Study on Optical Properties of Lithium Barium Bismuth Phosphate Glasses Doped with Sm^{3+} ions

Natthakridta Chanthima[1,2], Johnny Tongdang[3], Suwimon Reungsri[3] and Jakrapong Kaewkhao[1,2]

[1]Center of Excellence in Glass Technology and Material Science (CEGM),
Nakhon Pathom Rajabhat University
[2]Science Program, Faculty of Science and Technology, Nakhon Pathom Rajabhat University
[3]Chemistry Program, Faculty of Science and Technology, Nakhon Pathom Rajabhat University
natthakridta@webmail.npru.ac.th and johnnytongdang@gmail.com

Abstract

Lithium barium bismuth phosphate (LBBP) glasses doped with samarium oxide were prepared by melt quenching technique at 1000 ^{0}C. The absorption spectra of LBBPSm glasses were recorded in the UV-Vis-NIR region at room temperature. All the absorption transitions originated from $^6H_{5/2}$ ground state to the various excited state including $^4D_{3/2}$, $^4L_{17/2}$, $^4L_{15/2}$, $^6P_{3/2}$, $^4M_{19/2}$, $^6P_{5/2}$, $^4G_{9/2}$, $^4F_{5/2}$, $^4I_{13/2}$, $^4I_{11/2}$, $^4M_{15/2}$, $^4I_{9/2}$, $^4G_{7/2}$, $^4F_{3/2}$, $^4G_{5/2}$, $^6F_{11/2}$, $^6F_{9/2}$, $^6F_{7/2}$, $^6F_{5/2}$, $^6F_{3/2}$, $^6H_{15/2}$, and $^6F_{1/2}$ excited states, respectively. Also, it was found that the shape of the absorption peaks were similar in all glasses. Only minimal variations of peak intensity were observed.

Keywords: samarium, glass, optical properties

1. Introduction

Currently, amorphous materials have been extensively researched in various optical applications such as color displays, sensors, optical fiber, lasers, and solar energy converters. Oxide based glasses such as silicates, phosphates, borates, germinates, vanadate and tellurite are the promising hosts for photonic applications. Glasses doped with rare-earth (RE) ions are receiving special attention because they emit intense radiation in visible, NIR and IR regions under appropriate excitation conditions which make them have very stable emission (Basavapoornima et al., 2014: 233-241). Addition of rare-earth elements like dysprosium, samarium, europium, erbium etc., to oxide based glasses has been found to occur the luminescence phenomenon. In physic, absorption is the process by which a lower energy quantum mechanical state of a particle becomes converted a higher one through the absorption of a photon.

The efficiency of the luminescence of the rare-earth ions depends strongly on phonon energy of the host material and active ion concentration. Therefore, the choice of appropriate host matrix crucial for efficient luminescence. Among different glass hosts, oxide based phosphate glasses have unique physical and optical properties due to their good structural properties such as relatively low phonon energy when compared to other glasses, low refractive index, high thermal expansion coefficient, low melting temperature, low glass transition temperature, low viscosity and high ultraviolet transmission. These properties have made them ideal materials for fundamental studies of the glass transition and devitrification effects (Lingana et al., 2013: 118). However, their relative poor chemical durability precludes their practical utilization. Therefore, it has been noticed that the addition of metal oxides (MO) like BaO or Bi_2O_3 resulting in the formation of M-O(P) bonds, leads to improve the chemical durability and thermal stability of the phosphate glasses and enhance the radiative transition rates of RE^{3+} ions (Preet Kaur et al., 2016: 87-92). These favorable features make phosphate glasses useful in optical devices.

Among lanthanides, the Sm^{3+} ($4f^5$) ion is the one of the interesting ions because of its potential applications in various optical devices such as high density optical storage, under sea-communication, colors displays and visible solid-state lasers as a result of its bright emission in orange/red regions (Nayab Rasool et al., 2013: 82-90).

In this work, lithium barium bismuth phosphate glasses doped with Sm^{3+} have been fabricated. The optical properties of the glass samples were studied to determine the potential of the glasses using as solid-state lighting applications.

