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OPTICAL PROPERTIES OF SINGLE STEP SYNTHESIZED NANOSTRUCTURED BISMUTH OXIDE USING HYPERBOLIC BAND MODEL

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ABSTRACT

The nanostructured bismuth oxide (Bi_2O_3) was synthesized by chemical method with different concentration of HMT at room temperature. The particle size dependence of Bi_2O_3 on HMT was studied from UV-VIS spectroscopy. Optical band gap analysis of synthesized material was studied using hyperbolic band model. With the same model particle size of synthesized materials were also computed.

Key words: Optical properties, Bismuth oxide, Hyperbolic band model

INTRODUCTION

Nanocrystalline particles generally display properties different from their bulk counterparts from which they are derived. Due to their unique physical and chemical properties, bismuth oxide nanoparticles have been used widely as an important component in the field of solid oxide fuel cells, gas sensors, varistors, electric and optical materials, high temperature superconductor materials, functional ceramics and catalysts, etc.[1,2]. Bismuth oxide (Bi_2O_3) is used in a variety of areas, such as sensor technology, optical coatings and electrochromic materials[3,4], due to its high refractive index, dielectric permittivity, marked photoconductivity and photoluminescence[5]. Bismuth trioxide nanoparticles are widely used in various applications such as electronics and catalytic materials due to their high oxygen-ion conductivity and selective oxidation of hydrocarbons[6,7]. Recently, α-Bi_2O_3 bismuth trioxide has found extensive applications as an oxidizing component in nanoenergetic materials (NMs) or metastable intermolecular composites (MIC)[8,9]. High purity bismuth nitrate, $Bi(NO_3)_3.5H_2O$, was used as the oxidizer. Bismuth oxide as a component finds use in wide applications in varistors, catalyst and gas sensors. Bismuth oxide (Bi_2O_3)-based compounds are much better solid electrolytes than well-known stabilized zirconia, because the face-centred cubic (FCC) Bi_2O_3 exhibits the highest ion conductivity of all oxide ion conductors[10,11]. Bi_2O_3 is also used as an additive in paints. These special features explain the great effort devoted to the investigation of Bi_2O_3 polymorphs over the past few years. Bi_2O_3 has five main polymorphic forms, denoted by α-, β-, γ-, δ- and ω-Bi_2O_3[12,13]. Among them, the band gaps of the low-temperature α-phase and high-temperature metastable β-phase are 2.85 eV and 2.58 eV, respectively[14].

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Many chemical methods have been employed to prepare Bi_2O_3 nanoparticles, e.g. precipitation[15,16], flame spray pyrolysis[17], and sol–gel methods[18]. In this work, Bi_2O_3 composite particles were synthesized by chemical method and characterized by UV visible spectrophotometer.

EXPERIMENTAL

AR grade chemicals were used in this study. The bismuth oxide was synthesized by single step chemical method. The hexamethylele tetramine (HMT) with different concentration (0.25-1 M) was dissolved in 5 mL double distilled water separately. After rigorous stirring, 1 M bismuth nitrate was added in the solution. The reaction was stand for 4 h. The precipitate so obtained was vacuum filtered and filtrate was first dried at room temperature of 24 h and sintered at 100°C for 3 h. In this way, four samples of Bi_2O_3 were prepared. The samples were characterized by UV-Vis analysis on Perkin Elmer Spectrophotometer.

RESULTS AND DISCUSSION

The UV-vis analysis was carried out to know the optical properties of prepared samples. The particle size of the samples was estimated roughly from optical band gap value. The UV-vis spectra of samples were displayed in Fig. 1, 2, 3, 4. This analysis provides optical information of synthesized materials. Using various models regarding the optical properties can apply to this data, gives very interesting result. In our present investigation we apply hyperbolic band model to study the optical properties of prepared samples and the particle size also computed from same characterization.

