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The luminescence characteristics of Eu^{3+}-doped lithium-gadolinium borate glasse

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Abstract

Eu-doped lithium-gadolinium borate glasses with the formula [$60Li_2O$:$10Gd_2O_3$:(30-x) B_2O_3:xEu_2O_3] (LGBO:Eu^{3+}) were fabricated using melt quenching technique. The 5 glass samples with different concentrations of Eu_2O_3 were prepared under atmospheric pressure. The samples were investigated on their properties: density, molar volume, absorption spectra and photoluminescence. The trend of density swings at the first 2 concentrations and then tends to decrease with the increment of the concentrations. The molar volume trend is in the opposite way to that of the density. It is obvious that there are 2 peaks for near infrared wavelengths and other 2 peaks for the visible range which show the Eu^{3+} in the glass structure. The higher concentration of the dopant, the higher peaks of intensity. The excitation spectra show 6 peaks representing the energy transitions from the ground state $^7F_0$ to different excited states. The emission spectra were measured with 395 nm light from Xenon compact arc lamps. The spectra trends to increase with increasing concentration of the dopant.

Keywords: Glass, Eu doped, Luminescence glass

1. Introduction

White light emitting diodes (LEDs) are the optical devices which are extensively used in many applications. There are many techniques used in the production of this type of diodes. The interesting option for this application is rare-earth-doped glasses. Some properties of the glass systems such as absorption and luminescence properties can be applied to this application. There are some evidences that borate glasses are good hosts for rare-earth ions [1].

Several researches studied on Eu^{3+} ion utilized the simplicity of its energy level structure with non-degenerate ground ($^7F_0$) and excited ($^5D_0$) states [2-7]. White light can be produced using the conventional technique by exciting multiple phosphors to generate white combined light. Unfortunately, this method depends on different sources, therefore it is not stable. Some materials can be excited by ultraviolet light and consequently the white light can be emitted directly, therefore this kind of materials can be used in the application. Eu-doped glasses are materials of choice for this application.

The present work studies on the densities, molar volume, absorption, photoluminescence of the Eu-doped lithium-gadolinium borate glasses with the formula [$60Li_2O$:$10Gd_2O_3$:(30-x) B_2O_3:xEu_2O_3] (LGBO:Eu^{3+}).

2. Materials and Methods

The Eu^{3+}: LGBO glasses of chemical composition range of (in mol %) $60Li_2O_3$: $10Gd_2O_3$: (30-x)B_2O_3: xEu_2O_3 (where x = 0.05, 0.1, 0.5, 1.0 and 1.5 mol %) were prepared by conventional melt quenching technique. All glass samples of 15 g batch compositions of homogeneous powders were melted at 1,000 °C in alumina crucibles for about 3 hours in an electrical furnace. They were quenched at room temperature under an air atmosphere on a couple stainless steel and annealed at 300 °C for 3 hours to remove thermal strains [8]. The polished glass samples were cut into 1.0 × 1.5 × 0.3 cm^3 shape for optical measurements. Densities (ρ) of glasses were measured by using the Archimedes method using a digital balance (4-digit sensitive microbalance A&D, HR-200) and then molar volumes were calculated. UV-VIS-NIR spectrophotometer (UV-3600 Shimadzu) was used to measure the absorption spectra ranged from 400 to 2500 nm. Emission and excitation spectra were measured using Cary Eclipse Fluorescence Spectrophotometer with 395 nm excited radiation from a Xenon compact arc lamps.

3. Results and Discussion

Density and molar volume

As shown in Fig. 1, the trend of density swings at the first 2 concentrations because of preparation of chemicals need to calculate mole%, first. After that convert to wt% to get weight of chemical composition. Weight results of Gd_2O_3 will be reduced when Eu_2O_3 content increased that affects the uncertainly of density trends and then trends to decrease with the increasing of Eu_2O_3 concentrations. The molar volume trend is in the opposite way to that of the density. The increases of the molar volume result the increases of the inter-atomic spacing of the glass network. It can be predicted that the Eu_2O_3 acts as network modifier and produces more non-bridging oxygen (NBOs) in glass matrices [9-10].

