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Quantum Confinement effects on the Band Gap of Bi_2S_3 Thin Films using Chemical Bath Deposition

Balasubramanian V.[1*], Suriyanarayanan N.[2] and Kannan R.[3]
[*1]Department of Physics, Tamilnadu College of Engineering, Karumathampatti, Coimbatore, Tamil Nadu, INDIA
[2]Department of Physics, Government College of Technology, Coimbatore, Tamil Nadu, INDIA
[3]Department of Physics, KSR College of Engineering, Tiruchengode-637215, Tamil Nadu, INDIA

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Abstract

Chemical bath deposition technique has been used to prepare Bi_2S_3 thin films for various applications. Optical absorption studies were carried out using UV-VIS-NIR Spectrophotometer (Model-V-570) in the wavelength range 190 nm to 2500 nm at room temperature. Transmittance spectra of Bi_2S_3 thin films increases monotonically with the increase in wavelength; but decreases monotonically with the increase in film thickness. Optical band gap energy was decreased with increase in thickness.

Keywords: Bismuth sulphide, thin films, chemical bath deposition, optical properties, quantum confinement effect, band gap.

Introduction

Quantum-confined semiconductor structures, including quantum wells, quantum rods, and quantum dots, have been extensively investigated in the past few years[1]. One of the most interesting effect of low-dimensional semiconductor structures is the size-dependent band gap. Semiconductors, which have changed properties resulting from quantum confinement, have drawn considerable interest and are currently being investigated. Semiconducting thin films exhibit size-dependent electronic band gap energies melting temperatures, solid phase transition temperatures and pressures. In addition to these, doped semiconducting thin films have tremendous potential for use in light emitting applications. These properties of nanomaterial make them an interesting category of material for opto-electronic applications[2]. These semiconducting materials may find applications in nonlinear optical devices, photo catalysis, etc. Semiconductors have immense technological importance in different applied branches of science and technology. Bismuth sulphide (Bi_2S_3) is an important binary semiconducting material and it has been studied due to its wide applications as solar absorbers and in optoelectronics[3]. The Bi_2S_3 thin film is prepared using various methods such as spray pyrolysis, sputtering, sol-gel spin coating, pulsed laser deposition (PLD), chemical vapor deposition, and chemical bath deposition[4–10]. In spite of few studies regarding to the chemical bath deposition method, the chemical bath method has some merits, such as the easy control of chemical components, and fabrication of thin film at a low cost to investigate structure and optical properties of Bi_2S_3 thin films. In this paper we report some optical properties and quantum confinement effect on of Bi_2S_3 thin films prepared by chemical method.

Material and Methods

The film preparation was previously described in our previous paper[3]. Different thickness Bi_2S_3thin film samples are prepared on to well cleaned glass substrates by chemical bath deposition method. Optical absorption studies were carried out using UV-VIS-NIR spectrophotometer (Model-V-570) in the wavelength range 190 nm to 2500 nm at room temperature using unpolarised lights from deuterium and tungsten lamps which are used at near normal incidence.

Results and Discussion

Chemically deposited Bi_2S_3 films were characterized by optical absorption and transmittance measurements. The measurements have been taken in the wavelength range 190-2500 nm. The optical absorption and transmittance spectra of Bi_2S_3 films of three different thicknesses 246 nm to 899 nm are shown in figures-1-6. It can be observed that in general a increase in film thickness improves the absorption.

