# Effect of different sputter power on ITO/p-GaN and their interface investigations

**藍志學、黃俊達**

E-mail: 9509677@mail.dyu.edu.tw

**ABSTRACT**

Interface and contact properties of Indium-tin-oxide (ITO) on p-GaN has been investigated, in which ITO was deposited by RF sputtering with different power. It is found that with increasing of sputtering power, the nitrogen vacancies increase on the surface of p-GaN by using Auger electron spectroscopy (AES). The nitrogen vacancy will act as a donor and thus increase the electron concentration between ITO and p-GaN interface. The increase in electron concentration will compensate the holes of p-GaN films therefore the contact resistance of ITO to p-GaN will increase as a result of the decreasing of concentrations in p-GaN. While increasing sputtering power further, the electron concentration of surface below ITO will increase further and then the surface of p-GaN will be inversed into n-type. This phenomenon will be confirmed by using current-voltage (I-V) characteristics, in which the I-V curve transfers from quasi-ohmic to rectifying behavior. Following, the ITO/p-GaN devices were annealed in rapid thermal annealing (RTA) system with temperature ranging from 600 to 800°C under nitrogen ambient. In 800°Cannealing temperature, the I-V curve transfers from rectifying to quasi-ohmic. Possible reason is that the nitrogen vacancies below the ITO surface are compensated .

Keywords : GaN, Indium-tin-oxide, sputter

**Table of Contents**

**REFERENCES**

[1] S. Nakamura and G. Fasol, The Blue Laser Diodes, Springer Heidelberg (1997).
[2] S. Nakamura, T. Mukai, and M. Senoh, " Candela-class high-brightness InGaN/AlGaN double-heterostrusture blue-light-emitting diodes, Appl. Phy. Lett. Vol.64, p.1687 (1994).
[3] S. Nakamura, M. Senoh, N. Iwasa, S. Nagahama, T. Yamada, and T. Mukai, " Superbright Green InGaN Single-Quantum-Well-Structure Light-Emitting Diode ", Jap. J. Appl. Phy. Vol.34, p.L1332(1995).
[4] T. Mukai, D. Morita, and S. Nakamura, " High-power UV InGaN/AlGaN double-heterostructure LEDs ", J. Cryst. Growth, Vol.189/190, p.778(1998).
[5] T. Mukai, H. Narimatsu, and S.Nakamura, " Amber InGaN-Based Light-Emitting Diodes Operable at High Ambient Temperature ", Jan. J. Appl. Phys. Vol.37, p.L479(1998).
[6] M. S. Shur, " GaN Based Transistors for High Power Applications ", Solid-State Electronics, Vol.42, p.2131(1998).
[7] M. A. Khan, J. N. Kuznia, A. R. Bhattarai, and D. T. Oslon, " Metal semiconductor field effect transistor based on sigle crystal GaN ", Appl. Phy. Lett. Vol. 62, p.1786 (1993).