Absorption spectrum and energy levels

The absorption spectra of the LGBO glasses doped with Eu^{3+} in VIS regions (400-500 nm) and NIR regions (1700-2500 nm) are shown in Fig. 2 and Fig. 3 respectively. The absorption bands of Eu^{3+} represent the transitions from the ground state $^7F_0$ to various excited states. The absorption spectra shown four bands in all regions can be separated as two regions. Fig. 2 shows two bands due to $^7F_0 \rightarrow ^5L_7$ (392 nm) and $^7F_0 \rightarrow ^5L_6$ (464 nm) transitions in the VIS regions. NIR regions shows two intense bands due to $^7F_0 \rightarrow ^7F_6$ (2095 nm) and $^7F_1 \rightarrow ^7F_6$ (2205 nm) transitions in the NIR regions. It is well known that, except for Eu^{3+} ion, all the other trivalent RE $^{3+}$ ions possess single populated ground state.

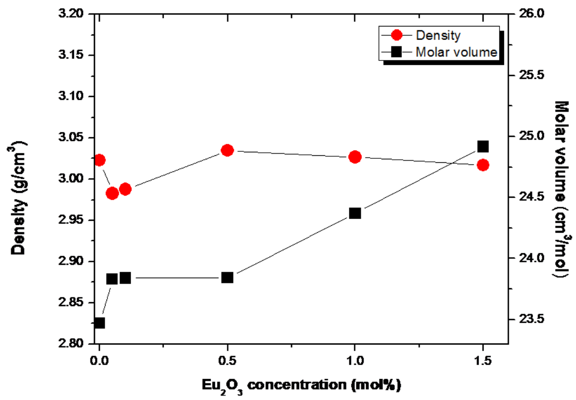

Fig. 1 Densities and molar volumes for different concentration of Eu_2O_3

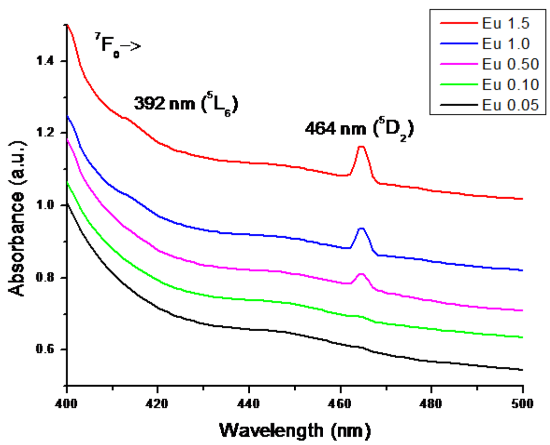

Fig. 2 The absorbance spectra for LGBO: Eu^{3+}glasses in VIS range

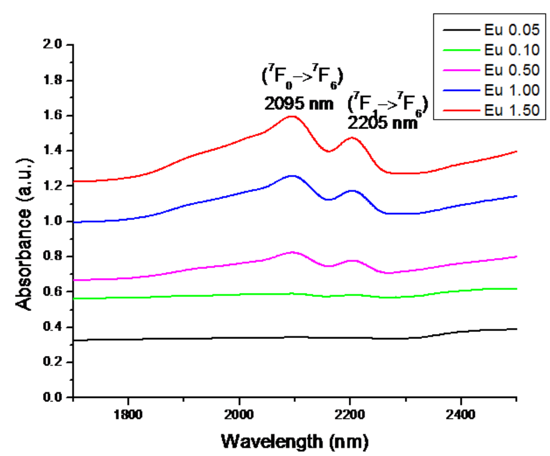

Fig.3 The absorbance spectra for LGBO:Eu^{3+}glasses in NIR range

Excitation and emission spectra

In Fig. 4, six obvious peaks in excitation spectra represent the transition from the ground state $^7F_0$ to the excited states: $^5D_4$ (363nm), $^5L_7$ (383nm), $^5L_6$ (395nm), $^5D_3$ (414nm), $^5D_1$ (465nm) and $^7F_1$ to $^5D_1$ (533nm) of Eu^{3+} but the $^7F_0$ to $^5D_1$ (485nm) was not observed. The excitation spectrum exhibited the transitions originating not only from the ground state ($^7F_0$), but also from the first excited state ($^7F_1$) to $^5D_1$. As shown in Fig. 4, the $^7F_0$ to $^5L_6$ transition is most intense compared to other transitions.

