Investigation on Physical and Optical of Praseodymium Doped Sodium Aluminium Barium Phosphate Glasses

N. W. Sangwaranatee¹, N Kiwsakunkran²,³, J Kaewkhao²,³

¹Informatics Mathematics, Faculty of Science and Technology, Suan Sunandha Rajabhat University, Bangkok 10300, Thailand
² Physics Program, Faculty of Science and Technology, Nakhon Pathom Rajabhat University, Nakhon Pathom 73000, Thailand
³ Center of Excellence in Glass Technology and Materials science (CEGM), Nakhon Pathom Rajabhat University, Nakhon Pathom 73000, Thailand

Email : Nisakorn.su@ssru.ac.th

Abstract. Sodium aluminium barium phosphate glasses doped with different concentration of Pr₂O₃ were synthesized by melt quench technique. These glasses were varied concentrations of Pr₂O₃ at 0, 0.05, 0.10, 0.50, 1.00 and 2.00 mol%. Their physical properties like density (ρ) and refractive index (n) were measured at room temperature. Also, optical absorption and photoluminescence spectra of these glasses have been acquired at room temperature. It was found that the intensity were increase with increasing concentration of Pr₂O₃. UV-Vis and NIR (250-2500 nm) spectra have been measured for all studied glass samples and discussed. The photoluminescence spectra recorded under 445 nm excitation exhibited the emission bands at 528, 598 and 639 nm corresponding to the emission transitions ³P₁ → ³H₅, ¹D₂ → ³H₄, and ³P₀ → ³F₂ respectively. The Judd-Ofelt (JO) parameters Ωλ (λ = 2, 4 and 6) have been calculated to explore the bonding environment around the Pr³⁺ ions. The CIE chromacity color coordinates (x,y) are calculated from the emission spectra which indicates the located in the yellow-orange region. The prepared glasses are potential candidates for laser applications.

1. Introduction

Currently, Glasses have a vital role in several fields of engineering and technology due to their potential applications in thermomechanical sensors, electro-optic devices and reflecting windows [1]. Their trivalent rare earth (RE³⁺) ions doped glass matrices are widely used for the development of many optoelectronic devices such as optical fibers, optical amplifiers, lasers, sensors, light converters, etc. [2-6]. Among RE³⁺ ions, Pr³⁺ shows visible emission spectrum in blue, green and red region depending on the host matrices and it is an attractive optical activator, which offers the possibility of simultaneous blue, green and red emission for laser action as well as IR emission for optical amplification [7-8]. The study of phosphate glasses presents considerable interest due to phosphate (P₂O₅) glasses possess several advantages over conventional silicate (SiO₂) and borate (B₂O₃) glasses. They are distinguished by unique attributes such as high transparency, low melting point, high thermal stability, high gain density, excessive solubility of rare earth (RE³⁺) ions, low refractive index and dispersion [9-12]. The poor chemical durability of phosphate glasses makes them generally unsuitable for practical applications [13]. It was suggested that the chemical durability could be improved by the addition of one or more of multivalent oxides. The addition of metal (Na₂O) oxides the physical characteristics, glass forming ability, luminescence intensity, reduces the viscosity of the melt and lowers the melting temperature, resistance to moisture can be improve and the host structure can be
modify by changing structural accompanied by the formation of NBO's [14]. By adding Al$_2$O$_3$ into phosphate glass network increases the cross-links between PO$_4$ tetrahedral which results an increase in the durability, glass transition temperature, and the decrease in thermal expansion coefficient. It is often used to modify the glass structure, which improves chemical stability and physical properties. [15-18]. Introducing Ba$^{2+}$ modifies the glass network due to the fact that they exhibit ionic radii close to the RE ions [19-20]. The luminescent properties of trivalent rare earth elements have been described with reasonable success and the intensity of transitions of the rare-earth ions can be calculated using the Judd Ofelt (JO) theory [20-22]. This theory defines a set of three phenomenological parameters ($\Omega_2$, $\Omega_4$, and $\Omega_6$), which are sensitive to the local environment of the rare-earth ions in the crystal lattice or glass network. The $\Omega_2$, $\Omega_4$, and $\Omega_6$ intensity parameters can be used for calculation of the radiative transition probabilities ($A_R$) for spontaneous emission, radiative lifetimes ($\tau_R$) of the excited state, branching ratios ($\beta_R$), and stimulated emission cross-sections of the various emission. All these data are essentially required in order to obtain the best ion-host configuration and improve the luminescence efficiency of specific electronic transitions in the developing materials for lasers and other optical devices [1,22].