[8] M. A. Khan, J. N. Kuznia, D. T. Olson, W. J. Schaff, J. W. Burm, and M. S. Shur, " Microwave performance of a 0.25um gate AlGaN/GaN heterostructure field effect transistor ", Appl. Phy. Lett. Vol. 64, p.1121 (1994).
[9] F. Ren, C. R. Abernathy, J. M. Van Hove, P. P. Chow, R. Hickman, J. J. Klaasen, R. F. Kopf, H. Cho, K. B. Jung, J. R. La Roche, R. G. Wilson, J. Han, R. J. Shul, A. G. Baca, and S. J. Pearton, " 300°C GaN/AlGaN Heterojunction Bipolar Transistor ", MRS Internet J. Nitride Semicond. Res. Vol.3,41(1998 ).
[10] G. S. Nakamura, " InGaN-based violet laser diodes ", Semicond. Sci. Technol. Vol.14, p.R27(1999).
[11] M. A. Khan, J. N. Kuznia, D. T. Olson, M. Blasingame, and A. R. Bhattarai, " Schottky barrier photodetector based on Mg-doped p-type GaN film ", Appl. Phys. Lett. Vol.63, p.2455(1993).
[12] S. Strite and H. Morkoc, J. Vac. Sci. Technol. B10, 1237 (1992).
[13] M. Asif Khan, J. N. Kuznia, D. T. Olson, J. M. Van hove, M. Blasingame, L. F. Reitz, " High-responsivity photoconductive ultraviolet sensors based on insulating single-crystal GaN epilayers ", Appl. Phys. Lett. Vol.60, p.2917(1992).
[14] Z. C. Huang, D. B. Mott, P. K. Shu, R. Zhang, J. C. Chen, D. K. Wickenden, " Optical quenching of photoconductivity in GaN photoconductors ", J. Appl. Phy. Vol.82, p.2707(1997).
[15] J. C. Carrano, T. Li, P. A. Grudowski, C. J. Eiting, R. D. Dupuis, J. C. Campell, " Comprehensive characterization of metal-semiconductor-metal ultraviolet photodetectors fabricated on single-crystal GaN ", J. Appl. Phy. Vol.83, p.6148(1995).
[16] Q. Chen, M. A. Khan, C. J. Sun, and J. W. Yang, " Visible-blind ultraviolet photodetectors based on GaN p-n junctions ", Electron. Lett. Vol.31, p.1781(1995).
[17] E. Monroy, E. Munoz, F. J. Sanchez, F. Calle, E. Calleja, B. Beaumont, P. Gibart, J. A. Munoz, F. Cusso, " High-performance GaN p-n junction photodetectors for solar ultraviolet applications ", Semicond. Sei. Technol. Vol.13, p.1042(1998).
[18] D. Walker, A. Saxler, P. Kung, X. Zhang, M. Hamilton, D. Jiaz, M. Razeghi, " Visible blind GaN p-i-n photodiodes ", Appl. Phys. Lett. Vol.72, p.3303(1998).
[19] E. Monroy, M. Hamilton, D. Walker, P. Kung, F. J. San-chez, M. Razeghi, " High-quality visible-blind AlGaN p-i-n photodiodes ", Appl. Phys. Lett. Vol.74, p.1171(1999).
[20] E. Monroy, F. Calle, E. Munoz, F. Omnes, P. Gibart, J. A. Munoz, " AlxGa1-xN:Si Schottky barrier photodiodes with fast response and high