2. Experiment

2.1 preparation

Phosphate glasses with chemical composition of $5Li_2O$: xBaO : (35-x)Bi_2O_3 : $59P_2O_5$: $1Sm_2O_3$ where x = 5, 10, 15, 20, 25 and 30 mol% containing fixed concentration of RE^{3+} ions were prepared by conventional melt quenching technique using lab grad $(NH4)_2HPO_4$, Li_2CO_3, Ba_2CO_3, Bi_2O_3, Dy_2O_3 and Sm_2O_3 as starting materials. The glass compositions are shown in Table 1. About 20 g of the batch composition was thoroughly ground in an agate mortar and this homogeneous mixture was taken into an porcelain crucible and heated in an electric furnace at 1000 °C for 2 h. The melt was air quenched by pouring it onto a preheated stainless steel mold and annealed at 500 °C for 3 h to remove thermal strains and then slowly allowed to cool to room temperature (RT). After that, the glass samples were cut and polished into 1.0×1.5×0.3 cm^3 shape to get good transparency and flat surfaces for optical measurements.

Table 1 Glass compositions and corresponding label of glass system.

Glass composition	Label
$5Li_2O$: 5BaO : $30Bi_2O_3$: $59P_2O_5$: $1Sm_2O_3$	LBBPSm05
$5Li_2O$: 10BaO : $25Bi_2O_3$: $59P_2O_5$: $1Sm_2O_3$	LBBPSm10
$5Li_2O$: 15BaO : $20Bi_2O_3$: $59P_2O_5$: $1Sm_2O_3$	LBBPSm15
$5Li_2O$: 20BaO : $15Bi_2O_3$: $59P_2O_5$: $1Sm_2O_3$	LBBPSm20
$5Li_2O$: 25BaO : $10Bi_2O_3$: $59P_2O_5$: $1Sm_2O_3$	LBBPSm25
$5Li_2O$: 30BaO : $5Bi_2O_3$: $59P_2O_5$: $1Sm_2O_3$	LBBPSm30

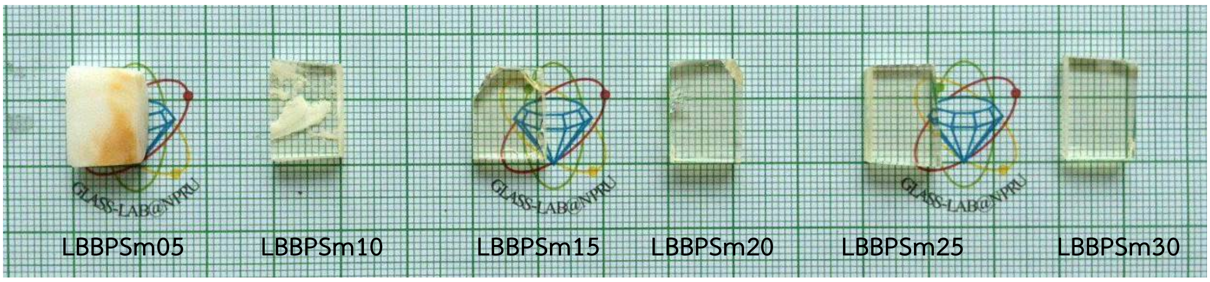

Fig. 1. Glass samples**.**

2.2 Optical properties

The optical absorption spectra were obtained using UV-Vis-NIR spectrophotometer (Shimadzu, UV-3600)