The present reports the physical and spectroscopic properties of sodium aluminium barium phosphate glasses compositions. In order to predict radiative properties such as radiative transition probabilities, radiative lifetimes, branching ratios, and emission cross-sections the detailed JO analysis has been carried out. The spectroscopic behavior of glass samples with the variation of Pr$^{3+}$ ions concentration were discussed in detail relation to the practical applications of these materials as a potential for visible laser media.

2. Experiment

2.1 Glass preparation

Sodium aluminium barium phosphate glasses were prepared by the conventional melt quenching technique with the following compositions 10Na$_2$O : 5Al$_2$O$_3$ : 20BaO : (65-x)P$_2$O$_5$ : xPr$_2$O$_3$, where x = 0.0, 0.05, 0.10, 0.50, 1.00 and 2.00 mol%, which label as NABPPr1, NABPPr2, NABPPr3, NABPPr4, NABPPr5 and NABPPr6, respectively. The batched mixture about 20 g is place in a porcelain crucible and this homogenous mixture was heated in an electric furnace at 1200 °C for 3 hours. The glass melt become homogenous and then cast on a brass plate quickly and subsequently annealed in a muffle furnace at 500 °C for 3 hour and then cooled to room temperature. Figure 1 shows optically polished glasses for optical absorption measurements. It was observed that with the addition of Pr$_2$O$_3$, glass samples become green in color.

![Figure 1. Glass samples with different Pr$_2$O$_3$ concentration](image)

2.2 Density and molar volume

The densities ($\rho$) of glass samples were measured by applying the Archimedes principle Eq. (1) with four digits electric balance (AND, HR-200). In order to obtain accurate result, all measurement were repeated three times at room temperature.

$$\rho = \frac{W_a}{W_a - W_v} \times \rho_v \quad (g/cm^3)$$  (1)
where \( w_a \) is weights of the glass simple in air, \( w_w \) is weights of the glass simple in water and \( \rho_w \) is density of water. The molar volumes \( (V_m) \) of the developed glass samples were measured by the density values according to talk following relation

\[
V_m = \frac{M_T}{\rho} \quad (cm^3/mol)
\]  

(2)

where \( V_m \) is the molar volume, \( M_T \) is the total molecular weight and \( \rho \) is the calculated density of the glass.

2.3 Spectroscopic measurements

The value of refractive index \((n)\) was measured on an Abbe refractometer with a sodium-vapor lamp as a light source (598.3 nm) and having mono-bromonaphthalene as a contact liquid. The absorption spectra of the glass samples in the wavelength range of 200–2500 nm was recorded with UV-Vis-NIR spectrophotometer (shimadzu, UV-3600). The excitation and emission spectra of polished samples were recorded by cary eclipse fluorescence spectrophotometer (Agilent technologies Inc.) as the emission and excitation source at a wavelength of 597 and 445 nm respectively.

