

THE EFFECT OF GLASS SUBSTRATES ON THE ELECTRICAL PROPERTIES OF PURE NICKEL OXIDE FILMS PREPARED BY SILAR METHOD

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Abstract:

Nickel oxide (NiO) films were produced using different substrates by successive ionic layer absorption and reaction (SILAR) method. NiO films were deposited on Glass, FTO and ITO substrates, and NiO/FTO, NiO/ITO, and NiO/Glass films were obtained. The electrical properties of the films were investigated by current-voltage (I-V) characterization. The films (NiO/ITO) were characterized by Schottky diode behavior and different results than the films (NiO/FTO, NiO/Glass) which showed Ohmic behavior. In this study, sheet resistances (R_s) of the samples were in the range $\sim 0.155 - 30 \text{ K}\Omega$, and some variables such as ideality factor (η) and barrier height (ϕ_B) values for the membranes were calculated in the range $\sim 14.4 - 34.4$ and $\sim 0.57 - 0.61 \text{ eV}$, respectively.

Keywords: NiO Film, FTO, ITO, Glass, Substrates, SILAR method, Ideality factor Barrier height.

Introduction

INTRODUCTION

Considered Translucent conductive oxides (TCO) are one of the primary materials used in the manufacture of thin films and the latter has attracted the interest of many researchers through its contribution to the development of many industrial fields. The great expansion of the uses of (TCO) as thin films on different types of materials and their specifications has led to the emergence of an urgent need for the emergence of preparation techniques commensurate with the properties of these films and their fields of application. The preparation techniques are great developments, as they introduced many methods that were not known [1], and with the increase of scientific and technological progress, the methods of preparing thin films have developed and become more and more accurate in determining the thickness and homogeneity, and there are many ways to prepare films, and each method has its own specificity to serve the purpose for which it was made.

Nickel oxide (NiO) is considered among important transparent carrier oxides in the form of thin films as it has entered into many physical applications due to its outstanding optical and electrical properties, including gas sensitivities, solar cells and more. [2]

With different types of materials and their specifications, there is an urgent need for the emergence of preparation methods that suit the properties of the membranes and their applications. There are several methods for thin film deposition, some of which depend on film deposition from gaseous media (steam) as in the methods of dissolution or evaporation, or from liquid media as in the technique of thermochemical decomposition, or through repeated ionic deposition, which is the method used for research.[3].

Thin film deposition on various substrates plays a crucial role in determining the structure and characteristics of the deposited films.

Although determining the relationship between deposition parameters and the morphology of precipitated thin films is quite complex due to the interaction of several factors that affect the nucleation and growth stages, it is still possible to find some common stereotypes for a variety of thin films that define the method, by which the absorbed atoms are incorporated into the final growth process thin-films morphology when atoms collide with substrates [4].

This article presents a comprehensive study investigating the effects of Glass substrates Indium-doped tin oxide (ITO), Fluorine-doped tin oxide (FTO) and (glass substrate) on the properties of (NiO) thin films.

EXPERIMENTAL DETAILS

Substrate Preparation

Glass, FTO, and ITO materials were used as the glass substrates for the growth of the samples. The substrates were cut to 8 mm wide and 25 mm long. After the cutting process, the glass substrates, FTO, ITO and Glass were washed thoroughly with soapy water to get rid of dirt. After washing, the substrates were ultrasonically cleaned in acetone for 10 minutes. The clean Glass, FTO, and ITO glass substrates were then dried in nitrogen gas. All operations were performed at room temperature and ambient pressure.

Solutions Preparation

Solutions were prepared to obtain nickel oxide layers by dissolving nickel (II) nitrate and aqueous ammonia in distilled water in a flask (one hundred milliliters) to obtain a ketone precursor and form a compound ions ($[\text{Ni}(\text{NH}_3)_4]^{+2}$) with (pH $\approx$ 10), where the reagents are used analytical for NiCl_2 (99%) and concentrated ammonia (NH_3) (28%). The specific concentration values for a nickel (Ni) solution were 0.1 M and the molar ratio of Ni: NH_3 was 1:10 obtained as a result of several experiments.

The SILAR growth cycle consists of four successive steps :

(i) Dipping the substrate into the ($[\text{Ni}(\text{NH}_3)_4]^{2+}$) complex solution for 30 seconds to create a thin liquid film containing ($[\text{Ni}(\text{NH}_3)_4]^{2+}$) on the substrate; (ii) immediate dipping of the extruded substrates into hot water (90°C) for 7 seconds to form a NiO layer; (iii) dry the substrates in air for 60 sec (iv) then keep them in distilled water at room temperature for 30 minutes. Thus the SILAR cycle is completed.