3. Results and discussions

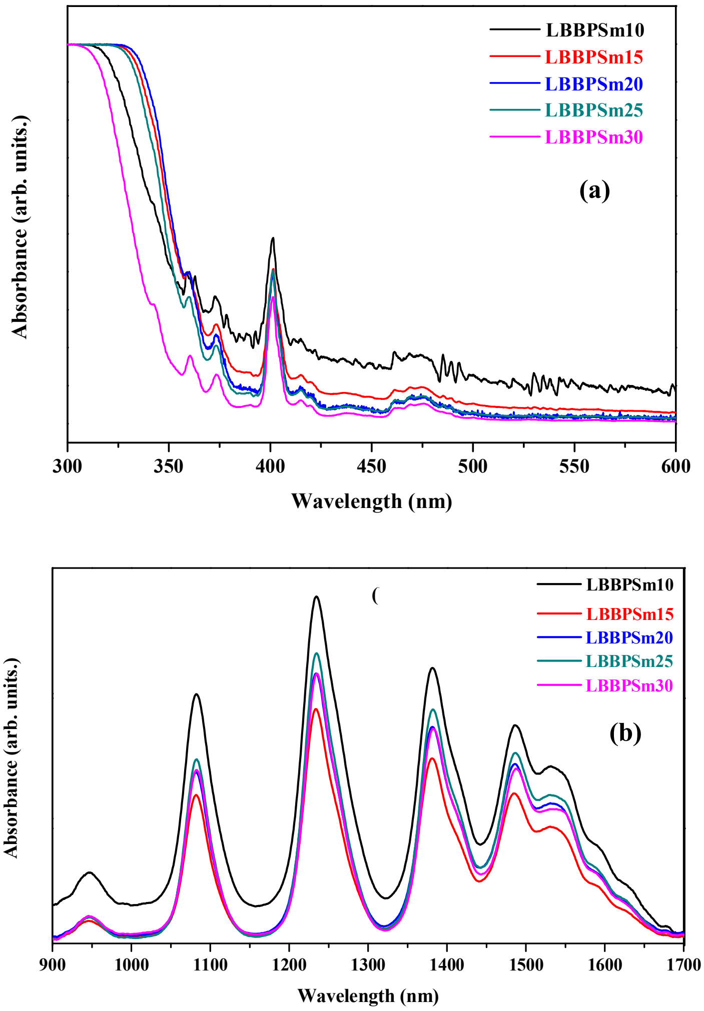

Fig. 2. Absorption spectra of Sm^{3+} ions -doped phosphate glasses (a) in UV-Visible and (b) NIR regions.

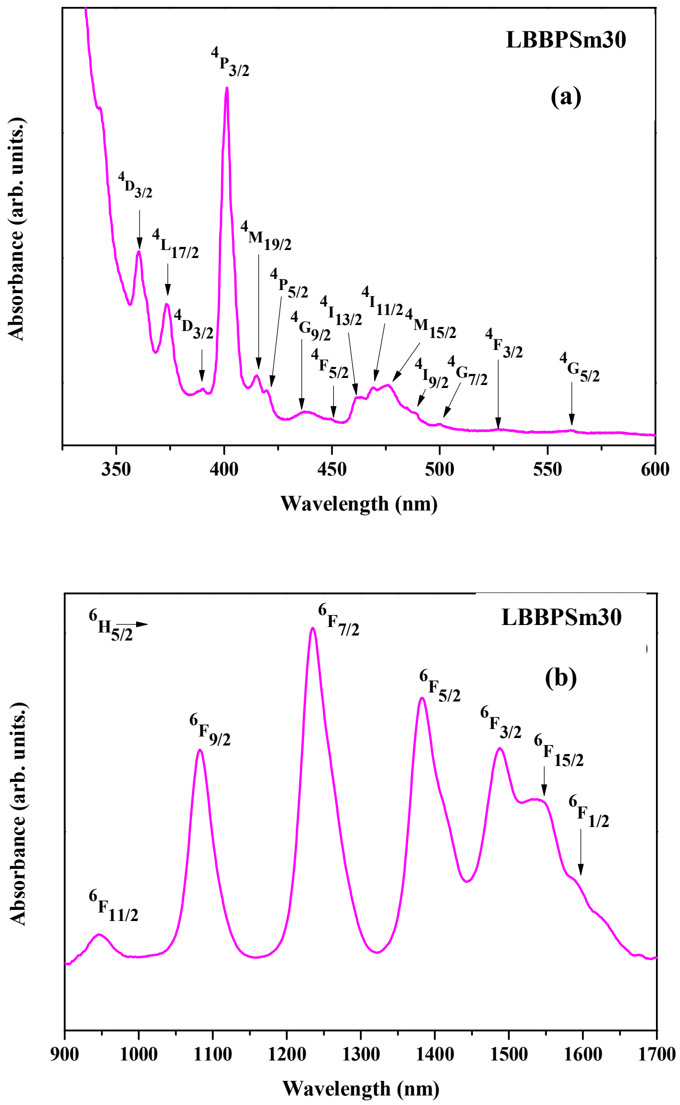

Fig. 3. Absorption spectra of Sm^{3+} ions -doped phosphate glasses (a) in UV-Visible and (b) NIR regions.

