INVESTIGATIONS ON SPECTROSCOPIC PORPERTIES OF Dy^{3+} ION IN ZINC BARIUM BORATE GLASSES

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Received 27 December 2016; Revised 27 March 2017; Accepted 10 April 2017

ABSTRACT

Zinc barium borate glass samples doped with Dy^{3+} ion in chemical formular of $(60\text{-}x)B_2O_3$ - $10ZnO\text{-}30BaO\text{-}xDy_2O_3$ with $0.3 \leq x \leq 2.5$ (in mol% of Dy_2O_3) have been synthesized by normal melt quenching technique at 1,100°C for 3 hours. In order to understand the role of Dy_2O_3 in zinc barium borate glasses systems, the physical, optical and luminescence properties were investigated. The results shown that the density and the molar volume increased with increasing Dy_2O_3 concentrations. The optical absorption spectra of glasses were measured in the UV-VIS and NIR range of 450–2,500 nm. The intensity of all absorption bands increased with increasing Dy_2O_3 contents. In addition, the luminescence properties of Dy^{3+} doped ZnO - BaO - B_2O_3 glass system were carried out using excitation wavelengths of 388 nm for Dy_2O_3 doped glasses. The luminescence peaks around 575 nm were observed.

KEYWORDS: *BiBaBO; Spectroscopic properties; Dy^{3+}; Borate glass*

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INTRODUCTION

Recently, the researcher inrerested to select material for using in science and industry. Glass is one of all material which has a important because of their properties. The chemical, physical and optical properties of glasses lead to applications such as optical device, instrument for science, laser medium material, etc. At present, developing processes of optical devices based on materials doped with rare earth ions is one of the interesting field of research. Rare earth doped glasses are generally found in laser materials, optical amplifiers, optical memory devices, magneto-optical devices, medical lasers, eye safe lasers, flat panel displays, fluorescent lamps, white LED's etc. [1] Borate glasses have interesting for physical properties such as their high transparency, low melting temperature point and good chemical solubility. They are considered as suitable hosts for optical materials [2] Zinc oxide (ZnO) is one of an important components added into the matrices of oxide glasses. The zinc barium borate (ZBaB) glasses are preferred because they have low melting temperature point, great refractive index and high chemical properties. [3] Barium-contained glasses are very interested due to their various applications such as making barrier of plasma display ribs, gamma ray shielding material, and crown optical glasses. [4] Hence Dy^{3+} ion come on the scene by incorporated into several glasses in order to obtain two principal emissions regarding to yellow and blue luminescence materials. Combining these emissions, the white light can be generated. [1] The trivalent dysprosium ion (Dy^{3+}) is one of the best candidates to use in modern white lighting due to their intensive emission in blue (480 nm) and yellow (570 nm) regions, which correspond to $^4F_{9/2} \rightarrow {}^6H_{15/2}$ and $^4F_{9/2} \rightarrow {}^6H_{13/2}$ respectively. [5]

In this research paper, the physical, optical and photoluminescence properties of Dy^{3+} ion doped zinc barium borate glasses have been studied for the different concentration of Dy_2O_3 in the glasses.

MATERIALS AND METHODS

The glass samples of Zinc barium borate were doped by Dy^{3+} at concentration (x = 0.3, 0.5, 1.0,1.5,2.0, and 2.5 mol%) in composition of (60-x)B_2O_3-10ZnO-30BaO-xDy_2O_3 which prepared by using melt quenching technique. Appropriate amount of chemicals were weighed and mixed together in a mortar-pestle powders of 15 g for each batch formular of all the glass samples were melted at 1,100 °C in alumina crucibles for 3 hours in an electrical furnace. The melts were air quenched by pouring onto a preheated casting graphite plate and annealed at 500 °C for 3 hours to remove the thermal stresses. The glass samples were cut and polished into 1.0 × 1.5 × 0.3 cm^3 shape for optical measurements. The densities (ρ) were measured by Archimedes method. The optical absorption spectra of the glasses were recorded in the UV-VIS- NIR regions in the range of 450-2,500 nm using a UV-3600 Shimadzu UV–VIS–NIR spectrophotometer. The photoluminescence spectra were determined by using Cary Eclips fluorescence spectrophotometer.

