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UV-VISIBLE STUDY OF OPTICALLY TRANSPARENT NICKEL OXIDE THIN FILM PREPARED BY CHEMICAL SPRAY PYROLYSIS TECHNIQUE

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UV-Visible Study of Optically Transparent Nickel Oxide Thin Film Prepared By Chemical Spray Pyrolysis Technique

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Abstract – Highly transparent nickel oxide (NiO) thin film was deposited onto the glass substrates by using simple and economic Chemical spray pyrolysis technique. Aqueous solution of nickel chloride ($NiCl_2.6H_2O$) was used as a precursor solution. The precursor solution of molarity 0.5 M was sprayed through glass nozzle on pre-heated glass substrate. The substrate temperature was kept constant at 400 °C during the film deposition. Optical property of prepared film was studied by means of UV-visible spectrophotometer in the spectral range 300-900 Å. Optical study revealed the excellent optical transparency of NiO film. Average transparency above 80% has been observed in the entire visible region which offered a strong candidature for thin film based coating applications.

Key words: Thin Film, UV-vis, Spray Pyrolysis Technique, Oxide

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INTRODUCTION

Investigations on transparent materials are being pursued with increasing interest on account of their exclusive use as buffer layers in thin film solar cells, liquid crystal displays, solar heat mirrors and advanced applications [1,2]. In these technological applications, transparent and semiconducting oxide films (Such as SnO_2, In_2O_3 etc.) have been used intensely during past few decades [3,4]. All of these are n-type. Although, coatings of p-type semiconducting transparent materials are also needed as electrode material in Li-ion batteries, solar thermal absorbers, sensors, and flat displays [5]. Such p-type semiconductors are relatively rare. NiO is one of the most exhaustively investigated p-type transition metal oxide that can be used in electrochromic applications, smart windows, display devices, hetrojunction devices, UV detection and in gas sensors [6-9].

Pure nickel oxide is stiochiometric with rock salt FCC structure [10]. Although, the nickel ion vacancy in NiO crystallites results in non-stiochiometric nickel oxide that shows wide spread physical properties based on the parameters involved in the process of film fabrication. During recent years, several techniques e.g. PLD, Solution cast, spray pyrolysis etc. with various deposition parameters such as molarity, RF power, substrate temperature etc. have been adapted to improve the optical performance of NiO thin films [11-14]. Among the various film deposition methods, the spray pyrolysis deposition technique is unique, safe, simple and most economic. Thus in this study, nickel oxide thin film has been prepared using Chemical spray pyrolysis technique. The optical studies have been done UV-visible spectrometer within the wavelength range 300nm-900nm using UV-vis spectrophotometer (Perkin Elmer Lambda 950).

EXPEIMENTAL WORK

In the present study, thin film of NiO have been prepared onto microscopic glass substrates using spray pyrolysis technique (CSPT). The apparatus used in CSPT is described in Ref [10]. In this technique, the chemical solution was sprayed through glass nozzle and atomizes into the stream of fine droplets which were further heat treated at the substrate temperature of 400 °C to get high quality films. The solution flux rate coming out from the nozzle was maintained at 5ml/min by means of carrier gas compressed at constant pressure. For uniform deposition of films, the spray nozzle was moved back and forth at a constant height of 20 cm over the glass substrates.

The spray solutions were prepared by mixing appropriate volume of de-ionized water, nickel chloride and tin chloride of 0.5M concentrations. The solutions were stirred for few minutes to yield a clear and homogeneous solution. The precursor solution so prepared was sprayed onto the preheated glass substrates, which undergoes evaporation, solute precipitation and pyrolytic decomposition, thereby resulting in the uniform deposition of films following the reaction [15]:

$$NiCl_2.6H_2O \rightarrow NiO + 2HCl\uparrow + 5H_2O\uparrow$$

All the substrates were chemically and ultrasonically cleaned before deposition. For this, first of all they were cleaned with detergent solution 'Labolene' then washed with water. In the next step, they were dipped in nitric acid and NaOH solution respectively for 15 min. After that, the substrates were washed with de-ionized water. Finally, they were treated in ultrasonic bath for few minutes and then dried before placing on the hot plate. They were kept at the constant deposition temperature for 3 hour, prior to spraying the solution.

RESULTS AND DISCUSSION

The spectral variation of transmittance data for NiO film is given in Fig. 1. The plot revealed the excellent optical transparency of NiO film. In fact, an average transparency above 80% has been observed in the entire visible region which offered a strong candidature for thin film based coating applications. In Fig.2, the optical absorption curve is plotted as a function of wavelength. Curve show weak absorption in visible region and strong absorption near U-V region. A sharp decrease in absorption with an absorption edge near UV region has been observed for NiO film which may be attributed to the fundamental band gap absorption of investigated film.

