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Luminescence properties of Sm^{3+} ions doped aluminium barium phosphate glasses

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Abstract

In this paper, the physical, optical and photoluminescence properties of alkali metals on Sm^{3+} ions doped aluminium barium phosphate (R_2O-Al_2O_3-BaO-P_2O_5, where R = Li, N, K) at 1 mol% Sm_2O_3 have been investigated. These glasses were prepared by melt quenching technique at 1200 ℃. The density and molar volume of Sm^{3+} ions were calculated. The absorption spectra consist of nine peaks corresponded the transitions from the $^6H_{5/2}$ ground state to various excited energy levels. Photoluminescence spectra shows four prominent emission bands corresponding to the $^4G_{5/2} \rightarrow {}^6H_J$ (J = 5/2, 7/2, 9/2 and 11/2) transitions and the intensities of all band are enhanced by Sm^{3+} ion content.

Keywords: phosphate glass, samarium, physical properties, optical properties, luminescence properties

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1. Introduction

At present, many researchers focus on race earth (RE) ions doped optical material for solid state lighting (SSL) applications such as light emitting diodes (LEDs), traffic signals, fill-color displays, optical storage devices, display monitors, sensors and cellular phone illumination etc. [1, 2]. The investigations on absorption properties of the trivalent samarium (Sm^{3+}) ions have indicated that the optical , properties of these rare earth ions can be affected by varying the glass composition, thus opening up the possibility of engineering application-friendly composition [3]. With the increasing demand of various visible lasers and light sources, further investigations in other RE ions such as Sm^{3+} ions, are becoming more significant. Oxide glass are attracting host for obtaining efficient luminescence in RE ions [3].

Among various glass materials, interestingly phosphate glasses are opted due to its unique characteristics that include high transparency, low melting point, high thermal stability, high gain density, high solubility of RE ion and low dispersion. Because of this behavior, phosphate glass have been well chosen for fast ion conducting material and other significant application such as laser hosts, waveguides and the molding of optical elements [4]. These phosphate glasses enhance their chemical durability and physic-chemical properties like electrical conductivity and thermal expansion with the backing of certain metal oxides, aluminium oxide (Al_2O_3) and potassium oxide (K_2O) etc., as glass network modifiers. Al_2O_3 is a worthy host matrix component due to its high solubility and structural similarity towards RE ions. The neighboring oxygen's of the aluminium (Al^{3+}) ions, counter balances the change of RE ions as a consequence, the RE ions are homogeneously dispersed in the glass structure [5]. K_2O improves stability and optical quality of the glasses even under high temperature treatment (with optical losses lower than 0.02 cm^{-1}) [6]. Alkali elements (e.g. K^+, Na^+, L^+, ...) are becoming increasingly essential for improving glasses materials with a greater focus on end-user application requirements, reduction of development costs and a decrease in the time to market [7-8].

This paper intends to study effect of Sm^{3+} ions on physical, optical and luminescence properties of aluminium barium phosphate glasses. In the present paper we discuss density, molar volume, optical absorption spectra and luminescence spectra of glasses prepared by melt quenching technique.

2. Experimental details

2.1 Preparation technique

The chemical compositions of alkali metals aluminium barium phosphate glasses doped with Sm_2O_3 in the present work are as follows:

LABSm: $10Li_2O + 5Al_2O_3 + 20BaO + 65P_2O_5 + 1Sm_2O_3$

NABSm: $10Na_2O + 5Al_2O_3 + 20BaO + 65P_2O_5 + 1Sm_2O_3$

KABSm: $10K_2O + 5Al_2O_3 + 20BaO + 65P_2O_5 + 1Sm_2O_3$.

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Calculated quantities of chemicals were taken in on a gate mortar and then pondered well to obtain a homogeneous mixture. The mixture was melted at 1200 °C for 3 hours. The glass melt become homogenous and then cast on a brass plate quickly and subsequently annealed in a muffle furnace at 500 °C for 3 hours and cooled to room temperature. The obtained glass samples were in circular in shape and have dimensions of $1.5 \times 1 \times 0.3$ cm^3.

2.2 Optical absorption

The bulk sample were used to measure the absorption spectra in ultraviolet (UV), visible (Vis) and near infrared (NIR) region at room temperature. The measurement was recorded using UV-Vis spectrophotometer and UV-Vis-NIR spectrophotometer in the wavelength rang 200–600 nm and 800–1700 nm, respectively.

2.3 Photoluminescence

Cary eclipse fluorescence spectrophotometer was used to measure photoluminescence spectrum. This method is to investigate the excitation and emission spectra of the samples.

