistivity of as-grown Mg-doped GaN [2,3,4]. It is believed that an activation process by thermal annealing or low energy electron beam irradiation which results in the decomposition of Mg-H complex can be used to get low resistivity *p*-type GaN.[5] In this article, we doped the Mg into GaN by a diffusion method and observed the decay phenomenon of blue emission. The Mg-related transition at different temperatures was traced to explore the origin of Mg-related transition in GaN film.

2 Experiment

The undoped GaN films were grown on the c-face sapphire substrates by MOCVD with a horizontal reactor. Trimethylgallium (TMG) and ammonia (NH_3) were used as the source of Ga and N, respectively.

In this study, Mg_3N_2 was diffused into the undoped GaN at 900 — and 1000℃, respectively, which we labeled them as sample A and sample B. The time-resolved PL spectra for the undoped GaN film and Mg-doped GaN films at different temperatures, *i.e.* 7.5 K , 10 K, 15 K and 35 K, were measured. There existed temporary blue emission at these temperatures for the sample A and B, but no blue emission was observed for the undoped GaN..

3 Results

Figure 1 shows the time-dependent intensity curves of PL spectra at different temperature using 325.5 nm He-Cd laser irradiation (55 mW) for the sample A. Both samples A and B have the same phenomenon. According to the wavelength-dependent PL spectra obtained, but not shown here, we found that both samples have the same band-edge emission near 356 nm (3.483 eV) and an exiton emission at 364 nm (3.407 eV). When sample was kept at the same temperature, e.g. 10 K, after irradiation, it would not recover its intensity in the next irradiation. On the other hand, when it was back to R.T. to achieve thermal equilibrium for a while (30 min in this study) and then cooled down to 10 K, it would recover its intensity and then decay again.

$$I(t) = I_0 + A_1 \exp\left(\frac{-t}{\tau_1}\right) + A_2 \exp\left(\frac{-t}{\tau_2}\right) \qquad (1)$$

Figure 3 is shown the AFM morphology of the samples A and B. The surfaces are rather rough; even pits appear on the surface. The appearance of nodules implies the presence of many defects in the films. The roughness for sample A is more serious than sample B, because two pits can be clearly seen on the scanned surface of sample A.

4 Discussion

In this study, a trapping-level mechanism is proposed to explain the degradation and enhancement in the sample. Similar phenomenon on un-intentionally doped GaN had been discussed in elsewhere[6]. However, in our case, it is thought that the electron-trapping states on shallow Mg-related acceptor-level are easy to trap electrons. The trapping states are induced by Mg-incorporation during diffusion process. From the morphology obtained by AFM, it indicates that there must be a number of defects in the films. Consequently, there must have many trapping states in the films. In equation (1), the time constant —$_1$ represents the lifetime of the free Mg-related acceptor states , and —$_2$ represents the lifetime of free donor states . In the beginning, the holes occupancies of Mg-related level are low. With the sample excited by laser, electrons on the donor level and holes on the Mg-related acceptor level are then created. Therefore, the donor-level and acceptor-level are capable of trapping carriers. The sample should be in thermal equilibrium before irradiation. After the sample was excited by laser irradiation, carriers were generated on each level, and a new steady-state dynamic equilibrium should be established. Due to the electrons trapped on the Mg-related acceptor level and the donor-level, the intensity therefore decreased gradually. Finally, a steady state equilibrium was reached with stable emission intensity.

5 Conclusion

Mg-doped GaN at 900 — or 1000 — has a number of defects which cause meta-stable blue emission. At high temperature, all carriers in films are easy to stay in thermal equilibrium. On the contrary, at lower temperature, carriers are easy to trapped by defects, which cause decaying phenomenon of blue emission.

