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Preparation of Bismuth Oxide Thin Films by Spray Pyrolysis Method and Its Characterizations

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The Bi_2O_3 thin films were prepared onto glass substrates by spray pyrolysis method. The Bi_2O_3 thin films optimized at 320 °C spray pyrolysis temperature. The crystal structure, crystallite size, and surface morphology of Bi_2O_3 thin films were studied by X-ray diffraction (XRD) and scanning electron microscopy (SEM) techniques, respectively. The X-ray diffraction pattern of Bi_2O_3 thin films show polycrystalline in nature. The SEM images show porous morphology of Bi_2O_3 thin films. The optical absorption spectra of films were examined in order to study their band gap energy. The optical study shows a direct band gap of 2.90 eV for Bi_2O_3 films.

1. Introduction

In recent years, semiconducting thin films are used in material research due to their domestic as well as industrial applications. Bismuth oxide (Bi_2O_3) is one of the versatile and important transition metal oxide, which plays a significant role in modern solid state technology due to its properties such as band gap, refractive index, dielectric properties, etc. Due to the predominance of certain phase, which depends on preparation technology. The electrical conductivity of bismuth oxide may change by order of magnitude, while its band gap may change from 2 to 3.96 eV.

Currently, researchers work to focus on various semiconducting materials such as Bi_2O_3, ZnO, Cu_2O, TiO_2, MgO_2, etc.[1–7] Among these materials Bi_2O_3 is abundant, less toxic, and easily available. The Bi_2O_3 material is prepared via various deposition techniques such as spray pyrolysis,[8] DC sputtering,[9] solid state synthesis,[10] hydrothermal,[11] chemical bath deposition,[12] electrodeposition,[13] solution combustion method[14,15], etc. There are various applications of Bi_2O_3 material such as optical coatings, photovoltaic cells, supercapacitors, microwave integrated circuits, gas sensors, photocatalyst, etc.[16–19] Along with these applications, recently introduced applications of Bi_2O_3 are in fuel cells, oxygen sensors, and oxygen pumps.

This work reports the synthesis of Bi_2O_3 thin films via cost effective and less time consuming spray pyrolysis method. The spray pyrolysis method is suitable to synthesis number of Bi_2O_3 thin films. Our aim is to prepare low cost Bi_2O_3 thin films for various applications.

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2. Experimental Section

2.1. Preparation of Bi_2O_3 Thin Films

The bismuth nitrate $Bi(NO_3)_3 \cdot 5H_2O$ was dissolved in nitric acid. Then, the solution was diluted with deionized water to get the required amount strength of solution 0.05 M. The films were prepared by spraying 50 mL 0.05 M solution of bismuth nitrate onto glass substrates. The substrate temperature was maintained at 320 °C during the deposition. The spray rate was kept at about 40 mL h^{-1}. The source to glass substrate distance was kept constant at 24 cm. The modified spray unit described to move the spray nozzle to and fro over the substrates. After spray, the films were washed with double distilled water and used for characterization.

2.2. Characterizations

The crystal structure were characterized by X-ray diffraction (XRD) technique using model Bruker D8 Advance with Cu Kα radiation ($\lambda = 1.54$ A°) in the range (2θ) of 20°–80°. The surface morphology was studied by scanning electron microscope (SEM) of model JEOL JSM-6360. The Raman spectra was calculated by micro-Raman Renishaw spectrometer of wavelength 532 nm. Optical absorption studies were carried out using UV-visible spectrophotometer SYSTRONICS 119.

3. Results and Discussion

3.1. XRD Study

For the structural elucidation of the bismuth oxide, X-ray diffraction was exploited in the 2θ range of 20°–80°, respectively. **Figure 1** shows typical XRD pattern of bismuth oxide thin film deposited on glass substrates. The bismuth oxide films are polycrystalline in nature. The XRD data show eight peaks of Bi_2O_3 which are (310), (321), (411), (035), (235), (631), (640), and (356), respectively. These hkl planes are in good agreement with standard JCPDS data card values.[20] The (310) plane is a more intensive plane of Bi_2O_3 material. There are no other impurity peaks present in XRD pattern of Bi_2O_3 thin films.

The crystallite size (D) of Bi_2O_3 are determined by the Debye Scherrer's equation[21]:

$$D = 0.9\lambda/\beta\cos\theta \qquad (1)$$