2.4 Density and molar volume

Densities of samples were calculated by using Archimedes method Equation (1). In order to obtain accurate result, all measurement was repeated three times at room temperature.

$$\rho = \frac{w_a}{w_a - w_w} \times \rho_w \qquad (g/cm^3) \qquad (1)$$

where w_a is weights of the glass simple in air, w_w is weights of the glass simple in water and ρ_w is density of water. The molar volumes of the developed glass samples were measured by the density values according to talk following relation

$$V_m = \frac{M_T}{\rho} \qquad (cm^3/mol) \qquad (2)$$

where V_m is the molar volume, M_T is the total molecular weight and ρ is the calculated density of the glass.

3. Results and discussion

3.1 Density and molar volume

Density is the simplest, important and informative physical quantity of a glass which demonstrates modification in the geometrical configurations of the glass network, change in coordination, degree of the structural compactness, and variation of the dimensions of the interstitial holes. The density of 1.0 mol% of Sm^{3+}: LABSm, NABSm and KABSm glasses were found to be 3.0034 ± 0.0017, 2.9189 ± 0.0019 and 2.8994 ± 0.0065 g/cm^3, respectively. It is evident from Table 1 that the density of the as made glasses not depend on atomic weight of the alkali oxide cation (Li^{1+} < Na^{1+} < K^{1+})

The LABSm glass sample has the highest density among the investigated samples. The molar volume increase with the increase in ionic radii of alkali metals oxide cations following the order Li^{1+} < Na^{1+} < K^{1+}. The molar volume of KABSm has higher value than NABSm and LABSm, respectively.

3.2 Absorption spectra

The optical absorption spectra of the prepared glasses in the UV-Vis-NIR region are shown in Figure 1 (a) and 1 (b), respectively. There are seven peaks of LABSm and six peaks of NABSm and KABSm glass in the visible region. There are six peaks of glass sample in the NIR region. The absorption bands of all glass samples are presented in Figure 1 [9,10].

For all the prepared glasses, we obtain almost the same wavelengths for all the absorption transitions. However, their spectral intensities differ for different alkali metals oxides, such as Li_2O, Na_2O and K_2O combinations of these.

3.3 Luminescence spectra

Figure 2 (a) represent the excitation spectra of the Sm^{3+} doped LABSm, NABSm and KABSm glasses, by monitoring the photoluminescence emission at a wavelength of 598 nm. From the excitation spectra of glass samples exhibited seven peaks, which correspond to the energy transition from the ground state to the excited state. From all the transition above, the transition $^6H_{5/2} \rightarrow {}^6P_{3/2}$ at 401 nm is most prominent. Therefore, we recorded the emission spectra of all the prepared glasses that were excited at a wavelength of 401 nm.

Figure 2 (b) shows the emission spectra of the Sm^{3+} doped LABSm, NABSm and KABSm glasses under an excitation wavelength of 401 nm. The wavelength corresponds to the transitions from excited state to the ground state. Among these, $^4G_{5/2} \rightarrow {}^6H_{7/2}$ showed highest intensity peak located at wavelength of 598 nm.

4. Conclusions

In this work, the physical and luminescence properties of Sm_2O_3 doped alkali metals (Li, Na and K) aluminium barium phosphate glasses were systematically investigation under condition of the same doped and fixed Sm_2O_3 concentration.

Table 1 Physical properties of RABSm (R = Li, Na, K) glasses

Physical properties	RABSm (R = Li, Na, K) glasses		
	LABSm	NABSm	KABSm
Density (g/cm^3)	3.0034 ± 0.0017	2.9189 ± 0.0019	2.8994 ± 0.0065
Molar volume (cm^3/mol)	44.3113	46.6937	48.1180

