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Influence of annealing on properties of spray deposited nickel oxide films for solar cells

*[a]Ukoba, O.K., Inambao, F.L[a] and Eloka-Eboka, A.C[a]

[a]Discipline of Mechanical Engineering, University of KwaZulu-Natal, Durban, 4041, South Africa

Abstract

Nickel oxide thin films were deposited on soda lime glass substrates by spray pyrolysis technique (SPT). Post-deposition annealing was carried out at 450 ºC. Effects of annealing on the structural, elemental and surface morphological properties of the thin NiO films were investigated. XRD confirms polycrystalline with cubic crystalline structures of deposited and annealed NiO films. Preferred orientation was along (1 1 1) peak with intensity along (2 0 0) peak improved by annealing. The annealing process improved on formation of crystalline phases. XRD patterns have peak diffraction at (2θ = 37 º, and 43 º) for (1 1 1) for deposited and annealed. Peak diffraction at (2θ = 64 º, and 79 º) for (2 0 0) planes for 0.1 M and annealed respectively. Annealing improved on the film thickness by over 10 %. Surface morphology of deposited and annealed NiO films reveals nanocrystalline grains with uniform coverage of the substrate surface with randomly oriented morphology. Larger flakes are formed as a result of the annealing process. EDX elemental NiO films composition revealed presence of Ni and O elements in NiO films. A decrease in oxygen concentration was also observed confirming positive effect of annealing as an optimization process. Optimization of nickel oxide deposition process parameters offers opportunities for efficient and affordable solar cells.

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Keywords: NiO; solar cells material; annealing, spray pyrolysis technique

1. Introduction

Population growth geometrically increases the need for more demand for energy [1]. Solar energy is a viable source of sustainable energy. Present solar panels are still not affordable to low income earners. This is caused by the expensive nature of silicon. Current solar photovoltaics market is dominated by silicon. Silicon is an abundant element

* Corresponding author. Tel.: +27640827616 and +2348035431913; fax: +0-000-000-0000 .
E-mail address: ukobaking@yahoo.com

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but large production of it for photovoltaic is expensive. Key Materials selection for future solar cells are abundance and inexpensive elements for large scale production [2]. Nanostructured metal oxides fit this description. Metal Oxide thin films have promising technological potentials in solar cells. They require both vast area electrical contact and optical access in visible region of light spectrum [3]. Fabrication of nanostructure metal oxide films has generated interests over the years [4-8]. There are wide range of applications in radiation detector, solar cells, semiconducting devices, laser materials and thermoelectric devices optoelectronic devices [9-12].

Nanostructured metal oxides with p-type conductivity are rare. Nickel Oxide (NiO) is a one of few p-type semiconductors [13] with wide band gap from 3.5 eV to 4.0 eV [14]. It offers great prospect for large scale production of efficient low cost solar energy. NiO has rhombohedral or cubic structure and possesses pale green color. It has excellent durability and electrochemical stability [15]. It possesses large range of optical densities due to better optical, electrical and magnetic properties. It is a promising material for various applications which includes: solar cells, UV detectors, electrochromic devices, anti-ferromagnetic layers, p-type transparent conductive thin films, chemical sensors [16-20].

Nickel oxide thin films have been deposited using different methods; laser ablation [21], sputtering [22], sol–gel [23], chemical bath deposition [24] among others. Spray pyrolysis has the advantages of easy, quick, economic and large area deposition [25]. Spray pyrolysis is a process for depositing films. Solutions are sprayed on a heated surface and constituents react to form chemical compounds [26]. Chemical reactants are chosen to enable unwanted product to be decompose at the deposition temperature [27].

Optimization of NiO deposition process parameters offers opportunities for its usage in varied applications especially solar cells [28]. This study is on the influence of annealing temperature on resultant properties of spray pyrolysis deposited nickel oxide thin films for possible solar cells application.

Several studies have used Nickel chloride over nickel acetate as precursor [29, 30]. Nickel acetate precursor is used in this study. It does not react with the spraying gun unlike the Nickel chloride which also leaves traces of chlorine [31]. This study is an improvement to existing approach of depositing NiO films for solar cells application.

2. Experimental Procedure

2.1. Substrate selection and Cleaning

Soda lime glass was used as substrate. It was first washed with detergent and cotton wool. Thereafter it was cleaned chemically using acetone, methanol and isopropanol for 15 minutes each in ultrasonic bath. It was finally washed with deionized water and dried by flow of nitrogen gas.

2.2. Preparation of the solution for spray pyrolysis

Analytical grade nickel (II) acetate tetrahydrate was used. Precursor solutions were sprayed on glass substrates with air as carrier gas by spray pyrolysis technique (SPT). Pure nickel oxide thin films were deposited with concentrations of 0.05 M and 0.1 M using nickel (II) acetate $Ni(C_2H_3O_2)_2.4H_2O$ as precursor. Each precursor concentration was dissolved in 50 ml of distilled water. Solution mixtures were stirred thoroughly with a magnetic stirrer for 15 minutes leading to the formation of a pale green solution. Solution was sprayed manually on the pre-heated glass substrate kept at 350 ºC. The sprayed 0.1 M films was annealed for 60 minutes at 450 ºC in a furnace. This became the annealed samples. Sprayed solution on the preheated substrate glass undergoes evaporation, solute precipitation and pyrolytic decomposition according to Equations (1) [32]. The end product is nickel oxide thin films.

$$\mathrm{Ni}(C_2H_3O_2)_2.4H_2O \xrightarrow{heat} NiO + 7H_2O \uparrow + 4CO_2 \uparrow \qquad (1)$$

Optimum deposition parameters of the spray deposited NiO films are shown in table 1. Thermocouple was fixed to substrate's surface to record substrate temperature. Prepared NiO films were observed to be gray in colour, uniform and strongly adhered to the glass substrate.