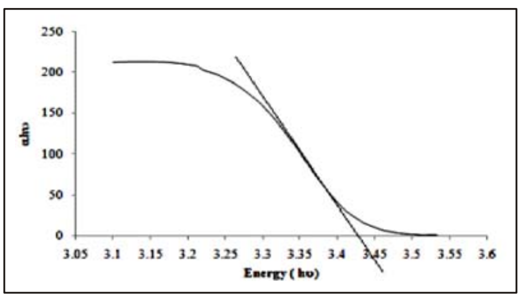

Fig. 1: UV-vis of 0.25 M HMT

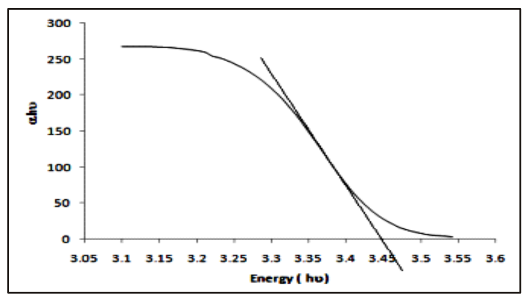

Fig. 2: UV-vis of 0.5 M HMT

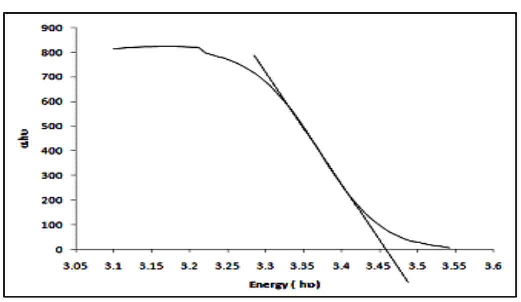

Fig. 3: UV-vis of 0.75 M HMT

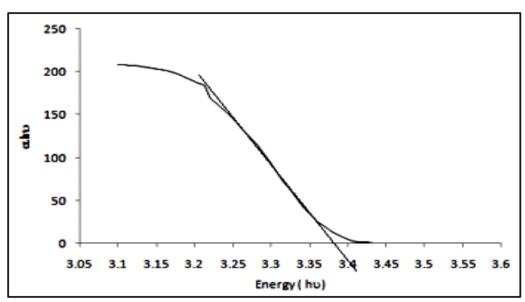

Fig. 4: UV-vis of 1 M HMT

By considering shifted absorption edge from 360-366 nm of Bi_2O_3 sample, average crystallite (particle) size has been estimated and found to be nm by using the following hyperbolic band model[19].

$$R = \sqrt{\frac{2\pi^2 h^2 E_{bulk}}{m^*(E_{nano}^2 - E_{bulk}^2)}} \qquad \ldots(1)$$

where, E_{bulk} is bulk band gap,

E_{nano} is band gap of nanomaterial,

m* is effective mass of electron (m* = 29.15 × 10^{-31} Kg)

Table 1: Values of Absorption wavelength, Optical band gap and Quantum dot radius (R) of samples of different concentration of HMT

S. No.	Sample	Absorption wave length (nm)	Optical band gap (eV)	Quantum dot radius (R) nm
1	0.25 M HMT	361	3.44	4.62
2	0.50 M HMT	358	3.45	4.58
3	0.75 M HMT	362	3.46	4.54
4	1 M HMT	366	3.38	4.89

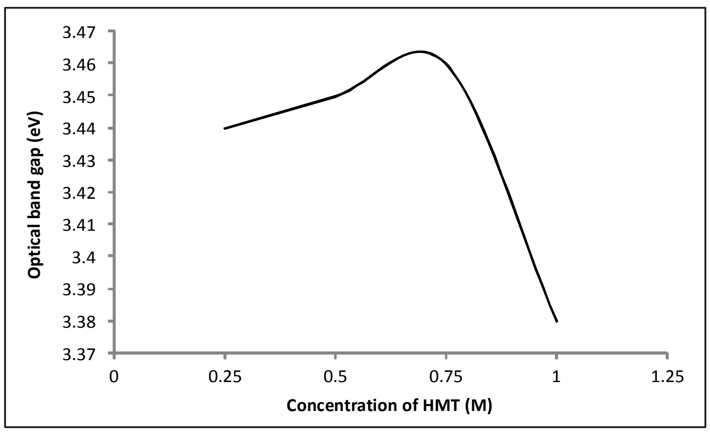

Fig. 5: Plot between HMT concentration versus optical band gap

CONCLUSION

Chemical synthesis of Bi_2O_3 nanoparticals is a simple, low cost and reliable technique. UV-vis study revels that the 0.75 M concentration of HMT showed maximum value of band gap 3.46 eV. Further increase in concentation of HMT, decreased the value of band gap. The quantum dot radius was found to be smallest at 0.75 M HMT concentration.

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