Application of PEC Processes for The Fabrication of GaN LEDs

范文轅、蕭宏彬

E-mail: 9607824@mail.dyu.edu.tw

ABSTRACT

In this thesis, we have demonstrated the enhancement in light extraction efficiency of InGaN/GaN LEDs using bias-assisted photoelectrochemical (PEC) technology. The bias-assisted PEC process with high reaction rate can be used to rough n-GaN surface and etch mesa sidewall for the formation of truncated-inverted-pyramid (TIP) shape. Both the surface roughness and TIP shape will benefit the light extraction efficiency due to the reduction of total internal reflection. In this experiment, there are two directions for PEC reactions. One is normal to surface and the other is parallel to surface. Surface roughness on n-GaN can be obtained using PEC process with normal to surface illumination. Both surface roughness and TIP shape can be achieved using PEC process with parallel surface illumination. All processed samples were examined by scanning electronic microscopy (SEM) and atomic force microscopy (AFM). Both I-V and L-I curves for before and after PEC processed LEDs were tested. Various of different KOH concentrations and bias voltages have been studied in this work. The output power can be enhanced by 13.4%, 33.87%, 47.34% and 29.7%, respectively, for the PEC-processed LEDs with 0.1M, 0.5M, 1M and 2M KOH solution and 2-V bias under normal to surface illumination. On the other hand, the output power can be increased by 52.23% for the PEC-processed LEDs with 1M KOH solution and 2-V bias under parallel illumination.

Keywords : photoelectrochemical ; n-GaN surface ; mesa sidewall

Table of Contents

REFERENCES

[1] S. Nakamura, M. Senoh, and T. Mukai, “ High-power InGaN/GaN double-heterostructure violet light emitting diodes, ” Appl. Phys. Lett. , vol.62, pp. 2390, 1992.

[2] M. Hansen, J. Piprek, P. M. Pattison, J. S. Speck, S. Nakamura, and S. P. DenBaars , “ Higher efficiency InGaN laser diodes with an improved quantum well capping configuration, ” Appl. Phys. Lett. , vol.81, pp. 4520, 2002.

[3] K. S. Stevens, M. Kinniburgh, and R. Beresford, “ Photoconductive ultraviolet sensor using Mg-doped GaN on Si(111), ” Appl. Phys. Lett. , vol.63, pp. 3518, 1995.

[4] A. F. M. Anwar, Richard T. Webster, and Kurt V. Smith, “ Bias induced strain in AlGaN/GaN heterojunction field effect transistors and its implications, ” Appl. Phys. Lett. , vol. 88, pp. 203510, 2006.

[5] J. Chen, J. F. Wang, H. Wang, J. J. Zhu, S. M. Zhang, D. G. Zhao, D.S. Jiang, H. Yang, U. Jahn and K. H. Ploog, “ Measurement of threading dislocation densities in GaN by wet chemical etching, ” Semicond. Sci. Technol. , vol. 21 pp. 1229 – 1235, 2006.

[6] S. Yoshida, S. Misawa, and S. Gonda, “ Improvements on the electrical and luminescent properties of reactive molecular beam epitaxially grown GaN films by using AlN-coated sapphire substrates, ” Appl. Phys. Lett. , vol. 42, pp. 427-429, 1983.

