Structural Characterization, Raman Spectroscopy and FTIR Spectroscopy Studies of Pr^{3+} Doped Tellurium Bismuth Borate Glasses

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Abstract

A set of composition-based undoped and Pr^{3+}-doped Tellurium Bismuth Borate glasses $20TeO_2$: (30-X)Bi_2O_3: $50B_2O_3$: XPr_2O_3 (where X= 0, 0.1, 0.3, 0.5, 0.7 mol%) have been fabricated via standard melt quenching technique. All of the manufactured glasses were made of completely amorphous material, according to X-ray diffraction (XRD) patterns. The refractive index, density, optical absorption, FTIR and Raman spectroscopy have been applied to investigate the structural and optical properties. FTIR spectral measurements have been utilized to identify the network vibration of Pr_2O_3 doped Tellurium glasses. FTIR reveals symmetrical stretching vibrations of Te-O in TeO_4 as well as B-O stretching (BO_3) units. Signals in the FTIR mainly observed around 1032 cm^{-1},1180 cm^{-1}, 1349 cm^{-1}, 1395 cm^{-1} and 1501 cm^{-1} while Raman scattering peaks are located at 436 cm^{-1}, 542 cm^{-1}, 770 cm^{-1}, 940 cm^{-1}, 1028 cm^{-1}, 1232 cm^{-1} and 1361 cm^{-1}. Both reflective index and density increases with increasing rare earth ion concentration.

Keywords: Tellurium Glasses, FTIR Spectroscopy, Raman Scattering and Optical Absorption.
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Introduction

Since they are optical glasses containing Pr^{3+} ions, they are useful as photonic materials in various technologies due to their broad absorption in the visible-near infrared region [1]. Commercially available GaN diode lasers provide good utilization due to their broadness and absorption at 443 nm, which corresponds to the energy of the Pr^{3+} ion $^3H_4$ - $^3P_2$ [3]. Telluride networks consist mainly of TeO_3 trigonal pyramidal (Tp) units with long electron pairs and TeO_4 trigonal bipyramidal (Tbp) units. Add iron oxides, alkali metals and alkaline earth metals to convert Tbp units to Tp units. Raman spectroscopy and infrared (IR) spectroscopy are the two most important vibrational non-invasive tools in many fields such as biology, geology, materials science and recently space exploration [4]. Combined Raman-infrared spectroscopy can be used to analyze various important properties including phonons, aggregation state and energy of functional groups of the crystal lattice. Therefore, the properties of the material have a direct effect on the Raman spectroscopy parameters (band frequency, intensity, band shape and full width at half maximum or FWHM). These constraints are: (1) Orientation of the crystal lattice or molecules; (5) Inconsistencies and stresses in the material (due to mechanical, thermal or acoustic effects) [5].

FTIR spectra recorded in the 1000–1600 cm^{-1} region for Pr^{3+}-doped alkali and mixed-alkali heavy metal borate glass matrices. In general, the vibrational modes of the borate glass network consist of three important band regions. The first group of bands, which occur at 1200–1600 cm^{-1} is due to the asymmetric stretching vibration of B -O bonds in BO_3 units. Therefore, the aim of this study is the spectral and fluorescence analysis of Pr^{3+} telluride bismuth borate glass for optical devices.

Method

In the tellurite bismuth borate glass system $20TeO_2$ was doped with Pr^{3+} ions as follows: (30-x) Using the solution quenching process, $20TeO_2$: (30-x)Bi_2O_3: $50B_2O_3$: XPr_2O_3 (where x = 0, 0.1, 0.3, 0.5 and 0.7 Mol%) was prepared. Chemical reagents, particularly TeO_2, Bi_2O_3, B_2O_3 and Pr_2O_3 were used in this study. Mix well using an agate mortar and pestle. After the lamb is melted in an electric muffle furnace at 950 °C for two hours and completely melted, it is quickly poured into a preheated stainless-steel mold. The mold is placed at 350 °C for two hours to eliminate thermal stress and tension. These models are always polished with a fine cerium oxide powder.

Table 1: Chemical Composition of Pr^{3+} doped TEBIB Glasses.

Glass System	Glass Composition
TEBIB (Pr0)	20TeO2:30Bi2O3:50B2O3
TEBIB (Pr0.1)	20TeO2:29.9Bi2O3:50B2O3:0.1Pr2O3
TEBIB (Pr0.3)	20TeO2:29.7Bi2O3:50B2O3:0.3Pr2O3
TEBIB (Pr0.5)	20TeO2:29.5Bi2O3:50B2O3:0.5Pr2O3
TEBIB (Pr0.7)	20TeO2:29.3Bi2O3:50B2O3:0.7Pr2O3

Result and Discussion

All of the manufactured glasses were made of completely amorphous in nature, according to X-ray diffraction (XRD) patterns. From the figure 2 and 3 it is clear that reflective index and Density of the samples increase with increases in rare earth ion concentration respectively. From the FTIR spectra peaks are available in the range from 1000 cm^{-1} to 1600 cm^{-1} that reveals symmetrical stretching vibrations of Te-O in TeO_4 as well as B-O stretching (BO_3) units. The prominent feature in most synthetic tellurium borate glasses Raman spectra are intensive bands in the 400 – 1400 cm-region due to symmetric stretching motions of Te-O in TeO_4 as well as B-O stretching (BO_3) units.

