ZnO Films Deposited by RF Magnetron Sputtering

Jing Li, SuntaoWu and Junyong Kang*

Pen-Tung Sah MEMS Research Center and Department of Physics
Xiamen University, Xiamen 361005, China
e-mail: jykang@xmu.edu.cn

ZnO nano films were deposited on p-Si (100) with different pre-deposited buffer layers by RF magnetron sputtering system under different processing conditions. The film surface morphology and crystal structure were characterized by scanning electron microscopy, atomic force microscopy, and X-ray diffraction. The results demonstrate that the grain sizes of ZnO films vary from 6~100 nm under different processing conditions. The film with the thickness about 300 nm was formed by ZnO nano-pillars dominantly orientated in c-axis direction. Moreover, the film surfaces are very smooth and homogeneous.

1. Introduction

Zinc oxide is a very promising functional material due to its significant properties, such as piezoelectric, photoelectric, and optical property. Recently ZnO has been widely applied in piezoelectric transducers, surface acoustic wave, and optoelectronic devices. Many technologies, such as vapor-liquid-solid [1], pulse laser deposition [2], molecular beam evaporation, thermal evaporation, metal organic chemical vapor deposition [3], sputtering [4] and so on, can be used to prepare the ZnO film on glass, sapphire or Si substrates. In our work, we prepared the ZnO nano polycrystalline film using radio-frequency (RF) magnetron sputtering technology under different conditions. The films' surface morphologies and crystal structures were characterized by scanning electron microscopy (SEM), atomic force microscopy (AFM), and X-ray diffraction (XRD).

2. Experiment

The RF magnetron sputtering system was used to deposit the ZnO film. Zn (99.99%) was used as the target with the diameter Φ100 mm. The bare silicon wafers with or without 300-nm-thickness buffered Si_xN_y or SiO_2 layers were used as substrates. During the processing, the gas pressure is maintained at 1 Pa. The distance between target and substrates was 50 mm. The ratio of sputtering gas Ar to O_2 was changed from 0% to 80%. The RF power was varied in a range of 75~200 W. The substrate temperature was kept at 200 °C.

3. Results and Discussion

The surface morphologies of the ZnO films deposited in different processing conditions were characterised by SEM. The ZnO films are formed by small compact grains. The grain size is in nano scale, as shown in Fig.1. With an increase of Ar/O_2 ratio, the grain sizes increase from 6 nm to 35 nm at sputtering power 75 W as the data listed in Table 1. This fact may be understood from that the oxygen has the higher electron capture ability and a lower

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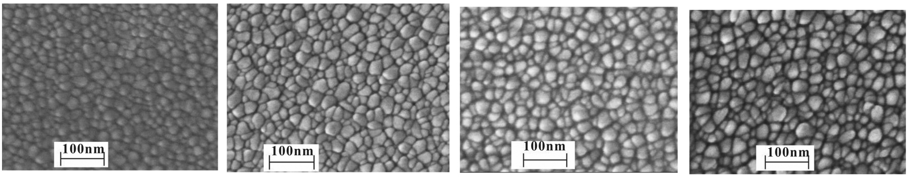


(a) (b) (c) (d)

Fig. 1 SEM images of the ZnO films on the Si_xN_y/Si (100) with different Ar/O_2 ratios: (a) 0%, (b) 25%, (c) 50% and (d) 80%

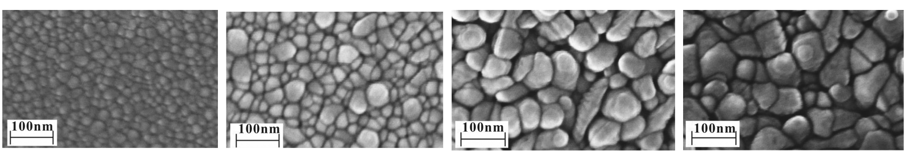
sputtering yield than argon, which will decrease the density of plasmas. As a result, the grain size increases as the Ar/O_2 ratio increases due to more atoms transferred from the target [5].

Table 1. The ZnO grain sizes (nm) processed in different conditions

Sputtering Power (W)		**75**				**120**	**160**	**200**
Ar : O_2 ratio (%)		**0**	**25**	**50**	**80**	**50**	**50**	**50**
Grain Size (nm)	**Substrate**							
	ZnO/Si (100)	6-12	6-12	8-15	25-35	25-35	30-60	50-100
	ZnO/ SiO_2/Si (100)	6-12	6-12	8-15	25-35	25-35	30-60	50-100
	ZnO/Si_xN_y/Si(100)	6-12	6-12	8-15	25-35	25-35	30-60	50-100

While at constant Ar/O_2 ratio of 50%, the grain sizes increase with the power increases from 75 W to 200 W as shown in Fig. 2. It is very clear that the higher sputtering power will increase the density of plasma. The higher density of plasma will bomb down more and bigger Zn particles from the target, which react with oxygen to form bigger ZnO particles on the substrates.

From the SEM section-view images of the ZnO films in Fig.3, we can find that the films are formed by compact nano pillars' array. This indicates that the ZnO nano grains are likely to grow in *c*-axis and form nano pillars. Moreover, the length of the nano pillars is uniform, which results in a homogeneous thickness of the film with a smooth surface. Therefore, it can be concluded that the ZnO films can be deposited well by the RF magnetron sputtering method.



