

Growth of ZnO Films on Different Substrates by Metal Organic Chemical Vapor Deposition

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Abstract: ZnO thin films were grown on two kinds of substrates of Corning glass and α -Al₂O₃ by metal organic chemical vapor deposition. The properties of the films were studied. It was found the sharp diffraction peak for ZnO (002) by X-ray diffraction method, not only in the sample of the substrate of α -Al₂O₃ (A), but also in the sample of the substrate of Corning glass (B), showing the two samples were highly *c*-axis oriented. The photoluminescence (PL) spectra of the ZnO films were studied. The UV emission at ~ 374 nm was found in sample A and B. The deep level emissions was found in the sample A, but not in the sample B, showing that the high quality ZnO films was grown on the substrate of glass. The surface morphology was studied by the AFM also. Though the average size of grain and the RMS (root-mean-square) value of the two samples is different, comparing sample A with B, the result shows that sample A is more smooth. It can be found that the samples A and B were all grown in a column-by-column growth process.

Key words: ZnO; thin films; growth; MOCVD

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1 Introduction

Zinc oxide, a wide direct band gap semiconductor, is attracting more and more attention from researchers for its potential applications in short-wavelength light emitting devices such as light emitting diodes (LEDs) ^[1], photodetectors ^[2], transparent thin film transistors ^[3-5] etc. ZnO films can be grown by many methods, such as magnetron sputtering ^[6], molecular beam epitaxy (MBE) ^[7-9], pulsed laser deposition (PLD) ^[10]

and metal organic vapor deposition (MOCVD) ^[11-13]. MOCVD provides the advantage of growing high-quality films due to its versatility in controlling the various thermo-dynamic interactions. It also offers high growth rate and growth efficiency, large area uniformity and different doping processes. In our paper, we grew the ZnO films by MOCVD on different substrates.

2 Experimental

ZnO films are grown on α -Al₂O₃ and Corning

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glass substrates by MOCVD. The detailed introduction about our growth system can be seen in reference [14,15]. The vacuum of the growth chamber is about 230 Pa. The growth temperature is ~ 510 °C. A continuous flow of carrier gas (high-purity N_2) is introduced uniformly into chamber from the top, its value is 400 mL/min. DEZ and O_2 are introduced into chamber by two injectors respectively, to reduce the pre-reaction. The Ar flow of 2 mL/min passes through the DEZ bubbler maintained at -12 °C. An additional Ar flow of 20 mL/min is introduced into the DEZ line immediately at the exit of the bubbler to reduce the transit time of DEZ to the reactor. The O_2 flow is varied from 150 mL/min to 180 mL/min. Under the above conditions, we grew the ZnO films. SIEMENS D08 Discover X-ray diffractometer was used to investigate the crystal quality. PL spectrum is measured by 325 nm He-Cd laser. Surface morphology was investigated by Digital Nanoscope IIIa AFM.

3 Results and Discussion

We found the sharp diffraction peak for ZnO (002) by X-ray diffraction method, showing the two samples were highly *c*-axis oriented (in Fig. 1 and 2, sample A: ZnO film on $\alpha-Al_2O_3$ substrate; sample B: ZnO film on glass substrate). The comparison of the samples of PL was shown in Fig. 3. We can see the UV emission at ~ 374 nm in both of the samples. Further, we found the deep level emission in spectrum of sample A,

but we didn't find it in that of sample B, showing we got the better high quality ZnO films on the substrate of glass under the same growth condition. Fig. 4 are the surface morphology of

Fig. 2 X-ray diffraction spectrum of ZnO film(sample B)

Fig. 3 PL spectra of ZnO film

Fig. 1 X-ray diffraction spectrum of ZnO film(Sample A)

Fig. 4 Surface images of ZnO film measured by AFM

the samples. The average size of grain and the RMS(root-mean-square) value of the two samples is different, comparing sample A with B, we can see the grain size of sample A is much smaller than that of sample B. But, we can see the same column-in-column growth process, showing the two samples' growth is in high quality.

4 Conclusion

The crystalline ZnO thin films were grown

on α -Al₂O₃ and Corning glass substrate respectively by MOCVD. XRD measurement showed that ZnO thin films grown on the two substrates were all strongly *c*-oriented. From the AFM, we find that the two samples were all grown in a column-by-column growth process. The UV emission was found at ~ 374 nm in the two samples, indicating the samples were in high quality.

