Effect of the synthesis method on the morphological, structural, and spectroscopic properties of rare earth monophosphates

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Abstract

The use of rare earth monophosphates as luminescent materials in optical devices is very popular in the last decades and their synthesis is an important research goal. This paper proposes a discussion of the morphological, structural, and spectroscopic properties of rare earth monophosphates phosphors as a function of the synthesis method. LnPO₄: Eu³⁺, Dy³⁺ have been synthesized by hydrothermal and combustion methods. The obtained phosphors have been identified by X-ray diffraction, SEM, and FTIR spectroscopy. The X-ray diffraction patterns collected for the prepared materials indicated the high purity of the crystalline phase with a monoclinic structure. The morphological properties depend on rare earth elements and the synthesis method. Photoluminescence properties have been investigated based on excitation and emission spectra, decay curves, and chromatic coordinates.

Keywords: rare earth monophosphates, hydrothermal method, combustion synthesis, morphology, luminescence, crystal structure.

1. Introduction

Rare earth monophosphates have long been attractive materials owing to their distinctive physical and chemical properties. They have been applied in different technological fields, e.g., in catalysts [1], bioimaging and labeling [2], photoluminescent materials [3], solid-state proton conductors [4], and hydrophobic materials [5]. However, it is known that the size and shape effect of nanoparticles in most of these applications is prominent [6]. Nanostructures of LaPO₄ with rods and spheres shapes attracted a lot of scientific interest because of their unique properties. For example, it is investigated that the spherical shape of LaPO₄ particles was useful in bio-labeling [7, 8] and photocatalytic activity [9], while nanorods are preferable in
photoluminescence [10] and hydrophobic nanocoatings [5]. Recently, many syntheses route of fine-structured LaPO₄ rods and spheres have been developed including co-precipitation [11], hydrothermal synthesis [12], sol-gel method [13], combustion method [14] and so on.

2. Structural properties
The X-ray diffraction patterns collected for the prepared materials by hydrothermal and combustion methods correspond to LaPO₄ and GdPO₄ crystallized in the monoclinic structure of the monazite type with high purity. The indexation of all diffraction peaks according to the space group P2₁/n confirms the substitution and the incorporation of luminescent Eu³⁺ and Dy³⁺ ions in the LnPO₄ host matrix (Fig. 1). All FTIR spectra of the obtained samples presented the same bands characteristic of the isolated PO₄³⁻ ion in LnPO₄ with monazite structure reported in the literature [15].

3. Morphological properties
The SEM images of LnPO₄ powder, obtained by the hydrothermal method, show that samples are formed by needles with the length between 0.5 mm and 2 mm and a diameter in the order of 0.1–0.2 mm. While the samples obtained by combustion route presented spherical shape particles with micrometric size.

![Figure 1](image1.png)

**Figure 1.** Images MEB des poudres de LaPO₄
4. Spectroscopic properties
The effect of morphological properties on the luminescence of Eu$^{3+}$ and Dy$^{3+}$ in LnPO$_4$ (Ln$^{3+}$ = La$^{3+}$ and Gd$^{3+}$) has been investigated based on excitation and emission spectra, decay curves, and chromatic coordinates. A promising red emission for field emission displays, compared to red phosphor material, has been obtained from LaPO$_4$: Eu$^{3+}$ (5%). A warm, natural, daylight, and cool white light emission have been obtained from (La, Gd)PO$_4$: Dy$^{3+}$ using a single emitting phosphor with different Dy$^{3+}$ concentrations or under excitation with different wavelengths. These results reveal the usefulness of this material in the white LEDs field.

5. Conclusion
The morphological, structural, and spectroscopic properties of (La, Gd)PO$_4$ doped with Eu$^{3+}$ and Dy$^{3+}$ are discussed as a function of the synthesis method. The activated host matrix shows good structural stability. It is found that the morphological properties depend on the synthesis method. A promising red and white light emissions have been obtained from LaPO$_4$: Eu$^{3+}$ and (La, Gd)PO$_4$: Dy$^{3+}$, respectively. The presented results indicate that the prepared phosphors have potential applications in lighting technology and are promising materials for white light devices.

References