Doctoral Dissertation

Ohmic Contact Formation of Gallium Nitride and Electrical Properties Improvement

Aiman bin Mohd Halil

December 2015

Graduate School of Engineering

Osaka University

Ohmic Contact Formation of Gallium Nitride and

Electrical Properties Improvement

Contents:

mechanism ($a_{3,2}$ and $\tau_{3,2}$) and the third mechanism ($a_{3,3}$ and $\tau_{3,3}$) of H release in the third model (Eq. 6.9), respectively.

The saturation value $a_{3,3}$ (2.8) and the exponential decay with time constant $\tau_{3,3}$ (7000) of the third mechanism of H release (H release through Pd film by applying current flow during annealing) are highest compared to the saturation values and exponential decay with time constant of other mechanisms of all the models. These values indicate that the H release has been significantly enhanced by this mechanism. Greater amount of H is released and the mechanism of H release occurring much longer before start to saturate. As shown in the Fig. 6.5, the current value is still increasing even after annealing for 10000 s, i.e., the H release is still occurring and electrical conduction of the contact is keep improved even after annealing for 10000 s.

From these results, it can be understand that by applying current flow during annealing and forming a contact with material that H can diffuse into, the H release from GaN substrate can be enhanced and the electrical conduction of p-type GaN contact can be significantly improved.

6.4 Summary

In this chapter, in order to improve the electrical conduction of Mg-doped p-type GaN contacts, enhancement of hydrogen release from GaN substrates is attempted. The electrical conduction profiles of the p-type GaN/Ni contact annealed at 573 K and 673 K for 3600 s while subjected to current flow show some improvement compared to the contact annealed without applying the current flow. From these results, it can be understood that by applying current flow through the GaN substrates during annealing process, hydrogen release form GaN substrates can be enhanced by even annealing at low

temperature. To understand the mechanism of hydrogen release by applying current flow during annealing, the change in current values p-type GaN contacts during annealing has been observed. By using regression analysis and kinetic model, the electrical conduction improvement achieve by applying current flow through GaN substrate during annealing have been analysis. The results suggest that that by applying current flow during annealing and by forming a contact with material that H can diffuse into such as Pd, the H release from GaN substrate can be enhanced and the electrical conduction of p-type GaN contact can be significantly improved.

References:

[1] S. J. Pearton, J. C. Zolper, R. J. Shul, and F. Ren, "GaN: Processing, defects, and devices," Journal of Applied Physics 86, No. 1 (1999), 1-78.

[2] S. Nakamura, N. Iwasa, M. Senoh, and T. Mukai, "Hole Compensation Mechanism of P-Type GaN Films," Japanese Journal of Applied Physics 31 (1992), 1258-1266.

[3] J. Neugebauer and C. G. Van De Walle, "Hydrogen in GaN: Novel Aspects of a Common Impurity," Physics Review Letters 75, No. 24 (1995), 4452-4455.

[4] B. Clerjaud, D. Cote, A. Lebkiri, C. Naud, J. M. Baranowski, K. Pakula, D. Wasik, and T. Suski, "Infrared spectroscopy of Mg-H local vibrational mode in GaN with polarized light," Physical Review B 61, No. 12 (2000), 8238-8241.

[5] S. M. Myers, C. H. Seager, A. F. Wright, B. L. Vaandrager, and J. S. Nelson, "Electron-beam dissociation of the MgH complex in p-type GaN," Journal of Applied Physics 92, No. 11 (2002), 6630-6635.

temperature. To understand the mechanism of hydrogen release by applying current flow during annealing, the change in current values p-type GaN contacts during annealing has been observed. By using regression analysis and kinetic model, the electrical conduction improvement achieve by applying current flow through GaN substrate during annealing have been analysis. The results suggest that that by applying current flow during annealing and by forming a contact with material that H can diffuse into such as Pd, the H release from GaN substrate can be enhanced and the electrical conduction of p-type GaN contact can be significantly improved.

References:

[1] S. J. Pearton, J. C. Zolper, R. J. Shul, and F. Ren, "GaN: Processing, defects, and devices," Journal of Applied Physics 86, No. 1 (1999), 1-78.