ACKNOWLEDGMENT

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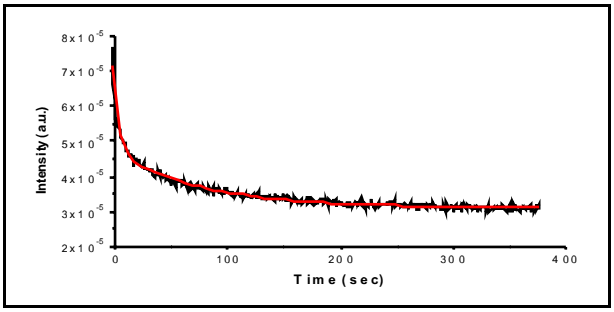
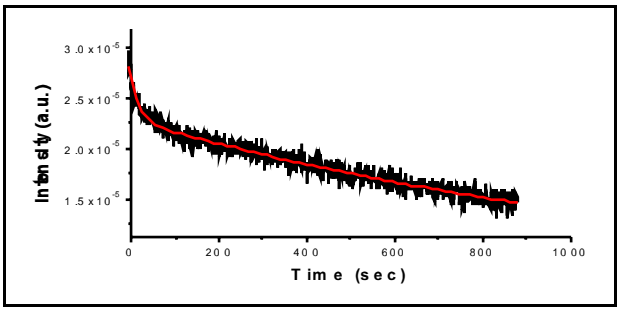
FIGURES AND TABLE

(a) Measured at 7.5 K



(b) Measured at 15 K



(c) Measured at 35 K

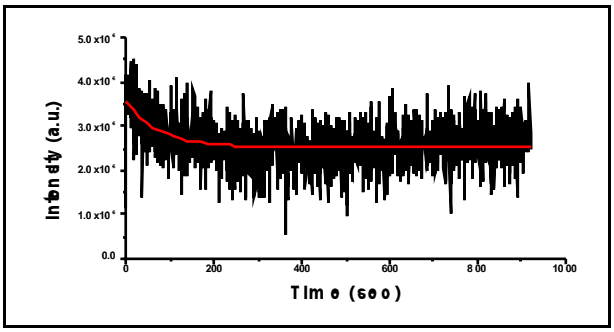
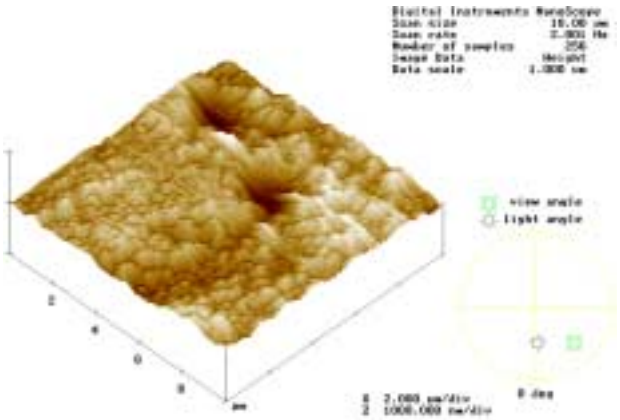


FIG. 1. The time-dependent PL intensity for blue emission measured at 450 nm at (a) 7.5 K with τ_1, τ_2 = 4.545 sec, 77.27 sec. (b) 15 K with τ_1, τ_2 = 18.16 sec, 1311.11 sec. (C) 35 K with τ_1, τ_2 = 72.73 sec, 20364.28 sec.

Table 1. Second order decay curve parameters.

Temp.	I_0(a.u.)	A_1(a.u.)	A_2(a.u.)	τ_1(sec)	τ_2(sec)
5K	3.25×10^{-5}	2.44×10^{-5}	1.65×10^{-5}	4.54	77.27
15 K	5.76×10^{-6}	5.27×10^{-6}	1.71×10^{-5}	18.16	1311.30
35 K	2.63×10^{-6}	1.03×10^{-6}	1.96×10^{-7}	72.73	20364.28

(a)



(b)

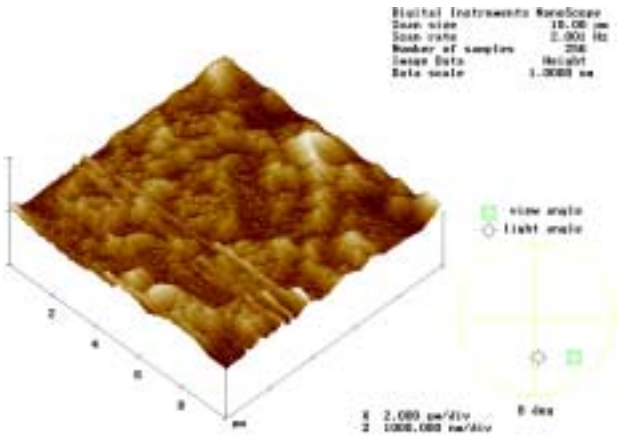


Fig. 3. The AFM morphology for (a) sample A diffused at 900 ℃ and (b) sample B diffused at 1000 ℃

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