Journal of Physics: Theories and Applications E-ISSN: 2549-7324 / P-ISSN: 2549-7316
J. Phys.: Theor. Appl. Vol. 5 No. 2 (2021) 51-55 doi: 10.20961/jphystheor-appl.v5i2.53809

Absorption Spectra Comparison of Tm/Ho-Codoped Bototellurite Glasses

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Received 27 July 2021, Revised 21 August 2021, Published 30 September 2021

Abstract: This paper presents a comparison study of absorption spectra of borotellurite glasses with compostion: $20TeO_2 – 15Bi_2O_3 – 3TiO_2 – (4\text{-}x)$ $Na_2CO_3 – 1Tm_2O_3 - xHo_2O_3$ where x = 0; 0.5; 1; 1.5; 2; 2.5 (mol%). All glasses are fabricated using melt quenching method. Absorption spectra were recorded at room temperature in the spectral range of 200 – 1100 nm. Within this range, glass with x = 0 mol % of Ho_2O_3 shows 2 absorption peaks which corresponds to electronics transition from $^3H_6$ to state to $^3F_3$ and $^3H_4$. For x = 0.5; 1; 1.5; 2; 2.5 (mol%), nine absorption peaks corresponding to electronics transition from $^3H_6$ to state to $^5G_5$, $^5G_6$, $^1G_4$, $^1G_4$, $^5F_3$, $^5F_4$, $^5F_5$, $^3F_3$, and $^3H_4$ are shown. It is shown that absorption at 680 nm and 790 are insensitive to the addition of Ho_2O_3 in contrast to that at 580 nm and 650 nm.

Keywords: Borotellurite glasses, Tm^{3+}/Ho^{3+} codoped glasses, absorption spectra comparison.

1. Introduction

Boron Oxide (B_2O_3) is a glass former meaning that it can form a glass by itself or there is no requirement that other materials need to be added. Borate glass is characterised by its low phonon energy, which normally in the range of 1300–1500 cm^{-1}, low melting point, high transparency, high chemical resistance, good thermal stability, homogeneity, relatively low melting point, and good solubility of rare-earth ions ((Mahraz *et al.,* 2013, Bhatia *et al.,* 2018; Rajagukguk *et al.,* 2019; Yang *et al.,* 2008). On the other hand, telluriumoxide (TeO_2) is a conditional glass former. It can form a glass by itself. To form a stable glass, addition of at least a glass modifier is needed. Tellurite glass is very attractive mainly because of its low phonon energy, which is about 650–880 cm^{-1} (Mao *et al.,* 2020), good chemical resistance, good thermal stability, high rare-earth ion solubility, high refractive index, and has low phonon energy of about 700 cm^{-1} (Jha *et al.,* 2012; Vemasevana *et al.,* 2011).

Borotellurite glass formed by combining borate glass (B_2O_3) and tellurite glass (TeO_2) may benefit from their outstanding properties especially relates to their low phonon energy, good thermal stability, a high refractive index of about 1.7, and high chemical resistance (Selvaraju *et al.,* 2012). In addition, it was also reported that that addition of

TeO_2 into a borate glass may reduce the hygroscopic properties of borate glass and increase IR transmission (Selvaraju *et al.,* 2013).

Possessing such properties, borotellurite glasses have been extensively researched. Among them are borotellurite glasses codoped with Tm^{3+} and Ho^{3+}. Tm^{3+}-doped glass is studied focusing at different electronic transitions, among them is transition at $^3F_4 \rightarrow {}^3H_6$ resulting in emission at 1.85 μm (Jackson, 2009). Meanwhile, Ho^{3+} doped glass is studied making use of radiative transition of $^5I_7 \rightarrow {}^5I_8$ in for its emission around 2.05 μm (Rao *et al.,* 2012) and also emission in the visible region around 547 nm which is also originated from $^5I_7$ level with a high lifetime and creating a broad peak stimulated emission cross-section (Rajaramakrishna *et al.,* 2019). Tm^{3+}/Ho^{3+} co-doped glass is studied partly because of emission at 2.1 μm. In order to explore a possible radiative transition originated from an excited state, knowing compositional dependence of an absorption is very important since it can provide information on the possibility to increase the emission intensity by changing composition. In this paper, dependence of maximum intensity of five absorption bands are compared.

2. Experiment

Borotellurite glass with composition (in nmol%): $57B_2O_3 – 20TeO_2 – 15Bi_2O_3 – 3TiO_2 – (4\text{-}x)\ Na_2CO_3 – 1Tm_2O_3 - xHo_2O_3$ where x = 0; 0.5; 1.0; 1.5; 2.0; 2.5 were fabricated applying melt-quenching method. Mixture was prepared in a glove box. About 10 g of this mixture was contained in platinum crucible and melted in electric furnace at 900^0C for about 60 minutes. Casting was carried out by pouring the molten into a square brass mould pre-heated at about 265^0C a let it cool down to room temperature naturally. Samples of the so obtained were annealed at temperature of 300°C for about 8 hours and then slowly cooled to room temperature with heating rate of 1^0C/min. For optical characterisation, samples were polished down to optical quality using sand paper of 1000 grids, 2000 grids and 5000 grids. UV-VIS-NIR absorption spectra were recorded using a Perkin Elmer Lambda 25 Spectrometer in the range 200 nm to 1100 nm at room temperature.

3. Result and Discussion

When a matter is exposed to light, light-matter interaction in the form of energy absorption may occur. Light with photon energy equals to the energy difference between ground energy level or any populated energy level to an excited energy level will be absorbed. Starting at ground state, electron will be excited to an excited state with different absorption cross-section (absorption probability). Study on compositional sensitivity of an absorption band intensity is very important since it relates to emission cross-section. As we know that emission is inverse process of absorption. If the way that electrons absorption to different energy state is well understood, the radiative process to a lower energy states can be easily understood.

