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

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Abstract

Spray pyrolysis technique was used to deposit various concentration of nickel oxide films on glass substrate. The Effect of varying precursor concentration on elemental, morphological and structural properties was investigated on the deposited NiO films. Nickel (II) acetate tetrahydrate precursor was used at substrate temperature of 350 ^{o}C. Precursor concentrations were 0.025, 0.05, 0.075 and 0.1 M. Scanning Electron Microscope (SEM) surface morphology revealed nanostructured films with particles densely distributed across substrates surface. Increased in surface grains was observed as the precursor solution increased. Elemental composition of NiO films revealed presence of Ni and O element. There was reduction in oxygen concentration as precursor solution increases. Amorphous structure was observed at concentration of 0.025 M while polycrystalline with cubic structure was observed at higher concentrations. Preferred orientation was along (1 1 1) peak with small intensity along (2 0 0) peak. XRD patterns have peak diffraction at (2θ = 37 ^{o} and 43 ^{o}) for (1 1 1) and (2 0 0) planes respectively and 64 ^{o} for (2 2 0) plane for 0.1 M. Film thickness grew with increase in precursor concentration. Film micro strain was observed to have compression for all precursor solution conspicuously revealing the effect of varied concentration on NiO films properties.

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Keywords: NiO; solar cells material; annealing, low income

1. Introduction

About one-fourth of earth's inhabitants lacks access to electricity with little or no changes in absolute terms since 1970s (Ahuja & Tatsutani, 2009). Most developing countries still struggle with affordable stable electricity (Ebhota,

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Eloka-Eboka, & Inambao, 2014). Renewable energy especially solar energy is one of envisaged solution. Solar energy is one of the best sources of renewable energy. Hourly solar influx on earth surface surpasses annual human energy needs (Lewis, 2007). Solar energy is environmentally benign. About 40 % million tons of CO_2 emissions is saved per year when 1 % of world electricity demand is supplied by solar grid (Gardner, 2008). However, cost is militating against successful deployment of solar technology worldwide because, converting solar energy into electricity occurs at a price comparable with fossil fuel. Solar cells are integral part of solar energy (Green, 1982). Large scale production and affordable cost is still researched into in fabrications of solar cells (Eslamian, 2014). This is attributed to difficulty in scaling up existing methods or expensive nature and complexities associated with vacuum environment fabrication. However, nanostructure metal oxide offers promises. Nanostructures materials offers potential improvement on efficiency of photovoltaic (PV) solar cells, reduction in manufacturing and electricity production costs (Serrano, Rus, & Garcia-Martinez, 2009). It is achievable by increased surface area to volume ratio of nanoparticles. This enhances solar energy collection and efficiency by exposing more conducting surfaces to sunlight. Nanostructures materials have unique characteristics that cannot be obtained from conventional macroscopic materials (Hussein, 2015). Conventional materials have weaknesses in the absorption properties of the conventional fluids which can lead to reduced efficiency of solar cells devices. Inorganic semiconducting materials are economical, environmentally friendly and viable sources for solar cells (Joshi, Mudigere, Krishnamurthy, & Shekar, 2014). In recent years, fabrication of nanostructured metal oxide films is attracting interest in terms of technological applications (Drevet et al., 2015; Rahal, Benhaoua, Jlassi, & Benhaoua, 2015; Shaikh, Inamdar, Ganbavle, & Rajpure, 2016; Zhang et al., 2006). They have been studied due to their vast usage (Soonmin, 2016). They have found applications in solar cells, UV detectors, electrochromic devices, anti-ferromagnetic layers, p-type transparent conductive thin films and chemical sensors (Li & Zhao, 2010; Magaña, Acosta, Martínez, & Ortega, 2006; Nam et al., 2015; Park, Sun, Sun, Jing, & Wang, 2013; Wu & Yang, 2015; Zhu et al., 2014). Nanostructured metal oxides often express n-type conductivity with few displaying p-type. Nickel Oxide (NiO) is a p-type semiconductor with wide band gap from 3.5 to 4.0 eV (Boschloo & Hagfeldt, 2001). Nickel oxides exist in various oxidation states (Subramanian et al., 2008). NiO has rhombohedral or cubic structure and possesses pale green color. NiO have excellent durability and electrochemical stability with a large range of optical densities. It is a promising material for various applications because of its better optical, electrical and magnetic properties. Nickel oxide thin films have been deposited using different methods; sputtering (Keraudy et al., 2015), sol–gel (Jlassi, Sta, Hajji, & Ezzaouia, 2014), electron beam deposition (El-Nahass, Emam-Ismail, & El-Hagary, 2015), laser ablation (Wang, Wang, & Wang, 2012), chemical bath deposition (Vidales-Hurtado & Mendoza-Galván, 2008). Spray Pyrolysis Technique is simple, low cost and feasible for mass production (Ismail, Ghafori, & Kadhim, 2013). Spray Pyrolysis is method that allows coating on large area by films of very thin layers with uniform thickness (Gowthami, Perumal, Sivakumar, & Sanjeeviraja, 2014). This study aims to optimize the precursor concentration of NiO films with motivation for efficient and affordable application in solar cells development. The scope involves: the preparation of a nanostructured NiO thin films on a glass substrate using SPT for deposition of aqueous solution of nickel (II) acetate tetrahydrate and determine the effect of varying the concentration on different properties of NiO films.

2. Experimental Procedure

2.1. Spray Pyrolysis set up

Experimental setup for spray pyrolysis used is shown in Figure 1. The set up consists of heater, air compressor, temperature controller, exhaust fan and pipe, spray gun with attached container. The container was used to hold the precursor solution. Spray gun was connected to the air compressor using hose or pipe. Temperature of 350 ºC was attained and read by thermocouple attached to the heater before commencing deposition. The carrier gas is compressed air at pressure of 1bar.