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Different property studies with network improvement of CdO doped alkali borate glass

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Highlights

- CdO doped alkali Borate glass samples are prepared by melt quenching method.
- Physical, structural and optical properties and network analysis of TM doped alkali borate glass.
- Different optical property studies were done with UV–vis spectroscopy and theoretical approach.
- Analysis of Raman spectra of glass is done by using deconvolution method.
- The correlation of glassy network formation and their modification due to varying CdO concentration.

Abstract

Quaternary alkali borate glass matrix doped with CdO (0, 2, 4, 6, 8, 10 mol%) have been prepared by using conventional melting and quenching technique. For these glass systems structural properties were investigated by using X-ray diffraction, FE-SEM, EDS, FTIR and Raman spectroscopy

characterization techniques. X-ray diffraction pattern and FE-SEM studies confirms the amorphous nature of prepared oxide glass. The optical absorption studies were done by using UV–Vis spectroscopy technique at room temperature. The physical parameters of all the glass samples were evaluated with respect to the composition, such as bulk density (ρ), average molar mass (M), molar volume (V_m), ionic concentration (N), interionic distance (r_i). They exhibit the non-linearity supporting evidence for the borate glass network modification. Investigations of FTIR and Raman spectroscopy of prepared glass samples have been employed to confirm the role of oxides in the formation of glass network. These glasses are made up from converting [BO_3] to [BO_4] units without increasing the concentration of non-bridging oxygen. Experimental fraction of 4-coordinated boron atoms expressed by the parameter N_4 was calculated and represented with the addition of concentration of CdO (mol%). The optical absorption studies revealed that the average refractive index (n_{av}), optical band gap energy (E_g) nonlinearly increases. The electronic polarizability and optical basicity of the oxide ion (α_{O2-}), as function of refractive index and optical band gap energy were also examined.

Introduction

Glass and glass ceramics are the inorganic compounds formed due to fusion, cooled at rigid conditions without crystallization [1]. Glasses are the transparent, amorphous in nature and having short range order in the crystal structure [[2], [3], [4], [5]]. Borate based oxide glass materials have special features like high transparency, low melting point and high thermal stability making it wide range of technological applications [6,7]. However in the category of oxide glass, only borate glasses will possess high phonon energy which cannot suppress the nonradiative decay process [8]. Borate glasses are commonly used materials in the field of optoelectronics, in nonlinear optical devices for frequency conversion in the ultraviolet region and piezoelectric actuator [9]. Therefore, these glasses are considered to be good candidates for the optically induced elastoopticity. In order to reduce this phonon energies, addition of transition metal oxide considerably in the borate glass matrix which can give intense fluorescence suitable for optical amplifiers [8,10].

Borate glasses are having the property to change the coordination number with oxygen from three to four which can easily form various structural units [11]. These structure formations are the most promising reasons to obtain the interesting properties with modified glass network. In order modify the borate glass addition of alkali oxides (Li_2O, Na_2O) will be useful to obtain mechanical stability and hygroscopic property of glass network. On this concern lithium oxide (Li_2O) can be useful to functioning as vacancy creation and improve the network connectivity. Also it helps to convert sp^2 planar [BO_3] units in stable sp^3 planar [BO_4] units and the possibility of creating non-bridging oxygen [6]. In the alkali borate glass systems, each alkali oxide is bound to associate with borate units. The number of the structural units depends on both the nature and the total concentration of the added modifiers, and can often give rise to tightly organized structures resulting in intermediate order [12]. The transition metal elements and their oxides have been widely used for the fabrication

of oxide glasses. Since, these TM can work efficiently as intermediate oxides and also as glass network modifier. In order to enhance the optical absorption edges of borate glass TM oxide plays the role of nucleating agents. The TM oxides like CdO were used to shorten the time taken for the solidification of glasses during the quenching process [13].

Cadmium containing glasses are of special interest owing to their applications in different fields of nonlinear optical materials. The glass structure and their properties are mainly depending on the role of network modifier or network former played during glass formation by the constituent's oxide [14,15]. In recent years, researchers have focused on cadmium oxide (CdO) due to its applications, specifically in the field of optoelectronic devices such as solar cells, phototransistors, diodes, transparent electrodes, and gas sensors [16]. These applications of CdO are based on its specific optical and electric properties due to particular covalent character and thermal stability of cadmium oxide. Addition of alkali oxide e.g. Li_2O, Na_2O into the borate glass matrix helps to increase the moisture resistance [17]. Reported literature confirms that the glasses containing alkali oxide are bubble free, moisture resistant, highly stable and suitable for the optical analysis [18]. Earlier studies were reported that the optical properties of glasses caused due to the electronic polarization of oxide content [[19], [20], [21]]. Hence, it is very useful to get the electronic polarizability of CdO doped alkali borate glasses by using refractive index and optical energy band gap.

The aim of the present study is to obtain physical, structural and optical properties in support of the glass network formation of prepared alkali borate glass. Network structure improvements were included by using Raman and Infrared spectroscopy of CdO doped mixed alkali borate glass. The oxides chemical-composition dependent specific data is also summarized in the present article. The optical study was done by using UV–vis optical spectra. The combined effect of transition metal oxide CdO and alkali oxide Na_2O, Li_2O on the optical properties of prepared oxide glass are taken into account by evaluating the optical parameters like optical band gap energy, Urbach energy, refractive index and electronic polarizability etc. Present oxide glass studies attempts to correlate the network modification due to TM and alkali oxides in the structure of borate glass network. Theoretical optical basicity of glass is also calculated.

Section snippets

Preparation method

Cadmium oxide doped mixed alkali borate glasses with the chemical composition as summarized in Table 1 were prepared by using conventional melting and quenching method. Mainly this synthesis method contains four major steps of grinding, melting, quenching and annealing. Raw materials used for the synthesis as source of oxides (Boric acid H_3BO_3, Sodium carbonate Na_2CO_3, Lithium carbonate Li_2CO_3, cadmium oxide CdO with AR grade of 99.99% purity) were toughly ground until homogeneous mixture…

Physical properties

As the density and molar volume of amorphous glass plays an important role for the structural changes and glass network formation. In case of glass and glass ceramics density totally decided by the oxides or the materials involved in preparation. Not only the contents, other factors are also responsible to decide the density of glass e.g. rate of crystallization, molar mass of dopant oxides, formation of NBO's and thermal treatment etc. [1]. The measured values of physical properties like…

Conclusion

Quaternary alkali borate glass system doped with transition metal oxide (CdO) with different concentration (0, 2, 4…10 mol%) successfully synthesized by melt-quenching technique. The following conclusions can be drawn:

- Powder X-ray diffraction and FE-SEM structural study confirms the non-crystalline nature of the prepared glass system. X-ray diffraction pattern showing the broad humps and noise with diffused scattering characteristics of non-crystalline glass. EDS studies also confirm the…

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