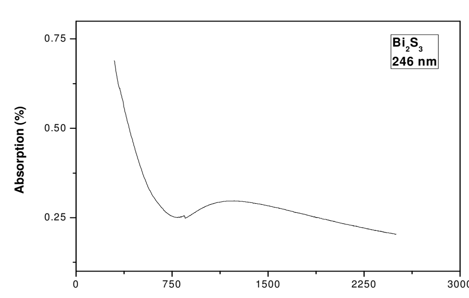

Figure-1
Absorption spectra of Bi_2S_3 thin films of thickness 246 nm

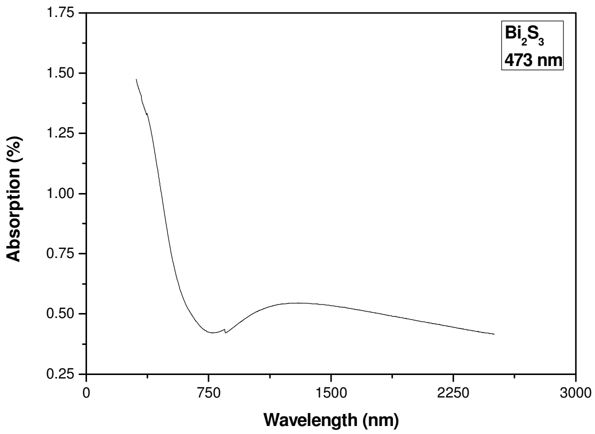

Figure-2
Absorption spectra of Bi_2S_3 thin films of thickness 473 nm

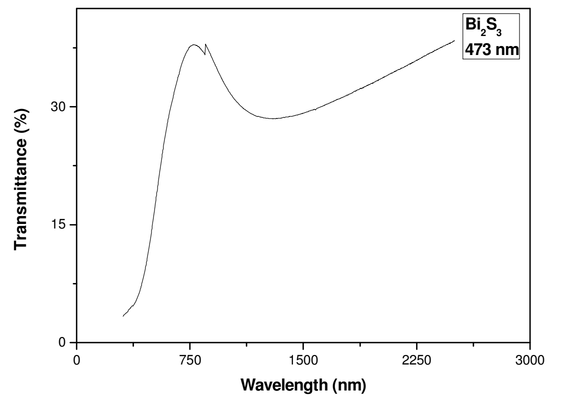

Figure-5
Transmittance spectra of Bi_2S_3 thin films of thickness 473 nm

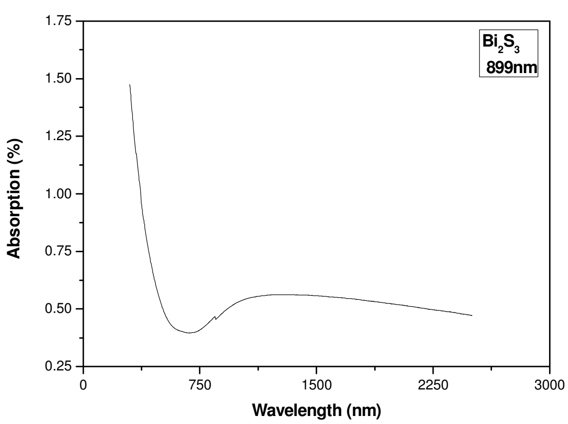

Figure-3
Absorption spectra of Bi_2S_3 thin films of thickness 899 nm

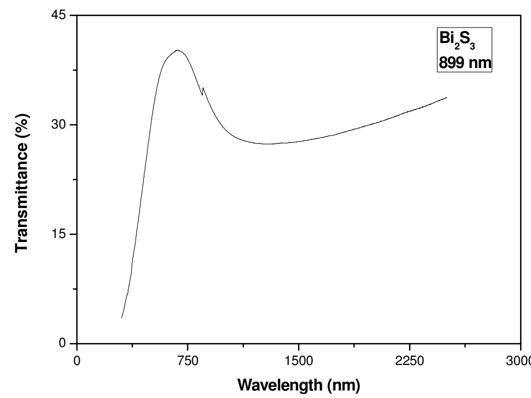

Figure-6
Transmittance spectra of Bi_2S_3 thin films of thickness 899 nm

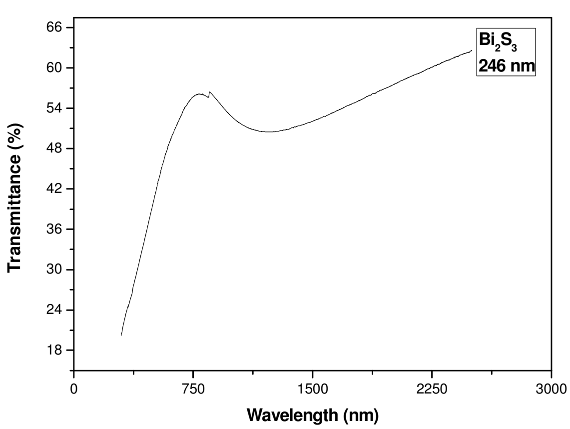

Figure-4
Transmittance spectra of Bi_2S_3 thin films of thickness 246 nm

Transmittance spectra show that Bi_2S_3 thin films increases monotonically with the increase in wavelength; but decreases monotonically with the increase in film thickness. Absorption coefficient of Bi_2S_3 thin films has been calculated using transmittance spectra. The high value of optical absorption coefficient confirms that Bi_2S_3 has direct band gap. Killedar et al.[11] have also observed that Bi_2S_3has direct band gap 1.8 eV. Depending on the band structure of material, direct or indirect optical transitions are possible[12].

The relationship between the absorption coefficient α and the incident photon energy can be written as

$$\alpha = a\,(h\nu - E_g)^n / h\nu \quad (1)$$

Where "a" is a constant, Eg is the band gap, n is a constant. The value of α is obtained from the relation

$\alpha = 2.303\ A / t$ (2)

where 'A' is the absorbance and 't' is the thickness of the film.