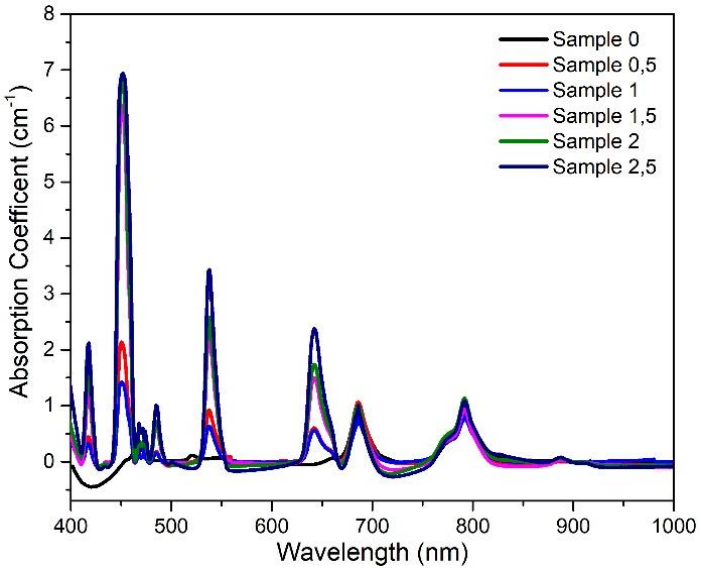

Figure 1. Absorption spectra of Tm^{3+}/Ho^{3+} codoped borotellurite glass containing different concentration of Ho^{3+} ions

Figure 1 is absorption spectra of Tm^{3+}/Ho^{3+} co-doped borotellurite glass which contans different concentration of Ho^{3+}. Sample with x = 0 contain only two absorption peaks, they are absorption at 686 nm and 792 nm corresponding transition from ground state (Tm^{3+}) $^3H_6$ to $^3F_3$ and $^3H_4$. For other samples (x = 0.5, 1.0, 1.5, 2.0 and 2.5 mol%), nine absorption peaks located at 415 nm, 452 nm, 472 nm, 487 nm, 538 nm, 642 nm, 868 nm, 792 nm and 980 nm are observed. Those absorption peaks belong to energy state: Ho^{3+} ($^5G_5$), Ho^{3+} ($^5G_6$ + $^5F_1$), Tm^{3+} ($^1G_4$) + Ho^{3+} ($^3K_8$), Ho^{3+} ($^3F_5$), Ho^{3+} ($^5S_2$+$^5F_4$), Ho^{3+} ($^5F_5$), Tm^{3+} ($^3F_3$) and Tm^{3+} ($^3H_4$); respectively.

Sensitivity of absorption spectra intensity at different absorption band to the change of Ho_2O_3 concentration described in more detail picture is given in Figure 2. As shown in Figure 2(a) and 2 (b), significant change of absorption spectra for different glass containing different concentration of Ho_2O_3 is observed. It can be seen from Figure 3 that absorption at 680 nm and 790 are insensitive to the addition of Ho_2O_3, in contrast to that at 580 nm and 650 nm. Further from Figure 3 it can also be seen that different Ho_2O_3 concentration responds different photon energy in different way. Glasses containing 2.5 mol% of Ho_2O_3 absorbs photon energy corresponding to wavelength of 680 nm and 790 nm less than those of 550 nm and 650 nm. Glasses possess 1.5 mol%, 2.0 mol% and 2.5 mol% of Ho_2O_3 absorb light at 550 nm and 650 nm more than those at 680 nm and 790 nm. At concentration of 0 mol%, 0.5 mol% and 1.0 mol%, nevertheless, absorption at 550 nm and 650 nm becomes weaker than those at 680 nm and 790 nm.

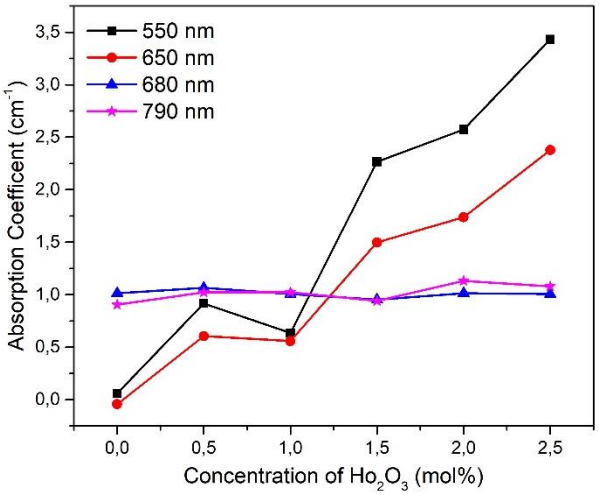

Figure 3. The maximum absorption peaks for absorption band peaking at 550 nm, 650 nm, 680 nm and 790 nm

4. Conclusion

Tm^{3+}/Ho^{3+} codoped borotellurite glasses having concentration (in mol%): $57B_2O_3$ – $20TeO_2$ –$15Bi_2O_3$ – $3TiO_2$ – (4-x) Na_2CO_3 – $1Tm_2O_3$ - xHo_2O_3 where x = 0; 0.5; 1; 1.5; 2; 2.5 were successfully fabricated. Absorption band intensity for recorded for different Ho_2O_3 content in glasses were compared. It was shown that absorption at 680 nm and 790 are insensitive to the addition of Ho_2O_3, in contrast to that at 580 nm and 650 nm. As Ho_2O_3 concentration is increased, an absorption change occurs significantly only at wavelength of 550 nm and 650 nm and at Ho_2O_3 concentration of 1.5 mol%, 2.0 mol% and 2.5 mol%.

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