detectivity ” , Appl. Phys. Lett. Vol.73, p.2146(1998).
[21] D. Walker, E. Monroy, P. Kung, J. Wu, M. Hamilton, F. J. Sanchez, J. Diaz, M. Razeghi, “ High-speed, low-noise metal-semiconductor-metal ultraviolet photodetectors based on GaN ” , Appl. Phys. Lett. Vol.74, p.762(1999) [22] E. Monroy, F. Calle, E. Munoz, and F. Omnes, “ Effects of Bias on the Responsivity of GaN Metal-Semiconductor-Metal Photodiodes ” , Phys. Stat. Sol. (a), Vol.176, p.157(1999).
[23] H. Jiang, N. Nakata, G. Y. Zhao, H. Ishikawa, C. L. Shao, T. Egawa, T. Jimbo, M. Umeno, “ Back-Illuminated GaN Metal-Semiconductor-Metal UV Photodetector with High Internal Gain ” , Jap. J. Appl. Phys. Vol.40, p.L505(2001).
[24] C. H. Chen, S. J. Chang, Y. K. Su, Senior Member,IEEE, G. C. Chi, J. Y. Chi, C. A. Chang, J. K. SHeu, and J. F. Chen, Member, “ GaN metal-semiconductor-metal ultraviolet photodetectors with transparent indium-tin-oxide Schottky contacts ” , IEEE photon. Technol. Lett. Vol.13, p.848(2001).
[25] H. Z. Xu, Z. G. Wang, M. Kawabe, I. Harrison, B. J. Ansell, C. T. Foxon, “ Fabrication and characterization of metal-semiconductor-metal (MSM) ultraviolet photodetectors on undoped GaN/sapphire grown by MBE ” , J. Crystal. Growth, Vol.218, p.1(2000).
[26] L. S. Yu, D. Qiao, L. Jia, S. S. Lau, Y. Qi, and K. M. Lau, Appl. Phys. Lett. 79, 4536(2001).
[27] S. Y. Kim, H. W. Jang, and J. L. Lee, Appl. Phys. Lett. 82, 61(2003).
[28] N. Biyikli, T. Kartaloglu, O. Aytur, I. Kimukin, and E. Ozbay, Appl. Phys. Lett. 79, 2838(2001).
[29] T. Margalith, O. Buchinsky, D. A. Cohen, A. C. Abare, M. Hansen, S. P. DenBaars, and L. A. Coldren, Appl. Phys. Lett. 74, 3930(1999).
[30] D. W. Kima,*, Y. J. Sunga, J. W. Parkb, G. Y. Yeoma, Thin Solid Films 398 – 399 (2001) 87 – 92 [31] J. K. Sheu, Y. K. Su, G. C. Chi, M. J. Jou, and C. M. Chang , Appl. Phys. Lett. 72, 3317(1998).
[32] X. A. Cao, S. J. Peartona), A. P. Zhang, G. T. Dang, and F. Ren, R. J. Shul and L. Zhang, R. Hickman and J. M. Van Hove, Appl. Phys. Lett. Vol.75,p.2569 (1999) [33] X. A. Cao, S. J. Pearton, Senior Member, IEEE, G. T. Dang, A. P. Zhang, F. Ren, and J. M. Van Hove, TRANSACTIONS ON ELECTRON DEVICES ,IEEE, VOL. 47, NO. 7, JULY 2000 [34] F. Braun, Annal. Phys. Chem. 153, 556 (1874).
[35] W. Schottky, Naturwissenschaften 26, 843 (1938).
[36] J. K. Sheu ,Y. K. Su, G. C. Chia), W. C. Chen, C. Y. Chen, C. N. Huang, and J. M. Hong, Y. C. Yu, C. W. Wang, and E. K. Lin,J. Appl. Phy. Lett. Vol.83, p.3172 (1998).
[37] Jin-Kuo Ho,a) Charng-Shyang Jong, Chien C. Chiu, Chao-Nien Huang, and Kwang-Kuo Shih, J. Appl. Phys. Lett. Vol.86, p.4491 (1999).
[38] M. Hanzaz and A. Bouhdadaa), P. Gibart and F. Omne`s, J. Appl. Phys. Lett. Vol.92, p.13 (2002).
[39] K.N. Lee a, X.A. Cao a, C.R. Abernathy a,*, S.J. Pearton a, A.P. Zhang b, F. Ren b,R. Hickman c, J.M. Van Hove c, Solid-State Electronics 44 (2000) 1203±1208 [40] X. A. Cao, H. Cho, and S. J. Pearton, G. T. Dang, A. P. Zhang, and F. Ren, R. J. Shul and L. Zhang, R. Hickman and J. M. Van Hove, Appl. Phys. Lett. Vol.75,p.232 (1999) [41] D.G. Kent a, K.P. Lee a, A.P. Zhang b, B. Luo b, M.E. Overberg a, C.R. Abernathy a, F.Ren b,*, K.D. Mackenzie c, S.J. Pearton a, Y. Nakagawa d, Solid-State Electronics 45(2001) 467-470 [42] L. S. Yu, L. Jia, D. Qiao, S. S. Lau, J. Li, J. Y. Lin, and H. X. Jiang, TRANSACTIONS ON ELECTRON DEVICES ,IEEE, VOL. 50, NO.2, FEBRUARY2003 [43] D.L. Pulfrey a,*, G. Parish b, D. Wee b, B.D. Nener b, Solid-State Electronics 49(2005) 1969-1973 [44] Yow-Jon Lina! and Yow-Lin Chu, J. Appl. Phys. Lett. Vol.97, p.104904 (2005).
[45] Z.Z. Chen*, Z.X. Qin, Y.Z. Tong, X.M. Ding, X.D. Hu, T.J. Yu, Z.J. Yang,G.Y. Zhang, Physica B 334 (2003) 188 – 192 [46] Z.X. Qina,*, Z.Z. Chena, H.X. Zhanga,b, X.M. Dinga, X.D. Hua, T.J. Yua,Y.Z. Tonga, G.Y. Zhanga, Materials Science in Semiconductor Processing 5 (2003) 473 – 475