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Spectral investigations of Sm^{3+} doped lead bismuth magnesium borophosphate glasses

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ABSTRACT

The multicomponent lead bismuth magnesium borophosphate glass systems (LBMBPS) doped with Samarium ions with the molar compositions of $(50-x)$PbO–$x$$Bi_2O_3$–25$MgHPO_4$–24$B_2O_3$–1$Sm_2O_3$ (where x=10, 20, 30, and 40) were fabricated using conventional melt quenching technique. The amorphous nature of these glass samples was confirmed with XRD studies. The spectral data from the optical absorption studies were employed to compute various spectroscopic parameters such as Judd–Ofelt intensity parameters. The Judd–Ofelt parameterization employed reflects the covalency and vibration frequencies of the ligands with Samarium ions. The radiative parameters such as radiative transition probabilities (A), the total radiative transitional probabilities (A_T), radiative life times (τ_R), branching ratios (β) and absorption cross sections (Σ) were computed for certain lasing levels. The glass systems thus developed indicate their potential lasing candidature. The emission cross sections (σ_E) for the significant lasing transitions $^4G_{5/2}\rightarrow{}^6H_{5/2}$, $^4G_{5/2}\rightarrow{}^6H_{7/2}$, and $^4G_{5/2}\rightarrow{}^6H_{9/2}$ evaluated from the photoluminescence spectra were reported. The radiative properties obtained in our investigations suggest their lasing candidature.

1. Introduction

Glasses prepared with heavy metal oxides become important for optoelectronic applications [1–3]. The relatively low phonon energy of these glasses increases the quantum efficiency of luminescence in these matrices and become efficient lasing candidates [4]. The high refractive index of heavy metal oxide glasses has provided an added advantage in higher stimulated emission cross-section, which enhances the gain of the amplifier. The addition of Bi_2O_3 in oxide glasses, modifies the network for lower concentrations and then actively participates in the network formation at higher concentrations of Bi_2O_3 [5]. Since Bi_2O_3 is a conditional glass former, the stability glass decreases with increase of Bi_2O_3 content [5]. Bi_2O_3 contributes significantly to the increase in optical nonlinearity in oxide glasses [6].

The large mass, low field strength and high polarizability of lead in the glass hosts contribute much to the lasing potencies of the glass systems [6]. Lead oxide has the ability to form stable glasses over a wide range of concentrations due to its dual role as a glass modifier and as a glass former [7]. The combination of PbO and Bi_2O_3 in the glass host improves chemical durability of the glass [8]. There is more photon absorption in the glasses containing Bi_2O_3 and PbO [9]. Molar volume decreases with increase in mole fraction of PbO in PbO–B_2O_3 glass system, whereas molar volume increases by replacing

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PbO by Bi_2O_3 in Bi_2O_3–PbO–B_2O_3 glass system. Substitution of lead by bismuth causes the expansion of glass network [10].

The glass former B_2O_3 has boron ions in the triangularly coordinated by oxygen and therefore the B_2O_3 units are corner bonded in a random configuration [11]. The phosphate might provide multiple sites for rare earth dopants, allowing for relatively high concentrations. Phosphate glasses exhibit good chemical durability, large thermal expansion and low optical dispersion [12,13]. Among various glass matrices, phosphate glass possesses a series of interesting properties such as low glass transition temperature (*Tg*), low melting temperature, high thermal expansion coefficient and biocompatibility [14]. The dopant Sm^{3+} ($4f^5$) ion is one of the most interesting RE ions to analyze the fluorescence properties as its emitting $^4G_{5/2}$ level exhibits relatively high quantum efficiency. The glass containing Sm^{3+} ions have the most interesting qualities due to their potential applications for high-density optical storage, under sea communication and color displays [15].

The authors in the present work reported the lazing properties of Sm^{3+} ions in varied compositions of Bi_2O_3 and PbO with glass formers $MgHPO_4$ and B_2O_3.