3. Results and discussion

3.1 Physical properties

The effect of composition on the physical properties of glasses are shown in Table 1. The results show that both of density \((\rho)\) and refractive index \((n)\) tended to increase with increasing of \( \text{Pr}_2\text{O}_3 \) concentration. The increase in density because of the replacement of \( \text{P}_2\text{O}_5 \) by \( \text{Pr}_2\text{O}_3 \) changes phosphorus to oxygen ratio which creates \( \text{PO}_4^- \) units results in compactness of glass structure and therefore density of glasses increases [10]. The higher molecular weight of \( \text{Pr}_2\text{O}_3 \) (329.81 g/mol) than weight of \( \text{P}_2\text{O}_5 \) (141.94 g/mol) also has significant effect on increase in density of glasses with \( \text{Pr}_2\text{O}_3 \) [23]. Refractive index is one of the fundamental properties of materials, because it is closely relate to the electric polarizability of ions and the local field inside the material. From the results, show that the values of refractive index \((n)\) range from 1.533 to 1.542. The increase in refractive index can be related to the increase of non-bridging oxygens (NBOs) and it is related mainly to the density [24] as can be seen in Table 1 and Figure 2 also.

| Glass samples | Density \((\rho)\) (g/cm\(^3\)) | Molar volume \((V_m)\) (cm\(^3\)/mol) | Refractive index \((n)\) |
|---------------|-----------------------------|--------------------------------|-------------------|
| NABPPr1       | 2.8928 ± 0.0057             | 46.3998                       | 1.5333            |
| NABPPr2       | 2.8970 ± 0.0011             | 46.3649                       | 1.5349            |
| NABPPr3       | 2.8950 ± 0.0014             | 46.4294                       | 1.5351            |
| NABPPr4       | 2.8951 ± 0.0032             | 46.6874                       | 1.5349            |
| NABPPr5       | 2.9154 ± 0.0000             | 46.6845                       | 1.5365            |
| NABPPr6       | 2.9717 ± 0.0028             | 46.4322                       | 1.5422            |

The molar volume of the glass samples were evaluated from their density following eq. (1). The effect of composition on molar volume \((V_m)\) of glass samples is shown in Figure 3. As can be seen the molar volume decreased from 0.00 – 0.05 mol\% and increased from 0.05 – 0.05 mol\% then decreased it again beyond 2.00 mol\% of \( \text{Pr}_2\text{O}_3 \) concentration. The increasing of molar volume with the addition of \( \text{Pr}_2\text{O}_3 \) may be due to the greater ionic radius of \( \text{Pr}^{3+} \) as compared to other glass constituents [25].
decrease in molar volume shows that addition of Pr$_2$O$_3$ may contract the structure of the loose network in the glass [23].

![Figure 2](image-url)  
**Figure 2.** Density and refractive index of the glass samples with different Pr$_2$O$_3$ concentration.

![Figure 3](image-url)  
**Figure 3.** Molar volume of the glass samples with different Pr$_2$O$_3$ concentration.

### 3.2 Absorption spectra and Judd-Ofelt (JO) intensity parameters

Figure 4 shows the absorption spectra of the glass samples with increasing Pr$^{3+}$ concentration from 0.05 - 3.0 mol% in range of 250 - 2500 nm. It was observed that all eight prominent absorption bands which are assigned to the transitions from the ground state $^5$H$_4$ to the various excited states $^3$P$_2$, $^3$P$_1$, $^3$P$_0$, $^1$D$_2$, $^1$G$_4$, $^3$F$_4$ and $^3$F$_3$ of Pr$^{3+}$ ions [26]. The absorption spectra of all the glass samples are similar in shape and peak position and assignments have been given in Table 2. As can be seen from Figure 4, $^5$H$_4$ $\rightarrow$ $^3$P$_2$ and $^5$H$_4$ $\rightarrow$ $^3$F$_3$ transitions are found to be relatively more intense than the other transition to the change in the local environment around the Pr$^{3+}$ ions and are called as hypersensitive transitions. Further these transitions obey the selection rules, $|\Delta S| = 0$, $|\Delta L| \leq 2$ and $|\Delta J| \leq 2$. 
The intensity of the absorption transitions of the Pr$^{3+}$ ions in sodium aluminium barium phosphate glasses can be expressed in terms of oscillator strengths ($f_{\text{exp}}$) and the same can be evaluated by measuring the integrated areas of the observed absorption bands using the expressions reported in the literature [19,27]. According to JO theory, the calculated oscillator strength ($f_{\text{cal}}$) of the absorption transitions from the ground state ($\Psi J$) to the excited state ($\Psi^\prime J^\prime$) depends on three JO intensity parameters ($\Omega_2$, $\Omega_4$, and $\Omega_6$) and is calculated using the expressions reported in literature [27-28]. Table 2 lists the experimental ($f_{\text{exp}}$) and calculated ($f_{\text{cal}}$) values of oscillator strengths for the NABPPr4 (0.50 mol%) glass absorption spectra along with the root mean square deviation ($\delta_{\text{rms}}$) between experimental and calculated oscillator strengths. $\delta_{\text{rms}}$ values are used to examine the quality of the fit between $f_{\text{exp}}$ and $f_{\text{cal}}$ values of the absorption transitions. $\delta_{\text{rms}}$ values can be determined using the below given expression