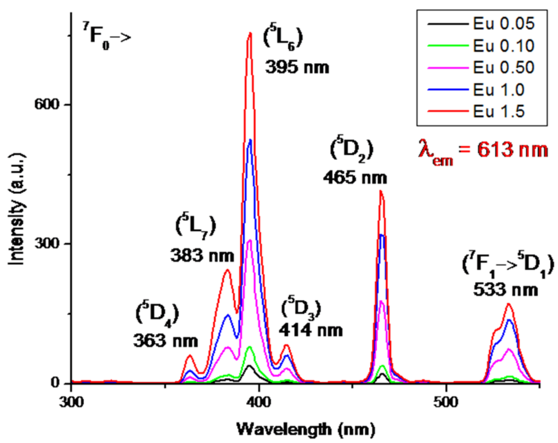

Fig.4 The excitation spectra for LGBO glasses doped with different mol% of Eu^{3+}

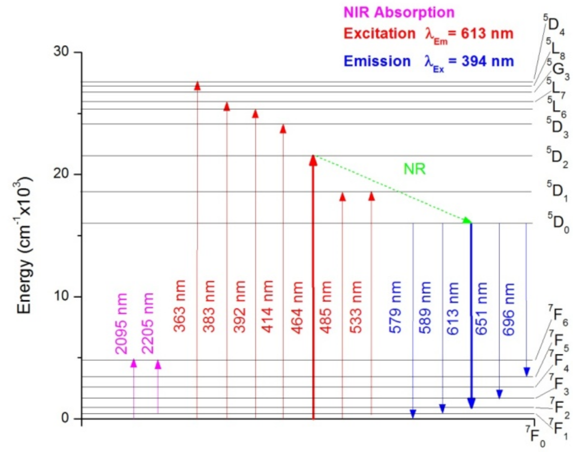

Fig. 5 The Energy level diagram for the transitions of Eu^{3+}-doped glasses

When Eu^{3+} ions are excited to any energy level above $^5D_0$ level, the non-radiative decay will transit down to $^5D_0$ level as shown in the energy level diagram in Fig. 5. The emission spectra were measured with 395 nm light from Xenon compact arc lamps. The Fig. 6 shows emission spectra of Eu^{3+}: LGBO glasses. All the spectra occurred four emission bands corresponding to the $^5D_0 \longrightarrow {}^7F_1$ (591 nm; orange), $^5D_0 \longrightarrow {}^7F_2$ (614 nm; red), $^5D_0 \longrightarrow {}^7F_3$ (652 nm; deep-red) and $^5D_0 \longrightarrow {}^7F_4$ (701 nm; deep-red) transitions [11-12]. All spectra were increased with increasing concentration of the dopant. The $^5D_0$ to $^7F_2$ transition shows the strongest peak compared to other transitions.

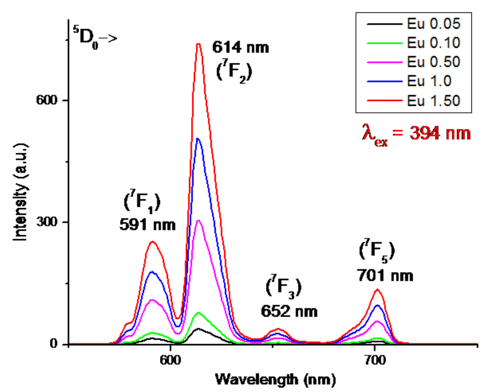

Fig.6 The emission spectra for LGBO glasses doped with different mol% of Eu^{3+}

4. Conclusion

Eu-doped lithium-gadolinium borate glasses were prepared. The samples were investigated on their physical and optical properties. The trend of density swings at the first 2 concentrations and then trends to decrease with increasing of the concentrations. The molar volume trend is in the opposite way to that of the density. It is obvious that there are 2 peaks for near infrared wavelengths and other 2 peaks for the visible range which show the Eu^{3+} in the glass structure. The excitation spectra show 6 peaks representing the energy transitions from the ground state $^7F_0$ to different excited states and first excited state ($^7F_1$) to $^5D_1$. The emission spectra trend to increase with increasing concentration of the dopant.

5. References

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