References:

- [1] Toru Aoki, Yoshinori Hatanaka, David C. Look ZnO diode fabricated by excimer-laser doping [J]. *Appl. Phys. Lett.*, 2000, 76(22):22-29.
- [2] Liu Y, Gorla C R, Liang S, *et al.* Ultraviolet detectors based on epitaxial ZnO films grown by MOCVD [J]. *Electron. Mater.*, 2000, 29(1):69-74.
- [3] Garcia P F, McLean P S, Reilly M H, *et al.* Transparent ZnO thin film transistor fabricated by rf magnetron sputtering [J]. *Appl. Phys. Lett.*, 2003, 82(7):1117-1119.
- [4] Satoshi Masuda, Ken Kitamura, Yoshihiro Okumura, *et al.* Transparent thin film transistors using ZnO as an active channel layer and their electrical properties [J]. *J. Appl. Phys.*, 2003, 93(3):1624-1630.
- [5] Hoffman R L, Norris B J, Wager J F. ZnO-based transparent thin-film transistors [J]. *Appl. Phys. Lett.*, 2003, 82(5):733-735.
- [6] Hinze J, Ellmer K. In situ measurement of mechanical stress in polycrystalline zinc-oxide thin films prepared by magnetron sputtering [J]. *J. Appl. Phys.*, 2000, 88(5):2443-2450.
- [7] Johnson M A L, Fujita Shizuo, Rowland W H, *et al.* MBE growth and properties of ZnO on sapphire and SiC substrates [J]. *J. Electron. Mater.*, 1996, 25(5):855-862.
- [8] Bagnall D, Chen Y, Zhu Z, *et al.* Optically pumped lasing of ZnO at room temperature [J]. *Appl. Phys. Lett.*, 1997, 70(17):2230-2232.
- [9] Iwata K, Fons P, Yamada A, *et al.* Nitrogen-induced defects in ZnO:N grown on sapphire substrate by gas source MBE [J]. *J. Crystal Growth*, 2000, 209(2-3):526-531.
- [10] Guo X L, Tabatga H, Kawai T. Pulsed laser reactive deposition of p-type ZnO film enhanced by an electron cyclotron resonance source [J]. *J. Crystal Growth*, 2000, 223(1-2):135-139.
- [11] Seung Yeop Myong, Koeng Su Lim. Highly stable and textured hydrogenated ZnO thin films [J]. *Appl. Phys. Lett.*, 2003, 82(18):3026-3028.
- [12] Kashiwaba Y, Katahira F, Haga K, *et al.* Hetero-epitaxial growth of ZnO thin films by atmospheric pressure CVD method [J]. *J. Crystal Growth*, 2000, 221(1-4):431-434.
- [13] Ogata K, Kawanishi T, Maejima K, *et al.* Growth mode control of ZnO toward nanorod structures or high-quality layered structures by metal-organic vapor phase epitaxy [J]. *J. Crystal Growth*, 2003, 248(1-4):25-30.
- [14] Yang Xiaotian, Du Guotong, Wang Xinqiang, *et al.* Effect of post-thermal annealing on properties of ZnO thin film grown on c-Al₂O₃ by metal-organic chemical vapor deposition [J]. *J. Crystal Growth*, 2003, 252(1-3):275-278.
- [15] 侯旭峰,荆海,谷长栋,等.高阻 ITO 基板上电化学沉积 ZnO 薄膜的研究 [J]. *液晶与显示*, 2007, 22(1):15-20.
- [16] 侯旭峰,荆海,张会平. ZnO 纳米棒/薄膜结构的电沉积制备及性能 [J]. *液晶与显示*, 2007, 22(6):694-700.

不同衬底上氧化锌薄膜的金属有机化学气相沉积方法生长

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摘 要

氧化锌薄膜通过金属有机化学气相沉积方法生长在康宁玻璃与 α -蓝宝石衬底上, 研究了有关薄膜的生长质量与发光特性。通过 X 光衍射方法测试研究发现, 不仅在以 α -蓝宝石为衬底的样品中, 同时, 在以玻璃为衬底的样品中都发现了氧化锌(0 0 2)方向生长的尖峰, 表明生长在两种衬底上的样品都是高度的 C 向生长。对两种样品的荧光谱研究发现, 两者的紫外峰位于 374 nm 附近, 在以 α -蓝宝石为衬底的样品中, 有深能级发射, 但在以玻璃为衬底的样品中没有发现, 表明在玻璃衬底上我们生长出了高质量的氧化锌薄膜。通过原子力显微镜, 对生长在两种衬底上薄膜的表面形貌做了观察, 其晶粒的大小与表面粗糙度有一定的差别, 表明二者都是以柱状形式生长的。

关 键 词: 氧化锌; 薄膜; 生长; MOCVD

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