$$\delta_{\text{rms}} = \sum \frac{(f_{\text{cal}} - f_{\text{exp}})^2}{N}$$

where, $N$ is the Avogadro’s number, $f_{\text{exp}}$ and $f_{\text{cal}}$ are the experimental and calculated oscillator strength values respectively.

It was observed from Table 2 the $\delta_{\text{rms}}$ deviation found to be $\pm 0.774$ and this value gives the quality of the fit between experimental and calculated oscillator strengths. The JO intensity parameter $\Omega_\lambda$ ($\lambda = 2, 4$ and $6$) were calculated and found to be in the order of $\Omega_4 > \Omega_6 > \Omega_2$ for the NABPPr4 glass and the variation in the $\Omega_\lambda$ parameters compared with literature for different glass systems [27-29] as presented in Table 3. The JO intensity parameters provides valuable information regarding the glass structure and transition rate of the RE ion energy levels. The change in covalency, structure and symmetry of the Pr$^{3+}$ ion to the surrounding ligand field is characterized using the JO parameter $\Omega_\lambda$ [29], whereas $\Omega_4$ and $\Omega_6$ are directly related to the basicity, rigidity, viscosity of the glass matrix and the dielectric nature of the glass samples [30]. The large value of $\Omega_2$ for NABPPr4 glass indicates the stronger asymmetry of the site occupied by Pr$^{3+}$ ion than the glass system such as PBAIPr [9], PPBGaPr [9], PPBlPr [9], ZnPbWTe [31], ZnAlBiB [31], Ga–Ge–Sb–Se [27], ZBP3 [30] except for ZnBP [30], TeO2–BaF2–NaF [28] and 0.5PrZTFB [29]. The NABPPr4 glass sample has the maximum value of $\Omega_2$ which signifies strong covalent bonding at optimum doping level. The $\Omega_2$ parameter revealed the highest sensitiveness to the environment as compared to $\Omega_4$ and $\Omega_6$. Furthermore, the $\Omega_4$ and $\Omega_6$ parameters displayed a monotonic variation as a function of Pr$^{3+}$ ion contents, indicating a low sensitivity to the environmental change of Pr$^{3+}$ ion.

Figure 4. Absorption spectra of the glass samples with different Pr$_2$O$_3$ concentration.
Table 2. Absorption spectra positions, experimental \(f_{\text{exp}}\) and calculated \(f_{\text{cal}}\) oscillator strengths \((\times 10^6)\) of NABPPr4 glass.

