Extended Abstracts of the 2004 International Conference on Solid State Devices and Materials, Tokyo, 2004, pp. 832-833

D-10-2

The novel method to improve electrical characteristics of *p*-type GaN by using Ni catalysis

B. R. Huang[1], S. M. Wang[1], C. H. Chen[2], S. J. Chang[3], Y. K. Su[3], H. Hung[3], and Y. T. Chou[3]

[1]Institute of Electronics Engineering, National Yunlin University of Science and Technology, 123, University Road, Section 3, Touliu, Yunlin, 640 Taiwan, R.O.C.
Phone: 886-55342601 ext.4392 E-mail: g9113716@yuntech.edu.tw
[2]Department of Electronic Engineering, Cheng Shiu University, Kaohsiung, Taiwan, R.O.C.
[3]Institute of Microelectronics and Department of Electrical Engineering, National Cheng Kung University, No1.Ta-Hsueh Road, Tainan City, 701, Taiwan, R.O.C.

Abstract

GaN and related compounds have attracted much attention as prospective candidates for wide band-gap optical devices such as short-wavelength light-emitting diodes or laser diodes [1-3]. Although the performance of these devices has been developed owing to a lot of breakthroughs in crystal growth and carrier control [4-5], several problems remain to be solved. In this paper, we used different conditions of Ni films and annealing temperature to research the electric property of p-type GaN, and further, control current spreading to improve LED performance.

Samples used in this study were all grown by metalorganic chemical vapor deposition (MOCVD). We first prepared a low-temperature GaN, an undoped GaN, and a p-type GaN epitaxial layer sequential onto the c-face (0001) sapphire substrates. The thickness of the GaN buffer layer was 30 nm. After growth of buffer layer, the 2 μm undoped GaN film was grown on buffer layer. Then we grow the 1 μm p-type GaN epilayers.

This as-grown wafer was cut into 5 mm × 5 mm pieces. Ni films with the thickness of approximately 2 nm, 10 nm, 20 nm, 50 nm were entirely deposited on the surface of the sample for activation by annealing at temperatures ranging from 200℃ to 800℃ in N_2 ambient gas for 10 min. After removing the Ni film and native oxides on the surfaces, all samples were cleaned in 50% HCl for 30 min at room-temperature, rinsed in DI water for 1 min, and dried by a N_2 blower.

Figure 1 shows the hole concentration as a function of the annealing temperature. It can be seen that the hole concentration of 4.35×10^{17} cm^{-3} was achieved by annealing at 400℃ by this method (Ni=10nm). The highest hole concen- tration of 3.25×10^{18} cm^{-3} with the mobility of 0.922 cm^2/Vs was obtained at the annealing temperature of 600℃ (Ni = 2 nm). This hole concentration of p-GaN with the Ni film is one order of magnitude higher than that of the sample without that at this annealing temperature. The Typical I-V curves of p-type GaN samples with and without Ni films annealed at 600℃ in N_2 ambient for 10 min were shown in Fig. 2. It was found that annealing in this thick Ni film and such high temperature range of 700℃ to 800℃ didn't yield a better I-V curve than as-grown sample. Nevertheless, annealing temperature at 600℃ with thin Ni film (2 nm) can obtained better I-V curve. The results shown in Fig. 2 indicated that the proper deposition thin Ni film and low annealing temperature are the critical conditions to improve the electrical properties of p-type GaN.

Figure 3 shows the I-V curve dropped abruptly form ohmic to Schottly state when samples annealed at 600℃ after etching 0.3 μm, 0.6 μm, via ICP system. The results revealed Ni-compound materials are the key factor in electrical characteristic. However, we must be careful with NiH to disturb electronic distribution of the p-type GaN.

In summary, the optimum result of concentration and I-V characteristic are deposited 2 nm Ni film, and then, annealed at 600℃ in N_2 for 10 min in our study. We observe that the Ni-compound materials were to form in the surface of p-type GaN, such as, the formation of NiO reduces specific resistance between contact and p-type GaN, NiH considerably perturb the electronic distribution of the surface of p-type GaN. In the future, we will continue to study the mechanism of Ni catalytic, Ni-compound materials and control current spreading to improve the light intensity of GaN-based LED.

Acknowledgements

This work is supported by the National Science Council under contract numbers NSC 92-2216-E-224-005 and NSC 92-2215-E-230-002.

References

[1] J. Neugebauer, Phys. Rev. Lett. 75, 4452 (1995).

[2] M. Miyachi and H. Ota, Appl. Phys. Lett. 72, 1101 (1998).

[3] I. Waki and H. Fujioka, Appl. Phys. Lett. 78, 2899 (2001).

[4] I. Waki and H. Fujioka, J. Appl. Phys. 90, 6500 (2001).

[5] Y. Kamii and I. Waki, Applied Surface Science 190, 348 (2002).

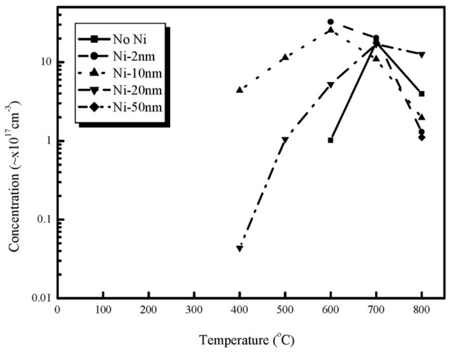

Fig. 1 The hole concentration as a function of the annealing temperature with Ni films and without Ni films.

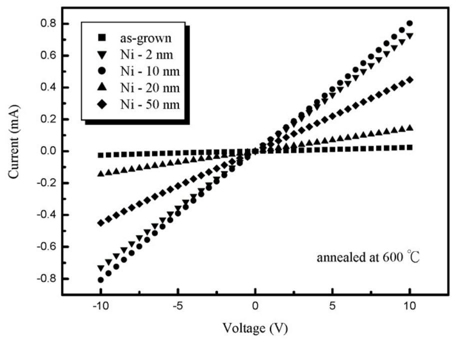

Fig. 2 Typical I-V curves of p-type GaN samples with and without Ni film annealed at 600℃ in N_2 ambient for 10 min.

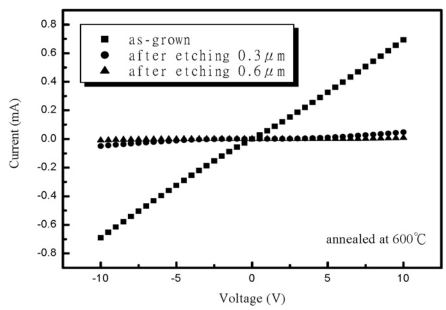

Fig. 3 Typical I-V curves of p-type GaN samples with Ni film (10 nm)