

Study of ITO/p-SiGe Contact System

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ABSTRACT

Indium-Tin-Oxide (ITO) has been deposited onto undoped Si_{0.8}Ge_{0.2} layer by using radio frequency (RF) sputtering system, where the Si_{0.8}Ge_{0.2} layer was grown onto n-Si substrate by using ultra-high vacuum chemical vapor deposition (UHV CVD). The undoped Si_{0.8}Ge_{0.2} layer, with a thickness of 150 nm, is a strain layer and p-type. The optimum sputtering conditions are sputtering power of 30 W, Ar flow rate of 110 sccm, pressure of 10 mtorr at room temperature. Under these conditions, the ITO film has a sheet resistance of 32.5 Ω/\square and reduced to 28.7 Ω/\square by post-annealed at 600 °C, where the transmittance of ITO films are more than 80% for all interested wavelength. ITO/p-Si_{0.8}Ge_{0.2} contact systems with Si capping layer (10 nm), i.e., ITO/Si/p-Si_{0.8}Ge_{0.2}, and without Si capping, i.e., ITO/p-Si_{0.8}Ge_{0.2}, have been prepared for our study. The specific contact resistance measured by transfer length model (TLM) are 2.78x10⁻² $\Omega\text{-cm}^2$ (600°C annealed) and 2.26x10⁻⁵ $\Omega\text{-cm}^2$ (without annealed) for ITO/Si/p-Si_{0.8}Ge_{0.2} and ITO/p-Si_{0.8}Ge_{0.2} structures, respectively. Finally, the metal-semiconductor-metal (MSM) photodetectors using ITO electrodes have been fabricated with and without Si capping. With 500 μW halogen lamp irradiation, the ITO/p-SiGe has a peak response at a wavelength of 1129nm and its responsivity is 0.58A/W under 1V bias. However, dual wavelength responses are observed for ITO/Si/p-SiGe structure under 1 V applied bias and is attributed to the absorption of Si and Si_{0.8}Ge_{0.2} layers. The 1 V bias would deplete Si capping and SiGe layers because Si (10 nm) and SiGe (150 nm) layers are very thin as a result of Schottky contact of ITO/p-Si. The responsivity are 0.639A/W and 1.105A/W for wavelength at 957nm and 1150nm. Higher responsivity at 1150 nm is due to thicker film of SiGe layer than the thickness of Si capping.

Keywords : RF sputtering system、Indium-Tin-Oxide、SiGe、annealing、responsivity.

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REFERENCES

[1] K. B.Sundaram, and Jila Blanchard, IEEE, pp. 230-232 (1997).
[2] X. Xiao, James C. Sturm, S. R. Parihar, S. A. Lyon, D. Meyerhofer, Stephen Palfrey, and F. V. Shallcross, IEEE Electron Device Letter, Vol. 14, No. 4, pp. 199-201 (1994).
[3] Hiroyuki Kanaya, Fumio Hasegawa, Eiso Yamaka, Takashi Moriyama, and Masakatsu Nakajima, Jpn. J. Appl. Phys. Vol. 28, No. 4, pp. 544-546 (1989).
[4] H. Kanaya, Y. Cho, F. Hasegawa, and E. Yamaka, Jpn. J. Appl. Phys., Vol. 29, pp. 850-852 (1990).
[5] W. Schottky, Naturwissenschaften 26, 843 (1938).
[6] E. H. Rhoderick, R. H. William, Metal-Semiconductor Contacts, Clarendon Press (1998).
[7] S. M. Sze, Semiconductor Device Physics and Technology, pp. 160 (1985).
[8] Hsing Kuen Liou, Edward S. Yang, and K. N. Tu, Appl. Phys. Lett., Vol. 63, pp. 911-913 (1993).
[9] G. K. Reeves, and H. B. Harrison, IEEE Electron Device Lett. EDL-3, 111 (1982).
[10] Pallab Bhattacharya, Semiconductor Optoelectronic devices, pp. 192-193 (2003).
[11] V. Ya. Niskov, and G. A. Kubetskii, Sov. Phys. Semicond. Vol. 4, pp. 1553 (1971).
[12] K. Bhaumik, and R. J. Mattauch, IEEE Southeastcon '90. Proceedings., Vol. 3, pp. 987-991 (1990).
[13] S. O. Kasap, Optoelectronics and photonics : principles and practices (2003).
[14] K. Utsumi, O. Matsunaga, and T. Takahata, Thin Solid Films, Vol. 334, pp. 30-34 (1998).
[15] P. Zhong, and Y. Zheng, Appl. Phys. Lett., Vol. 62, pp. 3259-3261 (1993).
[16] C. W. Ow-Yang, Y. Shigesato, and D. C. Paine, J. Appl. Phys., Vol. 88, pp. 3717-3724 (2000) [17] T. Maruyama, T. Tago, Appl. Phys. Lett., Vol. 64, pp. 1935-1937 (1994).
[18] D. Sueva, S. S. Georgiev, N. Nedev, A. Toneva, N Chikov, Vacuum, Vol. 58, pp. 308-314 (2000).
[19] Shewchun J, Burk D, Spitzer M, IEEE Trans Electron Devices, ED-27:705-706 (1980).
[20] D. Dutartre, G. Bremond, A. Souifi, and T. Benyattou, Physical Review B, Vol. 44, No. 20, pp. 11525-11527 (1991).