Correlation of radiative properties of rare earth ions (Pr$^{3+}$ and Nd$^{3+}$) in chlorophosphate glasses—0·1 and 0·5 mol% concentrations

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Abstract. Optical properties of chlorophosphate glasses of the type 50P$_2$O$_5$–30Na$_2$HPO$_4$–20RCl (R = potassium and lead) activated by 0·1 and 0·5 mol% of Pr$^{3+}$ and Nd$^{3+}$ have been investigated. Optical band gaps ($E_{	ext{opt}}$) have been reported for 0·1 and 0·5 mol% concentrations of Pr$^{3+}$ and Nd$^{3+}$ doped potassium and lead chlorophosphate glasses. Energy levels and optical transitions of Pr$^{3+}$ and Nd$^{3+}$ are assigned. Spectroscopic parameters ($E^1$, $E^2$, $E^3$, $\xi_{tt}$ and $\alpha$), spectral intensities ($f_{	ext{opt}}$), Judd–Ofelt intensity parameters ($\Omega_2$, $\Omega_4$ and $\Omega_6$) and radiative lifetimes ($\tau_q$) are correlated for 0·1 and 0·5 mol% concentrations of these two ions in potassium and lead chlorophosphate glasses.

Keywords. Optical band gaps; spectroscopic parameters; intensity parameters; radiative lifetimes.

1. Introduction


Cases et al (1991) studied the optical properties of Nd$^{3+}$ ions in ZnF$_2$–CdF$_2$ based glasses. Optical properties of Nd$^{3+}$ in tellurite and phosphotellurite glasses were studied by Weber et al (1981). Details of preparation of Nd$^{3+}$ doped fluorozirconate glass laser fibre were given by Hu et al (1995). Gatterer et al (1998) reported the suitability of Nd(III) absorption spectroscopy to probe the structure of glasses from the ternary system Na$_2$O–B$_2$O$_3$–SiO$_2$. Previously Ratnakaram and Viswanadha Reddy (2000a, b) reported the spectroscopic investigations of Pr$^{3+}$ and Nd$^{3+}$ doped different chlorophosphate glasses in 0·5 mol% concentrations of rare earth ions. These results included optical band gaps, spectral intensities, intensity parameters, radiative lifetimes and branching ratios. These results stimulated the present investigation of spectroscopic studies of Pr$^{3+}$ and Nd$^{3+}$ ions in 0·1 mol% concentration in potassium and lead chlorophosphate glasses. In this paper, we report the spectral studies of Pr$^{3+}$ and Nd$^{3+}$ ions in potassium and lead chlorophosphate glasses in 0·1 and 0·5 mol% concentrations. These glasses are of the type 50P$_2$O$_5$–30Na$_2$HPO$_4$–20RCl (R = potassium and lead). The aim of this study is to investigate the influence of the concentration of rare earth ions on optical band gaps, spectral intensities and radiative lifetimes.

2. Experimental

The analar grades of P$_2$O$_5$, Na$_2$HPO$_4$, KCl and PbCl$_2$ were purchased from E. Merck India Ltd., Bombay and PrCl$_3$ and NdCl$_3$ were obtained from M/s Indian Rare Earth Ltd., Kerala. All these chemicals were of 99·9% purity. The general composition of the glass was 50P$_2$O$_5$, 30Na$_2$HPO$_4$ and 20RCl (R = K and Pb). The rare earths were added in 0·1 and 0·5 mol% concentrations to the above glass composition. The glass samples were prepared by melting the required amounts of above chemicals in a specially made clay crucible at a temperature of 1100°C. The details of preparation of these glasses were explained elsewhere (Ratnakaram and Viswanadha Reddy 2000a). Density of the glass samples was determined by Archimedes principle using xylene as the immersion liquid with an accuracy of ±0·005 g/cm$^3$. The glass refractive indices were measured using Abbe’s refractometer with an accuracy of ±0·001. The absorption spectra were recorded at room temperature in UV–VIS–
NIR region using Hitachi U-3400 UV–VIS–NIR double beam spectrophotometer.

3. Results and discussion

Using Davis and Mott (1970) theory, the optical data are analysed for higher values of \( \alpha(\omega) \) above the exponential region by plotting \((\alpha \omega)^{1/2}\) as a function of photon energy, \( \hbar \omega \) for indirect transitions and by plotting \((\alpha \omega^2)^{1/2}\) as a function of \( \hbar \omega \) for direct transitions for Pr\(^{3+}\) and Nd\(^{3+}\) ions as shown in figures 1 and 2, respectively. The optical band gap, \( E_{opt} \), values are obtained by extrapolation to \((\alpha \omega)^{1/2} = 0\) and \((\alpha \omega^2)^{1/2} = 0\) and are presented in table 1 for both Pr\(^{3+}\) and Nd\(^{3+}\) ions in potassium and lead chlorophosphate glasses (0.1 and 0.5 mol% concentrations).