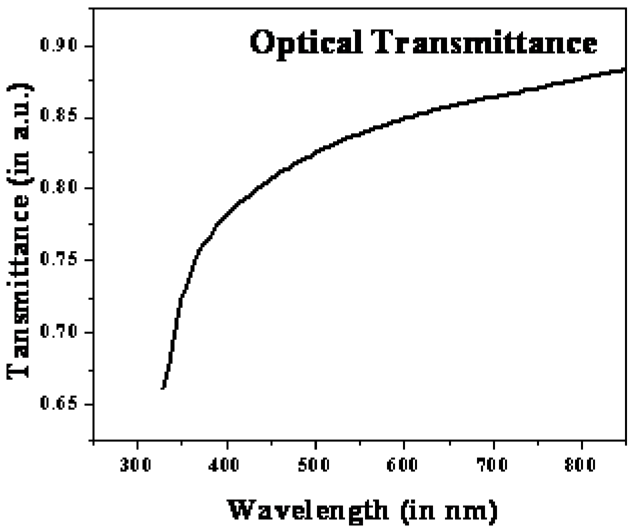

Figure 1: Spectral variation of optical transmittance for NiO film.

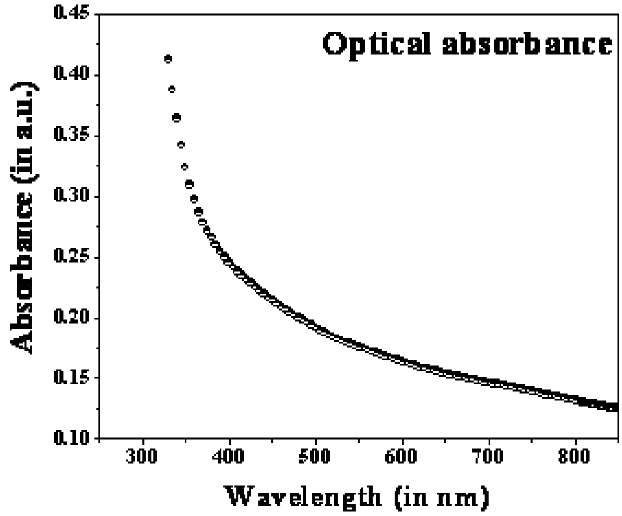

Figure 2: Spectral variation of optical absorbance for NiO film.

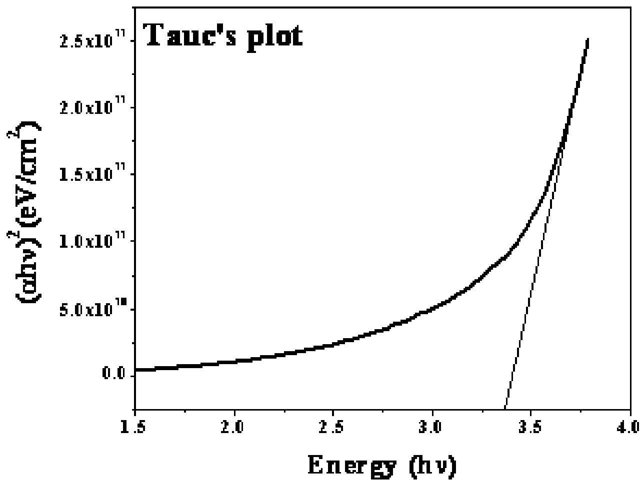

Figure 3: Plot of $(\alpha h\upsilon)^2$ versus hυ that gives the band gap of deposited film.

The optical band gap E_g was calculated using the relation [16]:

$$(\alpha h\nu) = A(h\nu - E_g)^k \qquad (2)$$

where α is the absorption coefficient, E_g is the band gap corresponding to a particular transition occurring in the film, A is a constant, ν is the transition frequency and k can take the values 1/2, 3/2, 2 or 3, for the transition corresponding to direct allowed, direct forbidden, indirect allowed and indirect forbidden respectively. The NiO is considered as material with direct band gap energy and hence the value of n has been taken to be 1/2 for direct allowed transitions. The band gap has been calculated by extrapolating the linear region of the plot $(\alpha h\nu)^2$ versus $h\nu$ on the energy axis as shown in Fig. 3. The value of band gap is found to be 3.4 eV NiO film this is in good agreement with the values reported in the literature [17].

CONCLUSIONS

Optically transparent thin film of NiO has been successfully deposited by Chemical spray pyrolysis technique. Deposited NiO film is found to be highly transparent in the visible region. In fact, NiO film retains an average transparency above 80 % throughout the visible region. A sharp absorption edge has been observed near UV region. Energy band gap calculation suggested the semiconductor nature of NiO film with optical band gap value of 3.4 eV.

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