Optical Absorption Behavior of Li₂O-Al₂O₃-P₂O₅ Glasses Mixed with Nd₂O₃

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Abstract: Li₂O-Al₂O₃-P₂O₅ glasses mixed with Nd₂O₃ have yielded useful applications in laser industry. Li₂O-Al₂O₃-P₂O₅ glasses mixed with Nd₂O₃ have been prepared by melt quenching method and the systematic studies like optical absorption behavior of Li₂O-Al₂O₃-P₂O₅ pure glass and Li₂O-Al₂O₃-P₂O₅ glass doped with 1.0 mol% of Nd₂O₃ systems have been carried out. The existence of Nd³⁺ in these glasses is expected to influence their physical properties to a large extent since these ions exist in different valence states. The optical absorption spectra of Li₂O-Al₂O₃-P₂O₅ glass doped with 1.0 mol% of Nd₂O₃ is recorded at room temperature in the wavelength region 300-2000 nm exhibited all from the ground state ⁴I₁₁/₂: these levels are assigned to the appropriate electronic transition.

Keywords: Li₂O-Al₂O₃-P₂O₅, Melt quenching, Nd2O3, Spectroscopic properties

1. Introduction

A glass is defined as an inorganic product of fusion which has been cooled to a rigid condition without crystallization. According to this definition, a glass is a non crystalline material obtained by a melt-quenching process [1]. Nowadays, non crystalline materials that cannot be distinguished from melt-quenched glasses of the same composition are obtainable by using various techniques such as chemical vapor deposition, sol-gel process, etc. The macroscopic properties of a glass such as optical transmission and absorption, refraction of light, thermal expansion, etc. are observed always equally in all directions, provided that the glass is free from stress and strain. That is, a glass is an isotropic material, whereas crystalline materials are generally anisotropic. During the last few decades a large variety of inorganic glasses have been developed with an attempt to achieve suitable optical, electrical and mechanical characteristics. These characteristics are associated with the improved physical properties such as electrical resistance, mechanical strength, glass transparency, IR transmission and absorption, refraction of light, thermal expansion, etc. are observed always equally in all directions, provided that the glass is free from stress and strain. That is, a glass is an isotropic material, whereas crystalline materials are generally anisotropic. During the last few decades a large variety of inorganic glasses have been developed with an attempt to achieve suitable optical, electrical and mechanical characteristics. These characteristics are associated with the improved physical properties such as electrical resistance, mechanical strength, glass transparency, IR transmission and absorption, refraction of light, thermal expansion, etc. are observed always equally in all directions, provided that the glass is free from stress and strain. 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For the present study, the chosen composition is (30−x)Li₂O–
10Al₂O₃−60P₂O₅:xNd₂O₃ with x = 1.0 mol%.

The details of the compositions are:
Nd₆: 30 Li₂O−10Al₂O₃−60P₂O₅
Nd₈: 29 Li₂O−10Al₂O₃−60P₂O₅:1.0Nd₂O₃

Analytical grade reagents of P₂O₅, Li₂CO₃, Al₂O₃ and Nd₂O₃ powders in appropriate amounts (all in mol%) were
thoroughly mixed in an agate mortar, calcinated at about 400°C for 2 h in a platinum crucible and subsequently melted
in a pre-heated brass mould and annealed at 300 °C in another furnace. The samples prepared were mechanically ground
and optically polished to the dimensions of 1 cm × 1 cm × 0.2

Fig. 1 Images of pure and doped glasses of the Li₂O-Al₂O₃-
P₂O₅ glass system

3. Characterization

The density of the glasses was determined to an accuracy of
(± 0.0001) by the standard principle of Archimedes’ using o-
xylene (99.99% pure) as the buoyant liquid. The mass of the
samples to be measured was an accuracy of 0.1 mg using Ohaus
digital balance Model AR2140 for evaluating the density.

The optical absorption spectra of the glasses were recorded to a resolution of 0.1 nm at room temperature in the spectral
wavelength range covering 250-900 nm using JASCO Model

4. Results and Discussion

The composition of Li₂O – Al₂O₃ – P₂O₅: Nd₂O₃ glass system
is an admixture of glass formers, modifiers and intermediates. P₂O₅ is a strong glass forming oxide, participates in the glass
network with PO₄ structural clusters. The PO₄ tetrahedra are
linked together by covalent bonding in chains or rings by
bridging oxygens. Neighbouring phosphate chains are linked together with covalent bonding in chains or rings by

The study of optical absorption, particularly the absorption
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electronic structure of the materials. It is possible to
determine whether the optically induced transition is direct or
indirect and allowed or forbidden by analysis of the
absorption edge. The optical absorbance of glass system has
been studied in the vicinity of the fundamental absorption
edge. The optical absorption spectra of Li₂O – Al₂O₃ –
P₂O₅ pure glass recorded at room temperature in the wavelength
range 300-2000 nm exhibited no absorption bands (Fig. 2).

