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Growth of (10$\bar{1}$3) semipolar GaN on Si substrate with a CrN interlayer by molecular beam epitaxy

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1. Introduction

GaN and other nitride-based compound semiconductors have much potential on optical and high-frequency electronic devices [1]. Especially, GaN has advantages of wide band gap (3.4 eV), excellent chemical and thermal stability. The c-plane sapphire is usually employed as a substrate in the growth of GaN epilayer; however, the thermal conductivity of sapphire is undesirable. Besides, Si (111) substrates have attractive properties in good thermal, electrical conductivity and low cost. So far, devices of GaN on Si substrates have been achieved, including light emitting diode [2][3], photodetector [4] and filed-effect transistor [5]. However, it has been known that the lattice mismatch between GaN and Si substrate is as high as 17% leading to thermal-induced cracks in the grown GaN films [6] The lattice constant of CrN is between GaN and Si, the rock-salt structure of CrN could reduce dislocation originated from lattice mismatch [10]. Additional, its chemical property is notable that could dissolve in specific acidic solution [7], this property could realize the chemical lift-off (CLO) in the device process without laser lift-off (LLO). Recently, application of CLO to GaN-based vertical light emitting diode (V-LED) on sapphire substrates has been reported [8]. In this work, we study the characteristics of GaN films grown on Si substrates grown by molecular beam epitaxy (MBE) with a CrN interlayer deposited by RF-sputter deposition.

2. Experimental procedure

Si (111) substrates were cleaned first by standard cleaning process, after that, an 8-nm-thick Cr thin film was coated on the Si substrates by RF-sputter deposition. A subsequent nitridation of the substrates was performed under 350 W N_2 plasma at 700 °C for 30 min in MBE chamber. The temperature of substrate was then varied to 500°C and 700°C for growing a low-temperature GaN buffer layer and a GaN epilayer. The thickness for the GaN buffer layer and epilayer is 100 and 600 nm, respectively. The structures and characteristics of the grown GaN epilayers with and without CrN interlayer were examined by X-ray diffraction, atomic force microscope (AFM) and photoluminescence (PL) measurements.

3. Results and discussions

Figure 1 (a) shows XRD-2θ scan of Cr on Si substrate after nitridation. Two peaks located at 43.29° and 53.88° in Fig. 1 are corresponding to CrN (200) and Si (222), respectively, showing an evidence for a nitridation production of CrN (200). It is noted that that the crystal orientation of CrN on Si is different from CrN/AlN/c-sapphire [9] and CrN/c-sapphire [10]. The surface topography of the CrN layer is shown in Fig. 1 (b), exhibiting an average grain size of about 100 nm.

Figure 2 shows the XRD spectra for the GaN layers grown on Si substrates with and without CrN interlayer, respectively. The orientation of the grown GaN epilayer without/with CrN interlayer was along c-axis and GaN (10$\bar{1}$3), respectively.. The carrier concentration obtained by Hall measurement for the samples grown with/without CrN interlayer were 2.1×10^{20} cm^{-3} and 1.23×10^{22} cm^{-3}, respectively. Apparently, the CrN interlayer could improve the crystalline quality [10] and reduced electron concentration of the GaN epilayers.

Figure 3 shows photoluminescence (PL) spectra of the samples grown with/without the CrN interlayer. The integral PL intensity and FWHM of the sample without CrN interlayer was less and wider than that of the sample with CrN interlayer, which implies that the crystalline of the grown GaN epilayer was apparent improved with the CrN interlayer. Remarkable the peak at 384 nm in the spectrum of the sample without CrN interlayer is corresponding to the donor-acceptor recombination due to the higher N and Ga defect in GaN.

4. Conclusion

In conclusion, we demonstrated that the GaN (10$\bar{1}$3) can be grown on Si substrates by MBE with CrN interlayer formed by nitridation of sputter-coated Cr metal thin film. Its electron concentration is reduced and the crystalline was improved by the CrN interlayer, as compare to the GaN grown on Si substrates without CrN interlayers. The results show that the interlayer of CrN play an important role in the growth of (10$\bar{1}$3) GaN epilayers.

Reference

[1] S. Nakamura, M. Senoh, S. Nagahama, N. Iwasa, T. Yamada, T. Matsushita, H. Kiyoku, Y. Sugimoto, T. Kozaki, H. Umemoto, M. Sano, and K. Chocho, ***Appl. Phys. Lett***. **72**(2), 211 (1998).

[2] S. Dalmasso, E. Feltin, P. de Mierry, B. Beaumont, P. Gibart, M. Leroux, ***Electron. Lett***. 36 ,1728,(2000)

[3] J.W. Yang, A. Lunev, G. Simin, A. Chitnis, M. Shatalov,M. Asif Khan, J.E. Van Nostrand, R. Gaska, ***Appl. Phys.Lett***. 76 ,273, (2000)

[4] Kim J.K, Lee J.L , ***ELECTROCHEM SOC***, 51 ,3, G190-G195, (2004)

[5] T. Egawa, N. Nakada, H. Ishikawa, M. Umeno, ***Electron.Lett***. 36, 1816, (2000)

[6] E. Feltin, B. Beaumont, M. Laügt, P. de Mierry, P. Vennègués, H. Lahrèche, M. Leroux, and P. Gibart, ***Appl. Phys. Lett***. 79, 3230 (2001).