[2] S. Nakamura, N. Iwasa, M. Senoh, and T. Mukai, "Hole Compensation Mechanism of P-Type GaN Films," Japanese Journal of Applied Physics 31 (1992), 1258-1266.

[3] J. Neugebauer and C. G. Van De Walle, "Hydrogen in GaN: Novel Aspects of a Common Impurity," Physics Review Letters 75, No. 24 (1995), 4452-4455.

[4] B. Clerjaud, D. Cote, A. Lebkiri, C. Naud, J. M. Baranowski, K. Pakula, D. Wasik, and T. Suski, "Infrared spectroscopy of Mg-H local vibrational mode in GaN with polarized light," Physical Review B 61, No. 12 (2000), 8238-8241.

[5] S. M. Myers, C. H. Seager, A. F. Wright, B. L. Vaandrager, and J. S. Nelson, "Electron-beam dissociation of the MgH complex in p-type GaN," Journal of Applied Physics 92, No. 11 (2002), 6630-6635.

[6] S. Nakamura, T. Mukai, M. Senoh and N. Iwasa, "Thermal Annealing Effects on P-Type Mg-Doped GaN Films," Japanese Journal of Applied Physics 31 (1992), L139- L142.

[7] A. b. M. Halil, K. Tsuchida, M. Maeda and Y. Takahashi, "Ni Nano Level Thin Film Formation on p-GaN and Improvement of Electrical Properties by Hydrogen Release Enhancement," Journal of Smart Processing 4, No. 2 (2015) 109-114.

[8] S. M. Myers, A. F. Wright, G. A. Petersen, C. H. Seager, W. R. Wampler, M. H. Crawford, and J. Han, "Equilibrium state of hydrogen in gallium nitride: Theory and experiment," Journal of Applied Physics 88 (2000), 4676-4687.

[9] L. L. Jewell and B. H. Davis, "Review of absorption and adsorption in the hydrogen–palladium system," Applied Catalysis A: General 310 (2006), 1-15.

[10] S. Hara, A. Caravella, M. Ishitsuka, H. Suda, M. Mukaida, K. Haraya, E. Shimano and T. Tsuji, "Hydrogen diffusion coefficient and mobility in palladium as a function of equilibrium pressure evaluated by permeation measurement," Journal of Membrane Science 421-422 (2012), 355-360.

Achievement:

Chapter 4

[1] A. b. M. Halil, K. Kimura, M. Maeda and Y. Takahashi, "Microstructures Observation of N-type GaN Contacts and the Electrical Properties," Transactions of JWRI 44, No. 1 (2015), 19-22.

[2] K. Kimura, A. b. M. Halil, M. Maeda and Y. Takahashi, "Effect of crystal orientation on ohmic contact formation for n-type gallium nitride," IOP Conference Series: Materials Science and Engineering 61 (2014), 012033.

Chapter 5

[3] A. b. M. Halil, M. Maeda and Y. Takahashi, "Electrical properties and structure of contact interface between Ti_3SiC_2 and p-type GaN," Journal of Physics: Conference Series 379 (2012), 012021.

[4] A. b. M. Halil, M. Maeda and Y. Takahashi, "Interfacial Nanostructure and Electrical Properties of Ti_3SiC_2 Contact on p-Type Gallium Nitride," Materials Transactions 54, No. 6 (2013) 890-894.

[5] A. b. M. Halil, M. Maeda and Y. Takahashi, "Effect of Ti_3SiC_2 formation on p-type GaN by vacuum annealing on the contact properties," IOP Conference Series: Materials Science and Engineering 61 (2014) 012034.

Chapter 6

[6] A. b. M. Halil, K. Tsuchida, M. Maeda and Y. Takahashi, "Improvement of Electrical Properties of p-type GaN and Au Contact Interface," Quarterly Journal

of the Japan Welding Society 33, No. 2 (2015) 84s-87s.

[7] A. b. M. Halil, K. Tsuchida, M. Maeda and Y. Takahashi, "Ni Nano Level Thin Film Formation on p-GaN and Improvement of Electrical Properties by Hydrogen Release Enhancement," Journal of Smart Processing 4, No. 2 (2015) 109-114.