| Transitions \(^6\text{H}_{5/2} \rightarrow \) | Peak positions | Oscillator strengths |
|----------------|----------------|---------------------|
| \(^3\text{P}_2\) | 444 nm 22523 cm\(^{-1}\) | \(4.2073 \times 10^6\) \(4.7517 \times 10^6\) |
| \(^3\text{P}_1\) | 468 nm 21368 cm\(^{-1}\) | \(1.7841 \times 10^6\) \(2.8047 \times 10^6\) |
| \(^3\text{P}_0\) | 481 nm 20790 cm\(^{-1}\) | \(1.5764 \times 10^6\) \(2.7642 \times 10^6\) |
| \(^1\text{D}_2\) | 590 nm 16949 cm\(^{-1}\) | \(0.4138 \times 10^6\) \(1.5405 \times 10^6\) |
| \(^1\text{G}_4\) | 1014 nm 9862 cm\(^{-1}\) | \(0.2195 \times 10^6\) \(0.4435 \times 10^6\) |
| \(^3\text{F}_4\) | 1447 nm 6911 cm\(^{-1}\) | \(4.4934 \times 10^6\) \(5.1698 \times 10^6\) |
| \(^3\text{F}_3\) | 1530 nm 6536 cm\(^{-1}\) | \(9.6714 \times 10^6\) \(9.1517 \times 10^6\) |
| \(^3\text{F}_2\) | 1954 nm 5141 cm\(^{-1}\) | \(9.9674 \times 10^6\) \(9.9994 \times 10^6\) |

\(\delta_{\text{rms}} = \pm 0.774\)

Table 3. Composition of Judd-Ofelt (JO) intensity parameters \((\Omega_\lambda, \lambda = 2, 4 \text{ and } 6) \times 10^{-20} \text{ cm}^2\) and their trend of NABPPr4 with various Pr\(^{3+}\) glasses.

| Glass | \(\Omega_2\) | \(\Omega_4\) | \(\Omega_6\) | Trends |
|-------|-------------|-------------|-------------|--------|
| NABPPr4 [present work] | 17.52 | 4.64 | 8.16 | \(\Omega_2 > \Omega_6 > \Omega_4\) |
| PBAIPr [9] | 4.97 | 2.25 | 2.46 | \(\Omega_2 > \Omega_6 > \Omega_4\) |
| PPBGaPr [9] | 5.26 | 2.60 | 2.81 | \(\Omega_2 > \Omega_6 > \Omega_4\) |
| PPBInPr [9] | 4.76 | 2.05 | 2.23 | \(\Omega_2 > \Omega_6 > \Omega_4\) |
| ZnPbWTe [31] | 4.29 | 1.16 | 1.28 | \(\Omega_2 > \Omega_6 > \Omega_4\) |
| ZnAlBiB [31] | 3.73 | 1.17 | 3.23 | \(\Omega_2 > \Omega_6 > \Omega_4\) |
| Ga–Ge–Sb–Se [27] | 8.02 | 6.27 | 4.79 | \(\Omega_2 > \Omega_4 > \Omega_6\) |
| ZBP3 [30] | 2.89 | 2.04 | 1.99 | \(\Omega_2 > \Omega_6 > \Omega_4\) |
| ZnBPr [30] | 1.52 | 3.85 | 6.97 | \(\Omega_6 > \Omega_4 > \Omega_2\) |
| TeO2–BaF2–NaF [28] | 5.44 | 3.54 | 7.87 | \(\Omega_6 > \Omega_4 > \Omega_4\) |
| 0.5PrZTBF [29] | 6.54 | 4.09 | 8.88 | \(\Omega_6 > \Omega_2 > \Omega_4\) |

3.3 Luminescence spectra and radiative properties

It is important to know the correct excitation wavelength of the dopant ion, Figures 5 shows the excitation of NABP glasses doped with different concentrations of Pr\(^{3+}\) ions, by monitoring the photoluminescent emission at a wavelength of 598 nm. From the spectra, we observed three excitation bands centered at 445 nm, 468 nm and 480 nm corresponding transitions to the ground state \(^3\text{H}_4\) to the various excited state \(^3\text{P}_2\), \(^3\text{P}_1\) and \(^3\text{P}_0\) respectively. From all the transitions above, the transition \(^3\text{H}_4 \rightarrow \) \(^3\text{P}_2\) at 445 nm is most prominent. Therefore, we recorded the emission spectra of all the glass samples that were excited at a wavelength of 445 nm.
Figure 5. Excitation spectra of the glass samples with different Pr$_2$O$_3$ concentration.