RESULTS AND DISCUSSION

Density and molar volume

The densities and molar volumes of the investigated Zinc Barium Borate (ZBaB) glasses, the density and the molar volume increased with increasing Dy_2O_3 concentrations. The values of density are in the range of 3.16–3.32 g/cm^3 are shown in Fig. 1 while their molar volumes (V_M) are in the range of 30.33–30.93 cm^3/mol. are shown in Fig. 2. The increase in density of the glass with the increasing Dy^{3+} doping content is due to a higher molecular weight of Dy_2O_3 as compared to other components in the glasses. While the increasing in the molar volume, indicates the increasing of inter-atomic spacing in the glass network. Dy_2O_3 acts as a network modifier and produces more bridging oxygen (BOs) in glass matrices.

Absorption spectra

The optical absorption spectra of the glass samples in the range 450–2,500 nm at room temperature were observed the intensity of absorption peaks increases with increasing in Dy_2O_3 concentration. The spectra consists of five absorption bands, These transitions are assigned from ground state $^6H_{15/2}$ to various excited state of Dy^{3+} ion. From this spectrum, the absorption bands of Dy^{3+} are located at the wavelength 848, 942, 1129, 1306, and 1711 nm. In all the absorption transition originated from $^6H_{15/2}$ to the various excited state $^6F_{5/2}$, $^6F_{7/2}$, $^6F_{9/2}$, $^6F_{11/2}$, and $^6H_{11/2}$ shown in Fig. 3.

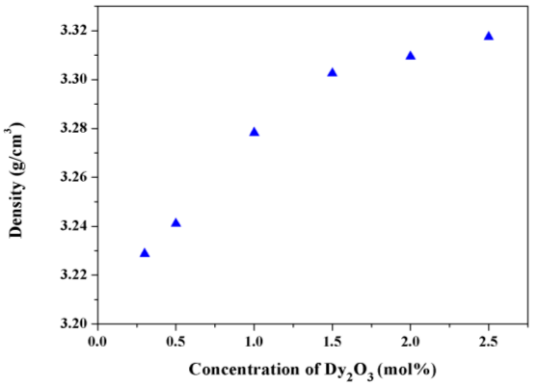

Fig. 1 Density of ZBaB glasses doped with Dy^{3+} ion.

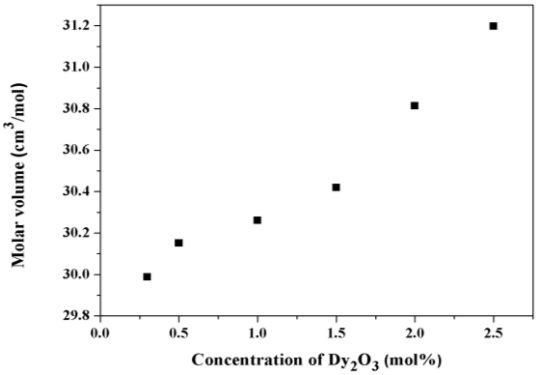

Fig. 2 Molar volume of ZBaB glasses doped Dy^{3+} ion.

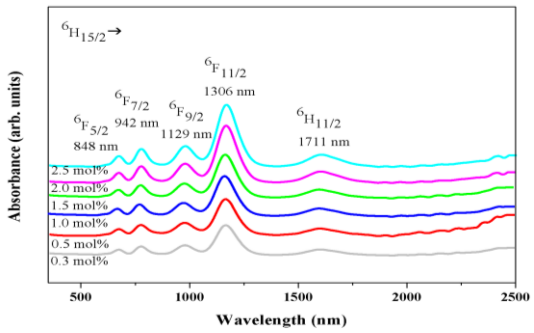

Fig. 3 The absorption spectra of ZBaB glasses doped with Dy^{3+} ion.

