TRANSPARENT CONDUCTING ZnO:In THIN FILMS PREPARED BY MAGNETRON DC SPUTTERING METHOD

Ho Van Binh, Le Vu Tuan Hung, Le Queo, Pham Thanh Tuan,
Duong Ai Phuong, Le Van Hieu
University of Science, VNU-HCM

(Manuscript Received on November 29th, 2010, Manuscript Revised September 10th, 2011)

ABSTRACT: *ZnO:In thin films was deposited on glass substrate by magnetron DC sputtering method from ceramic target. The ZnO:In ceramic targets have concentrations of In_2O_3 varying between 1 and 4wt%. The ZnO:In film has the resistivity with value of 1.79 x 10^{-3} Ωcm, at a layer thickness of about 1μm, corresponding with ZnO:In target (2%wt In_2O_3), at the substrate temperature of about 240-^{0}C. All ZnO:In thin films have the transparence above 85% in the visible spectra.*

Keywords: *Magnetron DC sputtering, ZnO:In, Transparent Conducting Oxide (TCO).*

1. INTRODUCTION

Transparent and conducting oxide (TCO) thin films with unique characteristics of low resistivity and high transparency over the visible wavelength region have numerous applications in optoelectronic devices including thin film solar cell, organic light emitting devices (OLED), and other flat panel displays. One of the common TCO films is ITO, it is used as anodes of several devices. However, indium is a rare metal in nature and the cost of experiment is increasing drastically. Recently, Al, Ga or In doped zinc oxide films have been considered as possible alternatives to ITO films because ZnO thin films are less expensive than the ITO films. ZnO thin films were deposited by several techniques such as radio frequency (RF) sputtering process, pulsed laser deposition (PLD), sol-gel method, and chemical vapor synthesis (CVS)…In this research, indium doped zinc oxide (IZO) thin films were prepared by magnetron DC sputtering method on glass substrates. the structural, optical, and electronic properties of the IZO films have been investigated with some different parameters depositing films such as the concentrations of indium and substrate temperature.

2. EXPERIMENT

IZO films were deposited on glass substrate by magnetron DC sputtering process. The ZnO:In ceramic targets were prepared by sintering the mixing 99% ZnO and 99.5% In_2O_3 powders with the indium concentration changed from 1 to 4wt%.The sputtering chamber was pumped down to 1 x 10^{-4} Torr by oiled diffusive pump. The substrate to target distance, sputtering time, working pressure, and sputtering currency, sputtering potential were kept at 3x3 cm, 35 min, 3m Torr, 0.2 A,

600 V, respectively. The substrate temperature of IZO films was changed from 50 ^{0}C to 300 ^{0}C.

The crystal structure, electrical and optical properties were investigated by X-ray diffraction (XRD) measurement, four probe method, UV-vis spectrometer.

3. RESULTS AND DISCUSSION

3.1. Structural and electrical properties

Fig. 1 shows XRD spectra of IZO films correspond with the indium concentration changed between 1 and 4wt%. As concentration of indium increases, the crystal structure of IZO films decrease, corresponding with the decrease of the (002) intensity peak. This could be explained that indium inserted in IZO films when the indium concentration increased, and the Indium itself had induced the crystal structure of IZO films.

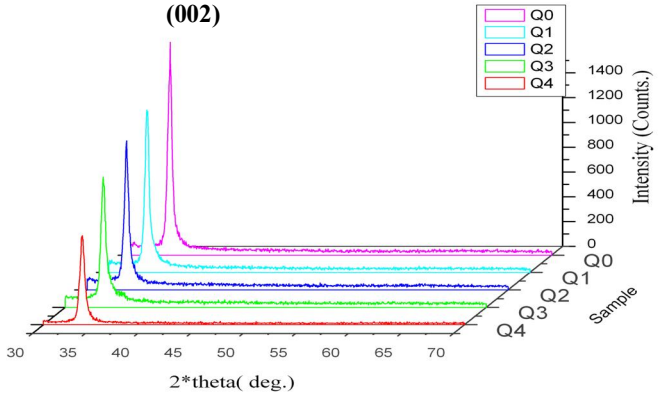

Fig.1. XRD patterns of IZO films with differences in concentrations of indium

Table 1. Researching the resistivity of IZO films deposited with different indium concentrations in IZO ceramic targets

%wt In_2O_3	0%	1%	**2%**	**3%**	4%
Thickness (nm)	1080	880	**960**	**950**	950
Resistant sheet Ω/□	31.3	34.1	**22.1**	**22.85**	35.16
Resistivity ρ(x10^{-3}) Ωcm	3.38	3.00	**2.12**	**2.17**	3.34

