Synthesis and Spectroscopic Investigation of Rare Earth Ions Pr^{3+} Doped Phosphate Glasses

Menka Meena[a], S S Meena[b], Pawan Kumar, Nitiksha Sharma, Beena Bhatia

Department of Physics, Jai Narain Vyas University Jodhpur, Rajasthan, India.

[a] menkameena1996@gmai.com
[b] ssmeenaphy12@gmail.com

Abstract

This paper presents the structure of the new glass (5-x) P_2O_3: $40Li_2O$: $55B_2O_3$: xPr_2O_3 (x = 0, 0.3, 0.5 and 0.7 mol%) prepared by melt quenching method. X-ray diffraction patterns confirm that the glass system is amorphous. The structural alternations of the glasses were examined using an FTIR (Fourier Transform Infrared) spectrometer. Pr^{3+}-doped glasses density and refractive index values were calculated. As the concentration of Pr^{3+} rises, the refractive index increases from 1.6621 to 1.6641. The Pr^{3+}-doped phosphate glasses are useful for application involving visible laser and optical signal amplifier.

Keywords: FTIR, Density, Refractive Index.
Received 29 January 2025; First Review 14 February 2025; Accepted 16 February 2025

*** Address of correspondence**
Menka Meena
Department of Physics, Jai Narain Vyas University Jodhpur, Rajasthan, India.

Email: menkameena1996@gmai.com

How to cite this article
Menka Meena, S S Meena, Pawan Kumar, Nitiksha Sharma, Beena Bhatia, Synthesis and Spectroscopic Investigation of Rare Earth Ions Pr^{3+} Doped Phosphate Glasses, J. Cond. Matt. 2024; 02 (02): 64-66.

Available from:
https://doi.org/10.61343/jcm.v2i02.94

Introduction

In recent years, glass has become important in many technological areas and processes due to its promise in thermomechanical sensors, electro-optic systems, and reflective windows [1]. The most flexible glass on the market is lithium borate glass. These glasses are promising materials for new technologies due to their strength, ability to form many compounds, high rare earth solubility, and unique boron anomalies. Although these glasses are often referred to as solid electrolytes, the rare earth oxides in these glass systems are helping to discover and create new materials for optical applications [2]. Praseodymium is a soft, silvery metal that is used as an alloying agent for magnesium in aircraft engines, imparting high strength and corrosion-inhibiting properties to the metal. It imparts a bright, transparent yellow colour to glass and enamels [3]. Many optoelectronic devices including optical fibres, optical amplifiers, lasers, sensors, optical converters, etc. have been designed using trivalent rare earth (RE^{3+}) ion doped glass substrates [4]. For example, they can be used as fluorescent lighting due to their light efficiency, long service life, energy efficiency and environmental properties [5]. The local structure of the rare earth element is directly related to the properties of rare earth ions. The distribution of dopant ions in the glass matrix. Due to the relationship between the additive ionic strength and the structure of the glass matrix, glass can be designed for many applications [6].

Method

The melt-quenching approach was used to create the following Pr^{3+} doped phosphate glass system (PLBPr) (5-x) P_2O_3.$40Li_2O$.$55B_2O_3$.xPr_2O_3 (where x = 0, 0.3, 0.5 and 0.7 mol%). P_2O_5, Li_2O, B_2O_3 and Pr_2O_3 are the analytical reagent class compounds used in this study. Mix thoroughly using the onyx mortar and pestle. After complete melting in the electric muffle furnace for two hours, the melt was immediately placed in the preheated stainless-steel mold and annealed at 450 °C for 10 hours to relieve thermal stress and filter. This sample was allowed to cool to room temperature. The samples are always polished using high quality cerium oxide powder. The glass structure is transparent and has a visually pleasing appearance.

Discussions

Figure 1 shows the XRD patterns for the prepared glass series. Only humps are seen in the patterns; the lack of any distinct crystalline peaks indicates that the measured XRD profile supports the ideal amorphous condition. The figure makes it clear that the crystalline phase is absent when there

are no peaks present.

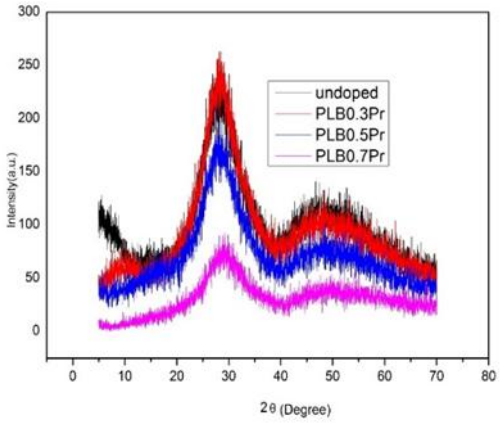

Figure 1: XRD patterns of Pr^{3+} doped PLBPr glass system.

FTIR spectroscopy is an effective method to analyse various bending and stretching vibrations found in modern glass samples. Figure 2 shows the FTIR spectrum of PLBPr glass obtained in the range of 300-4000 cm^{-1} at room temperature. Using FTIR analysis, the vibration energy (500~4000 cm^{-1}) can be clearly identified [7]. FTIR spectroscopy is an important tool to identify compounds and characterize their structures. The structural changes that occur upon the addition of Li_2O to the borate network can be observed by examining the changes in the FTIR spectrum [8]. The main purpose of FTIR spectroscopic analysis is to determine the chemical activity of the material. The network structure of phosphate glasses is formed by the association of PO_4 tetrahedral with P-O-P to form a polymeric structure. This glass contains 40% B_2O_3 with a network of borate-linked phosphate chains forming a three-dimensional structure to form BO_3 and BO_4 units.

