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Influence of substrate temperature on structural and optical properties of ZnO thin films prepared by cost-effective chemical spray pyrolysis technique

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ABSTRACT

Over the past few decades semiconductor metal oxides have stimulated research interests owing to their important role in fundamental research and future applications in the field of energy conversion and sensors. So the present research work has been focused on the synthesis, growth mechanisms and physical properties of ZnO thin films prepared by cost-effective chemical spray pyrolysis technique. Desirable properties of thin films can be easily tailored by chemical spray pyrolysis technique by optimising the spray parameters. ZnO thin films were deposited on glass substrates with various substrate temperatures ranging from 573 K to 723 K. The influence of substrate temperature on structural, morphological and optical properties have been analyzed via XRD, SEM, UV–VIS–NIR spectroscopy, PL studies respectively. The Structural study reveals that all the spray deposited ZnO thin films have polycrystalline nature with preferential orientation along (100) plane. Optical studies show that the direct band gap values increases from 3.14 to 3.20 eV. PL studies shows that the intensity of emission peaks differ according to the substrate temperature. Smooth and uniform morphology obtained from SEM analysis. The optical transmittance observed in the visible region is more than 85% for all films other than 573 K as substrate temperature.

1. Introduction

Nowadays ZnO based thin films have received much attention due to its potential applications in various fields such as solar cells [1], gas sensors [2], light emitting diodes [3], heat mirrors [4], liquid crystal displays [5] etc. So recently the production of high quality and efficient ZnO thin films are the main thirst of researchers. ZnO is a very important II-VI semiconductor compound and has a direct band gap around 3.2–3.37 eV with a high exciton binding energy 60 meV. Compared to currently using TCO materials (ITO and SnO_2) ZnO has emerged as one of the promising material due to its high chemical and mechanical stability, low cost, abundance in nature and nontoxicity. The deposition technique should

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fulfill all the requirements to produce high quality thin films during the deposition process. Many methods were employed to produce the ZnO thin films such as CVD [6], RF sputtering [7], sol gel [8], hydrothermal [9], atomic layer epitaxy [10], pulsed laser deposition [11], spray pyrolysis [12]. Present study exposes the importance of substrate temperature which determines the crystalline quality, orientation, defects, band gap and morphology of the films.

2. Material and methods

Chemical spray pyrolysis is a promising technique to produce high quality metal oxide thin films with thin layers. Thin film quality and properties are easily controllable one by the process parameters. Spray pyrolysis have much attention in industrial view due to large area deposition with low cost of source materials. On the other hand the substrate temperature is an essential parameter which determines the properties of thin films. The preliminary work is done on the growth of ZnO thin films using chemical spray pyrolysis technique. Physical properties of spray deposited ZnO thin films with various substrate temperatures are discussed in this paper.

Fig. 1 depicts the constructive elements of spray pyrolysis unit. It consists of an atomizer, precursor solution, substrate heater, temperature controller, k-type cromel-alumel thermocouple, and compressor. Thermocouple is used to indicate the temperature variation during the deposition process. Generally Film formation through spray pyrolysis consists of three steps: (i) Atomization of precursor solution-in this step the spray solution was converted into fine and uniform droplets which is driven by carrier gas. Compressed gas is one of the factors that determine the quality of the film. (ii) Transportation of aerosol-second step involves the fine droplets are allowed to hit on the pre-heated substrates. The production of high quality films strongly depends on the substrate temperature. (iii) Decomposition of the precursor salt on the substrate-in this last step nuclei growth leads to the continuous film formation.

Fig. 2 represents the mechanism of the film formation process while increasing the substrate temperature. Substrate temperature effect on film deposition process was proposed by Viguie and Spitz [13]. In lowest temperature atomized aerosols splashes on the substrate surface and decomposes and leads to homogeneous reaction (process A). In process B and C heterogeneous reaction takes place. In process D at highest temperatures the solid particles only reaches the substrate.

Pure ZnO thin films were prepared by the spray pyrolysis technique with various substrate temperatures 573 K, 623 K, 673 K and 723 K respectively. The precursor solution consists of 0.5 M of zinc acetate dehydrate ($Zn(CH_3COO)_2 \cdot 2H_2O$) (Merk>99%) dissolved in a mixture of deionized water, methanol, and acetic acid taken in the ratio (6:3:1) respectively.

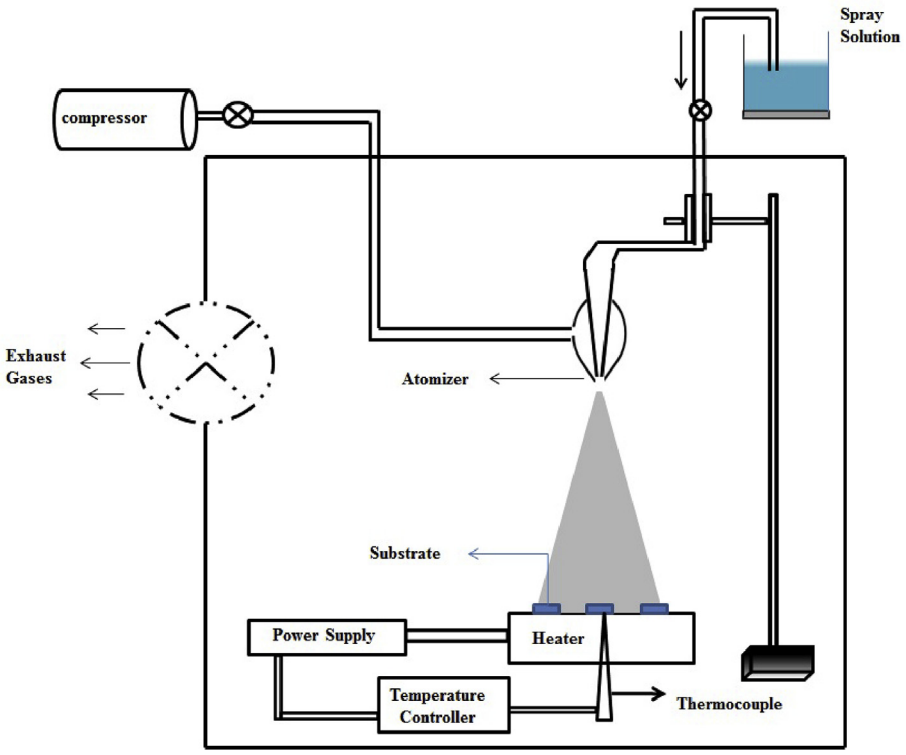

Fig. 1. Schematic diagram of spray pyrolysis unit.