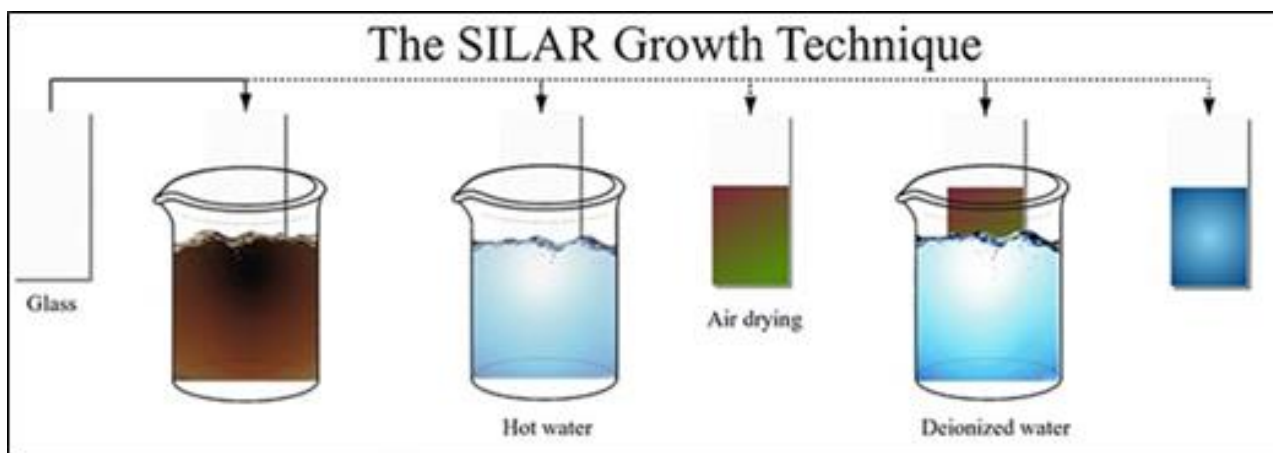


Fig.1 diagram representing the steps of sedimentation by Silar method to obtain nickel oxide films [5].

The sedimentation cycle (SILAR) was repeated 40 times and the mass of nickel (II) nitrate to be added is determined by the following relationship

$$m = C \times M \times V \quad (1)$$

C : molar concentration (mol /L)

V : solution volume (L)

M : The molar concentration of nickel (II) nitrate = 290. 79 gm / mol

m : The mass of nickel (II) nitrate to be added to the solution (gm)

The process was repeated 40 times for all samples under the same conditions and annealing temperature for 1 hour in Ash Furnace - Annealing Furnace.

RESULTS OF ELECTRICAL PROPERTIES

Sheet Resistance

We had define R_s is the surface resistance when d thickness of film it is the ratio between the electrical resistance ρ and the thickness of the thin layer d, and symbolized by the symbol R_s and its unit (Ω) and it is expressed by the relationship.

It can be known by the equation (2)

$$R_s = \frac{\pi V}{\ln(2) I} \quad (3)$$

The correction factor is equal to $\frac{\ln(2)}{\pi} = 4.532$ V: Voltage (Volt) I : electric current (Amp) .[6]

Based on the obtained I-V results, the surface resistance of the films can be measured by two tables following:

Table .1 Representing the surface resistance values in the forward bias

NiO Films	V (Volt)	R_s (Ω)
NiO-ITO	0.09-3	3030-155
NiO-FTO	0.09-3	10174-1011
NiO-Glass	0.09-3	5927 -9640

Table .2 Representing surface resistance values in reverse bias

NiO Films	V (Volt)	R_s (Ω)
NiO-ITO	(-3) - (-0.09)	1844-3320
NiO-FTO	(-3) - (-0.09)	1310-4695
NiO-Glass	(-3) - (-0.09)	8803-29210