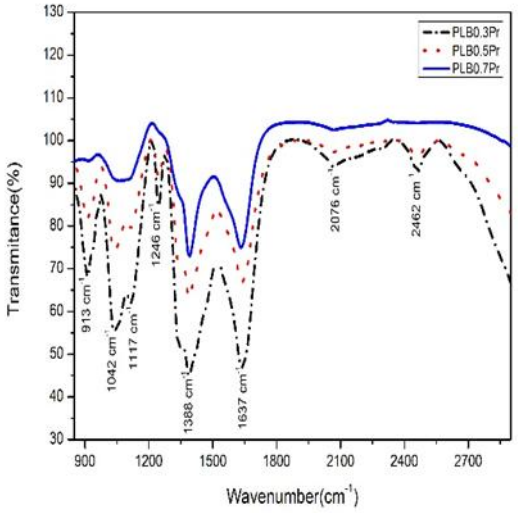

Figure 2: Fourier transform infrared spectrum of the Pr^{3+} doped PLBPr glass system.

The structural changes that occur upon incorporation of Li_2O into the borate network can be observed by examining the changes in the FTIR spectrum [9]. In this study, the energy bands at 2076 cm^{-1} and 2462 cm^{-1} are the source of the longitudinal oscillations of the B-O bonds of the BO_3 and BO_4 units, respectively. The B-O-B bending oscillations produce an energy band at 1117 cm^{-1} [10]. The increase in the doping level is associated with a decrease in the band width corresponding to the P-O-P symmetry and PO_2 symmetry stretching oscillations at 1246 cm^{-1} and 1637 cm^{-1}. It is important to note that the P-O-P asymmetric stretching band at 1388 cm^{-1} becomes stronger as the Pr^{3+} concentration increases. The band formed by PO^{2-} asymmetric species is located at 1042 cm^{-1}. The intensity band at 913 cm^{-1} is known to increase with increasing Pr^{3+}, which is comparable to the Pr-O bond [11]. FTIR analysis shows that the phonon energy of the glass is approximately 1388 cm^{-1}, respectively. The glass design was determined to be transparent and the physical properties of the PLBPr glass were calculated. These calculations are necessary to measure the specific spectral properties of the glass. Density is used to calculate many important parameters such as density, elastic properties, thermal conductivity of the material. The density of PLBPr glass was found to vary between 1.9421 and 2.9421 kg m^{-3}. These data show that the density of the network is quite sensitive to atomic weight and ion size. As the Pr^{3+} concentration increases, the conversion factor varies between 1.6621 and 1.6641.

Conclusion

The glass samples' amorphous nature was verified by the X-ray diffraction (XRD) method. An increase in Pr^{3+} concentrations improved the glass samples' density. The spectroscopic characteristics of the Pr^{3+} doped phosphate glasses were manufactured and examined after they were created at different Pr^{3+} doping concentrations. To identify the PLBPr glasses with a doped Pr^{3+} structural network and phonon energy. The FTIR measurements show that the phonon energy of the glass is around 1388 cm^{-1}. It was shown that there is more asymmetry and less covalency in the present Pr^{3+} phosphate. Luminescence intensities decreased with increasing Pr^{3+} ion concentration due to concentration quenching. Applications for visible lasers and optical signal amplifiers benefit from the Pr^{3+} doped phosphate glasses.

References

1. N W Sangwaranatee, N Kiwsakunkran, J Kaewkhao, *"Physical and optical studies of praseodymium doped sodium aluminium barium phosphate glass"*, Int. pr. body. thiab Matt. Appl. J. of Phy., 1428, 012-03, (2020).
2. D D Ramtek, R S Gedam, *"Impedance spectroscopic characterization of Sm_2O_3 containing lithium borate glass"*, Spectro. Acta A, 133, 19-23, (2014).

3. Mohammad Reza Ganjali and Morteza Pirali Hamedani, *"A Review on Praseodymium Selective Electrochemical and Optical Sensors"*, Anal. Bional. Electrochem., 15,78-89, (2023).
4. Maheshvaran K, Arunkumar S, Venkata Krishnaiah K thiab Marimuthu K, *"Study on luminescence of Er^{3+}/Yb^{3+} co-doped boron telluride glass"*, J. Mol. Struct., 1079 130-138, (2015).
5. Ahmad F, Hussin R and Ghoshal S K, *"Spectral properties of Er^{3+} doped magnesium zinc thiophosphate glass"*, J. Alloys Compd., 711, 94-102, (2017).
6. V P Alkseyev, V P Gapontsev, M E Zhabotinski, V P Kravchenko, Y P Rudritskii, Laser Phosphate Glass, Nauka, Moscow, (1980).
7. M A Marzouk, *"Optical characterization of some rare earth ions doped bismuth borate glasses and effect of gamma irradiation"*, J. Mol. Struct., 101, 80–90, (2012).
8. G B Rouse Jr, P J Miller, W M Risen, *"Spectroscopy and structure of mixed alkali iav"*, J. Amorphous. Solids, 28, 193–207, (1978).
9. E I Kamitsos, M A Karakassides, and A P Patsis, *"Spectroscopic study of carbonate retention in high-alkali borate glass"*, J. of Non-Cry. Solids, 111, 252–262, (1989).
10. S. Yusub, P. Srinivasa Rao, D. Krishna Rao, *"Ionic conductivity, dielectric and optical properties of lithium lead borophosphate glasses incorporated with manganese ions"*, J. Alloys Com., 663, 708 - 717, (2016).
11. V Arunaa, S Yusubb, M Venkateswarluc, A Ramesh Babua, K Anith, *"Effect of copper ions on lithium-ion conductivity, electron hopping, optical band gap, metallization pattern and morphology of Li_2O-B_2O_3-P_2O_5 glass"*, J. of Non-Cry. Sun, 536, 120015, (2020).