Figure 6. Emission spectra of the glass samples with different Pr$_2$O$_3$ concentration.

Figure 6 shows the emission spectra of NABP glasses doped with different concentrations of Pr$^{3+}$ ions. The luminescence spectra exhibited three emission bands in the visible region (500 – 750 nm) centered at 528, 598 and 639 nm corresponding to the emission transitions $^3P_1 \rightarrow ^3H_5$, $^1D_2 \rightarrow ^3H_4$, and $^3P_0 \rightarrow ^3F_2$ respectively. The results show that the emission intensity increases with the increasing content of Pr$^{3+}$ ions up to 0.5 mol%, then decreased beyond the content because of the quenching of fluorescence at higher concentrations of Pr$^{3+}$ ions which may be due to energy transfer via cross relaxation between Pr$^{3+}$-Pr$^{3+}$ ions. Concentration quenching does not occur at low concentration because the average distance among the Pr$^{3+}$ ions is so large that the interaction is very weak.

In order to understand the photoluminescence performance of Pr$^{3+}$ ions doped NABPPr4 glasses, the radiative parameters such as radiative transition probabilities ($A_R$), radiative lifetime ($\tau_R$), luminescence branching ratios ($\beta_R$) for the emission $^1D_2 \rightarrow ^3H_4$ and $^3P_0 \rightarrow ^3F_2$ transitions of NABPPr4 glasses. It has been evaluate by using the JO parameters obtained from the absorption spectral measurements and are presented in Table 4 along with the other reported Pr$^{3+}$ doped glasses. In handling the fluorescence process, the radiative parameters such as $A_R$, $\tau_R$ and $\beta_R$ for the observed emission transitions are evaluated by using the expressions given in literature [29-30]. The stimulated
emission cross-section ($\sigma_e$) is an important parameter for glass material to act as a good luminescent host material and its value signifies the rate of energy extraction from the optical material. From the observed emission bands $\sigma_e$ can be estimated by using the following expression [29-30]

$$\sigma_e = \frac{\lambda_p^4}{8\pi cn^2 \Delta \lambda_{ef}} A_R$$  \hspace{1cm} (4)

$\lambda_p$ is the emission peak wavelength, $n$ is refractive index, $\Delta \lambda_p$ is the full width at half maximum which can be calculated by integrating the intensity at the peak wavelength.

Table 4. Emission peak wavelength ($\lambda_p$ (nm)), radiative transition probabilities ($A_R$ ($S^{-1}$)), radiative lifetime ($\tau_R$ ($\mu$s)), branching ratios ($\beta_R$) and stimulated emission cross-section ($\sigma_e$) for the observed emission transitions of Pr$^{3+}$ doped NABPPr4.

| Transition parameters | NABPPr4 [present work] | ZnBP [30] | CaBPr [27] | CdBPr [27] | Pr:CNGG [32] | Pr:CLNGG [32] |
|-----------------------|-------------------------|-----------|-----------|-----------|-------------|-------------|
| $^1D_2 \rightarrow ^3H_4$ | $\lambda_p$ | 598 | 571 | 571.9 | 570 | 606 | 606 |
|                        | $A_R$ | 6119 | 0.137$\times 10^{-4}$ | 0.132$\times 10^{-4}$ | 0.131$\times 10^{-4}$ | 714 | 751 |
|                        | $\tau_R$ | 13 | 191 | 193.2 | 193.3 | 224 | 177.8 |
|                        | $\beta_R$ | 0.08 | 26.22 | 25.44 | 25.33 | 0.15 | 0.13 |
|                        | $\sigma_e$ | 2.69 | 0.55 | 0.58 | 0.53 | 0.48 | 0.51 |
| $^3P_0 \rightarrow ^3F_2$ | $\lambda_p$ | 639 | 643 | 644 | 641 | 656 | 656 |
|                        | $A_R$ | 46385 | 0.540$\times 10^{-4}$ | 0.535$\times 10^{-4}$ | 0.510$\times 10^{-4}$ | 14644 | 15225 |
|                        | $\tau_R$ | 13 | 45.59 | 47.55 | 49.42 | 22 | 18.3 |
|                        | $\beta_R$ | 0.63 | 24.64 | 25.43 | 25.22 | 0.32 | 0.33 |
|                        | $\sigma_e$ | 3.53 | 4.76 | 4.07 | 3.84 | 19 | 29.6 |