[7] H. Goto, S. W. Lee, H. J. Lee, J.S. Ha, M. W. Chou, T. Yao, ***Phy stat. sol***. C 5, 1659 (2008)

[8] J. S. Ha, S.W. Lee, H. J. Lee, H. J. Lee, S. H. Lee, H. Goto, T. Kato, K. Fujii, M. W. Cho, T. Yao, ***IEEE Photonics Technol. Lett***. 20, 175 (2008)

[9] J. S. Ha, H. J. Lee, S. W. Lee, H. J. Lee, S. H. Lee, H. Goto, M. W. Cho, T. Yao, S. K. Hong, R. Toba, J. W. Lee, J. Y. Lee, ***Appl. Phys. Lett***. 92, 091906 (2008)

[10] W. H. Lee, S. W. Lee, H. Goto, H. C. Ko, M. W. Cho, T. Yao, ***Phy. Stat. sol***. (c) 3,No. 6, 1388-1391 (2006)

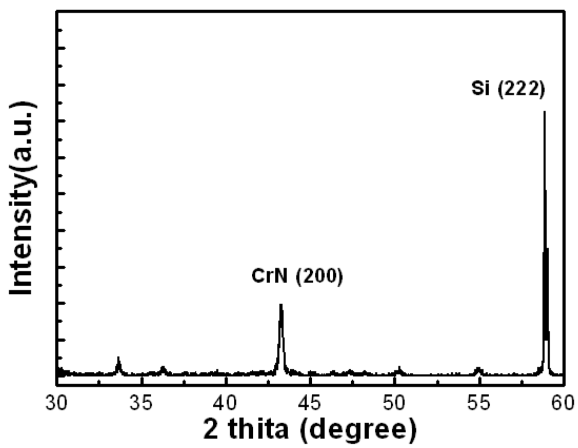

Fig. 1(a) XRD θ-2θ spectra for the Si substrates coated with Cr metal film after nitridation process.

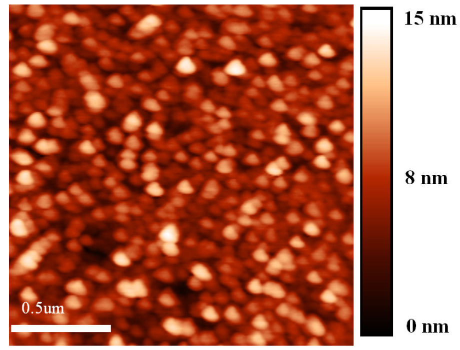

Fig. 1 (b) AFM image for the surface of Si substrate coated with Cr metal film after nitridation process.

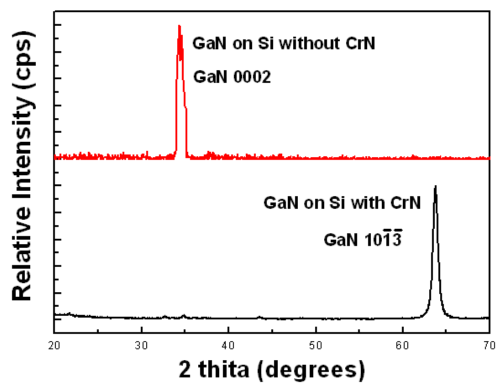

Fig. 2 XRD-2thita spectra for the MBE grown GaN samples with and without CrN interlayer. GaN (0002) was grown on Si substrate without CrN interlayer and GaN $(10\bar{1}3)$ was grown on Si with CrN interlayer.

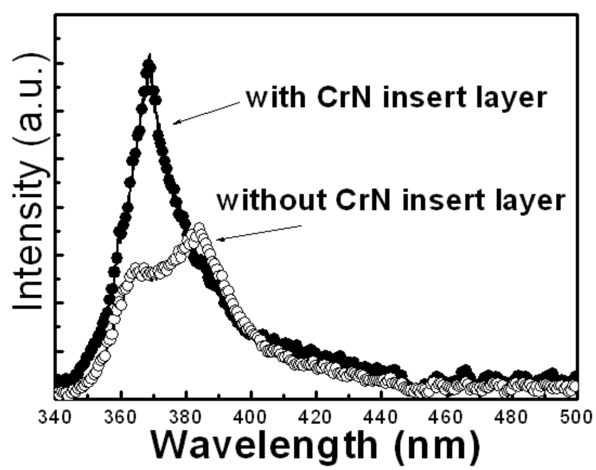

Fig. 3 Photoluminescence spectra of the MBE grown GaN samples with and without CrN interlayers.