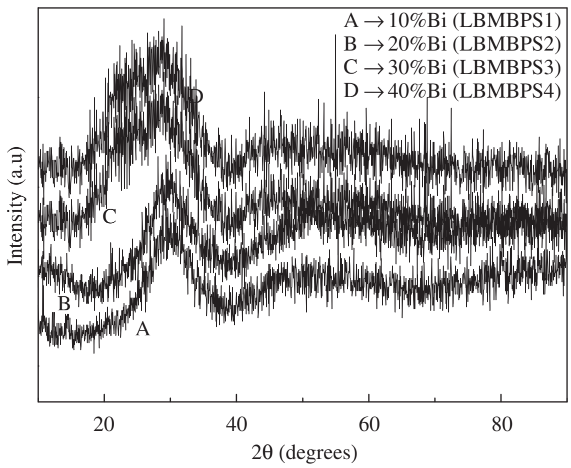

Fig. 1. XRD profile of Sm^{3+} ions in LBMBPS1 (A), LBMBPS2 (B), LBMBPS3 (C), and LBMBPS4 (D) glasses.

2. Experimental

Sm_2O_3 doped glass samples (LBMBPS) with the molar composition of $(50-x)$PbO–$x Bi_2O_3$–25$MgHPO_4$–24B_2O_3–1Sm_2O_3 (where $x=10$, 20, 30 and 40 mol%) were prepared by melt quenching technique [16]. These glasses are labeled as LBMBPS1, LBMBPS2, LBMBPS3 and LBMBPS4 for $x=10$, 20, 30 and 40 mol% respectively. Reagents of analytical grade were used and Sm_2O_3 added to the host glass was 99.99% pure. The chemicals of the required compositions of approximately 10 g were weighed in an electronic balance and grounded in an agate mortar to get a fine powder. The samples were transferred to an electric furnace at 400 °C initially for half an hour. The samples were subjected to a temperature of 1050 °C for an hour to yield good melting. The melt was then quickly quenched at room temperature in air by pouring it onto a preheated (300 °C) heavy brass plate. These glass samples were annealed around 400 °C to remove internal stress, which was verified by examining with a polarizing microscope (Rudalph Instruments). Samples were polished with fine powder of cerium oxide. These developed glass systems were subjected to X-ray diffraction studies for amorphous nature. The refractive index "*n*' of the samples was determined using conventional methods [17]. Absorption spectra were recorded for all the samples by taking the undoped glasses as references at room temperature on JASCO UV–vis–NIR V-670 spectrometer. The Infrared absorption spectra of these samples were recorded using KBr pellet method on JASCO FT/IR-5300 in the wavelength range 400–4000 cm^{-1} at room temperature. The luminescence spectra of the glass samples excited at a wavelength of 402 nm were recorded using Perkin Elmer Luminescence Spectrophotometer model LS50B in the spectral range 400–750 nm.

3. Results and discussion

The recorded XRD profile of Sm^{3+} doped lead bismuth borophosphate (LBMBP) glass shown in Fig. 1 has confirmed its amorphous nature by the absence of peaks in the spectra.

3.1. Physical properties

The physical and optical parameters such as refractive index (n), density (d), molar refractive index (R_m), molar

Table 1
Physical properties of Sm^{3+} ions in LBMBPS1, LBMBPS2, LBMBPS3 and LBMBPS4 glasses.

Physical property	LBMBPS1	LBMBPS2	LBMBPS3	LBMBPS4
Average molecular weight	197.7	222.0	246.3	270.6
Density (g/cm^3)	4.354	4.565	4.715	4.806
Refractive index 'n'	1.973	1.979	1.982	1.993
Concentration N (10^{22} ions/cm^3)	1.33	1.24	1.15	1.07
Polaron radius (r_p) (Å)	3.65	3.73	3.82	3.92
Inter ionic distance(r_i) (Å)	4.22	4.32	4.43	4.54
Field strength F (10^{16} cm^{-2})	0.225	0.215	0.205	0.195
Molar refractivity R_M (cm^{-3})	22.29	23.98	25.8	28.02
Electronic polarizability α (10^{-24} cm^{-3})	8.83	9.5	10.2	11.1
Molar volume V_m	45.4	48.6	52.2	56.3
Optical dielectric constant ()	2.89	2.92	2.93	2.97
Bonding parameter δ	−0.011	−0.012	−0.011	−0.010