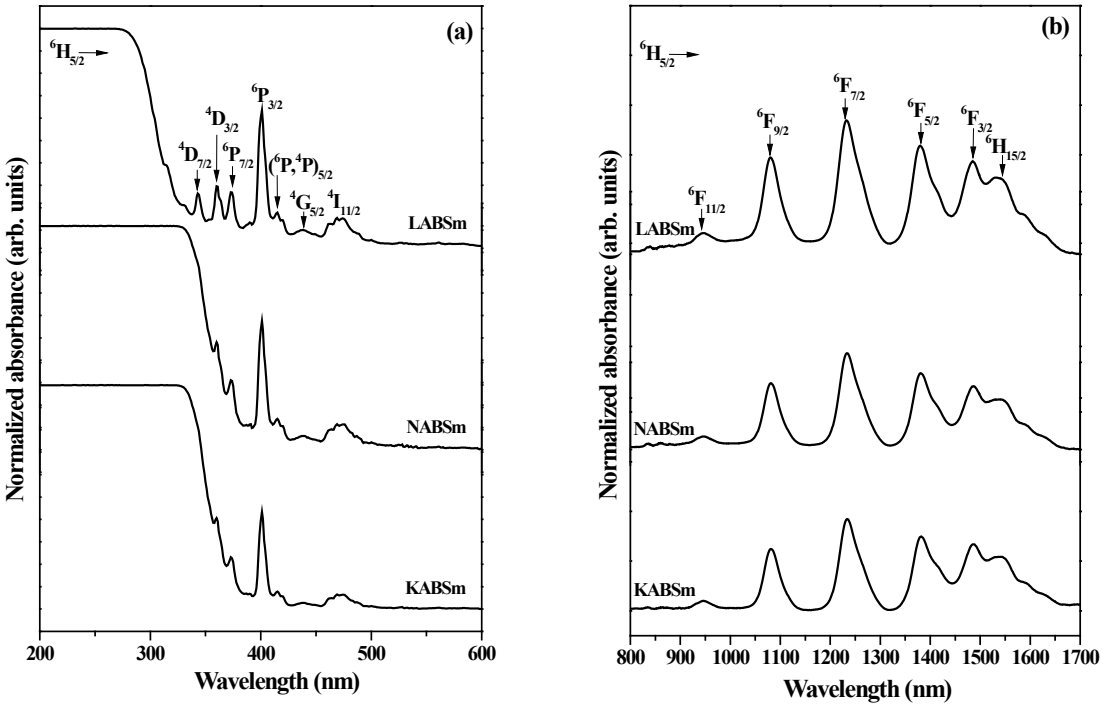

Figure 1 Absorption spectra of RABSm (R = Li, Na, K) glass in (a) UV-Visible and (b) NIR regions

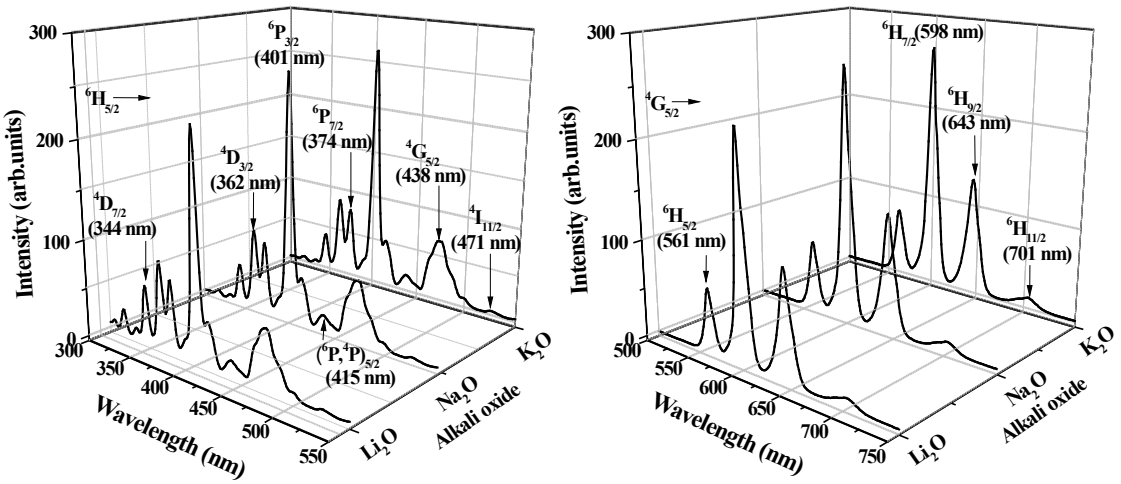

Figure 2 Luminescence spectra of RABSm (R = Li, Na, K) glass (a) excitation and (b) emission

The atomic number, ionic radius and field strength have important effect on the physical and luminescence properties of Sm_2O_3 doped alkali metals aluminium barium phosphate glasses. The density of LABSm has higher value than NABSm and KABSm respectively. The molar volume of KABSm has higher value than NABSm and LABSm respectively. The photoluminescence properties of Sm_2O_3 doped alkali metals aluminium barium phosphate glasses have been studied. The excitation spectra were recorded by monitoring an intense at 598 nm and seven obvious excitation peaks are observed and are assigned to $^6H_{5/2}\rightarrow{}^4D_{7/2}$ (344 nm), $^6H_{5/2}\rightarrow{}^4D_{3/2}$ (362 nm), $^6H_{5/2}\rightarrow{}^6P_{7/2}$ (374 nm), $^6H_{5/2}\rightarrow{}^6P_{3/2}$ (401 nm), $^6H_{5/2}\rightarrow({}^6P,{}^4P)_{5/2}$ (415 nm), $^6H_{5/2}\rightarrow{}^4G_{5/2}$ (438 nm) and $^6H_{5/2}\rightarrow{}^4I_{11/2}$ (471 nm). The emission spectra have exhibited four emission transitions, which are assigned to $^4G_{5/2}\rightarrow{}^6H_{5/2}$ (561 nm), $^4G_{5/2}\rightarrow{}^6H_{7/2}$ (598 nm), $^4G_{5/2}\rightarrow{}^6H_{9/2}$ (643 nm) and $^4G_{5/2}\rightarrow{}^6H_{11/2}$ (701 nm) transition, under 401 nm excitation wavelength. The luminescence of KABSm has highest emission spectra.

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