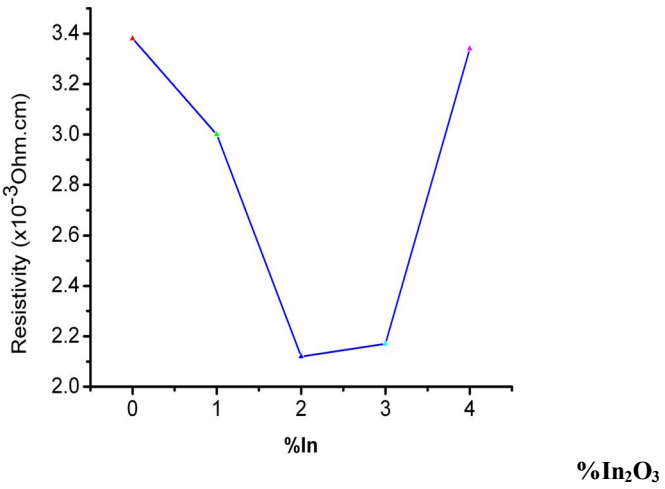

Fig. 2. The resistivity of IZO films deposited with different indium concentrations in IZO ceramic targets

Tab.1 and Fig.2 show that the resistivity of IZO films decreases when the indium concentration in target increases from 1 to 2-3 wt%, but if the In concentration continues increasing, the resistivity of IZO films also increase. This could be explained that firstly the increasing In concentration makes the carrier concentration of IZO films increase, result as the resistivity of IZO films decrease, On the contrary, when the In concentration exceeds the threshold value (about 2-3 wt%) the mobility of carrier will be decreased due to occurring in grain boundary scattering and leading to the resistivity of films increase.

Therefore, the best In concentration is about 2-3wt%. We can compare this results with that of scientists (J.Wienke và A.S Booij)[1] and shows that it is well appropriate.

Table 2: The resistivity of IZO films deposited with different substrate temperatures.

T_S (^{0}C)	100	140	180	200	**220**	**240**	260	280	300
Thickness(nm)	920	1010	960	970	**1020**	**910**	980	1050	950
Resistant sheet Ω/□	150	33.56	22.10	21.5	**18.04**	**19.7**	19.5	19.4	23
Resistivity (ρ) (x 10^{-3}) Ωcm	138	3.39	2.12	2.09	**1.84**	**1.79**	1.91	2.04	2.19

Tab.2 shows that as the substrate temperature increases, the resistivity of films decrease, because substrate temperature plays as catalysis to aid In inserting in IZO films more easily, and leading to the increase in carrier concentration. Moreover, temperature also helps films to improve their crystal structures, and the incorporation between substrate and films, and the incorporation between films and In donor. From that the resistivity of films decreases.[2,3]

3.2. Optical properties

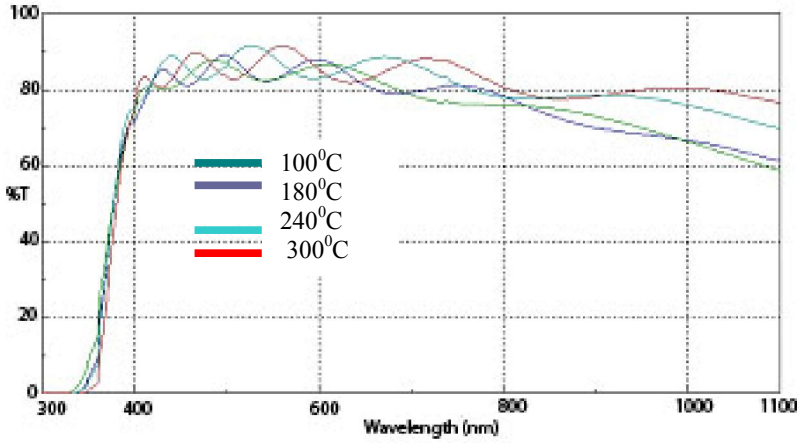

Fig.4. Optical transmittance of IZO films deposited with different substrate temperatures.