A plot of $(\alpha h\nu)^2$ versus ($h\nu$) in figures-7-9 are used to determine band gap of Bi_2S_3. It is found that the band gap of Bi_2S_3thin films is thickness dependent. It decreases with the increase in film thickness. Bi_2S_3thin films are polycrystalline. In thin films the particle size of crystallites is of the order of film thickness and proportional to thickness of films. Since grain size influences the energy level of electrons, the band gap will be dependent on thickness of films Band gap of thin films as a function of reciprocal of square of thickness [12]. It is linear.

The linear extrapolation of $(\alpha h\nu)^2$ versus ($h\nu$) curve to the energy axis gives the value of band gap of Bi_2S_3 as 2.6 eV, 2.16 eV and 2.1 eV which agrees with the reported value[13]. Table-1 gives the optical band of Bi_2S_3 thin films of different thicknesses. The optical band gap increases from 2.1 eV to 2.6 eV as thickness varied from 899 nm to 246 nm. The decrease in E_g and increase in crystalinity of the film as a function of the film thickness suggest that quantum confinement effect exists in chemically deposited Bi_2S_3 thin films[13-15].

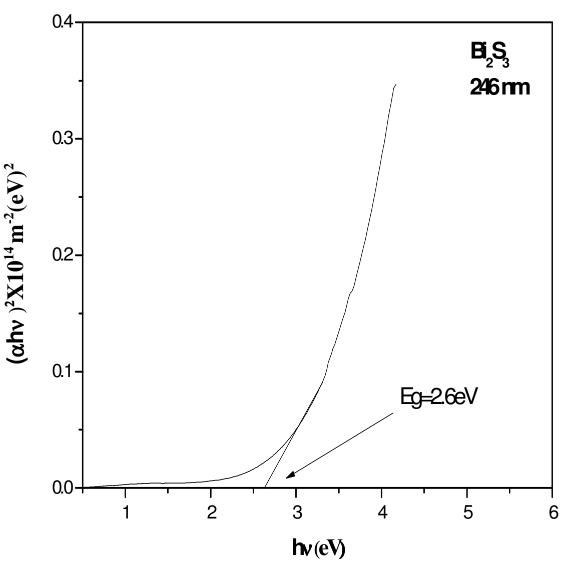

Figure-7
Band gap plot of Bi_2S_3 thin films of thickness 246 nm

Table-1
Optical band of Bi_2S_3 thin films of different thicknesses

Thickness (nm)	Band gap (eV)
246	2.6
473	2.16
899	2.1

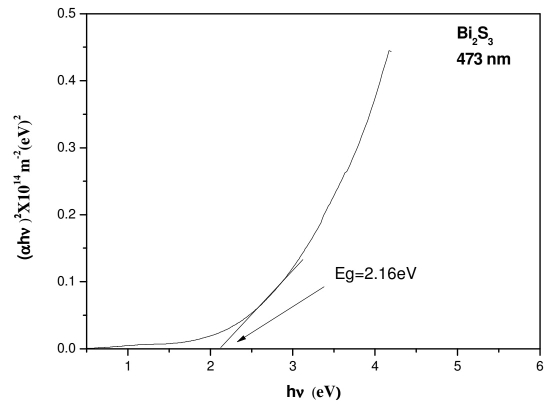

Figure-8
Band gap plot of Bi_2S_3 thin films of thickness 473 nm

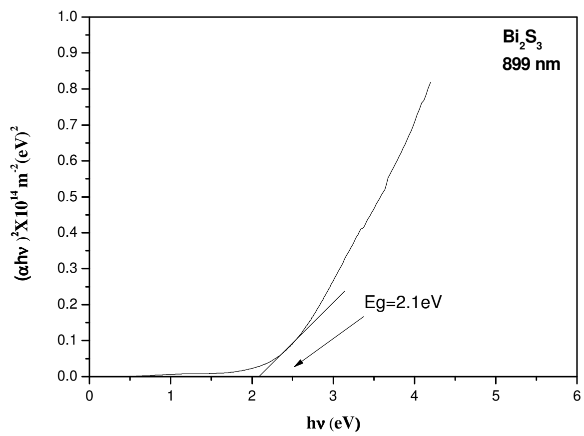

Figure-9
Band gap plot of Bi_2S_3 thin films of thickness 899 nm

Conclusion

Transmittance spectra of Bi_2S_3 thin films increases monotonically with the increase in wavelength; but decreases monotonically with the increase in film thickness. Optical band gap energy was decreased with increase in thickness. The decrease in E_g and increase in crystalinity of the film as a function of the film thickness suggest that quantum confinement effect exists in chemically deposited Bi_2S_3 thin films.

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