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Raman and photoluminescence studies of europium doped zinc-fluorophosphate glasses for photonic applications

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ABSTRACT

Europium (Eu^{3+})-doped zinc-fluorophosphate (PKAZfEu) glasses have been synthesized by usual melt-quenching technique. Optical absorption, photoluminescence excitation, photoluminescence and decay curves of these glasses were measured at room temperature and investigated. The Judd-Ofelt (JO) parameters (Ω_λ, $\lambda = 2$ and 4) were determined from the measured emission spectra and used for quantifying the radiative parameters that include radiative transition probability (A_R), radiative lifetime (τ_R), branching ratios (β_R), effective bandwidths ($\Delta\lambda_{eff}$) and peak stimulated emission cross-section ($\sigma(\lambda_P)$) for the $^5D_0$ luminescent state of Eu^{3+}. The electron-phonon coupling strength and phonon energy of the glasses were obtained from the phonon sideband spectrum. The chromaticity coordinates for different concentration of PKAZfEu glasses were evaluated by analyzing the emission spectra with Commission International de l'Eclairage (CIE) color diagram. Decay curves of Eu^{3+} ions for the $^5D_0 \rightarrow {}^7F_2$ transition have been obtained under 393 nm excitation. The decay curves exhibit a single exponential behavior for all the investigated glasses. Luminescence properties of Eu^{3+} ion for the $^5D_O \rightarrow {}^7F_2$ transition indicate that the PKAZfEu glasses could be a suitable gain medium for visible red lasers and display devices.

1. Introduction

Development of novel lanthanide (Ln^{3+})-doped luminescent materials for photonic devices have drawn significant interest in the scientific and technological point of view [1–4]. These Ln^{3+}-doped luminescent materials can find applications in diverse fields of photonics such as optical data storage, remote sensors, upconversion lasers, color displays, infrared laser viewers, indicators, optical printing, etc. Now-a-days, phosphate glasses were also investigated due to their immense potential for bio-applications. However, these glasses alone do not have much chemical durability compared to multi component-phosphate glasses. These glasses modified with sodium, calcium, magnesium, and zinc were established abundance of interest.

Moreover, fluorophosphate glasses exhibit the combined advantages of fluoride and oxide matrices including good moisture resistance, relatively low refractive index, extended transparency from near ultraviolet (UV) to mid infrared (MIR) range, relatively low phonon energy, therefore, these are the suitable hosts for Ln^{3+} ions [5,6]. However, ZnO plays a role of distribution of Ln^{3+} ions through the matrix to prevent non-radiative relaxations which leads to enhance the fluorescent emission [7]. It is challenging to reduce OH^- groups in phosphate glasses, however, these can be minimized significantly in fluorophosphate glasses without the use of control atmosphere for making the glass. Further, with the addition of zincfluoride content to the glass matrix, which minimize the OH^- groups and hence increases the radiative emission of the fluorescent level [8]. In the present host, Al_2O_3 is introduced to the phosphate glasses to expand their mechanical properties.

Usually, most of the Ln ions present a single valence state in glasses, i.e. 3+ state, while europium exhibit both valence states, 2+ and 3+. Addition of europium (Eu^{3+}) ion in these glasses brings a significant change in their optical, structural and magnetic behavior, which is useful in finding new applications. A detailed structural investigations of these glasses becomes highly essential. These Eu^{3+}-doped glasses are mostly utilized for field emission technology as a red emitting phosphors because of their narrow emission at around 610 nm [9]. The Eu^{3+}-doped glasses got a special attention due to the following reasons.

(i) At room temperature, persistent spectral hole burning has been applied to the $^5D_0 \rightarrow {}^7F_0$ transition of Eu^{3+} as it has a potential

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