Fig.4 shows that all IZO films have the transparent highly about 90% in the visible spectra. However, in the near infrared, the transparent of IZO films trend to decrease due to the high carrier concentration.[4]

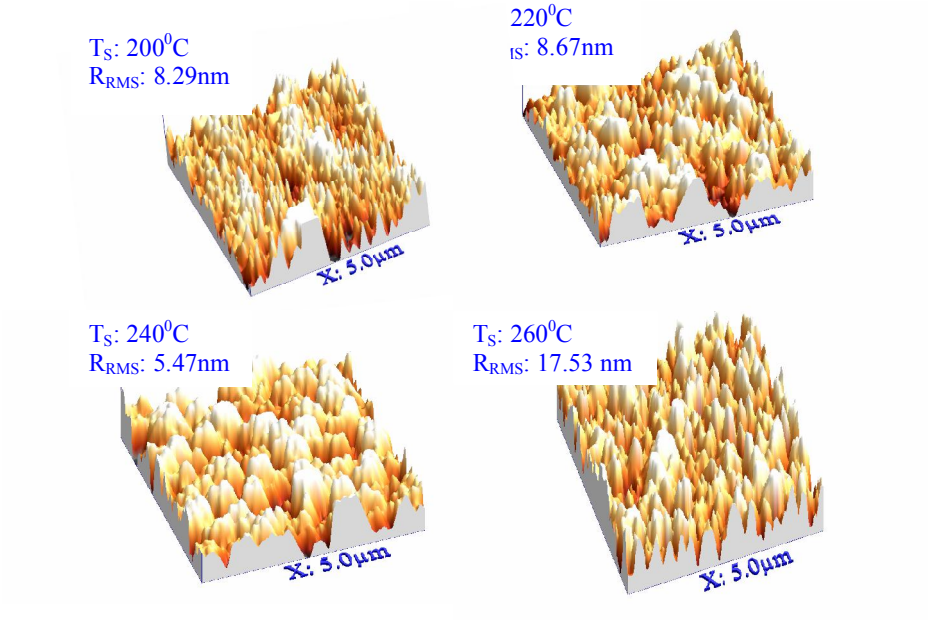

Fig.5 AFM images on IZO films with different substrate temperatures.

Fig.5 shows that the lowest root mean square (R_{RMS}) of surface roughness was 5.47 nm. This value corresponds with the IZO film at the substrate temperature 240^{0}C and this sample also had minimum resistivity 1.79 x 10^{-3} Ωcm.[5]

4. CONCLUSIONS

From the results of this research, we can conclude that IZO thin films has been sucessfully deposited by magnetron dc sputtering technique on glass substrate.

- Studying the electrical and optical properties of IZO films with difference of In concentrations in ceramic targets, it has been indicated that the best concentration in target to make best IZO thin films is In 2-3wt%, with the resistivity at 2.12 x 10^{-3} Ωcm and the transparent above 80% in the visible spectra.

- As the substrate temperature increases, the resistivity of IZO films trends to decrease. At the temperature about 240^{0}C, the resistivity of films can reach 1.79 x 10^{-3} Ωcm and the transparent of films about 85% in the visible spectra, corresponding with the transparent conducting very well.

CHẾ TẠO MÀNG DẪN ĐIỆN TRONG SUỐT ZnO:In BẰNG PHƯƠNG PHÁP PHÚN XẠ MAGNETRON DC

Hồ Văn Bình, Lê Vũ Tuấn Hùng, Lê Quẹo, Phạm Thanh Tuân,
Dương Ái Phương, Lê Văn Hiếu
Trường Đại học Khoa học Tự nhiên, ĐHQG-HCM

TÓM TẮT: *Màng ZnO:In được chế tạo trên đế thuỷ tinh bằng phương phún xạ magnetron dc từ bia gốm ZnO:In. Các bia gốm ZnO:In có nồng độ In_2O_3 thay đổi từ 1 đến 4% khối lượng. Màng có điện trở suất 1.79 x 10^{-3} Ωcm với độ dày màng khoảng 1μm ứng với bia gốm có 2%In_2O_3, nhiệt độ đế khoảng 240^oC. Tất cả các màng ZnO:In đều có độ truyền qua trên 85% trong vùng ánh sáng khả kiến.*

Từ khoá: *Màng oxide dẫn điện trong suốt (TCO), Phún xạ magnetron dc, ZnO:In*

REFERENCES

[1]. J.Wienke, A.S.Booij, Thin Solid Films (2007).

[2]. Young Ran Park, Eung Kwon Kim, Donggeun Jung,Tae Seok Park, Young Sung Kim, Applied Surface Science **254** (2008), 2250-2254.

[3]. K.J.Chen, F.Y.Hung, S.J.Chang, Z.S. Hu, Applied Surface Science **225** (2009), 6308-6312.

[4]. D.G. Kim, S.Lee, D.H.Kim G.H. Lee, M. Isshiki, Thin Solid Films **516** (2008), 2045 – 2049.

[5]. M.N. Jung, E.S. Lee, T.-I. Jeon, K.S. Gil, J.J. Kim, Y. Murakami, S.H. Lee, S.H. Park, H.J. Lee, T. Yao, H. Makino, J.H. Chang *Journal of Alloys and Compounds* 481 (2009), 649-653.