Characterization of ZrO_2 thin films fabricated by glancing angle deposition

K M A Sobahan, Yong Jun Park and Chang Kwon Hwangbo

Department of Physics, Inha University, Incheon 402-751, Republic of Korea.

asobahan@yahoo.com

Abstract: The glancing angle deposition (GLAD) technique was used to fabricate ZrO_2 thin films by electron-beam evaporation. The crystal structure, cross-sectional structure, surface morphology and optical properties are characterized by X-ray diffraction meter (XRD, Rigaku, Cu Kα – radiation), scanning electron microscope (SEM), and spectrophotometer, respectively.

Glancing angle deposition (GLAD) technique has recently attracted the interest of many researchers[1] due to its potential applications in sensing technology, catalysis, optical devices, and biochip devices, etc. The thin films deposited by GLAD exhibit optical anisotropy originating from the microstructure and porosity due to self-shadowing effects and limited adatom diffusion. The optical anisotropy of the thin films has various applications, such as optical retardation plates, anisotropic antireflection coatings, birefringent omnidirectional reflectors, three dimensional photonic band-gap crystals, and so on.

Zirconium dioxide (ZrO_2) is one of most the promising materials in modern science and technology because of its superior thermal, mechanical, optical and electrical properties and is widely used as optical coatings, solid electrolyte, thermal barriers, wear resistant, refractory buffer and catalyst[2]. In this communication, we report the characterization of ZrO_2 thin films fabricated by GLAD technique. Various deposition angles are employed to control the microstructure of the films. The XRD patterns of as-deposited and annealed ZrO_2 thin films deposited at angles of 0° and 70° are shown in Fig. 1. It is seen that there is no evident diffraction peak for as-deposited and annealed ZrO_2 films deposited at 70°, indicating amorphous in nature. This may happen due to shadow effects and low adatom diffusion which inhibits the diffusivity of deposited atoms even in the post-deposition annealing process. But, the result is different for ZrO_2 thin films deposited at normal incidence

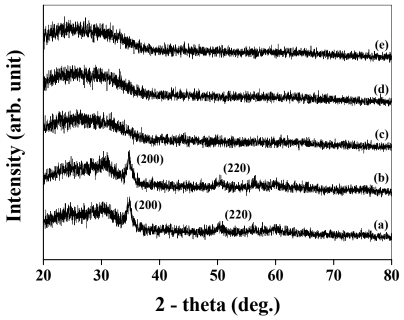

Fig. 1. XRD patterns of GLAD ZrO_2 films deposited at 0°: (a) as-deposited; (b) annealed at 200°C and that of deposited at 70°: (c) as-deposited; (d) annealed at 200°C; (e) annealed at 300°C.

in which the films show cubic phase with preferential (200) orientation. Fig. 2 and 3 illustrate the cross-sectional images and surface morphology of ZrO_2 thin films deposited at angles of 0^o and 70^o, respectively. It is clear that the GLAD ZrO_2 films are composed of slanted columns resulting from shadow effect as shown in Fig. 2.

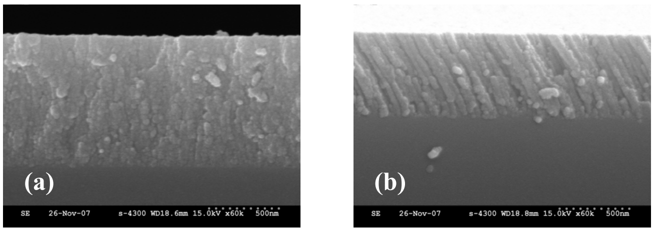

Fig. 2. Cross-sectional SEM images of ZrO_2 films deposited at: (a) 0^o and (b) 70^o

In Fig. 3, the surface of the film deposited at 0^o is smooth, but that of deposited at 70^o show many voids and pinholes. It is also found that the shape of the voids on the film's surface is asymmetric in the x- and y-directions and the void in the x-direction is more porous.

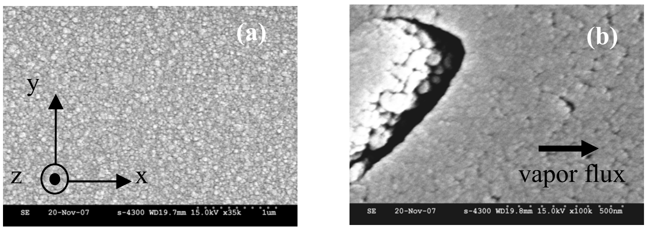

Fig. 3. Surface morphology of ZrO_2 films deposited at: (a) 0^o and (b) 70^o

The measured in-plane birefringence ($\Delta n = n_y - n_x$) of the ZrO_2 thin films deposited at various angles is shown in Fig. 4. It is seen that the in-plane birefringence increases with the increase of deposition angle and reaches maximum value of $\Delta n = 0.038$ at an angle of 70° which is good agreement with the previous report[3].

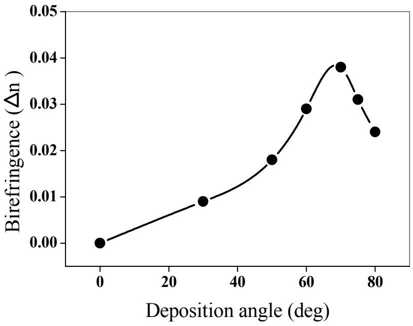

Fig. 4. Measured in-plane birefringence of ZrO_2 films different deposition angles at 633 nm.

Thus, it is concluded that the microstructure and the optical anisotropy of the ZrO_2 thin films can be controlled by GLAD technique.

References

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