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Studies on effect of oxygen flow rate in textured grain growth of ZnO thin films

Deepu Thomas\textsuperscript{1,2,*}, Sunil C Vattappalam\textsuperscript{2}, Sunny Mathew\textsuperscript{2} and Simon Augustine\textsuperscript{2}

\textsuperscript{1}Research and Development Centre, Bharathiar University, Coimbatore, India-641046.
\textsuperscript{2}Department of Physics, St.Thomas College, Pala, Kottayam, India-686574.
E-mail: deepuskariankal@gmail.com

Abstract. ZnO thin films were deposited on glass substrate by Successive Ionic Layer Adsorption Reaction (SILAR) method. Effect of oxygen flow rate in textured grain growth, resistance and band gap of the thin films have been done. Textured grain growth of the samples were measured by comparing the peak intensities from XRD. Textured grain growth was found to be maximum when the oxygen flow rate is 2.5 litre/minute. It is found that as the oxygen flow rate increases above this limit, textured grain growth decreases and resistance the samples increases. The optical band gap of ZnO film was found to be increased with the increase of oxygen flow rate.

Key words: ZnO thin film, SILAR method, textured grain growth, Oxygen flow rate.

1. Introduction

ZnO thin films possess very interesting properties in the electrical and optical application fields. They have low electric resistance and high transparency in the visible wavelength range [1-4]. The material is composed of cheap and abundant elements, and is readily produced for large-scale coatings. These films have attracted interest in many applications such as solar cells, gas and optical sensors, ultrasonic oscillators, transducers, optical waveguides and photoprotective coatings. Various deposition techniques can be used to prepare ZnO thin films, such as reactive and ion-assisted evaporation, laser ablation, spray pyrolysis [6], sol–gel processing [5], chemical vapour deposition [4] and sputtering[3]. In this work, ZnO films were deposited by chemical deposition techniques which is relatively low cost process and can be easily scaled up for industrial applications [7]. Even though, there are reports on studies of enhanced textured grain growth in ZnO under different experimental conditions, a study on the variation of textured grain growth in ZnO annealed in different oxygen flow rates were not yet studied widely. In course of the present investigations, the variations in the textured grain growth in ZnO thin films annealed in different oxygen atmosphere is studied. ZnO thin films having crystallinity with preferential orientation is a prerequisite for the fabrication of devices like UV diode lasers, acoustic-optic devices etc. [1-4].

2. Experimental

ZnO thin films were prepared by Successive Ionic Layer Adsorption Reaction (SILAR) method. In which, the ZnO thin film was coated on the glass substrate (26 × 76 mm) by alternately dipping the substrate in sodium zincate bath at room temperature and then in hot water maintained at 90-95°C. The samples were annealed at 450°C for half an hour in different oxygen flow rates.

*To whom any correspondence should be addressed. deepuskariankal@gmail.com
analysis of the thin films were done by X-ray diffraction. X-ray diffraction was performed on Bruker AXS-8 using CuKα radiation. The resistance of ZnO thin film at room temperature was measured by Keithley 2100 6 1/2 Digital Multimeter. The optical absorbance was measured in the wavelength range of 190-1100 nm by means of a UV-VIS spectrophotometer. Textured grain growth of the samples was measured by using an orientation index (O. I.), which is the ratio of the intensities of (002) reflection ($2\theta = 34^\circ$) to (101) reflection ($2\theta = 36^\circ$) in the XRD.

$$\text{O.I.} = \frac{I_{002}}{I_{101}}$$

The average grain size of the ZnO crystals in the films was calculated by using Scherrer’s formula: $D = \frac{0.9\lambda}{\beta \cos \theta}$, where $D$ is the grain size, $\lambda$- the wavelength of X-ray used, $\beta$- the FWHM(full width half maximum) and $\theta$- Bragg angle [8].

3. Results and Discussion

3.3 Structural and Morphological Studies

The figure 1 (a) and (b) show the typical XRD patterns of ZnO thin films annealed at oxygen flow rates of 2.5 and 4.5 litre/minute.

![XRD patterns](image)

**Figure 1(a-b) shows the XRD pattern of sample annealed in oxygen atmosphere with flow rate at 4.5 litre/min and with flow rate 2.5 litre/min, respectively.**

From fig.1 it can be seen that, the (002) peak has maximum intensity, which indicates that the film is c-axis-oriented perpendicular to the surface. The sample under the flow rate 2.5 liter/min has maximum orientation index. When the oxygen flow rate exceeds this limit, the textured grain growth was found to be decreased. Table 1 gives the flow rate, orientation index, grain size, resistance and band gap of different samples.

Table 1 gives the flow rate, orientation index, grain size, resistance and band gap of different samples.
3.2 Resistance Measurements

![Graph showing variation of resistance with grain size of different samples.]

Figure 2 shows variation of resistance with grain size of different samples.

3.3 Optical Properties of ZnO Films

The figure 3 shows the optical absorbance spectrum of ZnO thin film (annealed in oxygen atmosphere with flow rate 4.5 litre/min) using UV-visible region. Figure 3 (inset) depicts the plot of $(αhν)^2$ vs energy, $hν$. 
The corresponding optical band gap of the sample is estimated by extrapolation of the linear relationship between \((\alpha h\nu)^2\) and \(h\nu\), according to the equation \(h\nu = A(h\nu - E_g)^{1/2}\), where \(\alpha\) is the absorption coefficient, \(h\nu\) is the photon energy, \(E_g\) is the optical band gap and \(A\) is a constant. The values of direct band gap \((E_g)\) are calculated from the intercept of \((\alpha h\nu)^2\) vs \(h\nu\) curve. The presence of a single slope in the plot suggests that the film has direct and allowed transition. The figure 4 shows the optical absorbance spectrum of ZnO thin film (annealed in oxygen atmosphere with a flow rate of 2.5 litre/min). Figure 4 (inset) depicts the plot of \((\alpha h\nu)^2\) vs energy, \(h\nu\). Table-1 shows that band gap decreases with increase in grain size of the film [9].

4. Conclusion

From the studies following conclusions can be drawn. Textured grain growth in ZnO thin film was found to be maximum when the oxygen flow rate is 2.5 litre/minute. It is found that as the oxygen flow rate increases above this limit, textured grain growth decreases and resistance the samples
increases. The optical band gap of ZnO film was found to be increased with the increase of oxygen flow rate.

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