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Synthesis and optical properties of poly (vinyl acetate)/bismuth oxide nanorods

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Poly (vinyl acetate) (PVAc) loaded bismuth oxide (Bi_2O_3) nanorods were successfully prepared at ambient pressure. X-ray diffraction (XRD) and transmission electron microscopy were used to characterize the final product. It was found that Bi_2O_3 nanorods were formed and the diameter of the rods was confined to about 8 nm. The diameter and length of formed rods were found to increase by increasing the bismuth oxide concentration in the PVAc matrix. The optical properties of the nanocomposite films were characterized from the analysis of the experimentally recorded transmittance and reflectance data in the spectral wavelength range of 300–800 nm. The values of some important parameters of the studied films are determined such as refractive index (n), extinction coefficient (k), optical absorption coefficient (α), and band energy gap (E_g). According to the analysis of dispersion curves, it has been found that the dispersion data obeyed the single oscillator of the Wemple–DiDomenico model, from which the dispersion parameters and high-frequency dielectric constant were determined. In such work, from the transmission spectra, the dielectric constant (ε_∞) and the third-order optical nonlinear susceptibility $\chi^{(3)}$ were determined.

Keywords: bismuth oxide; PVAc; optical

INTRODUCTION

In recent years, an enormous amount of research work has been devoted to the study of one-dimensional (1D) nanostructure materials such as nanowires, nanotubes, and nanobelts, due to their novel properties different from conventional bulk materials and potential applications in nanoscale electronic and optoelectronic devices.[1] Nanowires of various compositions have been synthesized using a wide variety of methods including carbothermal reactions, vapor–liquid–solid (VLS) growth, vapor_solid (VS) growth, template-assisted route, and solvothermal synthesis.[2] Moreover, some nanowires have been employed to construct such exciting systems as nanowire integrated systems[3] and nanolasers.[4] Considering the importance of metal oxides in catalysis, electrochemistry, optics, functional ceramics, and sensors, their fabrication in 1D nanostructured morphology appears to be a particularly attractive goal.

Recently, bismuth oxide (Bi_2O_3) has been investigated extensively due to its optical and electrical properties such as refractive index, large energy band gap, dielectric permittivity as well as remarkable photoluminescence, photocatalysis, and photoconductivity. These properties make bismuth oxide an interesting candidate for applications in the fields such as optoelectronics, optical coatings, gas sensors, Schottky barrier solar cells, metal–insulator–semiconductor capacitors, microwave integrated circuits, etc. Bi_2O_3 shows four main structures that are denoted by α-,β-, γ-, and δ-Bi_2O_3.[5] The low-temperature α-phase and high-temperature δ-phase are stable, and the others are high-temperature metastable phases.[6] These special features explain the great effort devoted to the investigation of Bi_2O_3 polymorphs over the last years.

Typically Bi_2O_3 is prepared via the addition of alkali-metal hydroxides to bismuth salt solution.[7–9] These powders on calcination yield fine particles of Bi_2O_3. Flame spray pyrolysis[10] is also used to produce nano-sized Bi_2O_3 particles. The properties of ceramics are greatly affected by the characteristics of the powder such as particle size, morphology, purity, and chemical composition. Using chemical methods, e.g. co-precipitation, sol–gel, hydrothermal, and colloid emulsion technique have been confirmed to efficiently control the morphology and chemical composition of prepared powders. Here, we report a simple urea-nitrate process for the preparation of nanowire Bi_2O_3. This method is commonly used for preparation of various oxides[11–14] and not yet reported for the preparation of Bi_2O_3 ceramics. Urea is used as a fuel, precipitating agent, and as a resin former with formaldehyde. When urea is used along with nitrate salt of a cation and heated at 400°C, the exothermic reaction between nitrate (oxidant reactant) and urea (fuel) leads to formation of corresponding nanowire oxides.

The purpose of the present contribution is to present new data for the effect of Bi_2O_3 nanorod on the structure and optical properties of poly(vinyl acetate) (PVAc).

EXPERIMENTAL

Materials and processing

To synthesize Bi_2O_3 with the shapes of nanorods and nanowires, 0.3 mol bismuth nitrate pentahydrate ($Bi(NO_3)_3{\cdot}5H_2O$) was

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