Table 1 Physical parameters of Li₂O–Al₂O₃–P₂O₅ glasses
doped with Nd₂O₃

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Nd₆: 30 Li₂O−10Al₂O₃−60P₂O₅
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network with PO₄ structural clusters. The PO₄ tetrahedra are
linked together by covalent bonding in chains or rings by
bridging oxygens. Neighbouring phosphate chains are linked together by cross-bonding between the metal cation and two
non-bridging oxygen atoms of each PO₄ tetrahedron. The presence of such PO₄ units in the titled glass samples is
evident from the IR spectral studies [4, 5]. Among various rare earth ions, Nd³⁺ doped glasses that give rich emission in the ultraviolet, visible and near infrared region (at ~2.0 μm).

The introduction of Neodymium ions in the glass network
will create bond defects liberating non bridging oxygen
atoms (NBOs) and also suitable cations for giving rich emission. So these glasses are best candidates for lasing
materials. From the measured values of the density and

average molecular weight M of the samples, various other
physical parameters such as rare earth ion concentration Ni,
mean rare earth ion separation R, and molar volume for all
the glass samples were evaluated and presented in Table 1.

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edge, has proved to be very useful for elucidation of the
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P₂O₅ pure glass recorded at room temperature in the wavelength
range 300-2000 nm exhibited no absorption bands (Fig. 2).

Fig. 2 Optical absorption spectra of Li₂O–Al₂O₃–P₂O₅
glass recorded at room temperature

From the observed absorption edges, we have evaluated the optical band gaps (Eₒ) of these glasses by drawing Tauc plot
between (α h ω)½ and h ω as per the equation:

\[ \alpha(\omega) \propto (\hbar \omega - E_o)^{2} \]  \hspace{1cm} (1)

Fig. 3 represents the Tau plot of this glass in which a
considerable part of each curve is observed to be linear. From the extrapolation of the linear portion of these curves, the values of optical band gap (Eₒ) obtained for Li₂O – Al₂O₃ –
P₂O₅ glass is presented in Table 1.
The optical absorption spectra of Li₂O–Al₂O₃–P₂O₅ glass doped with 1.0 mol% of Nd₂O₃ is recorded at room temperature in the wavelength region 300-2000 nm exhibited all from the ground state ¹I₉/₂, these levels are assigned to the following appropriate electronic transition:

\[ \text{Nd}^{3+}: \quad ¹I₉/₂ \rightarrow ²P₁/₂, ²D₃/₂, ²G₉/₂, ²G₇/₂, ²H₁₁/₂, ²F₉/₂, ²F₇/₂, ²F₅/₂, \text{and} ²F₃/₂ \]

Tauc plots of Li₂O–Al₂O₃–P₂O₅ glasses doped with Sm³⁺ ions were drawn from Fig. 4 and optical band gap was estimated.

**Figure 4:** Tauc plots for evaluating the optical band gap of Li₂O–Al₂O₃–P₂O₅ glasses doped with Nd³⁺ ions

5. **Conclusion**

Li₂O–Al₂O₃–P₂O₅ pure glass and Li₂O–Al₂O₃–P₂O₅ glass doped with 1.0 mol% of Nd₂O₃ systems are prepared by melt quenching method. The systematic studies like physical parameters evaluation and optical absorption behavior of Li₂O–Al₂O₃–P₂O₅ pure glass and Li₂O–Al₂O₃–P₂O₅ glass doped with 1.0 mol% of Nd₂O₃ systems have been carried out. Optical absorption spectra of Li₂O–Al₂O₃–P₂O₅ pure glass recorded at room temperature in the wavelength region 300-2000 nm exhibited no absorption bands. The optical absorption spectra of Li₂O–Al₂O₃–P₂O₅ glass doped with 1.0 mol% of Nd₂O₃ is recorded at room temperature in the wavelength region 300-2000 nm exhibited all from the ground state ¹I₉/₂; these levels are assigned to the appropriate electronic transition. Summing up the entire work presented in this project it is felt that the study of various physical and spectroscopic properties of Li₂O–Al₂O₃–P₂O₅ glasses doped with Nd₂O₃ have yielded some valuable information which will be useful for the practical applications of these materials in the laser industry.

**References**