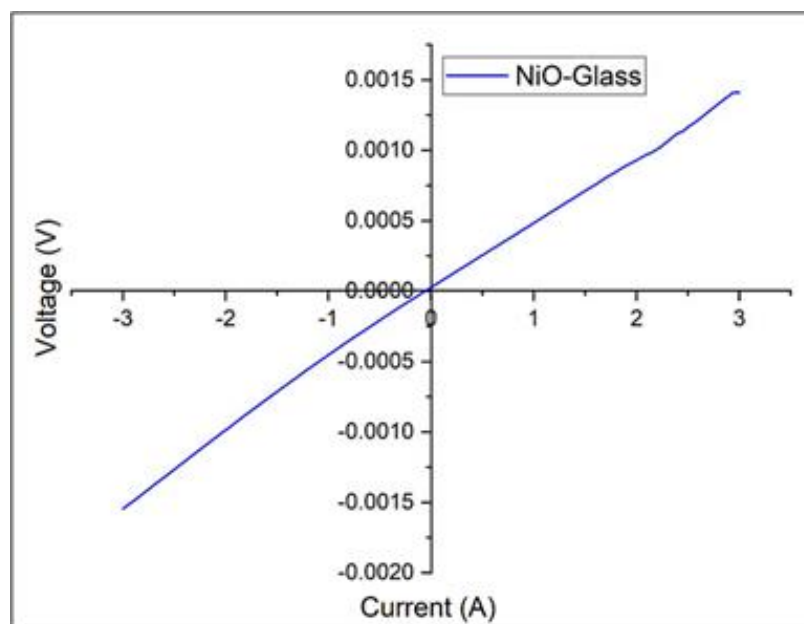


Fig.2 Voltage and current curve of (NiO-Glass)

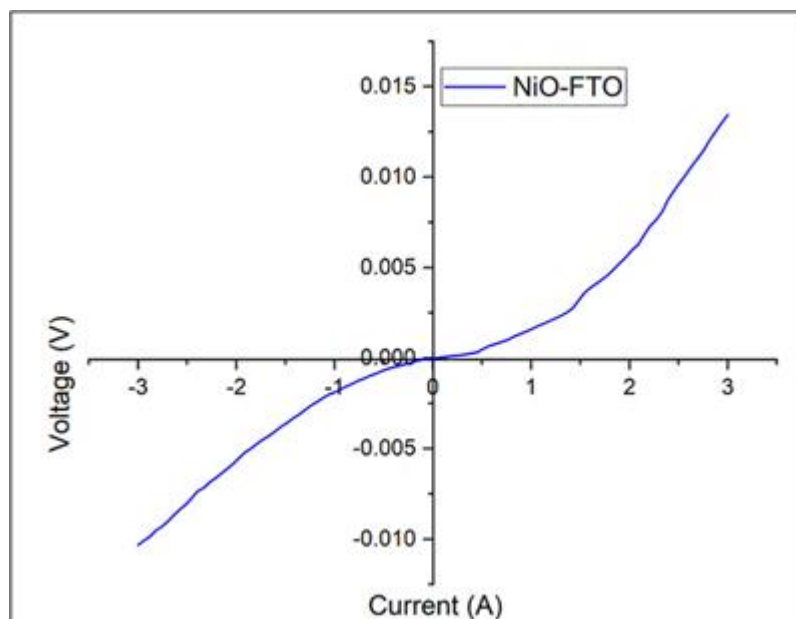


Fig .3 Voltage and current curve of (NiO-FTO)

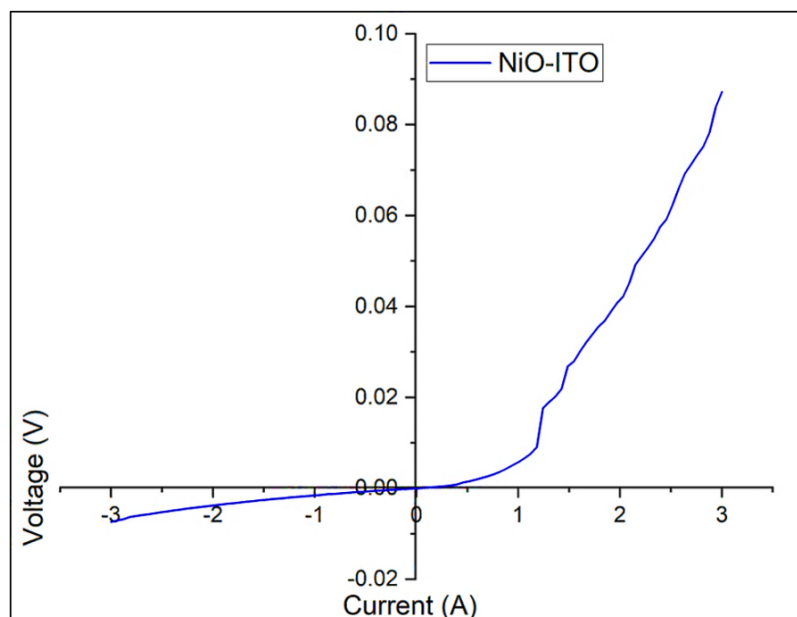


Fig. 4 Voltage and current curve of (NiO-ITO)

Through the graph and the values of the surface resistance, the results showed that Nickel oxide films deposited on glass substrates (NiO-Glass) exhibit linear Ohmic behavior in both cases of forward and reverse bias as shown in Fig (2). The films deposited on glass fluorine-doped tin oxide (NiO-FTO) showed a nonlinear behavior closer to exponential than ohmic behavior in both forward and reverse bias cases as shown in Fig (3).