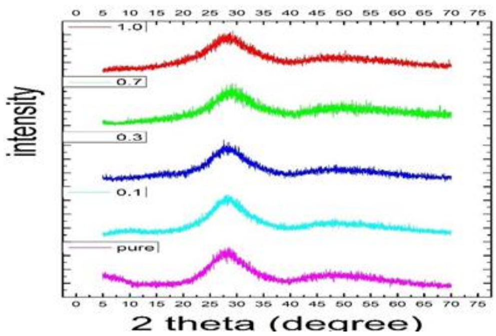

Figure1: X-ray diffraction pattern of Pr^{3+} doped TEBIB Glasses.

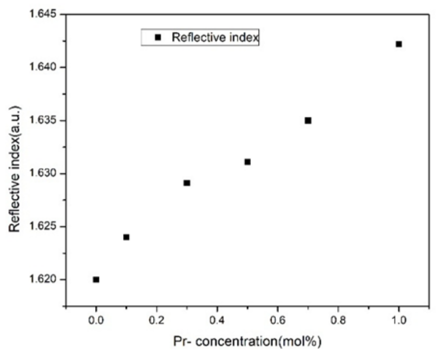

Figure 2: Reflective index v/s Pr- concentration (mol%) of Pr^{3+} doped TEBIB Glasses.

Table 2: Physical properties of Pr^{3+} doped TEBIB Glasses.

Properties	TEBIB	TEBIB0.1Pr	TEBIB0.3Pr	TEBIB0.5Pr	TEBIB0.7Pr	TEBIB1.0Pr
Reflective index(n)	1.6200	1.6240	1.6291	1.6311	1.6350	1.6422
Density(gm/cm^3)	3.1021	3.2410	3.2641	3.3320	3.3785	3.4413

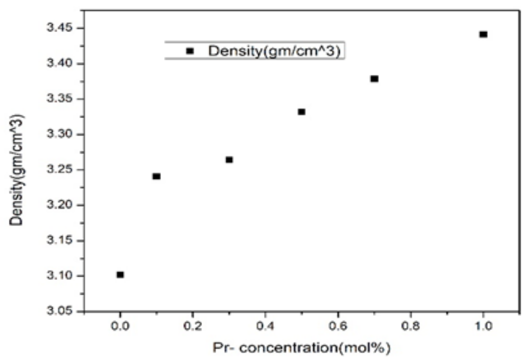

Figure 3: Density v/s Pr- concentration (mol%) of Pr^{3+} doped TEBIB Glasses.

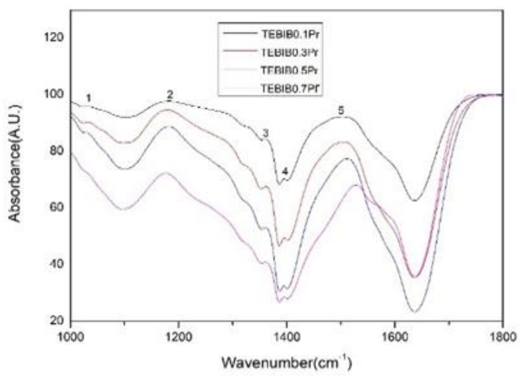

Figure 4: FTIR Spectra of Pr^{3+} doped TEBIB Glasses.

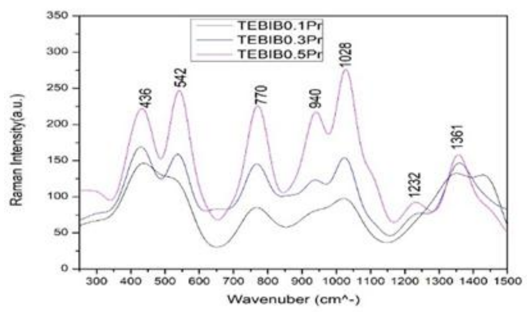

Figure 5: Raman Spectra of Pr^{3+} doped TEBIB Glasses.

Conclusion and Future Prospective

For a bismuth telluride borate glass sheet Pr_2O_3 with the composition of $20TeO_2$:(30-X), undoped and Pr^{3+}-doped Bi_2O_3:$50B_2O_3$:(X), use the usual melt quenching process to produce it (where X = 0, 0.1, 0.3, 0.5 and 0.7 mol%

vibration of Pr_2O_3-doped tellurium). The glass was characterized by FTIR spectroscopy. FTIR shows the symmetric stretching vibrations of Te-O and B-O stretching (BO_3) units. Although Raman scattering peaks appear around 446 cm^{-1}, 542 cm^{-1}, 770 cm^{-1}, 940 cm^{-1}, 1028 cm^{-1}, 1232 cm^{-1} and 1361 cm^{-1}, the FTIR signal usually appears at 1032 cm^{-1}, 1180 cm^{-1}, 1349 cm^{-1}, 1395 cm^{-1} and 1501 cm^{-1}. Both reflective index and density increases with increasing rare earth ion concentration.

References

1. Pisarska, M. Kowal, M. Kochanowicz, J. Zmojda, Optic Express 24 (2016) 2427 243.
2. Q. J. Chen Wenjie, Zhang, XY, Huang, G. P. My husband is tivthaiv. 513 (2012) 139-144.
3. Okamoto, K. Kasuga, I. Hara, Y. Kubota, Optic Express 17 (2009) 20227-20232.
4. E. A. Lalla, M. Aznar, M. Constantinidis, Polarized Raman Analysi ntawm (RE^{3+}) - Folded Florotellurite Glasses tiab Ceramics, Vibration Spectrum. 103 (2019) 102934.
5. Cantarero, Applications of Raman Scattering in Materials Science, Procedia Mater. education. 9 (2015) 113-122.