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Complex optical study of V_2O_5–P_2O_5–B_2O_3–Dy_2O_3 glass systems

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Abstract

In this study, complex optical parameters such as absorption, extinction coefficient, refractive index, optical conductivity and real and imaginary dielectric constants of V_2O_5–P_2O_5–B_2O_3–Dy_2O_3 glass systems were studied. The conformation of the glassy phase in a sample was accomplished by X-ray diffraction analysis, and the material's optical parameters were analyzed using ultraviolet–visible spectroscopy. The extinction coefficient and real and imaginary dielectric constants were found to linearly increase above 225 nm, and the optical conductivity in V_2O_5–P_2O_5–B_2O_3–Dy_2O_3 glass systems was found to gradually increase near 225 nm.

Keywords: Complex optical properties; Dy_2O_3; Ultraviolet–visible spectroscopy

1. Introduction

In modern applications, rare-earth co-doped glass systems have many potential applications in various fields, such as solar cells, telecommunication, light emitting devices and Li-free battery materials, which have been improved using the special properties of rare-earth materials. Additionally, rare-earth oxide glasses are currently applied to take advantage of the Faraday rotation effect in an optical attenuator, circulator and magnetic field sensor. All of these applications are primarily based on unidirectional light propagation in optical isolators, which results in large Verdet constants, which are primarily influenced by the concentration of rare-earth materials in a glass system [1].

Reddy et al. prepared (Dy^{3+})-doped sodium–aluminium–phosphate glasses and studied their optical absorption, excitation, emission spectra and decay time. The authors of Ref. [2] concluded that these properties are related to the nature of the host matrix. Jimenez et al. studied the spectroscopic properties of a $50P_2O_5$:50BaO glass matrix containing CuO, SnO and Dy_2O_3 prepared by melting followed by heat treatment. The primary accomplishment of this study is the determination of the stoichiometric amounts of CuO and SnO dopants along with the source of Dy^{3+} ions that results in the effective precipitation of Cu nanoparticles [3]. Marzouk et al. prepared Dy_2O_3-doped lead phosphate glasses using a melt-quenching technique and characterized them using infrared absorption spectra, photoluminescence and UV–visible optical absorption measurements. It was shown that the density of non-bridging oxygen increases

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due to the effects of rare-earth dopants on lead phosphate glass, which significantly affects the material's optical parameters [4]. A Dy-doped phospho-vanadate glass system was reported by Barde et al., who studied the material's transport and physical properties. The authors of Ref. [5] showed that ionic conductivity is dominant over the electronic conductivity with values that range between 82% and 96%. Park et al. prepared bismuth-borate glasses systems with various dopants, such as CeO_2, Nd_2O_3, Er_2O_3, Dy_2O_3 and Pr_2O_3, in difference concentrations using the melt-quenching technique. The primary achievement of this work was showing that X-ray luminescence only shows an emission peak at 575 nm in Dy_2O_3-doped glass systems [6]. Hayakawa et al. studied the effect of the concentration of Tb_2O_3/Dy_2O_3 on various properties including the Faraday rotation, optical attenuation, circulator and magnetic field of B_2O_3–Ga_2O_3–SiO_2–P_2O_5 glass systems produced by a conventional melt-quenching method [7]. Nahm et al. reported the electrical properties and DC-accelerated ageing characteristics of ZnO-Pr_6O_{11}-based varistors doped with various Dy_2O_3 contents and sintering times. Increases in concentration and sintering time led to a reduction in nonlinearities [8]. Ekhelikar et al. described the binary systems of Bi_2O_3–Dy_2O_3 and Bi_2O_3–Pr_2O_3 by varying the doping concentration of Dy_2O_3 and Pr_2O_3 prepared by the ceramic method [9]. Ramteke et al. synthesized Li_2O–B_2O_3–Dy_2O_3 glasses using the melt-quenching technique for different concentrations of Dy_2O_3. In this investigation, it was observed that the conduction mechanism is independent of the temperature because the AC conductivity and electric modulus overlap on the single master curve [10].

Therefore, the goal of this study was to investigate the complex optical properties of V_2O_5–P_2O_5–B_2O_3–Dy_2O_3 systems. To the best of our knowledge and from a thorough literature survey of material science papers, no unified report on this topic has been published. This work explores the complex optical properties associated with V_2O_5–P_2O_5–B_2O_3–Dy_2O_3 glass systems analyzed with ultraviolet-visible spectroscopy.

2. Experimental

In this study, AR grade chemicals were used to prepare glass samples. The glass systems with compositions of 60 V_2O_5–5P_2O_5–$(35-x)B_2O_3$–xDy_2O_3 created by varying concentrations at an interval of x = 0.4, 0.6, 0.8, 1 and 1.2 mol% were prepared by the regular melt-quenching method. For convenience, these glass systems described by x = 0.4, 0.6, 0.8, 1 and 1.2 mol% are henceforth referred to as S1, S2, S3, S4 and S5, respectively. With proper stoichiometry, chemicals were weighed and mixed, and each mixture was crushed to make it homogenized and thus melt in an alumina crucible in a muffle furnace at 1073 K for 4 h. Then, the mixture was poured onto a stainless steel plate to quench. To avoid internal strain, the sample underwent a heat treatment at 573 K for 2 h.

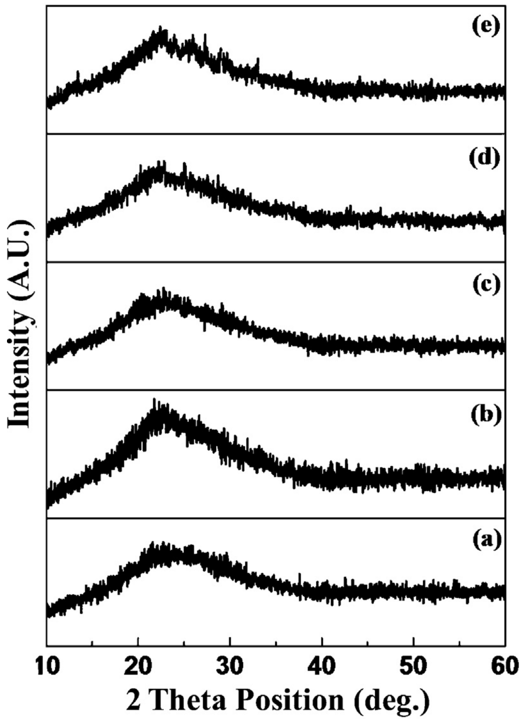

Fig. 1. XRD patterns of 60 V_2O_5–5P_2O_5–$(35-x)B_2O_3$–xDy_2O_3 for: (a) S1, (b) S2, (c) S3, (d) S4 and (e) S5.

Each material was characterized using X-ray diffraction (XRD) (Rigaku Miniflex-II, X-ray diffractometer) to confirm a glassy phase in the as-prepared samples. Similarly, the optical properties of the samples were determined by ultraviolet–visible spectroscopy (Agilent Cary 60 UV-Vis Spectrophotometer). The UV–VIS spectra of the samples were recorded in absorption mode within the wavelength range of 200–600 nm. The optical properties of the glass samples were analyzed in powder form.

3. Results and discussion

Fig. 1 shows the XRD patterns of the 60 V_2O_5–5P_2O_5–$(35-x)B_2O_3$–xDy_2O_3 glass systems. The noisy nature of the pattern clearly indicates the formation of a glassy phase in the as-prepared glass systems. No characteristic peaks were observed in the entire 2θ range, which identified the amorphous nature of