Excitation and Emission spectra

The excitation spectrum of ZBaB glasses doped Dy^{3+} at 0.3 to 2.5 mol% obtained by monitoring the emission with 675 nm. The spectrum contains seven bands at 324, 350, 365, 388, 425, 452 and 472 nm corresponding to the transitions from the ground state ($^6H_{15/2}$) to $^4K_{15/2}$, $^4M_{15/2}$+$^6P_{7/2}$, $^4I_{11/2}$, $^4I_{13/2}$+$^4F_{7/2}$, $^4G_{11/2}$, $^4I_{15/2}$ and

$^4F_{9/2}$ excited states, respectively., Fig. 4 The $^4I_{13/2}$+$^4F_{7/2}$, transition is the more intense compared to other transitions. Hence, the emission measurements were performed by exciting the samples at 388 nm wavelength using a xenon flash lamp. Fig. 5 shows the room temperature emission spectra of Dy^{3+}: ZBaB glasses. All the spectra exhibited with four emission bands corresponding to the $^7F_{9/4}$→ $^6H_{15/2}$ (482 nm), $^7F_{9/4}$→ $^6H_{13/2}$ (575 nm), $^7F_{9/4}$→ $^6H_{11/2}$ (663 nm), and $^7F_{9/4}$→ $^6H_{9/2}$ (752 nm) transitions. The luminescence intensity of luminescence materials is known to be dependent on the doping concentration of luminescent ions. It is also found that the intensity of relatives intensity of $^7F_{9/4}$→ $^6H_{13/2}$ transition of Dy^{3+} various as a function of Dy^{3+} concentration (x = 0.3, 0.5, 1.0, 1.5, 2.0, and 2.5 mol%). The maximum luminescence intensity was observed at x = 0.5 mol% of Dy_2O_3. The decrease in emission intensities with the increase of 1.0, 1.5, 2.0, and 2.5 mol% of Dy_2O_3 concentration is due to the rise in non-radiative decay channels, which are enhanced due to the concentration quenching effect. If the concentration of an activator is higher than an proper value (typically several mol%), the emission intensity will be decreased. This is called concentration quenching. [6] Fig.7 shows the energy level diagram with corresponding to the transitions state in this glass.

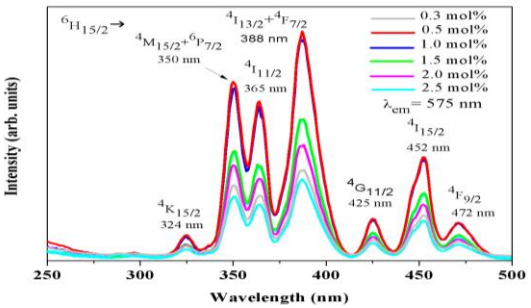

Fig. 4 The excitation spectra of ZBaB glasses doped with Dy^{3+} ion.

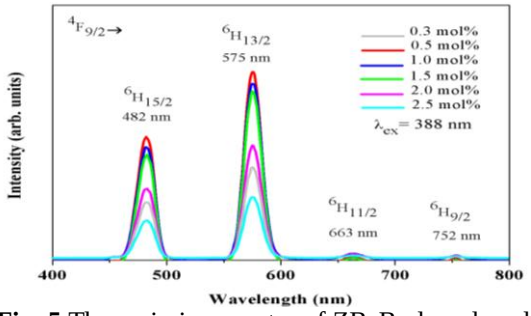

Fig. 5 The emission spectra of ZBaB glass doped with Dy3+ ion.

X-ray induced luminescence

The X-ray induced emission spectra Dy^{3+}: ZBaB glass system were irradiated with X-ray at 50 kV and 20 mA. Although the excitation source was different, the spectral results were nearly identical to those from the photoluminescence. From Fig. 8 found the highest at 482 nm (blue), 577 nm (yellow) all of the intensity peaks increases with increasing Dy_2O_3 concentrations.