Fig. 3. shows the absorption spectra of Sm^{3+} -doped phosphate glasses in the visible and near-infrared region for 300-1700 nm. The assignment of the band is also shown in this figure. For all of the Sm^{3+} doped glasses, 24 peaks have been identified and are assigned. All transitions in the absorption spectra of Sm^{3+} start from the $^{6}H_{5/2}$ ground state to the various excited states which including $^{4}D_{3/2}$, $^{4}L_{17/2}$, $^{4}L_{15/2}$, $^{4}P_{3/2}$, $^{4}M_{19/2}$, $^{4}P_{5/2}$, $^{4}G_{9/2}$, $^{4}F_{5/2}$, $^{4}I_{13/2}$, $^{4}I_{11/2}$, $^{4}M_{15/2}$, $^{4}I_{9/2}$, $^{4}G_{7/2}$, $^{4}F_{3/2}$, $^{4}G_{5/2}$, $^{6}F_{11/2}$, $^{6}F_{9/2}$, $^{6}F_{7/2}$, $^{6}F_{5/2}$, $^{6}F_{3/2}$, $^{6}H_{15/2}$, and $^{6}F_{1/2}$ excited states locate at 360, 373, 390, 401, 415, 420, 438, 449, 461, 469, 476, 487, 500, 527, 560, 946, 1083, 1235, 1383, 1488, 1539 and 1577 nm, respectively.

It is evident that $^{6}H_{5/2}$--->$^{6}P_{3/2}$ (401 nm) and $^{6}H_{5/2}$--->$^{6}F_{7/2}$ (1235 nm) transitions are found to be relatively more intense than other transitions.

4. Conclusions

The Sm^{3+} -doped phosphate glasses have been prepared by conventional melt quenching technique and are characterized by absorption spectra. The Sm^{3+} doped glass samples appear slightly yellow in glass matrix but still sustain transparency. As can be seen Fig 2, peak positions of all samples occur at the same location. The highest peak intensity locates at 401 nm wavelength due to $^6H_{5/2}$--->$^6P_{3/2}$ transition. From such wavelength is used as an excited wavelength in further study of luminescence but it was not discussed in this work. There is no evident relativity between absorption and the increase of BaO concentration. The absorption spectra of glass samples were measured at 200-2500 nm that is the UV-Vis-NIR region. As can be seen that there are 24 transitions from ground state to excited state in which reveal two intense bands due to $^6H_{5/2}$--->$^6P_{3/2}$ (401 nm) and $^6H_{5/2}$--->$^6H_{7/2}$ (474 nm) transitions in UV-Vis region. As such wavelength of two intense bands is in the blue absorption region results in the pale yellow visibility of human eye. As a result, can be seen that all the glasses have the most intense peak at 401 nm owing to $^6H_{5/2}$--->$^6P_{3/2}$ transition which was a popularly used wavelength to excite the particles from a lower level to a higher level and then become converted a lower one by an energy exhalation. Therefore, these prepared glasses have good sensitivity for UV-Visible radiation that makes it as a promising glass for solid lighting applications and other photo-intensive works.

5. Acknowledgement

Researcher would like to thank Center of Excellence in Glass Technology and Material Science (CEGM), Nakhon Pathom Rajabhat University for supporting this research.

6. References

R. Vijaya, V. Venkatramu, P. Babu, C.K. Jayasankar, U.R. Rodriguez Mendoza and V. Lavin. (2013). Spectroscopic properties of Sm^{3+} ions in phosphate and fluorophosphate glasses. Journal of Non-Crystalline Solids, (365), 85-92.

K. Lingana, Ch. Srinivasa Rao and C.K. Jayasankar. (2013). Optical properties and generation of white light in Dy^{3+} -doped lead phosphate glasses. Journal of Quantiative Spectroscopy & Radiation Transfer, (118), 40-48.

Sk. Nayab Rasool, L. Rama Moorthy and Ck. Jayasankar. (2013). Optical and luminescence properties of Dy^{3+} ions in phosphate based glasses. Solid State Science, (22), 82-90.

Ch. Basavapoornima and Ck. Jayasankar. (2014). Spectroscopic and photoluminescence properties of Sm^{3+} ions in Pb-K-Al-Na phosphate glasses for efficient visible lasers. Journal of Luminescence, (153), 233-241.

Preet Kaur, Deuinder Singh and Teibir Singh. (2016). Optical, photoluminescence and physical properties of Sm^{3+} doped lead amino phosphate glasses. Journal of Non-Crystalline Solids, (452), 87-92.

I. Soltani, S. Hraiech, K. Horchani-Naifer, J. Massera, L. Petit and M. Ferid. (2016). Thermal, Structural and optical properties of Er^{3+} doped phosphate glasses containing silver nanoparticles. Journal of Non-Crystalline Solids, (438), 67-73.