The films (NiO-ITO) showed slightly different electrical behavior than the other samples, as this sample has characteristics Schottky diode behaviour and a small saturation current compared to the other samples as shown in Fig (4). It was found that the calculated surface resistance values are within the theoretical limits for nickel oxide films, and are roughly consistent with previous studies ([5,7-10]), taking into account that the surface resistance values for the same prepared films are affected by different parameters such as the technology used, the preparation conditions, the thickness of the film formed, and the purity of the prepared material.

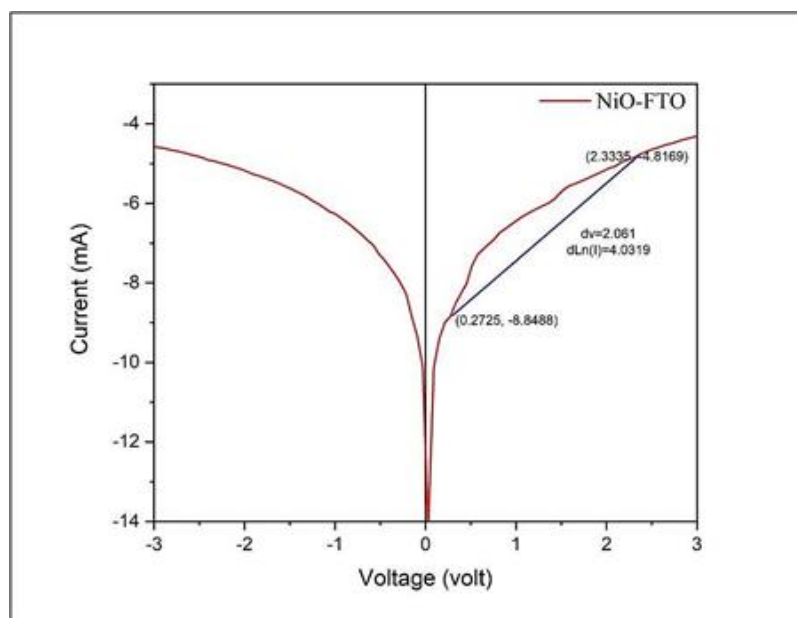


Fig.5 I-V curve between Log(current) and Voltage for (NiO-FTO)

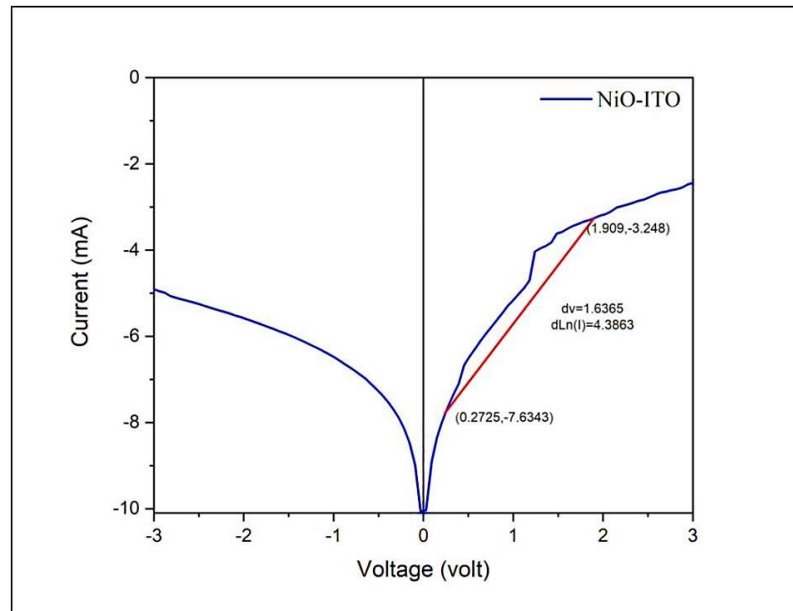


Fig.5 I-V curve between Log(current) and Voltage for (NiO-ITO)