[7] H. Amano, N. Sawaki, I. Akasaki, and Y. Toyoda, " Metalorganic vapor phase epitaxial growth of a high quality GaN film using an AlN buffer layer, " Appl. Phys. Lett., vol. 48, pp. 353-355, 1986.
[8] M. Hao, S. Mahanty, T. Sugahara, Y. Morishima, H. Takenaka, J. Wang, S. Tottori, K. Nishino, Y. Naoi, and S. Sakai, " Configuration of dislocations in lateral overgrowth GaN films, " J. Appl. Phys. , vol. 85, pp. 6479-6507, 1999.
[9] E. Fred Schubert, Light-Emitting Diodes, Cambridge University Press, pp. 15-22, 2006.
[10] T. N. Oder, K. H. Kim, J. Y. Lin, and H. X. Jiang, " III-nitride blue and ultraviolet photonic crystal light emitting diodes, " Appl. Phys. Lett. , vol. 84, pp. 466-468, 1999.
[11] Y. J. Lee, T. C. Lu, H. C. Kuo, S. C. Wang , T. C. Hsu, M. H. Hsieh, M. J. Jou, and B. J. Lee, " Nano-roughening n-side surface of AlGaInP-based LEDs for increasing extraction efficiency, " Materials Science and Engineering B, vol. 138, pp. 157-160, 2007.
[12] Y. J. Lee, J. M. Hwang, T. C. Hsu, M. H. Hsieh, M. J. Jou, B. J. Lee, T. C. Lu, H. C. Kuo, and S. C. Wang, " Enhancing the output power of GaN-based LEDs grown on wet-etched patterned sapphire substrates, " IEEE Photonics Technology Letters, vol. 18, pp. 1152-1154, 2006.
[13] M. R. Krames, M. Ochiai-Holcomb, G. E. HOfler, C. Carter-Coman, E. I. Chen, I.- H. Tan, P. Grillot, N. F. Gardner, H. C. Chui, J.-W. Huang, S. A. Stockman, F. A. Kish, M. G. Craford, T. S. Tan, C. P. Kocot, M. Hueschen, J. Posselt, B. Loh, G. Sasser and D. Collins, " High-power truncated-inverted-pyramid (AlxGa1-x)0.5In0.5P/GaP light- emitting diodes exhibiting > 50% external quantum effciency, " Appl. Phys. Lett. , vol. 75, pp. 2365-2367, 1999.
[14] J. W. Seo, C. S. Oh, H. S. Jeong, J. W. Yang, K. Y. Lim, C. J. Yoon, and H. J. Lee, " Bias-assisted photoelectrochemical oxidation of n-GaN in H2O, " Appl. Phys. Lett. , vol. 81, pp. 1029-1031, 2002.
[15] Z. H. Hwang, J. M. Hwang, H. L. Hwang, and W. H. Hung, " Electrodeless wet etching of GaN assisted with chopped ultraviolet light, " Appl. Phys. Lett. , vol. 84, pp. 3759-3761, 2004.
[16] 莊達人，VLSI製造技術，高立圖書有限公司，1996.
[17] S. k. Ghandhi, VLSI Fabrication Principles, John Wiley & Sons, p.613, 1994.
[18] S. J. Fonash, " Advances in Dry Etching Processes-A Review, " Solid State Technology, pp. 150, 1985.
[19] 劉博文，ULSI製造技術，新文京開發出版有限公司，2003.
[20] C. Youysey, I. Adesida , L.T. Romano, and G. Bulman, " Smooth n-type GaN surface by photoenhanced wet etching, " Appl. Phys. Lett. , vol. 72, pp. 560-562, 1997.
[21] T. Rotter, D. Mistele, F. Fedler, J. Aderhold, J. Graul, and M.Heuken, " Photoinduced oxide film for mation on n-type GaN surfaces using alkaline solution, " Appl. Phys. Lett. , vol. 76, pp.3923-3925, 2000.
[22] L. Y. Chang, " Etching Study of GaN by Photoelectrochemical Reaction Method, " Department of Electrical Engineering, Da-Yeh University, June, 2006.
[23] D. J. Fu, Sh. U. Yuldashev, Y. H. Kwon, N. H. Kim, S. H. Park and T. W. Kang, " Photoelectrochemical Oxygenation of GaN Epilayers, " Journal of the Korean Physical Society, Vol. 39, pp. S313-S317, 2001.
[24] J. E. Borton, C. Cai and M. I. Nathan, P. Chow, J. M. VanHove, A. Wowchak, and H. Morkoc, " Bias-assisted photoelectrochemical etching of p-GaN at 300K, " Appl. Phys. Lett. , vol. 77, pp. 1227-1229, 2000.
[25] Chia-Feng Lin, Jing-Hui Zheng, Zhong-Jie Yang, Jing-Jie Dai, Der-Yuh Lin, Chung-Ying Chang, Zhao-Xu Lai, and C. S. Hong, " High-efficiency InGaN-based light-emitting diodes with nanoporous GaN:Mg structure, " Appl. Phys. Lett. , vol. 88, pp. 083121, 2006.
[26] A. P. Vajpeyi, S. J. Chua, S. Tripathy, E. A. Fitzgerald, W. Liu, P. Chen, and L. S. Wang " High optical quality nanoporous GaN prepared by photoelectrochemical etching, " Electrochem. Solid-State Lett. , vol. 8, pp. G85-G88, 2005.
[27] J. M. Hwang, J. T. Hsieh, H. L. Hwang, and W. H. Hung, " A damage-reduced process revealed by photoluminescence in photoelectrochemical etching GaN, " MRS Internet J. Nitride Semicond. , Res. 5S1, W11. 73, 2000.
[28] C. C. kao, H. C. Kuo, H. W. Huang, J. T. Chu, Y. C. Peng, Y. L. Hsieh, C. Y. Luo, S. C. Wang, C. C. Yu and C. F. Lin, " Light-output enhancement in a nitride-based light-emitting diode with 22 ° undercut sidewalls, " IEEE Photonics Technology Letters, vol. 17, pp. 19-21, 2005.
[29] C. F. Lin, J. J. Dai1, R. H. Jiang, J. H. Zheng, Z. J. Yang, C. C. Yu, and W. C. Lee, " Photoelectrochemical sidewall etching enhances light output power in GaN-based light emitting diodes, " Phys. stat. sol. , vol. 3, pp. 2182-2186, 2006.