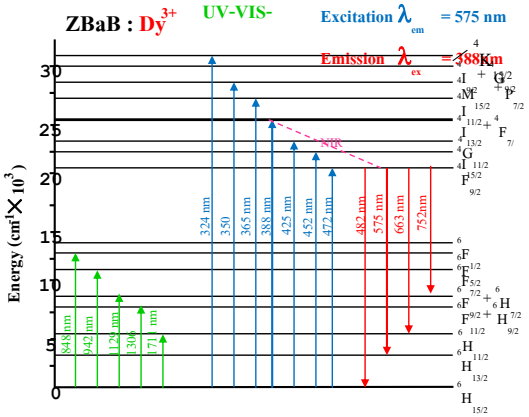

Fig. 6 The energy level diagram for zinc barium borate glass doped with Dy_2O_3.

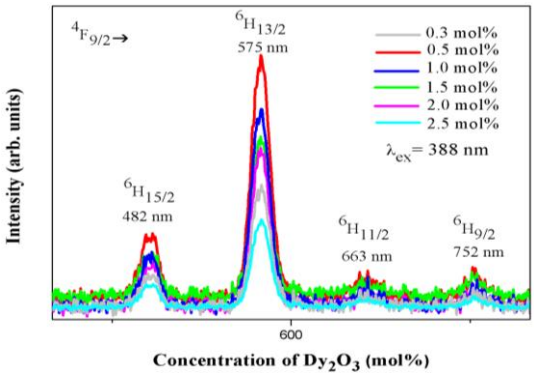

Fig. 7 The X-rays induced optical luminescence spectra of the ZBaB glasses doped with Dy^{3+} ion.

CONCLUSION

Zinc barium borate (ZBaB) glass doped with Dy_2O_3 have been synthesized by conventional melt quenching technique. The results showed that the density and the molar volume increased with increasing Dy_2O_3 concentrations. The absorption bands of Dy^{3+} are located at the wavelength 848, 942, 1129, 1306, 898 and 1711 nm. All of intensity bands peak increased with increasing of Dy_2O_3 concentrations. The emission spectra from excitation wavelengths at 388 nm by using xenon

flash lamp and X-rays source given the highest peak at 575 nm ($^4F_{9/2} \rightarrow {}_6H_{13/2}$) and the intensity peaks increases with increasing Dy_2O_3 concentrations.

ACKNOWLEDGEMENTS

The authors would like to thank national Research Council of Thailand (NRCT) and Nakhon Pathom Rajabhat University for support of this research.

REFERENCES

[1] V.B. Sreedhar, D. Ramachari, C.K. Jayasankar, Optical properties of zinc fluorophosphates glasses doped with Dy^{3+} ions, J. Phys. B. 408 (2013) 158–163.

[2] F. Zaman, J. Kaewkhao, N. Srisittipokakun, N. Wantana, H.J. Kim, G. Rooh, Investigation of luminescence and laser transition of Dy^{3+} in Li_2O-Gd_2O_3-Bi_2O_3-B_2O_3 glasses, J. Opt. Mater. 55 (2016) 136–144.

[3] J. Kaewkhao, K. Boonin, P. Yasaka, H.J. Kim, Optical and luminescence characteristics of Eu^{3+} doped zinc bismuth borate (ZBB) glasses for red emitting device, J. Mater. Sci. 71 (2015) 37–41.

[4] F. Zaman, G. Rooha, N. Srisittipokakunb, H.J. Kimd, E. Kaewnuamc, P. Meejitpaisanb, J. Kaewkhao, Scintillation and luminescence characteristics of Ce^{3+} doped in Li_2O-Gd_2O_3-BaO-B_2O_3 scintillating glasses, J. Radiat. Phys. Chem. 130 (2017) 158–163.

[5] S. Insitipong, J. Kaewkhao, T. Ratana, P. Limsuwan, Optical and Structural Investigation of Bismuth Borate Glasses Doped With Dy^{3+}, J. Procedia Eng. 8 (2011) 195–199.

[6] G. Ju, Y. Hu L. Chen, X. Wang, Z. Mu, Concentration quenching of persistent luminescence, J. Phys. B. 415 (2013) 1–4.