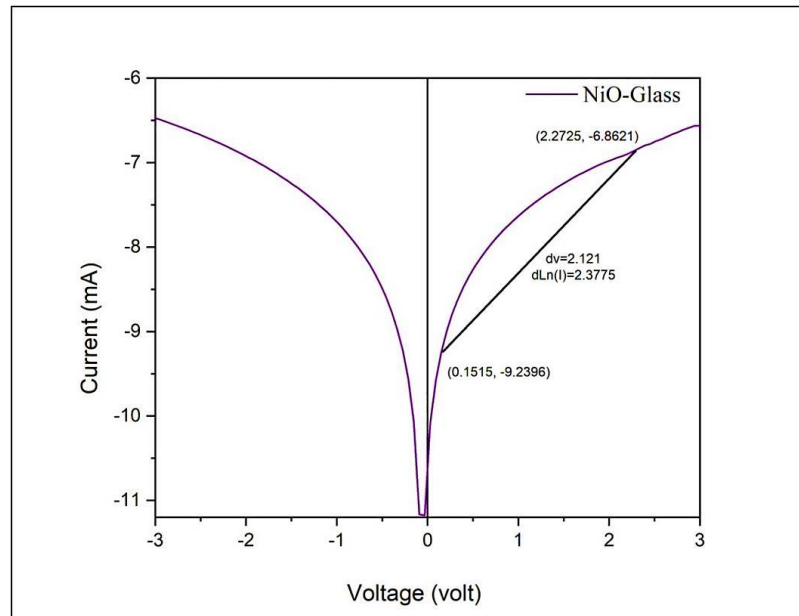


Fig.6 I-V curve between Log(current) and Voltage for (NiO-GLASS)

By using the theory of thermal emission (TE) and using (I-V) results of the deposited films, the parameters barrier height (ϕ_B), ideality factor (η) were measured by the following equations.

$$\phi_B = \frac{k_b T}{q} \ln \left(\frac{A A^* T^2}{I_0} \right) \quad (4)$$

where is contact area $A=4 \text{ Amp K}^{-2} \text{ cm}^{-2}$, Richardson constant $A^* = 96 \text{ Amp K}^{-2} \text{ cm}^{-2}$ and (ϕ_B) is barrier height at zero, q is electronic charge, V is applied voltage, K_b is Boltzman constant, T is the temperature (Kelvin).[6]

$$\eta = \frac{q}{K_b T} \left(\frac{dV}{d(\ln I)} \right) \quad (5)$$

Could $\left(\frac{dV}{d(\ln I)}\right)$ obtained from Log(current) and Voltage graphs in Fig (4) , Fig (5) and Fig (6) we got the η values .

It should be noted that the (I-V) diagrams of the samples are measured in a dark system to avoid light interaction with the samples.

Table 0. Electrical parameters calculated and results I-V

NiO Filmes	dV(volt)	dLnI	I ₀ (Amp)	T (Kelvin)	A* (Amp K ⁻² cm ⁻²)	A (Amp K ⁻² cm ⁻²)
NiO-ITO	1.6365	4.3863	0.007	300	96	4
NiO-FTO	2.061	4.0319	0.010	300	96	4
NiO-GLASS	2.121	2.3775	0.0015	300	96	4

Table 4. The parameters barrier height (ϕ_B) and ideality factor (η) .

NiO Filmes	ϕ_B (eV)	η
NiO-ITO	0.577492	14.42006
NiO-FTO	0.568263	19.75685
NiO-GLASS	0.617348	34.48019

The results of the ideality factor for the (NiO-ITO, and NiO-FTO) films roughly agree with the previous study [11], and although the ideality factor for the (NiO-Glass) films can be calculated, it is not taken into account because it is not characterized by Schottky behavior.

It can be considered that the barrier height calculated for all samples (NiO-ITO, NiO-FTO, NiO-GLASS) is within the correct limits and agrees with previous studies [7-10]. However, from a precise point of view, we can say that the effort barrier is affected by several factors, the most important of which are the conditions of preparation, the technique used, the thickness of the film and the type of material to be prepared.

Conclusions

The glass substrates and preparation method (SILAR) had an impact on the electrical behavior of the deposited films and can be summarized as follows:

- Films (NiO / ITO) were characterized by bi-Schottky behavior and their results were different from films (NiO / FTO, NiO / Glass) which showed ohmic behavior.
- Films deposited on glassy per fluorinated tin oxide (NiO-FTO) showed nonlinear behavior closer to exponential than ohmic behavior in both forward and reverse bias cases.
- The results showed that the nickel oxide films deposited on (NiO-Glass) substrates show linear ohmic behavior in both cases of forward and reverse bias.
- The surface resistivity levels of all samples are within the minimum values calculated in the previous literature, and this indicates a good indicator of the electrical conductivity of these films.

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