Among all the glasses investigated, NABPPr4 glass has got highest radiative transition probability $A_R$ for all transition. For a glass material to act as a good lasing material, the branching ratio ($\beta_R$) must be high. From Table 4 it is observed that the $\beta_R$ value for all the glasses is highest for transition $^3P_0 \rightarrow ^3F_2$. This indicates that this energy transition can give laser emission at about 639 nm in the prepared NABPPr4 glasses. Further, $\sigma_e$ is another significant parameter to estimate laser performance of a material. From Table 4, it were found that among all the emission transitions, a transition $^3P_0 \rightarrow ^3F_2$ observed at 639 nm possesses highest $\sigma_e$ value for all glass.

### 3.4 Chromaticity color coordinates

The characteristic emission color of the NABPPr4 glasses was determined using Commission International De l’Eclairage (CIE) 1931 chromaticity coordinates and is presented in Figure 7. The CIE chromaticity coordinate excited by 445 nm the values of NABPPr4 glass was 0.576 and 0.416 for x and y, respectively, which is located in the yellow-orange region of the CIE diagram. From the results indicated that NABPPr4 glass can be emitted yellowish-orang region and can act as a suitable solid-state material in designing the yellowish-orange lasers.
4. Conclusion
Investigation properties of Pr$^{3+}$ doped sodium aluminium barium phosphate glasses have been studied through absorption and luminescence. Physical properties and refractive indices for all the glasses were calculated. The increase in density ($\rho$) because of the replacement of $\text{P}_2\text{O}_5$ by $\text{Pr}_2\text{O}_3$ and the values of refractive index ($n$) range from 1.533 to 1.542. The increase in refractive index can be related to the increase of non-bridging oxygens (NBOs) and it is related mainly to the density. The photoluminescence emission spectra measured $\lambda_{ex} = 445$ nm have demonstrated a bright strong yellowish-orange emission ($^1D_2 \rightarrow ^3H_4$) at 598 nm and the emission intensity increases with the increasing content of Pr$^{3+}$ ions up to 0.5 mol%. The intensity parameters ($\Omega_2$, $\Omega_4$ and $\Omega_6$) have been evaluated using JO theory. The calculated JO intensity parameters revealed the trend of $\Omega_2 > \Omega_6 > \Omega_4$ of NABPPr4 glass. The value of $\Omega_2$ which is related to the structural changes in the vicinity of Pr$^{3+}$ ion indicates the highest covalent environment of Pr$^{3+}$ ion in $\text{P}_2\text{O}_5$ mixed glasses. Low value of the intensity parameter $\Omega_4$ and $\Omega_6$ indicates lower rigidity and viscosity of the glass host. The radiative properties for the NABPPr4 glass was forecast through JO theory. The radiative transition rate, the branching ratio and the stimulated emission cross-section are highest for $^3P_0 \rightarrow ^3F_2$ transition. Calculated CIE color chromaticity coordinates (0.576, 0.416) confirm the potential of this new material for use in display devices. The present glass system investigated is basing on spectroscopic study one can conclude that the NABPPr4 glasses compositions are promising luminescent materials for the yellowish-orange spectral region.

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Acknowledgments
The authors would like to thanks Center of Excellence in Glass Technology and Materials Science (CEGM), Nakhon Pathom Rajabhat University (NPRU) and Suan Sunandha Rajabhat University (SSRU)