(a) (b) (c) (d)

Fig. 2 SEM images of the ZnO films deposited on SiO_2/Si (100) with different power: (a) 75W, (b) 120W, (c) 160W and (d) 200W

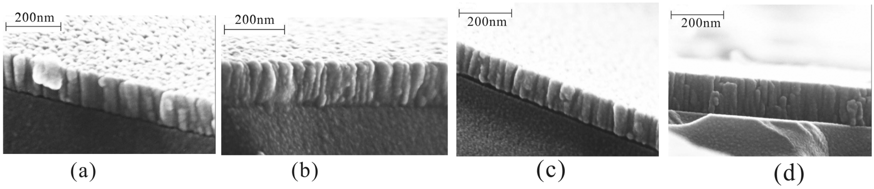


Fig. 3 SEM section-view images of the ZnO film deposited with the sputtering power of 75W on: (a) Si_xN_y/Si (100) (Ar: O_2=25%), (b) Si_xN_y/Si (100) (Ar: O_2=50%), (c) SiO_2/Si (100) (Ar: O_2=25%), and (d) Si (100) (Ar: O_2=80%).

The surfaces were imaged by AFM on the ZnO films deposited in different substrates, as shown in Fig. 4. The surfaces are smooth and uniform, which is consistent to the SEM observations above.

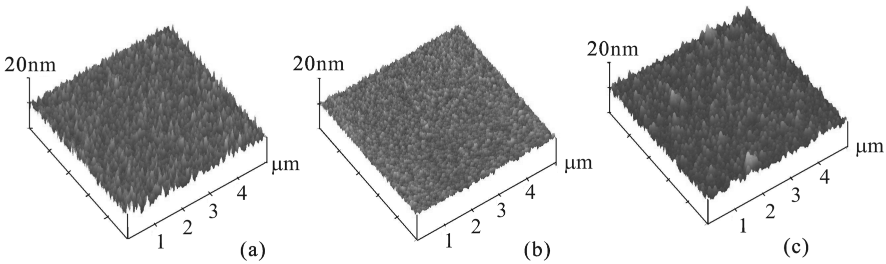


Fig. 4 AFM images of the ZnO film deposited with the sputtering power of 75W on
(a) Si_xN_y/Si(100) with Ar/O_2 ratio of 0%; (b) Si (100) with Ar/O_2 ratio of 0% and
(c) SiO_2/Si (100) with Ar/ O_2 ratio of 80%.

To characterise the crystal structures of the ZnO films, XRD measurement was carried out. The XRD patterns of the films are shown in Fig. 5. The dominant diffraction peak is at 34.2° which is assigned to the ZnO (002) plane, except for the peaks originating from Si substrate. The results indicate all the ZnO films on Si (100), SiO_2/Si (100), and Si_xN_y/Si (100) at different Ar/O_2 rations are all crystalline and well orientated in c-axis.

Besides the dominant diffraction peak, a weak peak can be recognized in the ZnO films deposited on the Si (100) substrate with Ar/O_2 ratios of 50% and 80%, respectively, as shown in Fig. 5(a). This peak is assigned to the ZnO (100) plane. Similarly, this peak also appears in the some films deposited on the SiO_2/Si (100) and Si_xN_y/Si (100) substrates with different Ar/O_2 ratios, as shown in Fig. 5(b) and (c), respectively. However, this peak is relatively strong in the films deposited on the SiO_2/Si (100) and Si_xN_y/Si (100) substrates. This indicates that the film quality is higher while deposited on the Si (100) substrate without buffer layer.

The XRD patterns show no big differences in the films deposited with different sputtering powers while kept the Ar/O_2 ratios at 50%. We believe that the sputtering power has no big influence on the crystal structure of the ZnO films though it has the effect on the ZnO grain size and surface roughness.

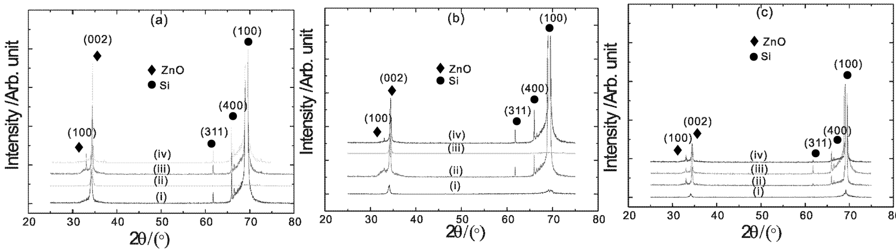


Fig. 5 XRD patterns of the ZnO film on (a) bare Si(100); (b) SiO_2/Si (100); and (c) Si_xN_y/Si(100) with different Ar/ O_2 ration (i) 0%, (ii) 25%, (iii) 50%, and (iv) 80% with the sputtering power of 75W.

4. Conclusions

The ZnO films were prepared on substrates of Si (100), SiO_2/Si (100), and Si_xN_y/Si(100) substrates at different Ar/O_2 ratio 0% to 80% with different sputtering powers. SEM, AFM, and XRD were used to characterise the film morphologies and crystal structures. It can be concluded that ZnO nano film with good quality can be obtained at certain processing conditions.

Acknowledgement

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References

[1] S.Y.Li, C.Y.Lee and T.Y.Tseng, *Journal of Crystal Growth* **247**, 357-362, 2003.

[2] S.H.Bae, S.Y.Lee and B.J.Jin et.al, *Applied Surface Science* **169-170**, 525-528, 2001.

[3] Z. X.Fu, B. X.Lin and J.Zu, *Thin Solid Films* **402**, 302-306, 2002.

[4] Y.Yoshino, T.Makino and Y.Katayama et.al., *Vacuum* **59**, 538-545, 2000.

[5] J.J. Chen, Y. Gao, and F. Zeng, et al., *Applied Surface Science* **223**, 318–329, 2004